CREATIVE INTEGRATION OF METAL INTO WOOD ART FORMS

By

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DECLARATION

I hereby declare that this submission is my own work towards the PhD degree in Art Education and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgment has been done in the text.

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ABSTRACT

Wood and metal have a long tradition, but materials or literature related to their joint application are farfetched. Though students learn to create works of art from wood and metal, learning on the two materials are done separately resulting in the lack of direct link between the two materials. Secondly materials and processes involved in working with wood and metal though may have certain similarities also have vast differences that pose threats to the success of wood-metal integration. Moreover works that result from the integration also lack necessary communication jargons, for that matter students or workers are torn between metal and wood terminologies that could do little to help. Also techniques involved in the use of the two materials lack proper documentation which results in the state of time marking or stagnant development. This is because there is no evidence of the latest ideas on which improvement or development could be based. In view of this the researcher adopted a mixed research methodology which includes the qualitative (content analysis, collective case study and ground theory study) and quantitative (experimental and descriptive research) for the collection and analysis of information drawn from the samples. Due to the heterogeneous nature of the population, the probability sampling techniques (simple random and stratified random sampling) and the nonprobability sampling techniques (purposive sampling and convenience sampling) were employed. The researcher therefore arrived at the evolution and current trends in the field of wood-metal integration; the knowledge of relevant information of the two materials for the successful or purposeful integration; information of wood and/or metal complementary materials relevant to the integration of both materials; bases for calculative and constructive measures to curb negative environmental influences on wood-metal integration. Based on these the researcher came up with the following

findings: factors that are worth considering prior to the integration of wood and metal; aspect of wood and metal that could be integrated; methods and techniques by which wood and metal integration could be achieved; convenient sizes and package of wood and metal specimens that could be kept as reference materials in the library and other places to enhance teaching and learning; and also jargons for the facilitation of easy communication of the findings among future professionals that may emerge through the education on the outcome of this research. This dissertation is recommended to institutions that study integrated art as a source of integration ideas. Also according to the vision of the researcher, it is a study that has just begun in the development of a new art paradigm of study in an unlimited scope. In view of this the researcher recommends its adaptation and developments as a specialty in art and art education that will deal with possibilities related to wood and metal. Recommended research areas include: wood integration into metal art forms; wood and metal integration as a tool for industrial waste management in the wood industry; and the essence of integration in art education notwithstanding others areas regarding the utilisation and behaviour of the two materials and their complementary materials. According to Koestler cited in McCreight (1991), “the principal mark of a genius is not perfection but originality”. This dissertation being the first of its kind deserves other supplementary studies to make it whole or perfect.

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CHAPTER ONE

INTRODUCTION

1.1 Overview

This beginning chapter declares the overall intentions of the study from the background of the study to its importance. These are as follows.

1.2 Background to the Study

Metalwork is the art of working with metal to fashion artefacts, structures, parts of machines and equipment, ornament among others that are executed with diverse procedures and technologies. Due to its flexibility, metal works are neither limited by size, form nor shape; they range from large bodies like marine crafts and aircrafts to tiny and intricate objects as found in jewelleries and small instruments like sewing needle among others. However, working with metal requires extensive skills and necessitates the use of many types of tools and equipment as well as sophisticated machines. As a result, the potentiality of metal as an art material cannot be overemphasized.

Metalwork began thousands of years ago when humans realized that different stones have different properties and that these lustrous rocks were able to melt, to be drawn and to be formed into various articles including ornaments and objects of art. The advent of metal technology brought to an end many environmental challenges facing man. Metal is capable of solving many problems in areas such as transportation, tools and equipment notwithstanding its use in the improvement of the appearances and functions of other materials. Metal is therefore endorsed as one of the main materials on which civilisation is based. And since civilisation must continue, the exploration of this material could not come to a halt.

Again, the popularity of metalwork is also because it is somehow boundless in its development and application, in that, it is virtually useful in various fields of art, for example ceramics, sculpture, architecture, picture making and textiles. Metals in this respect are either the main material or a complementary material for productions such tools and equipment:

- In textiles they play major roles in the production of fasteners and fittings such as zippers, buttons etc.

- In architecture, metals are employed both as building materials (rod, binding wires and more) and as finishes (louver frames, doors locks, burglar proofs, etc).

- In sculpture it is one of the main materials used in casting and also a complementary material in assemblage, construction and modelling. In wood construction it is basically the main material for all fittings, fasteners and appendages.

- In ceramics also, it is an important material for colouring wares in the form of glazes and metallic oxides.

- In picture making, it is normally used in the production of frames and also for the creation, colouring and finishing of pictures in various forms.

In this respect metals are not for the fond of it but, this is because they bare solutions to problems that are experienced with other materials of which wood is no exception.

Wood on the other hand is a ubiquitous material used everywhere by different people of different cultures for different purposes. Over the years, the use of wood has grown in importance and its exploitation has increased from time to time putting pressure on some of our dear forests. Rapid deforestation resulting from the massive exploitation of wood has raised many eye brows but is still on the increase: day in day out more and more people come up with wonderful ideas and design related to the use of wood accounting for the prevalent use of the material, especially in Art.

In some cases, there have been efforts to replace wood with other materials but it still attracts most attention because it is a material of choice for good reasons. Apart from being cost effective, sturdy and long-lasting, it is also beautiful, light in weight, temperature resistant, a good insulator and moreover renewable. These advantages of the material could not be overlooked, as a result, wood appears in most buildings, furniture, tools and equipment found around the world today. Courses of study have also been developed in relevant institutions among research institutions in various aspects of the material to further study the material for its effective development. Therefore, this study of fostering the use of metal in wood product development and production is no exception.

1.3 Statement of the Problem

Constant researches into wood have yielded countless results that are relevant to both its development as well as further research into the material. These results range from practicable characteristics, conditions and properties to natural limitation and deformities associated with the material. Some of these information have been very relevant to the activities of wood artists in the selection of the right wood for the right job; selection of the right tools for the right wood and also the right wood for the right environment. But most of the information is mostly concentrated on wood with little or no direct link with its complimentary materials such as metal**,** resulting in little information regarding the relevance and application of it in wood technology. This has also resulted in inadequate teaching and learning materials on the integration for effective education in the field, specifically in the Department of Integrated Rural Art and Industry in the Kwame Nkrumah University of Science and Technology-an art institution in Ghana where the emphases are on integration of materials.

The artists, especially the integrated rural ones hardly use wood solely, but are always seeking its usage in conjunction with other materials, one of which is metal-the material under discussion for this project. In view of this, most of the theories and principles designed for the handling of wood are not always adequate for the artist. Therefore the artist and art teachers have little information to apply in terms of practice and teaching respectively regarding the integration of wood and metal. Artist or art students tend to be good and commanding in the individual areas-wood or metal, but are not able to reconcile the two areas to achieve concrete results. This has resulted in a trial and error situation where wood metal integration is most of the time done under uncertainty.

It is therefore necessary to study these sister materials simultaneously in order to reconcile their properties and application by addressing problems associated with their combination in order to facilitate certainty in their integration to alleviate the prevalent trial and error situation on the ground. It is upon this foundation that this research is undertaken.

1.4 Objectives

The objectives of the research are as follows:

1. To establish factors that must be considered prior to the integration of wood and metal including the identification of possible means by which the two materials could be integrated.

2. To produce wood and metal integration specimens that will be assessed as reference materials to enhance the teaching and learning on the subject.

3. To generate technical jargons related to the project in order to facilitate easy communication and appreciation of the paradigm.

1.5 Research Questions

1. What factors are needed to be considered prior to the integration of wood and metals?

2. By what means could wood and metals be integrated?

3. By what possibilities could wood and metal integration pieces be kept as reference materials in the library?

4. How can technical jargons relevant to the communication of wood metal integrated art works be generate?

1.6 Delimitation

This project tackles the areas of art development and education. Specific areas include wood sculpture and integrated art. Metals considered are aluminium, lead, copper, brass and iron. The wood species considered include samples of the premium species, lesser known species (LKS), lesser used species (LUS) and alternative wood species (coconut wood and bamboo).

1.7 Limitations

The project could have been done more easily and could have also achieved other dimension, but circumstances like lack of sponsorship, adequate time and facilities somehow restricted the progress and the scope of the researcher resulting in the following limitations:

i. The test conducted on some of the specimens should have included mechanical testing for engineering purposes that was lacking. This is because the sample size specifications by ISO (International Standards Organisation) could not be afforded by the researcher. This has limited the application of the result of this thesis to the creation art pieces like sculpture and furniture only.

ii. The research was limited to only natural conditions. It did not include artificial conditioning of timber like kiln drying procedures and processes such as cross lamination and lignifications as a check on shrinkage and other natural limitations.

iii. In the designing aspects of the ideas related to the integration of the two materials, factors considered were limited to CAD (computer aided design) and hand forming techniques. Therefore, factors related to CAM (computer aided manufacture) were not considered.

1.8 Definition of Terms

This section is deals with the definition of certain terms as used in the dissertation. These are as follows:

Adornment**:** a decoration or ornament.

Aesthetics: relating to philosophical principles of art.

Alternative Wood Species: this is used to refer to other non-traditional wood species like those obtained from palm tree, bamboo and rattan.

Assemblage: artistic arrangement of miscellaneous items to form a work of art.

Automata: a mechanism that is relatively self-operating.

Blacksmithing**:** hot forming of iron using hand tool of hard and refractory surfaces.

Boulle: inlaid decoration of tortoise shell, yellow metal, and white metal in cabinetwork.

Butt: this is the flat surface of a piece of wood or metal to be joined.

Capping: making a hole in wood and covering it a metal sheet for the purpose of decoration or provision of contrasting look on a surface.

Commode: A movable washstand with a cupboard underneath.

Creative**:** having or showing imagination and artistic or intellectual inventiveness.

Curing: the solidification of adhesives that enable them to attach themselves to similar or other surfaces.

Ductility: the ability of metal to be drawn hammered or stretched thin without breaking.

Ergonomic: designed for maximum comfort and ease of use.

Edification: enlightenment on a subject matter.

Heat treatment: the process of physical, chemical and mechanical alteration of metal through the application of different temperatures of heat.

Horology: the study of the making of time pieces.

Integration: bringing of different materials of different qualities together for production such that they serve a common purpose.

Lapping: placing one material over the other and fastening it to the background material.

Lustre: the reflective quality and brilliance of metal surface.

Malleability: the ability of metal to be hammered or pressed into various shapes without breaking.

Metal smith: a person who makes or repairs metal objects.

Molten: a metal that is melted or liquefied by heat.

Paradigm: in the philosophy of science, a generally accepted model of how ideas relate to one another, forming a conceptual framework within which scientific research is carried out.

Piercing: hollowing of metal or wood by sawing using the coping, fret or piercing saw that starts and ends within.

Planishing: rendering of metal an even surface

Planting: this is the process of burying rods, wires or similar forms of metal partially lengthwise into wood to produce standing effects of the metals on the wood's surface.

Rebate: a step down cutting rendered at the ends and edges of wood to be joint in order to provide more nailing and/or gluing surfaces that make a stronger joint.

Recess: this is a corresponding depression created in wood to provide an accommodation for respective metals.

Rococo: Relating to an artistic style esp. of the 18th century characterised by fanciful curved asymmetrical forms and elaborates ornamentation.

Scientific: using science and its principles to ensure efficiency.

Specimen: something that is representative because it is characteristic of its kind or of a whole *OR* a sample, portion or quantity of material, process or items for use in testing, examination, or study due to its representative nature.

Status quo: the condition or state of affairs that currently exists.

Swivel: a device joining two parts so that one or both can pivot freely.

***Tinkering*:** This is a process of making all kinds of minor repairs in metal.

***Tinsmithing*:** the process of working in tin or tin sheet.

Trial and error: trying of different alternatives: a method of finding a satisfactory solution or means of doing something by experimenting with alternatives and eliminating failures.

Ubiquitous: existing or found everywhere

***Wood delicacy*:** the state of wood needing careful or deft handling.

***Wood Sculpture*:** three dimensional wood images, either in the round or relief.

Woomeint: wood and metal integrated art or wood and metal integration

1.9 Importance of the Study

The importance of this research is in four areas. These are to:

- education
- the art students
- wood and metal technologists and
- the government

1.9.1 Education

Apart from increasing knowledge in general education, the importance of the project in education can be looked at in two areas. These are:

- Education in art
- Education through art

1.9.1.1 Education in art: this is basically what the stakeholders in art education are to benefit from it. These are as follows:

- The project would be useful to schools offering woodwork and/or metalwork for the teaching and learning of ideas related to the use of both materials (wood and metal) simultaneously.
- It would also make it possible for students and local craftsmen to acquire knowledge of the benefits in the integration of both materials as solution to some basic problems related to the integration of wood and metal that they are deficient in.
- Students well trained in the integration of both materials would be more versatile and be in a better position to train others.
- This project would facilitate the teaching of wood-metal integration like carried out in the Department of Integrated Rural Art and Industry-KNUST.
- This project is also an addition to the language and techniques in art that would gradually foster the scope of creativity and appreciation of art from the schools and to other aspects of the industry.

- This project as a beginning of a new area of study is a contribution to the development of art and also as a base for the development of other areas.

1.9.1.2 Education through art: this is an area where an idea is communicated or imparted through the creative innovation of an artist. In this project certain ideas are communicated that are relevant to the development of other educational modules and the society at large. These are as follows:

The idea of integration, that is basically putting together two or more substances with the aim of achieving ultimate results that each of the substances could not produce, is communicated in other forms like unity is strength and too heads are better than one. This idea of integration in the research is a confirmation of the reality of these philosophies for the edification of other fields of study towards national development.

Another idea propounded by this project is the fact that a better idea can result from two or more ideas. This will encourage and educate the user of this project in the sharing of ideas and keeping away from selfishness.

This project also communicates the relevance of art and for that matter art education to other education modules. This will help promote the adaptation of some creative ideas in art that are relevant to other areas for the development of education.

1.9.2 The art students

The project is also important in the development of the art student in the following areas:

- The project is a good guide and a creativity aid that would facilitate the development of students in the detail use of wood and metal in the creation of art.

- The students trained in this field would apart from being capable of employing themselves by producing unique works of art for sale or producing solution for the metal or wood industry through the integration of the two materials for economic gains, they would also be capable of communicating what they do more effectively among themselves to speed up proceedings in the adventure.

- The project is also an area that would contribute to students' developmental processes of the 3Hs-the development of the Hand, the Head and the Heart, to make them more efficient in their problem solving activities especially in the use of wood and metal.

1.9.3 Wood and metal technologists

Wood and metal technologists as a target group would also benefit in the following areas:

- This project will serve as a guide to wood and metal technologists for easy diversification of their products to feed the contemporary market that is most of the time hungry for new things.

- This project is a reason for wood and metal technologist to embark on collaboration ventures as a means to promote the formation of guilds necessary for their development and for national development.

- This project is also a guide to wood technologists who inevitably would use metal to identify new ways of using them to improve on their trade for the benefit of the industry and the country at large.

- Similarly metal technologists who certainly use wood would also benefit from this project by capitalising on some of the ideas to improve their product.

- The project is also a guide for wood technologist on how to use metal to curtail some of the restrictions on wood for the development of their wood art forms.

- This project will also educate wood technologist on how metal can help to cut down on the excessive usage of wood. This will also minimise the pressure on Ghana's dear forest.

1.9.4 The Government

- The library reference material aspect of the project and the computer integrated aspect would contribute to the plan 2K14 (strategic plan) of the Kwame Nkrumah University of Science and Technology designed to fit into the new education review by government which has one of its intensions geared towards the improvement of the information facilities such libraries and the efficient application of the computer in the various educational modules.

- This project also communicates certain wood and metal integration processes that are geared towards the utilisation of wood industrial by-product. Example wood off cuts, wood shaves etc that can be used for useful works of art. This would cut down on the waste the industries produce to save the environment and lessen the burden related to waste management in the industry.

1.10 Organisation of the rest of the Text

Chapter two which follows, review literature related to the study: that establishes the theoretical foundation for the study. Chapter three – which is the Research Methodology spells out the strategic approach to the project. Following this is Chapter four which recounts the Presentation and discussion of findings. Chapter five outlines the procedures used in the execution of the project (practical demonstration of findings). Chapter six which follows after this is the presentation and discussion of two wood metal integrated works ("Metinwoods") from the research. Chapter seven which concludes the study is the summary of findings, conclusions and recommendations. This is which is followed by references and appendices

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Overview

The study seeks to establish creative application of metals to wood art forms under the topic "creative integration of metals into wood art forms". This could not be achieved successfully without any investigation into the research trends of the paradigm. Though much has not been done specifically in the area, there are theories, works or researches in the area of integration, timber, metals not withstanding instances of joint application of wood and metal. These aspects the researcher deems very relevant to the research are reviewed under the following topics: what is integration, the essence of integration, wood (source and classification, components, structure, conversion and processing, seasoning, movement of timber, defects, advantages and disadvantages, properties and utilisation); metal (types, structure, production, conversion, recycling, properties, uses, selected metal for the project); not withstanding instances of wood metal integration and their characteristics.

2.2 What is integration?

On searchcrm.techtarget.com (January 8, 2008), it is states that integration comes from a Latin word *integer*, meaning whole or entire. It further states that integration also means combining parts so that they work together or form a whole. However these parts are of different functions but each of the functions is a subset of the main function in the integration. It also refers to an activity by companies that specialise in bringing different manufactured products together into a smoothly working system. In this case the individual parts are produced with a unifying purpose.

From the above, if the base Latin word for integration means whole or entire, then the question becomes what the whole or entire is? In other words the wholeness or entirety must be defined in order to determine the integral components; the relevant constituents; or the pertinent essentials of the integration. This also means that, without the clear definition of the wholeness or entirety, the success of integration cannot be measured.

The document further mentions the common usages of integration and the first on the list is quoted below:

"Integration during product development is a process in which separately produced components or subsystems are combined and problems in their interactions are addressed."

This is a point that indicates that integration goes beyond just combination of parts, but combination of parts in a way that makes the result seen not as a group but a whole. Under this situation the point centres around the fact that when the conflict within the combination is addressed, the existence of the group changes, and with reference to the essence of the integration one cannot really differentiate or tell which member is more important. This is because there would not be the realisation of wholeness of purpose in the absence of a member because the roles of all the members are well defined and important. This therefore implies that the whole is nothing but the integration which is the solution to a predefined problem. In view of that integration also means wholeness of a solution.

The Cambridge International Dictionary of English defines integration in two terms: **"*of people*"-** to integrate is to mix with and join society or a group of people, often changing to suit their way of life, habits and customs.

"*Of systems and things*"-to integrate is to be suitable for each other and combine with each other or combine with what already exists. In both cases suitability is the key word which means that there can be a combination without integration when the members in the combination are not suitable for one another in terms of the common purpose they are coming together to serve. Integration therefore can also be termed a suitable combination of members to form a unified whole.

Moreover Boller et al (2004) define a system of farming known as integrated production whose primary aim is sustainability. The system of farming is designed such that the production is a cycle which makes room for the utilisation of everything including by-products. This is done by the coalescing of related farming practices in a dependency cycle which does not allow waste with the aim of reducing environmental hazard caused by the disposal of waste. This idea of attaching waste absorption and utilisation system to a production system is also employed in this project. Therefore metal designing and production to help make use of the industrial waste of wood become a waste absorption and utilisation system.

From the above definitions, integration is a result of unification of agreeing component or like-minded or intended members for the achievement of a common predefined purpose. This is also the foundation on which survival of the universe is based. This is because, the cycles of life is designed such that all things directly or indirectly affect one another in one way or the other in a perfect cycle that ensures the sustenance of the earth, therefore if perfection or the achievement of positive results becomes the ultimate goal of an endeavour, then there is the need to make scrupulous investigation in order to combine only agreeing relevant information or resources into a sure constructive solution. This coalescing of agreeing resources relevant to the solution of a well defined problem is called integration, which is the basis of this project.

2.3 The Essence of Integration

Can one imagine a house organised in only one material like wood, cement, metal or plastic? If one does, one may realise how costly, nondurable, uncomfortable or weak such a structure may be. One may also realise the essence of organising and putting together materials regarding their strength and advantages and also considering how suitable they may be at each time.

Has it ever also occurred to one if situations were such that things appear the same every time? Does one not think the environment and for that matter the world would have been boring? As it is said: man is never satisfied with his present conditions, man is always in the lookout for new things: new ideas, new innovation, new feelings, new environments etc. Anna Quindlen: a U.S. journalist and an author as quoted is McCreight (1991) states that "I don't yearn for the way things were and I don't honour the status quo. I'm always looking at how things can be." He makes no difference because new things edge life on and for that matter draw the most attention most of the time and are often more appreciable.

The basic importance of integration is to achieve optimum results through mutual support of the integrants. As the adage goes "unity is strength", the unity of processes and materials are no exception. This unity of processes in their right proportion suitable for an intended purpose becomes integration. The already manufactured components brought together are most often made up of different materials of different behavioural and physical properties. These materials have different roles to play in the product. These roles are aesthetic, scientific and ergonomic which are all functional purposes that constitute the quality of the product. Thus apart from the product's ability to serve its primary purpose it is also deemed important that it serves other purposes such as pleasing to the eye, and also being friendly to those who use it.

However the artist apart from creating things with practical functions also produces works that should only be perceived and appreciated. They are professionals who always seek to create something new. Sometimes, unlike the engineer who will introduce an integral material based on their function, an artist can do that for pleasure or for the sake of having been fed up with the old trend. Also social interaction and societal influence has also resulted in the synthesis of the two ideas. Now there are several works that combine aesthetics and function but are not done by supposed artists but are done because of their essence.

Johnston (1989) owns the patent to a wood and metal integration with a title statement "a combination of metal and wood window frame assembly having exterior and interior faces, comprising: a second wooden frame element which is rigidly deep-key interconnected to at least one of the said metal frame elements for providing an interior wooden aesthetic covering to the said metal frame member as well as for providing structural rigidity to the overall combination". In this case there are two materials in question: wood and metal serving the purpose of a window frame for caging a window. But the question is why the two materials?

The answer is that, in the combination the design of the metal frame was such that in as much as it was needed for the protections of the frame from damage by the weather and other living things, the metal was managed in order to avoid its excessive use resulting in the devoid of structural rigidity. Then with regards to the wood, despite its performance in the structural rigidity in the frame its textural beauty was also considered for the inner look of the frame. The cross section is shown in figure 2.1 below.

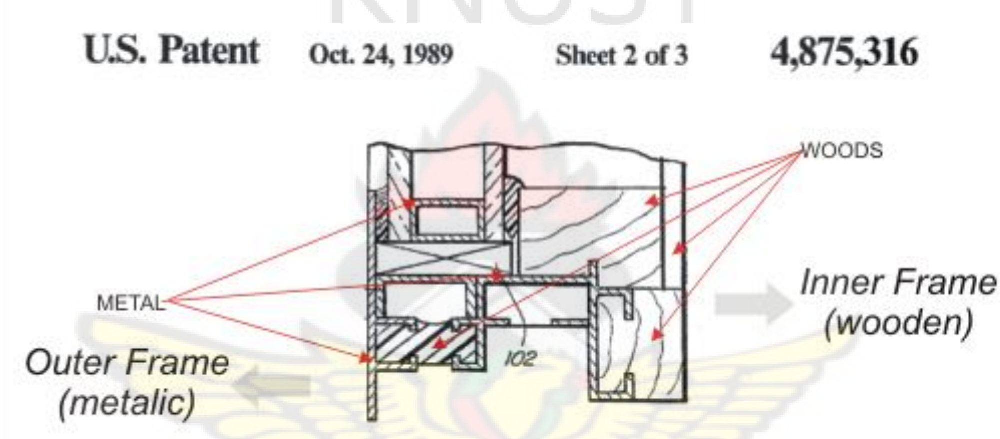


Figure 2.1 Wood and metal combination frame

Source: Johnston, 1989

Apart from other materials that may exist in the integration, the following deductions are made centring on only wood and metal which are the materials under emphasis. It could therefore be deduce that:

- The metal may have been chosen as the base material due to its natural forming and sizing tendencies that makes it applicable to complex form.

- Also the thin cross section of the metal suggests a wise application of the non renewable material that must also be managed so one can have them always.

- The metal was also chosen by the designer to face the outside probably because of its natural ability to withstand the harsh weather conditions like rain, temperature and climatic variations better than the wood.

- Apart from the wood inducing structural rigidity, it is a material of choice because it is a renewable material and for that matter cheaper.

- The wood again is a good insulator of temperature that could prevent harsh temperature from the outside from penetrating the frames through conduction.

Considering the points above it is definite that the quality of the window frame will never be as it is in the absence of one of the materials. This is so because each of the materials plays a major role in the frame that contributes to its quality: aesthetics, strength, durability, workability and peculiarity. This makes it a good example of material integration.

Rudd (2003) also owns a patent related to wood and metal integration, this is metal and wood composites used to create framing members (studs and tracks, joists and bands, rafters, headers etc), for lightweight construction. He says the metal is utilised for its high strength, resistance to rot and insects, cost stability and potentially lower cost through recycling. This is represented in figure 2.2 -sourced from US Patent number: 4875316.

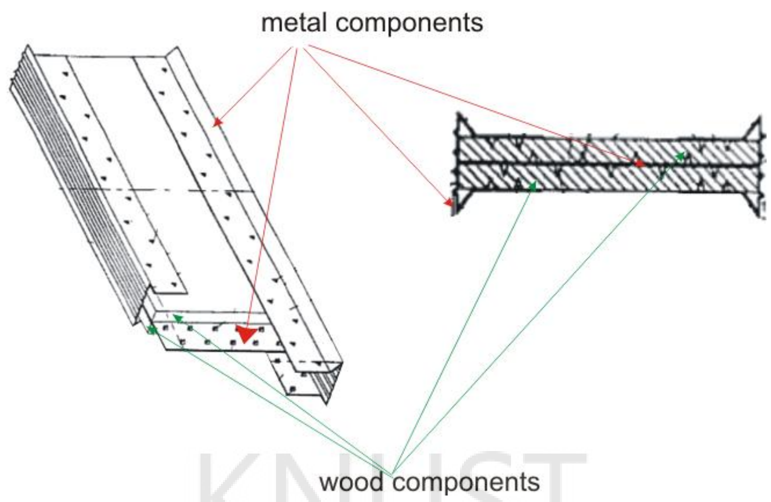


Figure 2.2: Wood and metal framing member

Source: Rudd, 2003

This integration is focused on creating a lightweight building material without sacrificing strength and durability. In this case metal alone for such a member could only cater for strength and durability sacrificing light weight and cost effectiveness. Wood on the other hand would cater for light weight and cost effectiveness sacrificing the other essential qualities: strength and durability. This means that one of the materials in the absence of the other will surely result in the devoid of the overall quality of the product. That notwithstanding, the problem that might have emerged in their integration was not taken for granted: the ability of wood to slip over metal when both surfaces are straight (devoid of friction). Therefore in the figure above it is obvious that there are friction mechanisms in the form of pricks on the metal that holds the wood in place. The totality of the above contributes to the success of the integration that comprises proper material management and utilisation, cost effectiveness, strength, durability and weight control.

Rarely can a material achieve a result solely without one problem or the other, probably of over exploitation. One of the theories of aesthetics states that beauty lies between two extremes: extreme beauty and extreme ugliness. and since aesthetics is one of the qualities of a product, it could not be in isolation from the other qualities. For example there can be no contrast in the mist of uniform textures, and since the same materials or ideas often give similar result it becomes necessary to put different materials or ideas together to achieve a difference. A difference that is more appealing to the eye because it is new; a difference that falls within the extremes of its constituents: the essence of integration. In relation to this theory, wood and metal represents the two extremes.

2.4 Literature on Wood

Since the project is not targeted at the mere combination of wood and metal for production but a sustainable integration, the nature of wood, its composition and traditional applications becomes pertinent, in order that its application with metal can be done more rationally.

2.4.1 Wood

Wood is a ubiquitous bio-material obtained from certain woody plants. Oteng-Amoako et al, (2006), advocate that, wood is the principal strengthening and water conduction tissues of the stems and roots of mainly trees. In relation to this the World Book Encyclopaedia states that, "wood is the tough inner portion beneath the bark of trees, shrubs and certain plants". As in other literature the difference between the two definitions is the fact that one is based on the physical appearance of the material and the other based on the scientific function of it as part of the parent tree. Wood is heterogeneous, hygroscopic, cellular and anisotropic and may also refer to other plant materials and tissues with comparable properties (http://en.wikipedia.org/wood, 2008).

However the material engineers who look more into the composition of materials describe wood as a natural composite (composition of other materials) - (Van Vlack, 1973).

These account for the fact that different people interpret the nature of the material differently and hence its varied applications that include extraction of raw materials from it, engineering of the material to suit different purposes and also its application also in building and decoration of forms. This also implies that information of wood available to the various areas of wood specialisation contribute to the success of the respective areas. This necessitates the organisation of information relevant in the intercommunication of wood and metal in the case of this research for the assurance of its success.

2.4.2 Wood source and classification

Wood is varied in appearance, behaviour and structure owing to the fact that, it is obtained from different plants that grow in different environments under different conditions. It is also necessary for the artist to have a fair knowledge of the sources and characteristics of wood and its parent tree in its natural environment. This is because the artist apart from sourcing labelled wood from the timber market might for one reason or the other want to also obtain wood from the natural environment. Also apart from the general classification of wood species and their behaviour, different parts of the wood or trees behave differently, hence the essence of the in-depth knowledge of this to make it possible for the artist to make the right choice at the right time.

The trees from which wood is obtained can be designated into one of two groups in the plants classification. These are Endogens (monocotyledons) and Exogens (dicotyledons)-(Chapman, 2001).

Chapman also elaborates on the two categories as follows:

Endogens (monocotyledons): these are trees in which most of the growth takes place inwardly in a hollow stem. Examples he gave include bamboo, palm, yucca and tree ferns. According to him, this species has little or no commercial value which is not the case in today's economic terms: looking at what is happening in China in relation to bamboo and in Malaysia in relation to palm.

Exogens (dicotyledons): these are outward growing and increase in size by adding new tissues in their growing season in the form of individual layers of concentric growth rings. The valuable exogens are divided into two classes; these are angiosperm well known as deciduous trees and gymnosperm also well known as coniferous.

Moreover both the class liliopsida (monocotyledon) and magnoliopsida (dicotyledon) belong to the angiosperm group of vascular plants known as the division anthophyta (flowering plants)-(Crosby et al., 2007).

2.4.3 Hard wood and soft wood

Woods from exogenous plants are classified into two main groups depending on the tree from which they come. Woods from broad-leaved trees are called hardwoods, and woods from coniferous trees are called softwoods, regardless of their actual hardness (Redmond, 2007).

Figure 2.3: An exogenous plant

Source: Microsoft® Student 2008

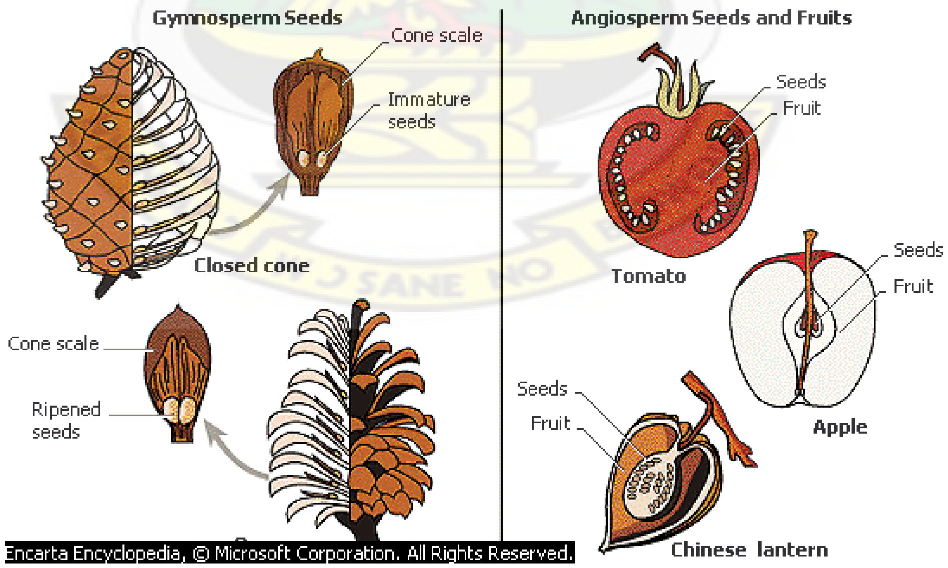


Figure 2.4: Gymnosperm seeds and angiosperm seeds in contrast

Source: Microsoft® Student 2008

Other wood writers and scientists such as Bridgewater A. and Bridgewater G. (2007) also advocate the general classification of wood under hardwood and softwood. They state that, *hard wood* are obtained from broad leafed deciduous trees that drop their leafs annually and soft *woods* are obtained from coniferous or cone-bearing evergreen trees that retain their foliage though there are exceptions.

But the fact remains that softwood are fast growing than hardwood. Also softwood contains more sap in them than hardwood. This also means that apart from identifying wood by the kind of flowers, seeds or fruits from the parent tree, the amount of fluid that comes out by cutting the back of a tree can assist the wood artist in determining whether the wood is soft or hard.

2.4.4 Components of wood

The component of wood can be best understood by its *basic chemical composition.* According to Tsoumis (1991), the elementary composition of wood is such that there are no important differences. He mentions the principal chemical element of wood as Carbon (C), Hydrogen (H), Oxygen (O) and Nitrogen (N) in small amounts. Also he states that the chemical analyses of a number of species (hardwood and softwood) show the proportions of the element in percent of the oven dry weight to be approximately as the following:

- Carbon (C) = 49% to 50%
- Hydrogen (H) = 6%
- Oxygen (O) = 44% - 45%
- Nitrogen (N) = 0.1% - 1%

Tsoumis (1991) also gives accounts of certain amount of mineral element that exists in wood ash that are seldom 0.2% or higher than 1% of oven dry weight of wood. These are principally calcium (C), potassium (K) and magnesium (M).

Organic components of wood: according to Tsoumis carbon, hydrogen and oxygen combine to form the principal organic components of wood structure namely: cellulose, hemicelluloses, lignin and small amount of pectic substances. According to him:

> Quantitatively, cellulose and the other chemical constituents are contained in wood in the following proportions (in percentage of the oven-dry weight of wood): cellulose 40–50 percent (about the same in softwoods and hardwoods), hemicelluloses 20 percent in softwoods and 15–35 percent in hardwoods, lignin 25–35 percent in softwoods and 17–25 percent in hardwoods, and pectic substances in very small proportion. In addition, wood contains extractives (gums, fats, resins, waxes, sugars, oils, starches, alkaloids, and tannins) in various amounts (usually 1–10 percent but sometimes 30 percent or more). Extractives are not structural components but inclusions in cell cavities and cell walls; they can be removed without changing the wood structure.

These confirm the composite nature of wood and dealing with it means dealing with multi materials, hence the essence for the consideration of relevant factors.

Cellular composition of wood: the cellular structure of wood is a result of specialised cells capable of division. These cells compose the so called generative or meristematic tissues responsible for the length growth (optical growth) and diameter growth (secondary growth) of the tree: the optical growth influenced by the optical meristems and the secondary growth influenced by the lateral meristem. However results of these quite vary between softwood and hardwood.

This growth system results in two categories of cells: the ray cells and the longitudinal cells summarised below in figure 2.5.

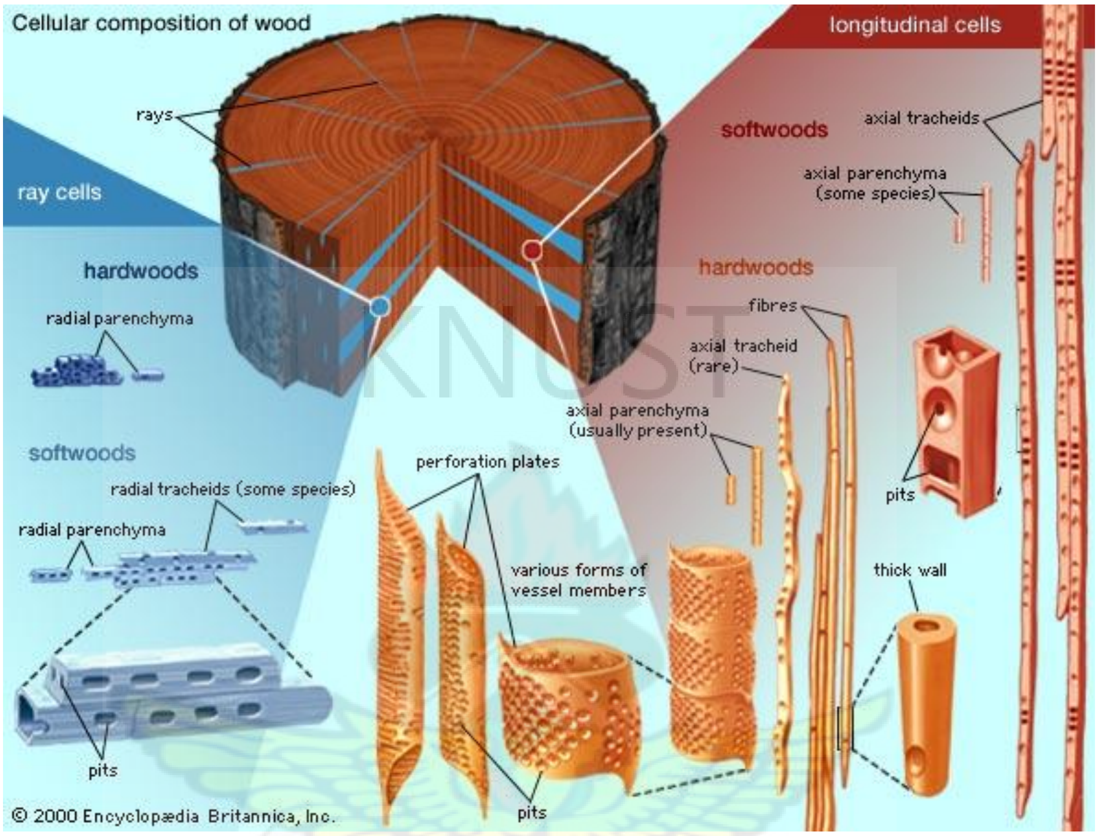


Figure 2.5: Cellular composition of wood

Source: Encyclopædia Britannica, Inc. 2008

The summary above illustrates the differences in cell structure which has a direct relation to the behaviour of the wood as well as the variation of behaviour in different species. The direction of the pores shows the direction of moisture movement in the wood. The thick cell walls of the hardwood giving a clue to why they are more denser than softwood in most cases. The pits on the tissues also indicate the wood’s ability to hold water and not draining off easily. The vertical and horizontal arrangement of the cell explains the strength distributions within the structure. The variations in cell distribution between the radial and axial also explain why the wood is stronger when sawn in certain directions than others. The cross nature of the cells and the wavy nature of the cells explain the looks of figure in wood. Theses among others explain the relevance of the cellular structure of wood to the artist with limitless ideas.

2.4.5 The structure of wood

The structure of wood is the architectural organisation of the wood that comprises the nature and arrangement of the physical (macroscopic, microscopic, ultramicroscopic) and chemical building components (Tsoumis, 1991).

By this statement it means that the structure of wood comes in two categories, those aspects that can be seen with the naked eyes and/or in conjunction with an eye aid: such as lenses and the other aspects that have to do with the chemical composition of the material.

2.4.6 The physical structure of wood

To Chapman and Peace (2001), the usefulness of various sections of wood can also be determined by their roles played in the mother tree before they are harvested. This they capture under a broader topic- *growth and structure* as follows:

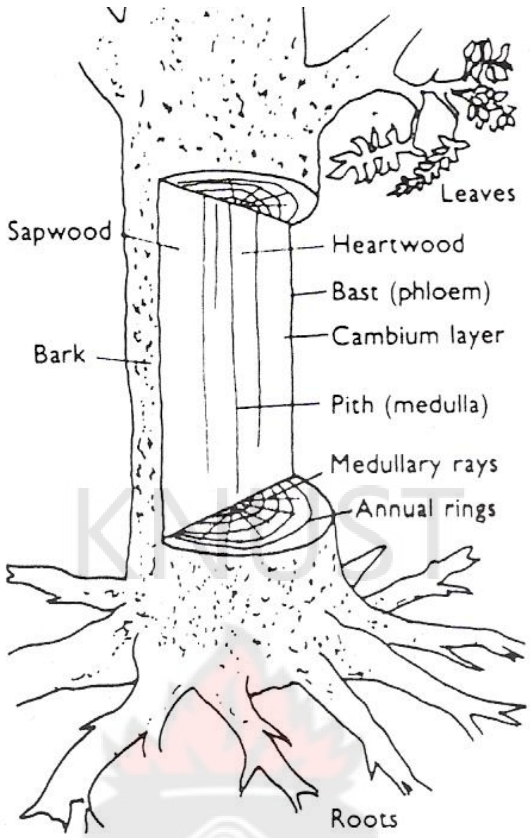


Figure 2.6: The physical structure of woody tree

Source: Chapman and Peace, 2001

According to them although hardwoods and softwoods have different types of cells and differ in the formation of tissues, their growth and overall structure are sufficiently similar to allow a combined study of how a tree grows. For that matter, as shown in figure 2.6 above is the structure of a typical tree, together with the cross-section of its trunk. The function of each labelled part is given as follows:

Roots**:** The root structure begins to grow as the seed sprouts and continues to develop through the sapling stage. Roots serve two basic purposes:

1. Root hairs absorb water and dissolve mineral salts to make crude sap.

2. They support and anchor the tree.

Sapwood**:** Sapwood is the newly formed wood made up of xylem cells. Sap water and mineral salts are carried through these cells up the tree by suction pressure to the leaves, where they are manufactured into food.

Often light in colour and quite soft, it is least resistant to decay and is prone to attack by insects and fungi.

In the young tree, all the stem and branches are required for conveying sap, but as the girth of the trunk increases the proportion of sapwood becomes progressively smaller.

Heartwood**:** Heartwood was once sapwood, which has matured and become inactive. Heartwood is made up of lignified (hardened) cells which serve to give strength and support the tree and provide storage for waste products such as resin.

It is much harder, stronger and often darker in colour than sapwood, and provides the most commercially useful part of the tree.

Pith or (medulla)**:** The pith is the centre of the trunk. It is the remains of the earliest growth of the sapling and is often soft. It is to be found throughout the length of the tree, forming in the crown or leading shoot as it extends upwards.

Medullary rays**:** These thin sheets of tissues or rays extend from the cambium to the pith (medulla) like the spokes of a wheel. They conduct and distribute waste products horizontally for storage, in the mature cells. They vary considerably in thickness and visibility, forming figure or silver grain, in some wood.

Leaves**:** Leaves take in carbon dioxide from the atmosphere and sunlight is absorbed by the chlorophyll (green pigment) in the leaves. The energy from the sun is used to synthesise organic compounds (in the form of sugars and starches) from carbon dioxide 'and water. This complex chemical reaction is known as photosynthesis.

The leaf surface has tiny vents or pores (stomata). Oxygen and carbon dioxide enter and leave through the stomata, and water vapour is also lost through the stomata, a process known as transpiration.

During daylight hours, when photosynthesis is taking place, carbon dioxide is absorbed and any excess oxygen is expelled.

At night when photosynthesis stops, excess carbon dioxide is expelled through the stomata. In this way trees help to maintain the .delicate balance of oxygen and carbon dioxide in the atmosphere.

Bark**:** Bark is a skin or protective coating which prevents transpiration from the trunk and serves to protect the tree from damage and the extremes of temperature. It is made from the outer layers of bast or phloem as they die, and expands as the tree grows, with the outer, corky layer becoming hard.

Bast or phloem**:** Bast or phloem is the inner bark made up of living tissue (phloem cells) which carries food in the form of sugars, amino acids to make up proteins, and hormones which control growth. These are mainly carried downwards from the leaves to other parts of the tree.

Cambium layer: This completely surrounds the sapwood and is where growth takes place by cell division. New wood cells (xylem) are formed on the inside and, to a lesser extent, new phloem (bast) cells on the outside.

Annual rings: These are commonly called growth rings, because they represent one season's growth. Each ring or band is made up of two distinct layers, the spring wood and the summer wood. The inner most spring wood consists of large, soft, thin-walled cells which help the flow of sap. In summer, with less sap, the cells are smaller, thicker walled and denser. It is this density which often accounts for darker variations in colour and texture. Viewed in cross-section, this growth cycle gives distinctive bands, by which the age of the tree can easily be determined.

By contrast, some tropical timbers show no visible annual rings because growth takes place uniformly throughout the year.

Cork cambium: Royal Forestry Society 2010 highlights the cork cambium. This is a zone of actively dividing tissue near the outer surface of a tree that produces cork. This is more significant in trees noted for cork production like the cork oak. This can be identified in fig. 2.7.

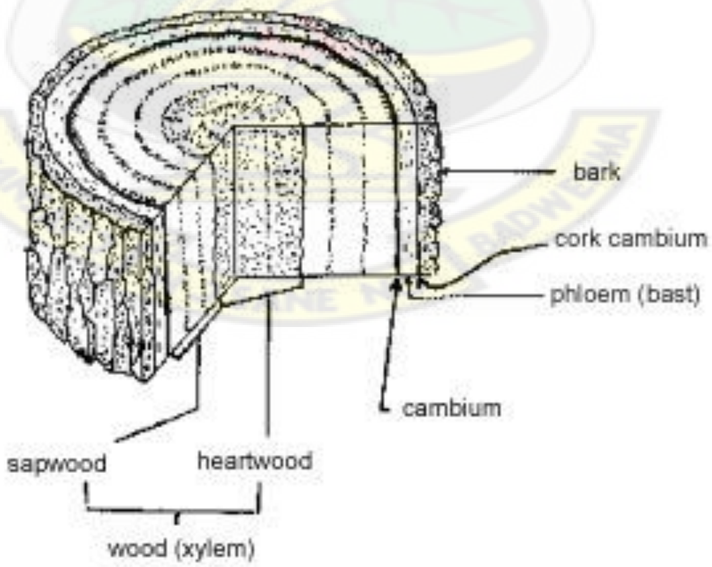


Figure 2.7: The structure of a corky wood

Source: © J. Jackson –Royal Forestry Society website

In spite of one exception or the other as shown in Figure 2.7, Chapman and Peace (2001), advocate that wood cells vary in size shape and function. According to them "this permits a botanical distinction to be made between hardwoods and softwoods based on the arrangements and types of cells". This they do by the consideration of the unique cells components of each category and also the differences that exist in the common cells.

2.4.7 The structure of softwood

The structure of softwood is more primitive than hardwood. The main types of cells are:

a) Tracheids

b) Parenchymas

c) Resin canals

Tracheids – in softwoods the trachieds form the bulk of the timber. They are thin, elongated tubes sealed at the ends and spliced together in the direction of growth. Communication between the cells for the passage of sap and food takes place through small openings in the cell wall known as the *pits*.

As they age the cells harden and serve to support the tree. They form in radial rows and it is the direction in which these cells lie that makes the grain of the wood.

Parenchymas – these are smaller than tracheids, with simple type pits, making up the remaining cells. These include *rays*, which in the case of softwoods are usually thin, only one or two cells thick. Rays are almost invisible, but they are a reliable means of identification between species when magnified,

Resin canals – these occur in most conifers (softwood trees) and are indication of the function of the rays, thus the means by which resins and gums (waste products) are carried (Chapman and Peace, 2001).

2.4.8 The structure of hardwood

This is characterised by *Fibres, Vessels* or *pores* and *Parenchymas.* See figures 2.8 and 2.9.

Fibres – unlike softwood fibres make up the bulk of hardwoods. They can be campared to the tracheids in conifers, but they are very much smaller and sharper, giving mechanical support to the tree. On the contrary to tracheids, they do not also carry sap and are not arranged in any form or pattern.

Vessels or pores – these are found only in hardwoods, they provide a positive means of identification. They form ducts or tubes and extend in the whole length of the tree with the primary function of carrying food. They are numerous and often clearly visible, and appear in two different forms dividing hardwoods, into two groups:

1. Diffuse porous - when they are equally spread throughout the tree (examples are tropical hardwoods like ebony and mahogany).

2, Ring porous - when they appear somewhat large in the early spring growth and considerably smaller in the summer. However, when the pores are only slightly larger than those produced later, they are called 'semi-ring porous' (e.g. walnut). .

Parenchymas –apart from existing in softwood, these are also found in hardwoods, forming radially in the rays which are often more outstanding. In oak especially, they can be 20 to 30 cells thick, producing the familiar silver grain. In some timbers these cells mark the end of each season's growth. Much rarer, in Burma teak, they form at the start of the growth ring (Chapman and Peace, 2001).

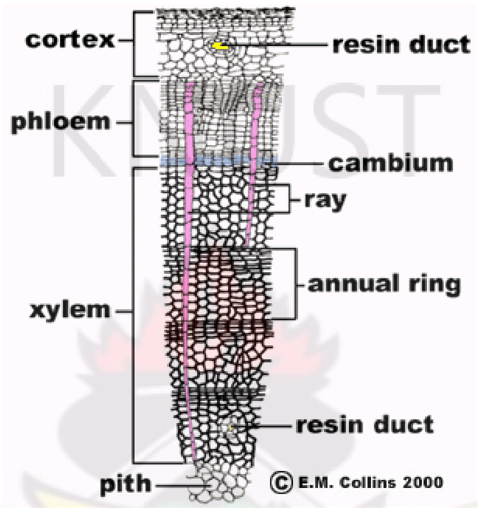


Figure 2.8: Softwood -microscopic view

Source: Collins, 2000

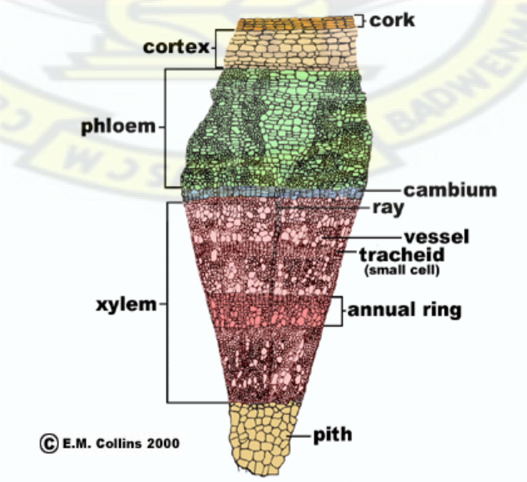


Figure 2.9: Hardwood -microscopic view

Source: W.P. Armstrong 1999

2.4.9 Anatomy of Monocot Stems

Monocot stems, such as corn, palms and bamboos, do not have a vascular cambium and do not exhibit secondary growth by the production of concentric annual rings. They cannot increase in girth by adding lateral layers of cells as in conifers and woody dicots. Instead, they have scattered vascular bundles composed of xylem and phloem tissue. Each bundle is surrounded by a ring of cells called a bundle sheath. The structural strength and hardness of woody monocots is due to clusters of heavily lignified tracheids and fibres associated with the vascular bundles. The following illustrations and photos show scattered vascular bundles in the cross sections of corn (Zea mays) stem (© W.P. Armstrong 1999). See figures 2.10a and 2.10b.

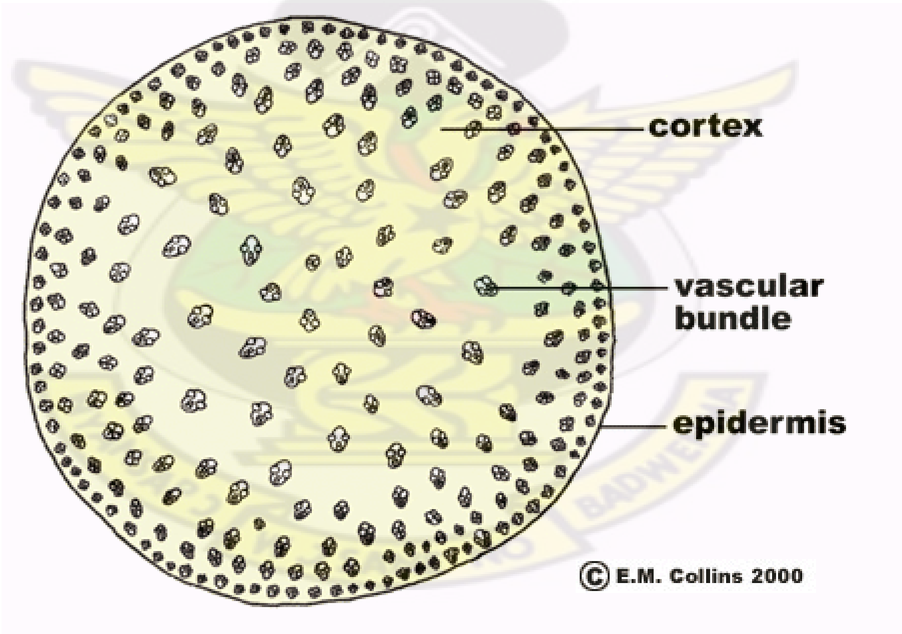


Figure 2.10a: The anatomy of a non woody monocot stem

Source: W.P. Armstrong, 1999

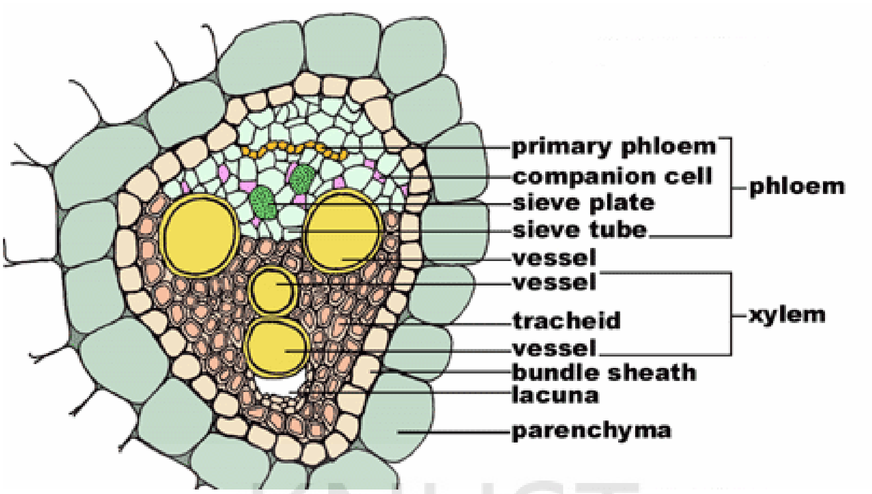


Figure 2.10b: The anatomy of a woody monocot stem

Source: W.P. Armstrong, 1999

This arrangement of cells could also not be different from what exists in the woody monocots like the palms. Plate 2.1 shows the trunk of a California fan palm (Washingtonia filifera). The palm was washed down the steep canyon during the flash flood of September 2004. The fibrous strands are vascular bundles composed of lignified cells.

Plate 2.1: The fibrous nature of woody monocots

Source: W.P. Armstrong, 2006

2.4.10 Processing of wood into good lumber

Bridgewater A. and Bridgewater G. (2007) opine that selecting solid wood is exciting, but one must avoid making expensive mistakes, such as the wrong type of wood, a poor quality wood. The best way of ensuring that one finishes up with wood that is good for its purpose is to know something about conversion, seasoning, grain and faults.

2.4.11 Conversion of wood

With reference to various available literature, wood conversion is the process of cutting wood into usable piece which cannot be achieved without considering the nature of wood in relation to its physical anatomy as shown in Figure 2.11. This is because the angle at which the saw meets the growth ring determines the behaviour, figure and strength of the wood.

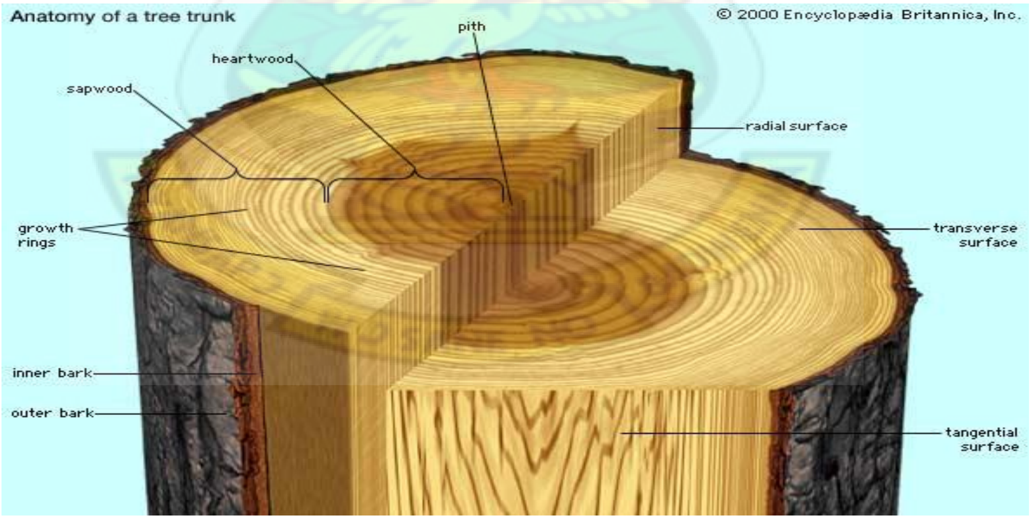


Figure 2.11: The anatomy of a tree trunk

Source: Encyclopædia Britannica, Inc. 2008

The size, shape and grain pattern of timber as purchased from the supplier are determined by the way the tree is sawn (converted). There are many traditional ways of converting a tree. It can be plain sawn to make a stack of planks, radial or quarter sawn, modularly sawn etc. The conversion method, and the resultant angle at which the growth rings within the tree meet the sawn face, are the factors that shape the grain as they appear on the finished lumber (A. Bridgewater and G. Bridgewater, 2007).

Conversion is the term giving to sawing the log into marketable timber. Many factors affect how this is achieved. Some of these are: the type of timber, market requirement and eventual use. It can also promote features like grain pattern and figure and also an increase in stability in use.

In some cases the conversion is done without stripping off the back in order to prevent rapid drying unlike most exported timbers that are debarked before shipping to avoid insect contamination. Bulk of timber is also sometimes produced which involve only the removal of the sapwood. However two basic methods are used in conversion, these are: Slab, plain or through and through sawing and Quarter (radial) sawing (Chapman and Peace, 2001).

Apart from the varied suitable conversion methods, Hilton (1980) also emphasises conversion as an effective means of production management. According to him conversion based on the intended use of the wood ensures that the required shapes and sizes of the material are always made available to avoid extra work by managing extraneous materials. This case he establishes as follows:

The sawing of logs, or breaking down into various shaped and sized pieces for specific purposes, is known as conversion. There are very few firms which take the logs in the round state. Timber is purchased mostly cut through and through, quartered or squared and carried out at the place of shipment in the case of softwoods. Purchasing timber in this way does mean that the buyer is able to select his material with the finished product in mind noting the quality, texture, grain, colour, etc., thus avoiding having to handle unsuitable materials often occupying valuable yard or floor space.

There are several ways of converting a log: Through and through or tangential sawing and Quarter or rift sawing. The term radial or tangential refers to the surfaces of the wood secured by the cut of the saw in relation to the growth rings of the tree. (Hilton)

2.4.11.1 Through and through or tangential sawing

This is the same as slab or plain as described by Chapman and Peace (2001). This is the straight forward cutting of the log into any required thickness without any regard for showing particular grains but with a minimum of waste. This plain method is usually the cheapest form of conversion. “In this method most of the boards will be flat sawn which means that the growth rings meet the face of the board in any part of an angle of less than 45 degrees”

Tangential sawing is adopted for timber types having clearly defined growth rings. In this method the through sawing happens such that boards have their faces tangential to the growth rings. When converting softwoods for floor joists and the like, where strength is most important, the lengths of timber must be tangentially sawn (Hilton, 1980).

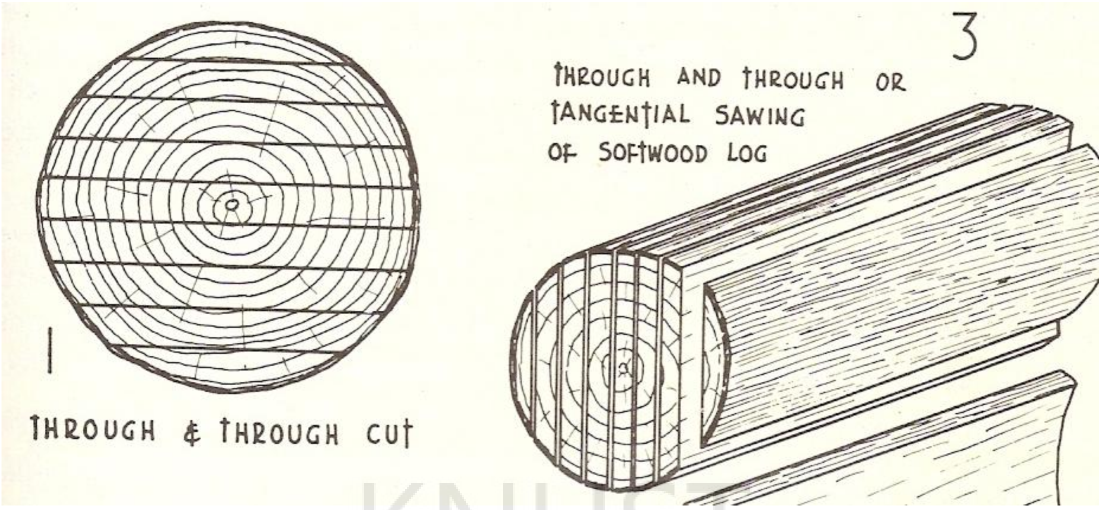


Figure 2.12: Through and through or tangential sawing

Source: Hilton, 1980

Though the through and through method and the tangential method of sawing appear to be the same and are used interchangeably, they are not. This is so because in tangential sawing the sawing is always through but in the through and through method the face of the lumber will not always be tangential to the growth rings especially when it is either running through the pith or taking place in wood without clearly defined grains.

2.4.11.2 Quarter or rift sawing

Quarter or rift sawing also known as radial sawing is a method of conversion in which the growth rings meet the face of the board at an angle of not less than 45 degrees. In achieving this, certain percentages of the log is lost or wasted in the process making quarter sawn lumber more expensive in relative terms with the plain methods. Though quarter sawn woods are expensive they carry the advantage of less shrinkage and also the provision of a more even ware in terms of figure and structural variation.

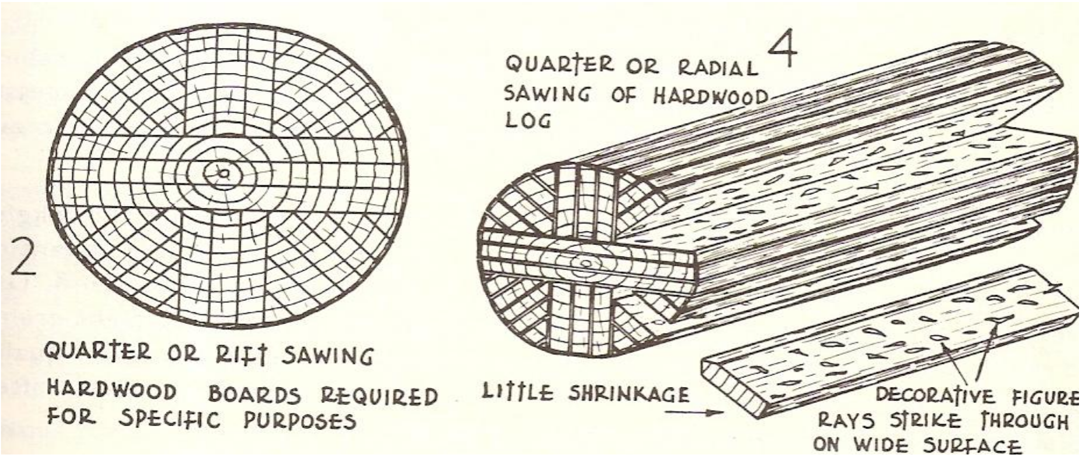


Figure 2.13: Quarter or rift sawing

Source: Hilton, 1980

__2.4.11.3 Operations in conversion__

Further breakdown of wood is accomplished in one or more operations. For example, a combination of circular and frame saws, or two frame saws in series, may be used. The first saw removes slabs (the outside pieces cut from a log) and, in certain cases, some boards. The piece produced is then turned 90° and introduced to the second saw, which converts it into boards (cant sawing). The second operation may be considered as resawing. In general, resawing consists of either dividing thick boards into thinner ones or producing boards from slabs. Ripping, or edging, is the removal of wane (edge areas with bark or some missing wood) from the sides of boards, frequently done by passing the board through a machine that has two small circular saw blades mounted on a shaft. One blade is stationary and the other can be moved sideways to set board width. Edging can also be done by chipping in a simultaneous sawing and chipping operation, with the chips directed to pulp, fibreboard, or particleboard manufacture. (Some valuable furniture woods are not edged in the sawmill.) Finally, certain boards are crosscut with trimmers to square their ends and remove defects.

Other examples of combinations of machines used for breakdown include two band saws (used as headsaw and resaw), followed by edger and trimmer, or a series of double band saws with chipping edgers. In some sawmills (and other wood-using industries) computers are employed to regulate positioning of logs and other operations (Tsoumis, 2010).

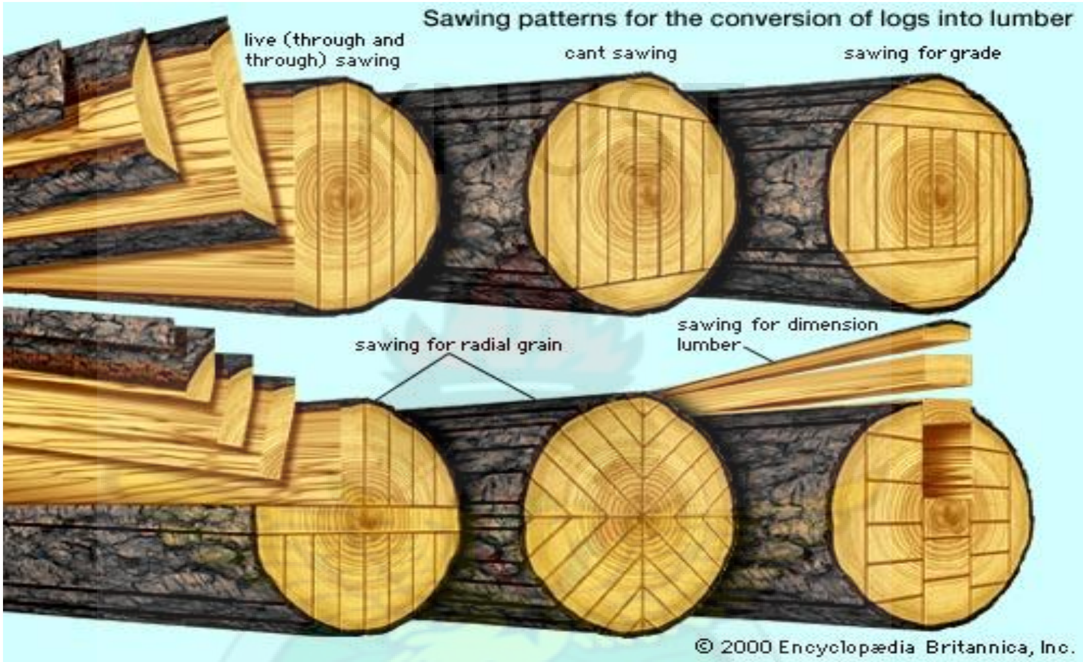


Figure 2.14: Basic log-sawing patterns

Source: Encyclopædia Britannica, Inc. 2008

From figure 2.14, live and cant sawing may be done with a frame saw for simultaneous sawing. In cant sawing, two slabs on opposite sides of the log are removed first, producing a cant for the frame saw. Sawing for grade, done with a band saw, involves turning the log after each cut according to revealed wood quality. Sawing for radial grain enhances the figure of some species and reduces distortions due to shrinkage and swelling; the lumber so produced is sometimes called quarter sawn, especially when the logs are quartered before being sawn into boards.

2.4.12 Seasoning of wood

Another area of concern is the fact that excessive water content of lumbers makes them fail in many instances. Many works by wood researchers emphasise the fact that-the drier the wood the stronger it becomes. In other words, the strength of wood is largely dependent on its moisture content. Apart from this, wet timber is also prone to bacteria attack, fungi growth, other biological degrading agents that may destroy its colour, grain pattern and other desirable properties. Excessive water may also react chemically with any complementary material that may be used in conjunction with the wood negatively.

"A growing tree contains more than its own dry weight in water" the objective of seasoning is to remove excess, unwanted sap and moisture from the timber (Chapman and Peace, 2001).

Timber is a hygroscopic substance, thus gives off water to the dry environment but absorbs water from the damp or wet environment or atmosphere. Consequently dry wood swells in damp environment and shrinks in a dry environment. Wet wood when used in products tends to shrink and poses problems like leaving gaps at joints, poor finishes among others. Seasoning therefore must ensure that the moisture content at the end is less than 20% (Chapman and Peace, 2001).

Chapman and Peace like other wood writers and researchers advocate that, there are two basic methods of seasoning. These are air seasoning and kiln seasoning.

2.4.12.1 Air seasoning of wood

Planks that are seasoned by air drying method are stacked on spacer battens at least 450mm apart. These air spaces between planks are essential to guard against mould or fungal attack. The stack is built in a dry shelter spot to allow air to circulate around it but protect it from rain and direct sunlight. It takes approximately one year to dry every 25mm (1in) of board thickness for hard wood and slightly less for drying soft wood. "With this method the timber can only dry to the ambient humidity-the humidity of the atmosphere it is drying in-which is generally about 15 percent". This is good for exterior use but if the timber is meant for interior use, then this must be reduced in the kiln where the extraction of the moisture can carefully be controlled or regulated (Simpson, 2001).

2.4.12.2 Kiln seasoning of wood

Kiln seasoning is more or less an artificial method of seasoning in which the timber are stacked and put in the dryer in a form of oven known as kiln in which temperature and humidity are carefully controllable. The woods are fed into the kiln on trolleys, then a mixture of hot air and steam is introduced then the humidity is slowly reduced to the moisture content required. The moisture content is normally 8 percent or less, after which the seasoned timber is stored in a controlled environment. If kiln seasoned wood is otherwise placed outside it will take moisture again. (Simpson, 2001)

2.4.12.3 Advantages of seasoning

A well seasoned timber has the following advantages that make it more applicable in production. Chapman and Peace (2001) put these under four tabulates as follows:

a) It makes it immuned from decay and increases it resistance to rot.

b) It increases timber strength and stability.

c) It helps preservatives to penetrate (dry wood takes finishes easily).

d) It makes timber considerably less corrosive to metals.

2.4.13 Other drying methods

Apart from the orthodox seasoning methods available there are other unconventional methods. Hilton (1980) mentions four of such methods. These include:

a) Radioactive frequency heating

b) Temperature gradient method

c) Chemical drying

d) Second seasoning

2.4.13.1 Radioactive frequency heating

In this method the wood is placed between two metal plates to which is applied an electric current oscillating at a very high frequency. This high frequency current, unlike in kiln heating, causes the moisture in wood to heat up at a more or less uniform rate throughout till boiling point is achieved. The steam formed is able to escape freely depending on the power input. This process takes advantage of the water conducting tissues of the wood to eliminate water. The greater the power input the greater the drying rate.

Because of the even heating that takes place in this method, the wood dries at equal rate void of case drying that avoids tension in the wood structure that leads to splitting in most cases (Hilton, 1980).

2.4.13.2 Temperature gradient method

In this method of drying, the core of the wood is heated by radio-frequency and the surface deliberately cooled by moist air thereby inducing moisture movement from the hotter or centre to the cooler surface till the required water is lost from the timber. This process is likewise very expensive (Hilton, 1980).

2.4.13.3 Chemical drying

In this process the surface of the timber in the green state is caused to absorb certain hygroscopic salts such as urea or even sodium chloride (common salt). This salt on the surface tends to keep the timber damp and inhibits shrinkage, but at the same time establishes an osmotic gradient that causes moisture from within to diffuse into the outer surface and then evaporate into the atmosphere. The seasoning in this method is not complete since it is always completed with either air or kiln drying. Another disadvantage is the tendency of discolouring the wood that may be caused by the chemicals involved (Hilton, 1980).

2.4.13.4 Second seasoning

Second seasoning as the name implies is applied to a seasoned timber, however this method of seasoning refers to after the material (wood) is machined into various parts of a product, instead of permanent assemblage, they are held together without wedges or fasteners. This assemblage is left in a convenient room where the moisture content on the various parts attain an equilibrium with its surrounding environment which is necessary as it provides the possibility to change members that may cause the whole project to fail. This renders the work fit for final assemblage prior to delivery on the site where it is meant for (Hilton, 1980).

2.4.14 Moisture content in wood

Though seasoning is aimed at removal of moisture, timber should retain some degree of moisture. Moisture content is the technical description of the amount of moisture contained in the wood which is expressed as a percentage of its dry weight. Seasoning aims to reduce the moisture content to below 18% for general outdoor use, falling to below 14% for indoor use, and to around 10% in centrally heated homes in cold region (Chapman and Peace, 2001).

Chapman and Peace among other works express the percentage of moisture content of wood as follows:

$$\% \text{ moisture content} = \frac{(\text{initial weight} - \text{dry weight}) \times 100}{\text{Dry weight}}$$

2.4.15 Movement of timber

Though the cutting down of trees ends their movement (growth of various parts of the tree), there are other movements that take place in the lifeless cell caused by the movement of water molecules in and out of the wood cells. This movement is normally seen as swelling and shrinkage that come with its own structural effect to the wood.

According to Chapman and Peace, (2001), "shrinkage is closely associated with seasoning. It occurs as the wood dries out. Wood cells contract, which often result in splitting and twisting". Similar work was also done by Hilton (1980). He talks about the variation of size and shape as a response to moisture content by wood and how they can be studied and compared by experiments. According to him the percentage of moisture movement may be calculated as follows:

$$\%\ \text{moisture movement} = \frac{\text{increase in length}}{\text{dry reading}} \times 100$$

In the drying movement, maximum shrinkage occurs along the direction of the annual rings and tangentially, the medullary rays close like a fun. Some though minimal, shrinkage takes place in the radial direction along the grain which is about half that of the direction of the annual rings. However there is negligible shrinkage in length (Chapman and Peace).

Figure 2.15: Distortion of wood due to shrinkage and swelling

Source: Encyclopædia Britannica, Inc. 2008

2.4.16 Physical properties of wood

According to Bridgewater A and Bridgewater G, (2007) “wood is the most versatile of all materials”, the reason being that, there are hundreds of colours, textures and grain patterns. One may wonder how a material could show so such numerous qualities.

According to Panshin and Carl de Zeeuw (1980), “basically all the physical properties of wood are determined by the factors inherent in its structural organisation. This he summarises under five headings. These are:

- The amount of cell wall substance present in a giving volume of wood.
- The amount of water present in the cell wall.
- The proportional composition of the primary chemical components of the cell wall and the quantity as well as the nature of the extraneous substance present.
- The arrangement and orientation of the wall materials in the cell and in the different tissues.
- The kind, size, proportion and arrangement of the cell making up the wood tissues.

Apart from a similar comprehensive work done by Tsoumis (1991) on physical properties, Negi (1997) also did a comprehensive work on the same subject. He opines that the physical properties include the properties connected with the physical state of the wood such as look or appearance, colour, density, weight and also the reaction of the wood to sound, heat, light etc. He goes on to state that physical properties do not include those which appear under the influence of external mechanical or chemical factors on the wood.

Under this he mentions nine important physical properties and three other properties he declares less important. These are:

i. *Colour*
ii. *Weight, density, and specific gravity*
iii. *Sound and wood*
iv. *Resonance*
v. *Light and wood*
vi. *Electricity and wood*
vii. *Heat and wood*
viii. *Permeability of wood*
ix. *Wood working and other properties*

2.4.16.1 Colour

Colour is the most common physical property of wood which varies in various species of wood. In many species of wood, the colour darkens on exposure to light. This is due to the chemical change that takes place on the exposed surface of the wood. Differences in colour also occur as a difference between heartwood and sapwood.

The *Lustre* of wood is also discussed as an important element so far as colour is concerned. This refers to the degree of the reflection of light from the walls of the wood cells.

2.4.16.2 Weight, density, and specific gravity

Though these three: weight, density and specific gravity have to do with pressure exerted by gravity. The differences are made clear by the following:

Weight of a wood is the total weight of all the matter it contains. This includes wood substance, the mineral and non-mineral components as well as the water content of the wood.

Density: the density of wood like most other substances is the mass of a unit volume of the wood. It may be expressed in kilogram per cubic metre.

Specific gravity is the ratio of the weight of the wood to the weight of an equal amount of water at a given temperature.

2.4.16.3 Sound and wood

Wood has different reactions to sound and these are important factors to consider when selecting wood for musical instruments. These reactions are known by others as wood's acoustic properties. Some of these properties with relation to sound as state by Negi (1997) are:

a) *Velocity of sound in wood*. This is affected by the elasticity and density of the wood.

b) *Absorption and reflection.* As sound hits the surface of wood, part of it is absorbed and the rest reflected. These are affected by the following variables: the nature of the surface of the wood; orientation of the fibres in the wood; structure and arrangement of the cells; moisture content and specific gravity.

2.4.16.4 Resonance

There occur vibrations or resonance in wood when periodic sound acts upon it. These may be force causing mechanical vibration or sound. These vibrations are referred to as resonance vibrations and are of three kinds: longitudinal resonance, tortional resonance and transverse resonance.

2.4.16.5 Light and wood

Wood responds to light also since the various colours of wood depend on the reflection and absorption of light by it. These are affected by the degree of smoothness of the surface; the plane surface-radial, tangential or transverse; the nature of tissues occurring in their surface and their comparison with the longitudinal tissues and the moisture content on the surface of the wood.

2.4.16.6 Electricity and wood

There are two types of electric current that have varying effects on wood: the direct current and the alternating current. In relation to direct current the most vital property of wood is its resistivity. This is known as electric resistivity and is measured in ohms-cms. On the contrary the reverse of resistivity is conductivity. The following factors affect resistivity of wood to direct current: moisture content, temperature, density and direction of grains.

2.4.16.7 Heat and wood

The reaction of wood to heat discussed in other works as thermal properties is put under six headings by Negi (1997). These are summarised as follows:

Thermal expansion: the ability of wood to increase in dimension in the presence of heat and constant moisture content.

Thermal capacity: the quantity of heat required by wood to raise its temperature by a specific amount.

Specific heat: this is the ratio of the heat required to raise the temperature of wood by a given amount to that of an equal weight of water by the same amount.

Thermal conductivity: wood, to some extent, allows the passage of heat through it. The more the water content the greater the conductivity. For this reason very dry wood serves as good insulators of heat as used for the handles of equipment used for cooking and heating.

Combustibility: this is the readiness or ability of wood to catch fire and continue to burn until only ash remains. This also varies from one wood to the other which explains why some wood burn faster than others.

Calorific value: this is the heating power of wood or the quantity of heat emitted by a given weight of wood during the process of combustion. This is expressed in terms of the number of heat units obtained by complete combustion of a unit of wood mass. It is denoted in calories.

2.4.16.8 Permeability of wood

The ability of wood to absorb liquid is known as its permeability. When wood is put in water it will absorb it till the cell cavities are filled. This may even cause the wood to sink. This absorption of water by the sapwood is faster than the heartwood. The end grains also absorb faster than the tangential surface which is also faster in its absorption than the radial section.

2.4.16.9 Wood working

This refers to properties based on which wood can be converted into finished products. Though it is not a direct physical property, it is very vital in deciding end use of a particular species of wood. Some of these include the following as outlined by Anon (1970) as cited in Negi (1997):

a) The qualities of species to machine operations like mortising, sawing, planing etc.

b) Qualities of species with regard to hand operations such as filing, chiselling, carving etc.

c) Finishing qualities of particular species with regard to the finishing agent or means in question

According to Anon (1970), the main wood working qualities of various species that may be taking into accounts are:

i. Feel on the hand of the worker during and machine operations

ii. The kind of marks produced of the various planes of the wood.

iii. Exposed and deviated fibres

iv. Chipped portions that may remain at the sharp corners

v. Broken or continuous wood shaving that may be produced

vi. Wood may blunt the tool while it is being worked.

vii. Efforts for good finishing

viii. Capacity to retain polish or paint

2.4.16.10 Other properties of wood

Anon (1970), describes the following as other physical properties with lesser importance:

a) *Porosity:* "This is a measure of the relative size of cells and abundance of cell cavities known as lumen". Wood cells with thinner cell walls have larger cell cavities which make them more porous than those lying on the contrary: those with thicker cell walls and for that matter lesser cell cavities. This property is highly related to the degree of paint adhesion, floatation and preservation treatment of wood.

b) *Odour:* Characteristic smells are emitted by different wood species. These are more often perceived in green wood than in a well seasoned wood. These scents are made possible by the present of resins, oils and other chemicals that may exist in the wood. Odour in wood may be advantageous since they can serve as an insect repellent.

c) *Taste:* This characteristic of wood is felt by the tongue and even in the throat. This has a link with the odour of the wood and is well felt in the heartwood than in the sapwood.

d) The above properties in one way or the other play major roles in wood production that must be always taken into consideration not withstanding wood and metal integration.

2.4.17 Defects in timber

The natural behaviour of wood as well as the careful studies of the material reveal certain defects (undesirable characteristics of wood). Defects in wood normally depend on the user. This is so because a defect to one wood user could be desirable to another. Simpson (2008) opines that, some timber defects can arise from felling, some from careless kilning and some from incorrect storage. Hilton (1980) talks of the defect under two categories: defect caused by shrinkage and natural defects in trees, thus defects developed during growth and after the tree has been felled.

However, Tsoumis (1991) categorises defects into two main groups: growth related defect and defects due to seasoning and machining which is in tune with the view of Appiah-Kubi (2009) that categorises defects into two main groups: natural defects and man-made defects. The following are the defects of wood by Tsoumis discussed under Appiah-Kubi's advocacy notwithstanding the consideration of other relevant source:

2.4.17.1 Natural defects of wood

These are natural occurrences that deviate the wood from the qualities that make it suitable for a particular purpose. These are normally growth related and also as a result of natural degrading agents.

Growth related defects: These are the results of various accidents and other natural occurrences in the life of a growing tree that affect the resultant wood. See table 2.1.

Table 2.1: Growth related defects in wood.

Grain direction deviation	The reduction of strength in the wood due to the deviation of grains from the straight grain condition that forms the strength of wood.
Knots	The result of a continuous addition of wood tissues unto the base of a dead branch which eventually becomes part of the wood.
Growth stress in trees	This occurs naturally from the normal development of the woody tissues. This arises from the deposition and polymerisation of lignin that causes the length of some of the cells to decrease resulting in the stress that results in shakes, warping compression failure etc.
Reaction wood	In logs that have eccentrically located pith, the wood showing greater growth does not conform to the pattern of structure and physical behaviour of a normal wood. Therefore, the wood that forms the wide side of the eccentric cross section of a log is the reaction wood.
Brashness	This is the abnormal condition of wood that causes wood to break suddenly and completely across the grain at stress level lower than expected. These also produce a smoother break surface than normal.
Frost injuries	These are defects caused as a result of freezing temperatures. This result in frost rings (deformation and discolouring of some cells) and frost cracks (radial cracks in the wood).

Pitch defects	These appear mostly in woods in which resin canals are normal. In this case the resin either changes the colour or accumulates at certain regions that may result in undesirable pocket. Appearance of this depends on the conversion method employed on the wood.
Bark pockets	This is a situation where the bark of wood is embedded in the xylem tissue.

<u>*Natural defect not associated with growth:*</u> Apart from the growth defects that happen internally there are other natural defects that are based on external factors. See table 2.2.

Table 2.2: Natural defects in wood not associated with growth

Wormholes	These are holes in the wood caused by insects and beetles.
Blue stain	This is the result of harmless fungi that stain the wood especially when they are closely packed.
Termite traces	These are the results of the degrading of termites.
Water marks	These are traces of water that appear as stains on the wood's surface.

2.4.17.2 Man-made defects of wood

These are the defects that occur when wood undergoes man-made processes aimed at preparing it for use. These are as follows:

<u>*Seasoning defects:*</u> These are defects that result in the process of the loss of water or moisture from wood. These are presented in table 2.3 below.

Table 2.3: Seasoning defects in wood.

DEFECT	DESCRIPTION
Checks	These normally occur along the grain of the wood as a result of rapid drying of the surfaces which causes the wood to split along the grain. This normally takes place at the edges of the wood.
Checked and loose knots	This is the result of rapid drying through the end grains of the knot as compared with the tangential surface. The difference in shrinkage causes crack in the knot and sometimes causing the knot to become loose in its hole.
Warping	Warping is the deviation of wood from the original plane of the wood during seasoning. This comes in types based on the appearance of the deformed piece. These are: *bowing* (longitudinal curvature between the two ends of the board flatwise); *crooking* (another longitudinal curvature but this time edgewise); *cupping* (this is a curvature between the two edges of the board; and *twisting* (this denote a situation in which the four corners of the board are no longer in the same plane).
Cross-sectional distortion	The difference in magnitude between radial and tangential shrinkage causes changes in the cross-sectional shape. Example a square like cross-section will give another shape when dry.
Casehardening	This is the result from the normal tension in the interior (core) and the compression in the outer layer of the cells (shell) during seasoning. If the drying and for that matter the shrinkage is not controlled certain magnitude of the difference may cause surface checks of the wood.
Reverse casehardening	This is the opposite of casehardening that normally results from over steaming of the timber which causes the core to shrink and induces tension in the shell. This result in permanent compression of the outside of the layer.
Collapse	This is the distortion of the wood as a result of excessive shrinkages by too rapid drying. Since collapse in wood displaces, deform and over shrink some of the cells, the shrinkages are normally uneven producing undulations in the wood.

Honeycombing	This defect also called internal horning is traceable to internal checking and splitting along the rays. This normally occurs in some lumber as it dries. One characteristic of honey combing is that it does not extent to the surface of the lumber.
Ring failure	Ring failure appears to be similar to shakes. But while shake develops in the standing tree, ring failure develops in perfectly sound lumber in stock during drying.
Box heart splits	These originate from the wood surrounding the pith during the initial stages and extend into the piece as drying progresses. These normally occur as a result of internal stress.

Machine defects: These are undesirable occurrences from the machine processing of wood. See table 2.4.

Table 2.4: Machine defects in wood

DEFECT	DESCRIPTION
Raised grains	This is the situation where the surface of a dressed lumber becomes roughened as a result of the harder summer wood rising above the softer spring wood producing a corrugated feel and appearance.
Loosened grains	This refers to the separation and curling of the tip of growth rings on the surface. This happens normally under the pounding effect of pressure machines.
Fuzzy grains	Surface fuzzing develops when individual fibres or small groups of fibres become loosened in large quantities on the surface of the lumber.
Chipped and torn grains	Wood surface from which pieces of wood have been scooped out or whittled or chipped by the action of cutting are said to have chipped and torn grains.
Machine burns	Darkening of parts of the wood due to overheating by the tools and rollers of machines.

2.4.18 Advantages and disadvantages of wood

Tsoumis (1991) opines that the knowledge of wood comprises its advantages and disadvantages. He states further that knowledge of the advantages and disadvantages of wood is prerequisite to rational utilisation of wood. The following sections outline the advantages and the disadvantages he mentions:

2.4.18.1 Advantages of wood

The advantages of wood are:

- It is mechanically strong in relation to its weight
- It is an insulator to heat and electricity
- It exhibits little thermal contraction and expansion
- It has acoustic properties for making musical instruments
- It does not oxidise (rust) and shows considerable resistance to mild concentration of acids
- It is easily machined by small consumption of energy
- Nailing and bonding with metal connectors as well as gluing is easily achieved
- It is the main source of cellulose which is the basis of many products

- It is found in most parts of the world and is a renewable resource. This is in contrast to petroleum, metal, ore and coal which are gradually but steadily exhausted.

- It is biodegradable

- It is a source of energy (it gives heat by direct burning and also gives combustible gases.

2.4.18.2 Disadvantages of wood

The disadvantages of wood are:

- Wood is hygroscopic – absorbs and holds water in contact with liquid water or water vapour

- Wood gains and looses moisture within certain limits resulting in dimensional changes

- It is a anisotropic material – present differential mechanical strength and differential dimensional changes in different directions

- It may burn or decay

- It has a variable structure and properties because it is a product of biological processes by many tree species and

- Its production is influenced by environmental factors and heredity

It may be concluded that although wood has disadvantages, there are possibilities of control in order to ensure the best possible utilisation of the precious natural material (Tsoumis, 1991).

2.4.19 Wood Utilisation

The consideration of the above advantages and disadvantages by woodworkers has resulted in many successes in the wood industry. Bridgewater A. and Bridgewater G. (2007), narrate that wood is probably the most versatile of all materials, due to the fact that it is easily cut and shaped; incredibly strong and available in hundreds of colours, texture and grain patterns. It also shows differently each time it is cut and everyone seem to like the warm rich natural texture of wood. This accounts for its use in various walks of life.

Possibilities in wood have been discussed by many writers. Some of these writers include Booth (1983), Chapman and Peace (2001), Simpson (2001), Emmitt and Gorse (2007), The Reader Digests Association Inc. (1971) and (1977), Oteng Amoako (2006), Komacel, Lawson and Horton(1990), Prisant (1999) Adams to mention but a few. The accounts on the utilisation of these writers and researchers can be categorised under two main heading. These are processing and production.

2.4.19.1 Processing of wood

Like conversion, it involves the transformation of the raw wood into usable materials for production. Examples are:

- Milling of wood pieces into chips

- Bonding of sawdust into fibreboards.
- Slicing of wood into veneer
- Bonding of veneers into plywood
- Lamination of wood pieces into boards
- Lamination of solid wood strips and facing them with plywood to form blockboards.
- Bonding of wood chips into chipboards.
- Pulping of wood and converting it into paper
- Preparation of wood into dowels, poles and mouldings among others

2.4.19.2 Production of wood

This is the conversion of the finished products of wood processing into finished goods not for a producer or manufacturer but for a final user of a wood product. These users include persons, homes, offices, galleries etc. However wood production as discussed by woodworkers, researchers and writers can be categorised under five headings, thus construction, casting, assemblage, carving and modelling.

Construction: This is a method of forming that deals with combining and arranging of wooden parts prepared from processed wood such as plywood, solid board, poles etc. together to form an intended product. Examples of products constructed are furniture, sculpture, shelter and games.

Casting: This is another method of production in which processed wood in the form of wood dust, veneer, and plywood or wood chips, by the help of an adhesive or natural lignin, is cast into a mould to produce a shape or form. The method is used for the production of wood fuel, Sculptures, construction components like chair seats or backs and other usable pieces or components for assemblage.

Assemblage: This is a method employed by wood producers in which wood is used in integration with junks, scraps and other materials such stone, metal and plastic. This is often employed in the making of sculpture which includes play toys, design models and works for decoration.

Carving: This is the method of wood production in which processed or converted wood in the form of logs, lumber or cast blocks are shaped by the subtractive method using cutting tools such as chisel, gouges, adzes, rotary cutters and other computerised means.

Modelling: This method is mostly employed by sculptors: a process by which saw dust is mixed with a binder and added on between intervals of drying to achieve an intended form. This is an additive method of producing wood work mostly done on a framework or skeleton technically called armature.

Apart from the five methods discussed above, a combination of any two or more is also found in the trend of wood production.

2.4.19. 3 Consumption of wood products

Among the many engineering materials, wood is one of the most ancient of them and still remains the favourite for the majority. Because it is a material of choice for good reasons which include its environmental friendliness, wood is explored for various uses especially in the furniture business. Maskayu (2007), as cited in www.globalwood.org/market, Indonesia is after Malaysia, is the world's second largest tropical exporter of furniture. Figures 2.16 and 2.17 show the upward trend of Indonesia furniture exports. According to Maskayu, exports were poised to grow from 3.5% in 2006 after growing 4% a year during the pass five years.

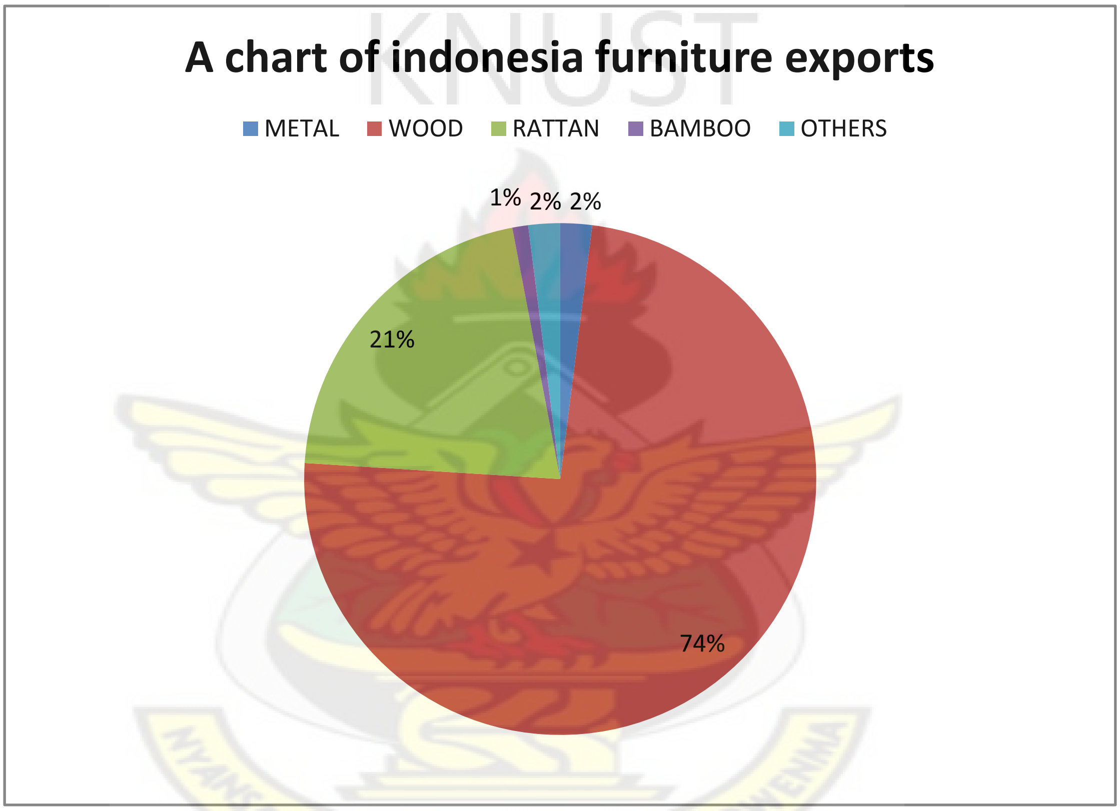


Figure 2.16: A chart of Indonesia furniture export

Source: www.globalwood.org/market

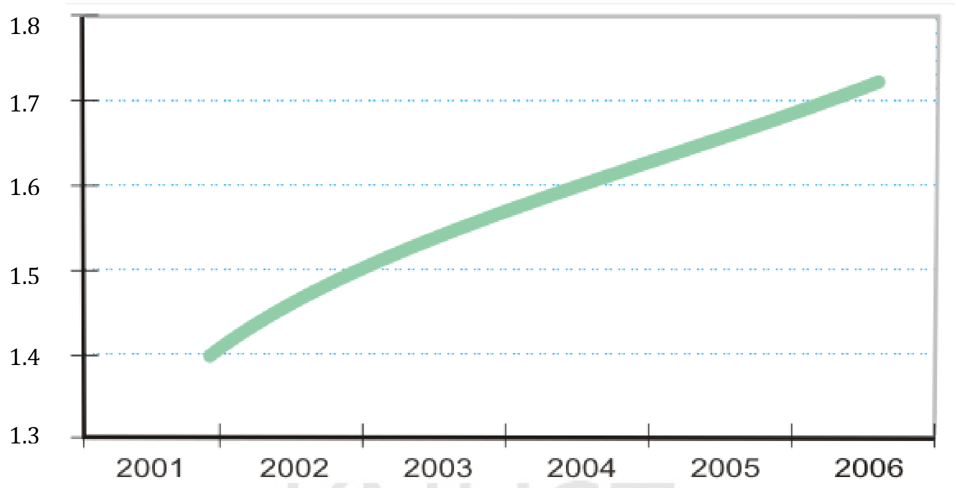


Figure 2.17: Indonesia exports of all types of furniture

Source: www.globalwood.org/market

Much efforts have been made to cut down on the exploitation of timber by diverse environmental protection agencies and forestry commission. Some of these efforts as Oteng-Amoako (2006) states include: Minimum felling diameter (MFD) also referred to as MFL (Minimum Felling Limit) and felling cycle. These are regulatory mechanism to control forest exploitation of Ghana. MFD was first introduced to Ghana in 1907 to protect immature timber species and also conserve their biodiversity. Secondly, the old system of awarding forest concession for timber exploitation was replaced with the Timber Utilisation Contract (TUC) that promotes efficiency, transparency and accountability. Part of this is the Annual Allowable Cut (AAC) to restrain the annual excessive cutting experiences.

Another measure was to promote the use of lesser used species (LUS) and lesser known species (LKS) other than the premium and commercial species. According to Oteng-Amoako (2006), a comparison of growing stock of 2001 and harvest volume from 2000 to 2003 from the reserve forest shows that 16.92% of premium species were harvested compared with 6.09%, 3.09% and 0.18% for the commercial species, LUS and LKS respectively. Figures 2.18, 2.19 and 2.20 show emphasis on the reason why the extraction of premium species must be controlled to curtail their possible extinction and rather promote harvesting and use of the LUS and LKS.

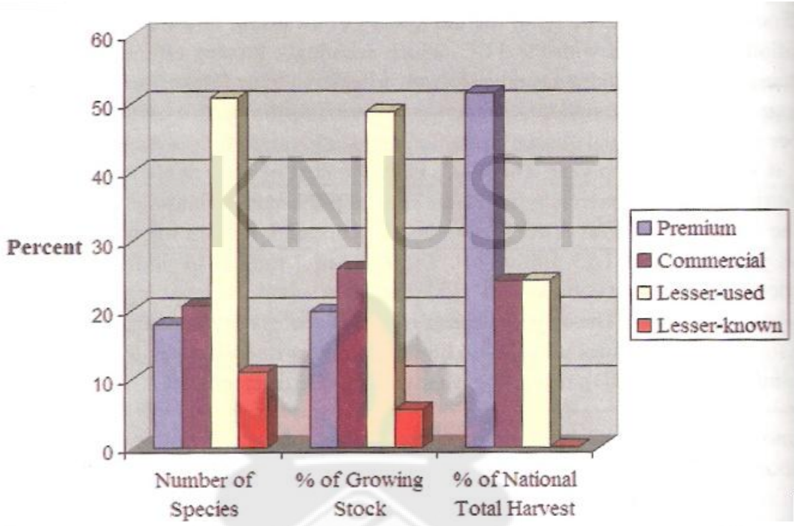


Figure 2.18: Number (%) of timber species, growing stock and total harvest (2001 – 2003) from reserved forest for four utilisation status

Source: Oteng-Amoako (2006)

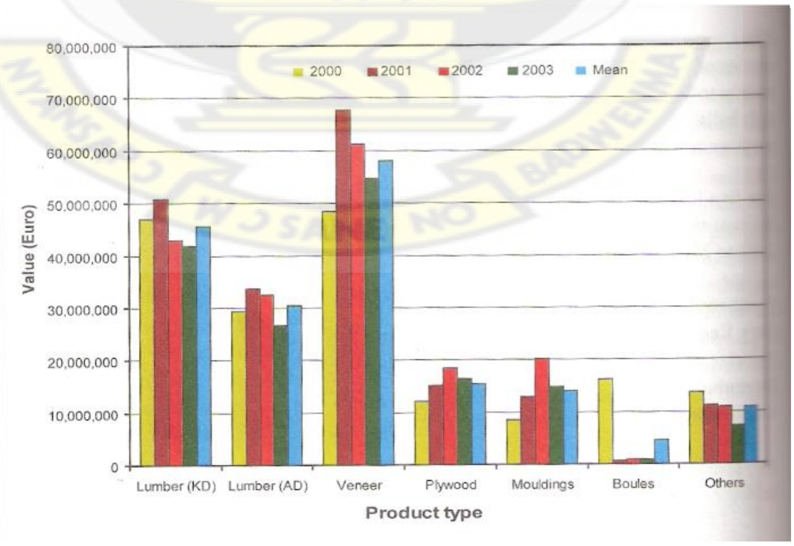


Figure 2.19: Value (euro) of timber and wood products export from 2000 to 2003

Source: Timber industry development division, Ghana forestry commission, 2003

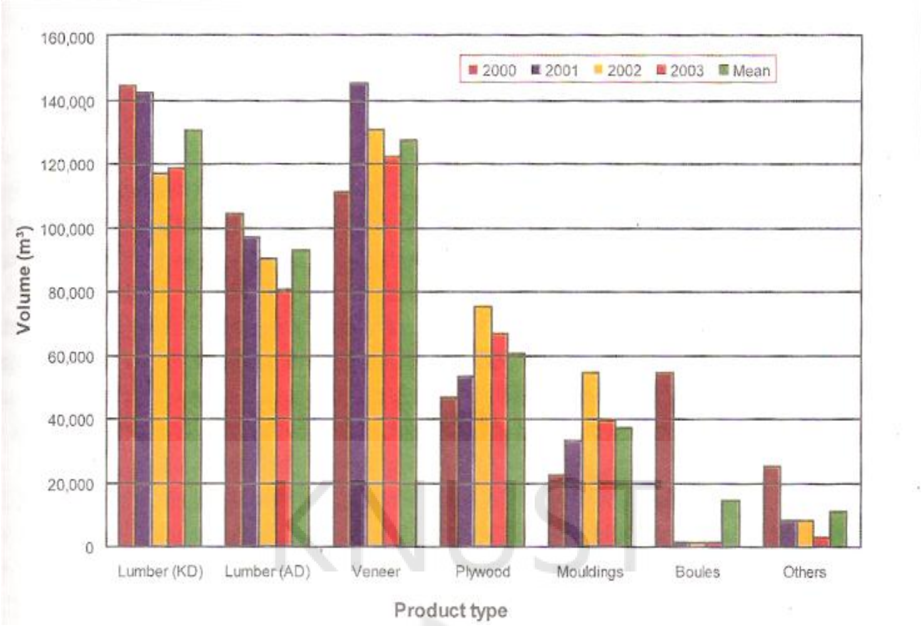


Figure 2.20: Volume (euro) of timber and types of wood products exported from 2000 to 2003

Source: Timber industry development division, Ghana forestry commission, 2003

Considering the massive exploitation of timber shown by the charts, the above measures among other taxes are all pertinent to the promotion of judicious use of timber to save our forest. However according to the Timber and Workers Union-TWU (2007) the fees and levies associated with timber production and export was killing the industry. About 7000 workers in the industry were estimated to have lost their jobs in 2006. The TWU as a matter of urgency urged the government to revive the industry to save more workers from being fired.

The utilisation of timber has become a struggle between the economy and the environment. Late 2006, according to www.globalwood .org/market, the Minister of Finance, Mr, Kwadwo Baah-Wiredu, charged the Ministry of Lands, Forestry and Mines together with industrial representatives to form a fiscal committee to review the fiscal financial framework of the forestry commission in particular, and the forestry sector in general to address the stakeholders concerns.

2.5 Literature on Metals

According to Bray (2003), it is considered normal that a carpenter or cabinetmaker should have knowledge of the properties of the wood to be used for a particular task. Indeed without the knowledge the end result could be a disaster. According to him, the woodworker would want to know how hard the wood is, how straight the grains are, its properties when sawn, planed or chiselled. Similarly it is also imperative for the metalworker in metal working, to have knowledge of the metal they propose to use, since similar factors apply.

Metal has a grain and hardness as well as machining and finishing properties about which one should know something without necessarily being a metallurgist. All metal used nowadays are alloys containing small percentages of other metals that result in a wide range of materials suitable for every purpose (Bray).

2.5.1 Metals

Any class of substances characterised by high electrical and thermal conductivity as well as by malleability, ductility, and high reflectivity of light is metal (Metal**.** (2010). Encyclopædia Britannica). Tarr (2010), partly advocates that a metal is a chemical element that is a good conductor of both electricity and heat and forms cations and ionic bonds with non-metals.

The etymology of the word metal comes from the Greek word "μέταλλον" - which sounds *métallon,* in English. This word stands for “mine", this is probably because the mining at the time was targeted at metals. Moreover, the chemist's point of view is that a metal is an element, compound, or alloy characterised by high electrical conductivity. According to the chemist, in a metal, atoms readily lose electrons to form positive ions (cations). Those ions are surrounded by delocalised electrons, which are responsible for the conductivity. The solid produced is held by electrostatic interactions between the ions and the electron cloud, which are called metallic bonds (Tarr, 2010).

Also, Chemists in their scientific gesture define metal as "those element which, when in solution in a pure state carry a positive charge and seek the negative pole in an electric cell". Only one non-metallic element (hydrogen) is an exception to this definition (The World Book Encyclopaedia M, volume 13-1966).

However, the generally accepted definition focuses on the bulk properties of metals. According to such definitions metals tend to be lustrous, ductile, malleable, and good conductors of electricity, while non-metals are generally brittle (if solid), lack lustre, and are insulators.

2.5.2 Types of metals

According to Chapman and Peace (2001), metal is divided into three basic categories, these are ferrous, nonferrous and alloys.

Ferrous: this group of metals consist of ferrite or iron with small addition of other substances. Examples of these are mild steel, cast iron, tool steel. This group of metals are basically magnetic.

Non-ferrous: this group of metals contain no iron in them and for that matter are not attracted by magnetic force. Examples of metals in this group are copper, aluminium, tin, lead.

Alloys: these are metals that are formed by mixing two or more metals and sometimes other elements to create a new metal which has improved or required properties. This process is known as alloying. This explains the reason for the endless range of metals. Alloys are also grouped into *ferrous alloys* that contain iron, example stainless steel (steel and chromium), high speed steel (steel and tungsten); and *nonferrous alloys* that contain no iron, example brass (copper and zinc), duralumin (aluminium and copper) (Chapman and Peace).

2.5.3 Metallic structure

Chapman and Peace (2001), opine that, to help in understanding the behaviour of materials, it is necessary to look at their physical make up or structure. According to McCreight (1991), this forms a fraction of the study of metallurgy-the scientific understanding of metals which includes classification systems; investigation into molecular and crystalline behaviours, notwithstanding the effects and uses of metals.

Van Vlack (1973), McCreight (1991), Chapman and Peace (2001), Mahan (2010) among others used the smallest part into which an element (metal) can be divided and still retain the chemical properties of that element (metal) as the basis for illustrating the structure of metal. This smallest part is the atom, Chapman and Peace liken the atom to the ecosystem advocating that, atoms of all elements and for that matter metals have the same basic structure but only differ in size and weight. Figure 2.21 show the structure of an atom.

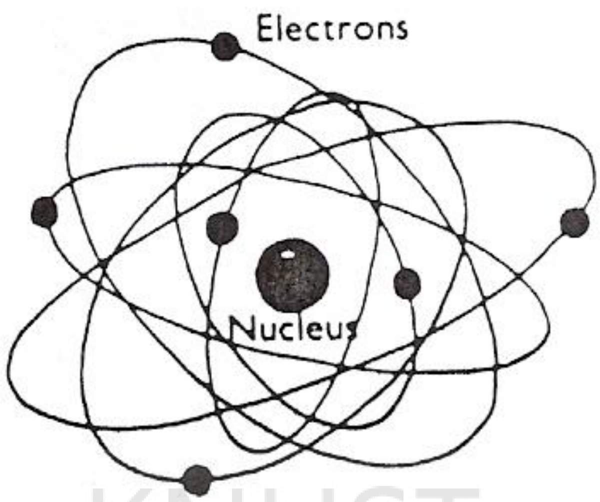


Figure 2.21: The atomic structure

Source: Chapman and Peace, 2001

The nucleus or centre of the atom consists of an association of protons and neutrons. Orbiting around the nucleus are light particles with negative electrical charges known as electrons. These electrons determine the physical and chemical behaviours of a metal.

2.5.3.1 Pure metals

According to Mahan (2010), metallic elements are found in a variety of crystal packing arrangements summarised in figure 2.22. The most common lattice structures for metals are those obtained by stacking the atomic spheres into the most compact arrangement. There are two such possible periodic arrangements. In each, the first layer has the atoms packed into a plane-triangular lattice: a regular geometrical arrangement in which every atom has six immediate neighbours. The following is a simple illustration of the metallic structure by Mahan.

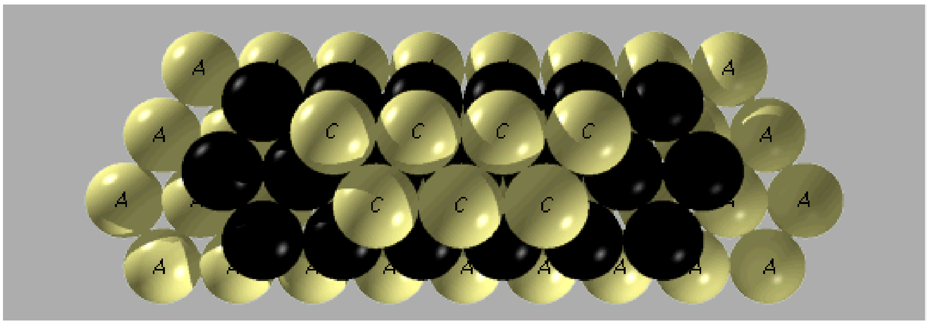


Figure 2.22: A crystal packing arrangement

Source: Encyclopædia Britannica, Inc. 2008

Figure 2.22 shows the arrangement for the atoms labelled *A*. The next layer is shaded in the figure. It has the same plane-triangular arrangement; the atoms sit in the holes formed by the first layer. The first layer has two equivalent sets of holes, but the atoms of the second layer can occupy only one set. The third layer, labelled *C*, has the same arrangement, but there are two choices for selecting the holes that the atoms will occupy. The third layer can be placed to correspond to the first layer, generating an alternate layer sequence *ABABAB* . . ., which is called the *hexagonal- closest-packed (hcp) structure*. Metals such as Cadmium and zinc crystallise with this structure which is also described by Van Vlack (1973) as noncubic metals. The hexagonal close-packed (hcp) as shown in figure 2.23 (hard-ball model and the stacking arrangement) has each atom having 12 close neighbours.

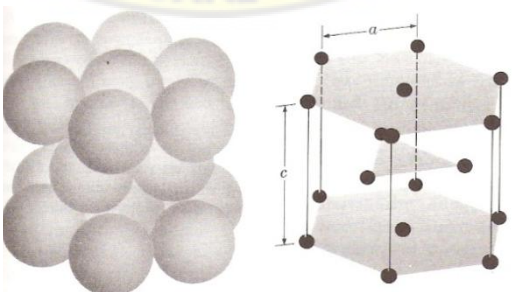


Figure 2.23: Hexagonal close-packed

Source: Van Vlack, 1973

The second possibility is to place the atoms of the third layer over neither of the first two but instead, over the set of holes in the first layer that remains unoccupied. The fourth layer is placed over the first, and so there is a three-layer repetition *ABCABCABC* . . ., which is called the *face-centred cubic (fcc),* or cubic-closest-packed lattice. Metals such as Copper, silver (Ag), and gold (Au) crystallise in fcc lattices which is an example of what is illustrated by Van Vlack as cubic metals. Figure 2.24 shows the *faces centred cubic (fcc)* configuration: the hard ball model with atoms at cube corners and face centers.

Figure 2.24: Faces centred cubic (fcc) configuration

Source: Van Vlack, 1973

In the *hcp* and the *fcc* structures the spheres fill 74 percent of the volume, which represents the closest possible packing of spheres. Each atom has 12 neighbours. The number of atoms in a unit cell is two for *hcp* structures and one for fcc. There are 32 metals that have the hcp lattice and 26 with the fcc (Mayan, 2010).

The other cubic metal configuration is the ***body-centred cubic (bcc)*** lattice, in which each atom has eight neighbours arranged at the corners of a cube. Each side of the unit cell is equal in dimension. The angle between each pair of edges is 90 degrees however the bcc lattice differs from the fcc lattice in that each atom has only eight neighbours. There are 23 metals with the bcc arrangement. Figure 2.25 shows the bcc lattice with atoms at cube corners and body centre.

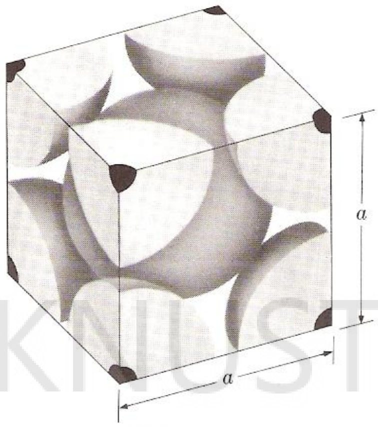


Figure 2.25: Body- centered cubic (bcc) lattice.

Source: Van Vlack, 1973

The sum of these three numbers (32 + 26 + 23) representing the hcp, fcc and the bcc metals respectively exceeds the number of elements that form metals (63), since some elements are found in two or three of these structures (Mayan).

2.5.3.2 Impure metals

According to van Vlack (1973), in some cases impurities are undesirable in metal, in others they are intentionally added to the metal as an alloying element. He also points that even commercially pure metals contain certain amount of other kinds of atom in them. Van Vlack describes the concept of introducing an impurity into a metal, be it a metallic or non-metallic element as the formation of solid solutions.

2.5.3.3 Solid solutions

Van Vlack (1973), again states that a similar situation as happens in solutions involving liquid also exists in metals. For example salt dissolves in water and loses its identity. The water absorbs the sodium and the chlorine ions of the salt within the structure of the liquid. In a similar situation, brass is a fcc copper in which approximately 30% of the copper atoms have been replaced by zinc atoms. The fcc structure accomadates the zinc atoms because they are approximately the same size as the copper atoms (R_{Zn} = 1.39Å versus R_{Cu} = 1.278Å) - the size advocated by Howard (1967) as not less than 15% or less. This is not withstanding their similar tendencies to release electrons. This type of structure is called *substitutional solid solution.* Figure 2.26 shows the structure of a substitution solid solution – brass (zinc in copper).

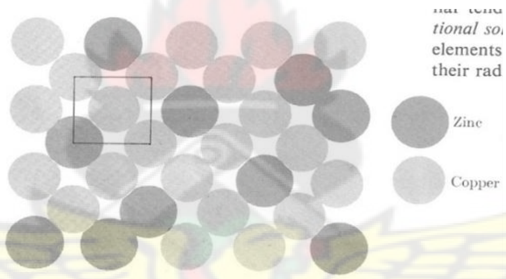


Figure 2.26: A substitutional solid solution arrangement – brass

Source: Van Vlack, 1973

The structure of one element may also dissolve atoms of a second element to form an interstitial solid solution. This results when the impurity atom is very small compared to the host atoms because it may reside within the empty space (interstices) of the arrangements of the larger atoms (Van Vlack).

Similar description are also given by Callister Jr. and William (2006) and Howard (1967)

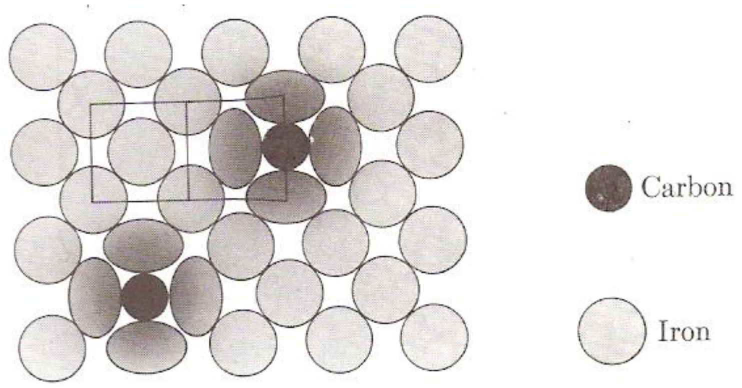


Figure 2.27: Interstitial solid solution (carbon in fcc iron)

Source: Van Vlack, 1973

2.5.3.4 Grains and grain boundaries

Small parts of metal called grains refer to individual crystals in which all the atoms are in a specific arrangement. In single component materials an adjacent grain has the same crystal lattice but a different orientation. There is therefore, a zone of mismatch where two crystals meet that is more coarse in structure called a *grain boundary*. This affects many of the characteristics of metals. A typical example is interference with plastic deformation at normal temperature which makes *fine-grained* metals stronger than *coarse-grained* metals. Figure 2.28 shows grains and grain boundaries with courser grains in metals.

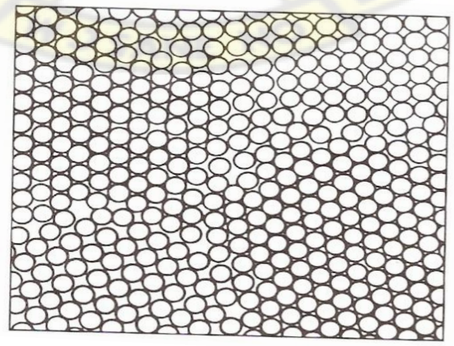


Figure 2.28: Grains and grain boundaries in metals

Source: Van Vlack, 1973

2.5.4 Metal production

According to Van Vlack (1973), the major operation in the processing of metals and alloys is removing them from the original source and refining them into the state or composition required by the user. According to chemists, metals form approximately 75% of the known elements. Figure 2.29 shows the division of the elements on the periodic table. Chapman and Peace (2001) states that, it forms about 25% of the earth's crust by weight- an evident in its commercial availability.

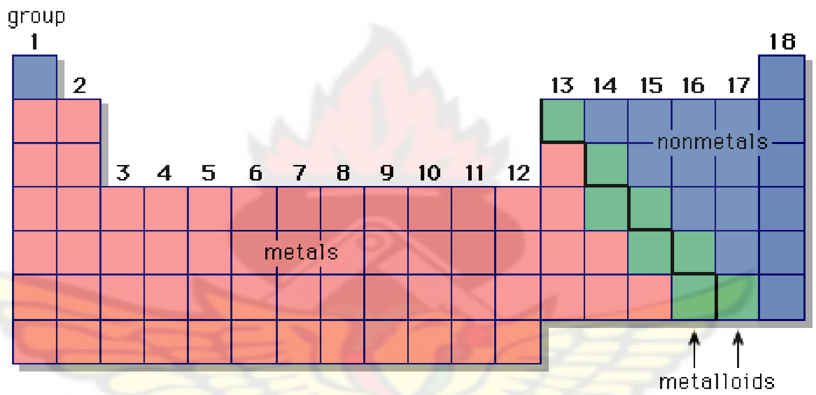


Figure 2.29: The division of the elements on the periodic table

Source: Encyclopædia Britannica, Inc. 2008

Clark (2005) defines an ore as any naturally-occurring source of a metal that you can economically extract the metal from. He believes that the ores are commonly oxides - for example: bauxite (Al_2O_3), haematite (Fe_2O_3), Rutile (TiO_2). or sulphides - for example: Pyrite (FeS_2), chalcopyrite ($CuFeS_2$). Therefore he advocates that the production of metal is by reducing a naturally occurring source of metal (the ore) which aims at separating and purifying the metal from all other impurities. This is carried out with the application of mechanical actions, heat and/or chemicals. Similar work is also done by Tracy (1971). Chapman and Peace (2001) mention some common metals and their sources. These are illustrated in table 2.5.

Table 2.5: Some common metals and their natural occurring source

Metal	***Natural occurring source***
Iron	Magnetite ores and haematite ore
Aluminium	Bauxite
Copper	Chalcopyrite
Lead	Galena
Zinc	Zinc blonde
Tin	Cassiterite

2.5.5 Metal conversion

After metal is reduced to its pure state through the mechanical, thermal and chemical means, it is then cast into various usable shapes. According to Chapman and Peace (2001), once the molten metal is produced it is shaped for use in one of three ways. These are:

- It may be poured into sand moulds to make castings
- It may be cast into ingots and allowed to solidify and later pressed into other shapes by rolling or hammering
- The molten metal may also be linked directly into a continuous casting machine to produce continuous castings in the form of rods, billets, slabs etc.

2.5.6 Recycling of metal

The use of metal is often endless through recycling (the reheating of metal to its molten state, purification of the metals and casting them into usable shapes again). Empirically, the use of metal comes to an end when it can no longer serve its purpose. This could be as a result of metal fatigue in the mechanical industry or in simple tools and equipment; the emptying of metal containers such as cans; when the use of the object into which the metal is integrated comes to an end. Clark (2005) advises thinking about the following:

i. Saving of raw materials and energy by not having to first extract the iron from the ore.

ii. Avoiding the pollution problems in the extraction of iron from the ore.

iii. Not having to find space to dump the unwanted iron if it was not recycled.

iv. (Offsetting these to a minor extent) energy and pollution costs in collecting and transporting the recycled iron to the steel works.

2.5.7 Properties of metal

Van Vlack (1973) advocates the properties of metal under three types of properties: mechanical properties (its physical responses to force), thermal properties (its responses to heat) and electrical properties (it's responses to electricity). Mudd (1972) is also of the view that the properties of a metal are those features which give it its own particular nature or identity. He also states that the properties determine the use to which the metal could be put and the process by which it could be worked. These he defines as follows:

Fusibility: the ability of a metal to flow easily when molten and also retain accurately the shape of the container into which it has been poured after cooling and solidification.

Weldability: the ability of a metal to melt and fuse together at a point subjected to an intense heat.

Ductility: the ability of a metals to be forced or drawn into different shapes without fracture.

Malleability: the ability of a metal to be beaten into different shapes without fracture.

Toughness: the ability of a metal to resist a change of shape although a change can be caused when enough force is applied.

Hardness: the ability of a metal to resist penetration or a change of shape until fracture occurs.

Brittleness: the resistance of a metal to change of shape to an extent that fracture occurs before any change take place.

Plasticity: the ability of a metal to change shape easily without fracture.

Tenacity: the ability of a metal to resist being pooled apart.

Elasticity: the ability of a metal to return to its original shape when the force causing the change in shape is removed.

Elongation: the amount of stretch produced between two fixed points on a metal.

Strengths: this is the forces required in various directions to set a metal apart. Some of these are tensile strength, compressive strength, tensional strength, stessses and strains.

Apart from these numerous properties, metal properties can also be adjusted through heat treatment techniques and alloying. That account for the fact that metals could have endless properties and for that matter used in diverse ways to achieve thousands of results even with other materials such as wood.

2.5.8 Uses of metal

McGrath (1995) states that experimentation is one of the most rewarding ways to discover how metal works and how one can use it. True to these words experimentation with metal has already produced thousands of results in ornamentation and various constructions due to its flexibility and adjustability.

McGrath (1997) also advocates the use of certain metals in jewellery making and to him, they go far deeper than the desire simply to reveal wealth or follow fashion. He again indicates that, in most cities of the world, in basements and hidden away in back streets are the workshops that produce the glittering displays that appear in the windows of fashionable stores. Also over the world, there are thousands of skilled men and women producing works in conditions and by methods that have changed little over centuries. He says further that, for some of these people, their workshops are a little more than a block of wood held in sand and a few simple tools.

Neumann (1982) argues that, the significant increase and the use of jewellery in the past few decades restate a truth that is many thousands of years old: “man needs personal adornment”.

According to Wikipedia (The Free Encyclopedia on www.wikipedia.org/wiki/metal working modified on 5th February, 2007) - by the historical periods of the Pharaohs in Egypt, the Vedic Kings in India, and the Tribes of Israel, and Mayan Civilization in North America among other ancient populations, precious metals began to have value attached to them. In some cases rules for ownership, distribution, and trade were created, enforced and agreed upon by respective peoples. Metal smiths became important members of society.

More individuals than ever before are learning metalworking as a creative outlet in the forms of jewellery making, restoration of aircraft and cars, blacksmithing, tinsmithing, tinkering, horology and in other art and craft pursuits. Moreover, because metals vary in appearance, behaviour and properties, each metal is good but not in all cases, therefore the uses of metals can only be dealt with considering specific metals. Literature on metal uses compiled by Tracy (1971) on steel includes the following:

- *Automobile industry:* the use of metal in various parts of mechanisms in the automobile industry include: rims, engine blocks, motor chains, frameworks and other metallic components that make up a vehicle.

- *Building industry:* this is the active role metal plays in building especially in storey buildings, sky scraper and most bridges.

- *Plumbing:* provision of conduits for the conveying of liquid and gas substances for easy accessibility in the home and work places.

- *Electrical:* this is the area of the use of metal to conduct electricity from one point to the other.

- *Agricultural:* the use of metal in the production of agricultural tools and implements.

- *Transportation:* the use of metal in the building of ships, vehicles and aircrafts for easy movement.

- *The food industry:* the making of means for food processing, storage and packaging.

- *The oil industry:* the manufacture of equipment for oil extraction, processing and transportation.

Similar work done by Bray (2003), mentions a range of metals and their uses. These also include the nonferrous group characterised by ornamentations and long lasting intention due to their freedom from rust.

2.5.9 Literature on selected metal for this project

The following are literature on selected metals for the study.

2.5.9.1 Iron

Mudd (1972), relates that, pure iron is seldom used in engineering because it is very difficult to produce or machine without tearing the surface. But the introduction of carbon into its structure results in the workable variety of iron or steel. According to Mudd, it is the percentage of carbon that determines whether the metal is an iron or steel. In other words iron with carbon content can still be iron. He also implies that iron contain more carbon than steel, for example cast iron contains 3% carbon as compared to tool steel which contains 1.4%. Mudd advocates a theory that if the combined carbon content of steel raises above 1.5% it ceases to be steel but iron. Showing from left in plate 2.2 is: bright mild steel; middle: high carbon steel; right: black mild steel.

Plate 2.2: Samples of steel

Source: Bray, 2003

2.4.9.2 Copper

This is a nonferrous metal distinguishable by its reddish colour. It conducts heat rapidly and does not rust. Though it work-hardens easily, it is very good for ornamentation works and generally easy to cut, drill and form into shapes. It is noted as a base for important alloys in the history of metal. Examples are brass and bronze. It is easy to solder and easy to anneal. It is available in sheets, round and square bars and tubes Bray (2003).

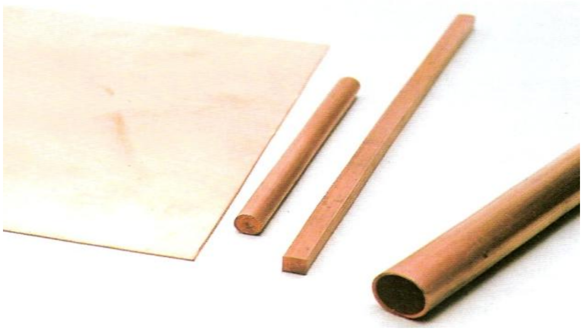


Plate 2.3: Samples of copper forms

Source: Bray, 2003

2.5.9.3 Brass

This is an alloy of copper and zinc that has a wide variety of uses. It is easily distinguishable by its yellow colour and available as sheets, all kinks of bars and tubes. It has a relatively low melting point and is good for casting especially when fine details are required. It is also an excellent material for hard and soft soldering. There are however two major problems with brass. Firstly, it does not accept paint easily and for that matter a special etching primer is needed in order for the metal to retain paint (Bray2003). Secondly, its zinc content would easily leach out when exposed to higher temperatures of water. These often make the brass porous and cause it to fail.

Plate 2.4: Samples of brass forms

Source: Bray, 2003

2.5.9.4 Aluminium

This is one of the most familiar metals because of its usage for domestic saucepans and other engineering works such as the building of aeroplanes. Aluminium does not only refer to aluminium in its pure state but also to all other alloys based on aluminium, all of which have vastly different properties. Generally aluminium alloys are priced for both their lightness and non-rusting properties. With properties related to their softness they vary between very soft and very hard. Most of the alloys machine well but have the tendency to build up deposits on tools. Fabrications are normally done by riveting or bolting parts together. Aluminium is available as sheets, bars or angles, or as castings that sometimes find their use in the workshop.

Plate 2.5: A casting of aluminium

Source: Bray, 2003

2.6 Review of Wood-Metal Integrations

Over the years to date, metal and wood have been used together intentionally or unintentionally (out of necessity) for many products. These products range from simple arts and crafts to complex edifices.

2.6.1 Some wood metal integrations in history

Adam (1999) giving accounts of art, shows many ancient art works that are still in existence, the most surviving of which are in metals. In the context of wood the most surviving are those in conjunction or preserved with metals. In this respect metals carry lasting effects on woods. Some of these:

A Lyre soundbox from the tomb of Queen Puabi Ur. 2685 B.C. made of wood with some parts inlaid with gold and the head gilded or covered with gold sheets. As shown in Plate 2.6 (a) presents all the parts: the golden head and the inlaid body; (b) the body inlaid in gold and (c) the gilded head in gold.

(a) (b) (c)

Plate 2.6: A Lyre soundbox from the tomb of Queen Puabi Ur.

Source: Adam (1999

Following this is a stag discovered in the 4th century B.C. This is fashioned in wood after which it is covered with gold, silver and bronze. This is shown in plate 2.7.

Plate 2.7: A stag made of wood, gold, silver and bronze

Source: Adam, 1999

Another example is an ancient mummy case made of wood and gold leafs bonded by stucco. This is shown below in plate 2.8.

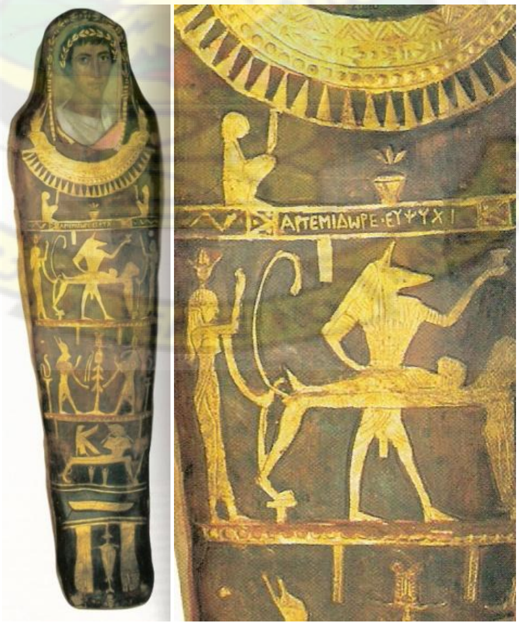


Plate 2.8: A mummy case in wood and metal

Source: Adam, 1999

There are also cases in which a wooden piece is made to look so metallic and precious. An example is the reliquary statue of Sainte Foy, 10th -11th century. It is made up of gold and gem stones over a wooden core as shown in Plate 2.9.

Plate 2.9: A wood sculpture in gold and gem stone cover

Source: Adams, 1999

Prisant (1999), in his compilation of literature on antiques presents some works and their respective artists regarding the eighteenth and nineteenth century. The wood metal integrations highlighted are as follows:

A work by Charles-Hanore Lannuier (fl. 1790-1919), a Frenchman who crafted the best high-style furniture in America-New York, employing gilding, figured mahogany, rose wood and bronze mounts in a good harmony. Plate 2.10 shows the metal embellishment on the central part and on the legs.

Plate 2.10: A Lannuier's classical table in wood with metal ornamentations

Source: Prisan, 1999.

Also as parts of his documentation is a work of André , a French cabinetmaker. This is a rococo commode with a boulle (inlaid decoration of tortoise shell, yellow metal, and white metal in cabinetwork) marquetry in the central panel with bronze mounts everywhere else. This is shown in plate 2.11 below:

Plate 2.11: A rococo commode in wood and metal

Source: Prisan, 1999

Also in the eighteenth century are wood and metal tall and short clocks an example of which is a Dutch clock spectacular in marquetry in gilt bronze and brass. This is shown in Plate 2.12.

Plate 2.12: A tall clock in wood and metal

Source: Prisan, 1999

Apart from the beautification and decoration oriented production from time of old, metal and wood also exist in the form of tools, equipment, fitted parts of wood construction, fixings and decorations. Under this, metals and wood are joined by variety of means to serve the purpose of the integration. Examples given by Bridgewater A. and Bridgewater G. (2007) are marking tools (marking gauge, try square and sliding bevel gauge), cutting tools (saws, knives, chisels and gouges), and wood fixings (bolts, nuts threaded inserts and washers) that are either fixed secretly in the interest of only their function or expose for beautification purposes. Also present are furniture hardware (catches and locks, hinges and stay, drawer runners, handles, castors and wheels) that normally perform functions that are not readily performed by wood. These shown in plates 2.13 to 2.18 are important aspects of wood metal integration experienced in these modern days.

Plate 2.13: Wood metal marking tools

Source: Bridgewater A. and Bridgewater G., 2007

Plate 2.14: Wood metal cutting tools

Source: Bridgewater A. and Bridgewater G., 2007)

Plate 2.15: Wood fixings

Source: Bridgewater A. and Bridgewater G., 2007

Plate 2.16: Wood furniture hardware

Source: Bridgewater A. and Bridgewater G., 2007

Plate 2.17: Metallic furniture hardware used on a wooden chair

Source: Bridgewater A. and Bridgewater G., 2007

Similar works have also been done by Simpson (2001). Apart from other uses of metal on wood, Simpson emphasises on special metal locks he describes as unusual locks. Also, as a furniture designer makes a conscious effort to use wood and metal in furniture designing. According to Simpson it is easy to achieve not withstanding its pleasing look.

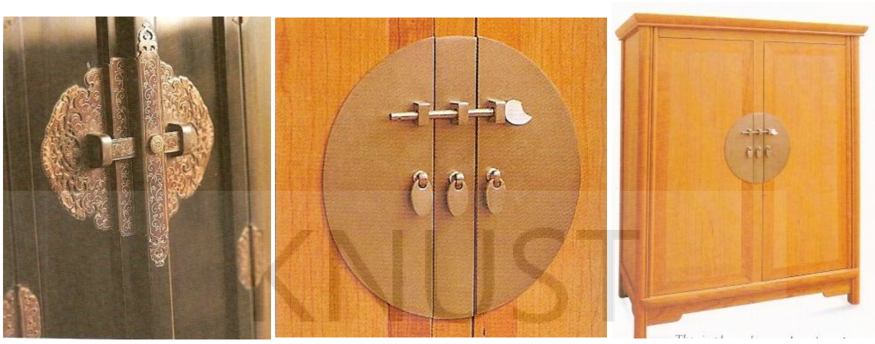


Plate 2.18: "Unusual locks" on wooden cabinets

Source: Simpson, 2001

Figure 2.30: A wood metal furniture design plan

Source: Simpson, 2001

2.6.2 Some wood metal integrations

Metal and wood are used in many instances, but for the purpose of this study, four of them are mentioned. These are the Peace Pole in KNUST-Commercial Area; the KNUST pedestrian bridge, a pedestrian walkway over-pass at the Railways near Asafo, Kumasi and a garden chair in the Department of Integrated Rural Art and Industry (IRAI).

2.6.2.1 The Peace Pole in KNUST-Commercial Area:

The Peace Pole is a complete carving from the full trunk of a mahogany tree. Due to the hygroscopic nature and the strength limit of the wood it is strongly connected to its concrete foundation with a steel connector designed to firmly hold the foundation and also prevent water from soaking and destroying the base. As shown in Plate 2.19, the topmost part is an eagle’s head designed in metal to carry its message and at the same time protects the end grains of the top from absorbing excessive water that may cause hydrolysis.

Plate 2.19: The Peace Pole in KNUST-Commercial Area

2.6.2.2 The wood metal garden chair

It is obvious in Plate 2.20 below that wood alone could not have achieve the fanciful effect created by the metal. Apart from the possibility of the design in the metal on the product it can also easily receive finishes that could withstand the ground conditions in the garden.

Plate 2.20: The wood metal garden chair

2.6.2.3 A pedestrian walkway over-pass

This walkway is a complete metal structure with wooden stairs. Though metal could have been used for the same purpose, wood which induces friction that makes it less slippery and convenient was obviously used for ergonomic reason.

Plate 2.21: The pedestrian walkway over-pass at Railways near Asafo, Kumasi (Source: Appiah-Kubi, 2010)

2.6.2.4 The KNUST pedestrians' bridge

This is a timber bridge made possible by the use of metal connectors. These connectors serve as reinforcement to the joints that constitute the strength of the bridge. The structure is shown below in figure 2.31.

Figure 2.31: The structure of the pedestrian bridge-KNUST, Kumasi

Source: Appiah-Kubi, 2010

2.7 Conclusion

The review of related literature has given the researcher a lot of insight regarding the trend and the extent of researches related to metal and wood. First of all the researcher has heen extensively exposed to timber classification and appearance pertinent to the selection of timber for specific purposes. Secondly, the review has revealed certain characteristic behaviours and pertinent calculations in timber that make its usage very successful. It has also enlightened the researcher on other advantages and disadvantages that carry the tendencies of either imposing positive or negative implications on wood metal integration. These have helped in selecting relevant tests that have been conducted on selected wood to ascertain their compatibility with the chosen metals.

Again, the researcher's scope of understanding related to metallic structure, behaviour and responses have widened. This has helped in the selection of the metals, production techniques and related materials for the various experiments and the project.

Moreover, the researcher has really been exposed to the world of wood and metal combination and the rationales behind them. This has formed the spring board for the ingenuity and innovation in the project. It has also been seen that wood metal integration is done for three purposes, thus the use of valuable metal to enhance the value of wood art pieces; the use of metal as a stronger material for fastening and reinforcing wood; and metal on wood for decorative purposes. These constitute one of the strong pillars of this study.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter outlines the general plan of the study and strategies adopted by the researcher to resolve the problems of the study. These include the research design, research methods, research tools, population and sampling, research experiments, data collection and data analyses plan.

3.2 Research Design

The research incorporates both the qualitative and the quantitative research approaches due to its multifaceted nature. The researcher has used the quantitative methods because there was the need to study relationships among measured variables regarding wood and metal for the purpose of explaining and predicting the phenomenon that exists between them. The qualitative methods have also been employed because the nature of the materials under discussion, especially wood is complex in nature and beyond the boundaries of quantitative description.

3.3 Research Methods

These have to do with the specific types of the qualitative and quantitative methods employed in the study.

3.3.1 Qualitative

According to Leedy and Ormrod (2005), one would need to choose qualitative research method when there is the need for the following: description, interpretation and verification. The researcher has studied within the said parameters: three qualitative methods have been adopted for the study; these are content analysis, collective case study and the ground theory study.

3.3.1.1 Content analysis

Leedy and Ormrod (2005) describe this system of research as a detailed and systematic examination of the content of a particular body of material for the purpose of identifying patterns, themes and biases. According to them, it is performed on forms of human communications which includes art, human interaction, books, videos and others of which information revolving around wood and metal integration are no exceptions. This method has been adopted for the study of the trends in wood metal integration and the purposes for which the two materials serve in the integration from selected literature.

3.3.1.2 Collective case study

According to Leedy and Ormrod (2005), sometimes research focuses on a single case, perhaps because of its unique and exceptional qualities. This is used to promote understanding or as a basis for similar situation. This is called case study. However, if it involves more that a case for generalisation it becomes a collective case study.

For this study, the method has been adopted for the study of some wood species and related materials for the establishment of facts relevant to similar situations.

3.3.1.3 Grounded theory study

This research method is least likely to begin with a theoretical framework. The main purpose of this is to begin with a data and use them to develop a theory. The term grounded refers to the idea that: the theory that emerges from the study is derived from and grounded in data that have been collected in the field rather than taken from the literature. This method of study is helpful when current theories about a phenomenon are either insufficient or nonexistence (Creswell, 2002 as referenced in Leedy and Ormrod, 2005).

This has been relevant to the study due to the scanty work done in the art of wood and metal integration. Under this, the study has been done in relation to the ideas, techniques and processes involved in the integration of woods and metals; peoples' reactions and description of similar ideas, techniques and processes; and the categorisation of the activities that constitutes the effort directed at the generation of terminologies or jargons for easy communication of the outcome of the study.

3.3.2 Quantitative

This is important because of the involvement of measured variable in the study that the researcher has undertaken. The qualitative methods employed are the experimental and the descriptive quantitative research methods.

3.3.2.1 Experimental

This has to do with cause and effect relationships in which two groups of variables are considered: the independent and dependent variables. In this method of research the dependent variable are affected by changes in the independent variable. Therefore the design is such that changes are caused to the independent variable in definite direction and the dependent variables are assessed to ascertain the degree of effect caused by the change (Leedy and Ormrod, 2005).

3.3.2.2 Descriptive Quantitative research

This method of research describes situations as they are. It does not seek to change or modify the situation under investigation nor intend to determine cause and affect relationships. This either involves identifying the characteristics of an observed phenomena or observing possible correlations among two or more phenomena. The research designs employed under this include:

Observation studies: This has been employed in the study of movement in the selected wood species with environmental factors.

Correlation research: this has been employed in relating the responses of the wood and for that matter wood metal integration to environmental changes. (Leedy and Ormrod, 2005)

3.4 Research Tools

Leedy and Ormrod (2005) say that, these are the specific devices or line of attacks the researcher uses to collect, manipulate or interpret data. Research tools as employed in this dissertation are as follows: the library and its resources; the computer and it software; statistics; the human mind and language.

3.4.1 The library and its resources

Apart from the empirical studies conducted the following libraries were also visited in search for relevant information for the study. These include some KNUST libraries

- The university library- KNUST, Kumasi.
- The Institute of Renewable Natural Resource Library, KNUST-Kumasi.
- The College of Engineering Library, KNUST-Kumasi.
- The Department of Material Science Library, KNUST-Kumasi.
- Faculty of Art Library, KNUST-Kumasi.
- The Department of Art Education Library, KNUST-Kumasi.

Other libraries that were visited outside the KNUST campus include:

- The Ashanti Library- Kumasi.
- The British Council Library, Kumasi.
- The Building and Road Research Institute (BRRI) Library-Kumasi
- The Forest Research Institute of Ghana (FORIG) Library-Kumasi
- The University College of Education –Kumasi Library

3.4.2 The computer and its software

The personal computer and related software such as the Microsoft excel, Microsoft word, CorelDraw (2-D software) and Rhinoceros (3-D software) were used in the word processing, data calculations, charts plotting, labelling, designing and modelling in the project. The Internet was also visited periodically to retrieve relevant information and new updates throughout the research.

3.4.3 Statistics

This is one of the ideal research tools typically used in fields such as education that presents data in a simpler manner. This has been adopted for the summary of the data which has made it less complicated and manageable.

3.4.4 The human mind

Though the scientific method of research has been adopted for the study, it has involved both the deductive and the inductive reasoning of the human mind. The research questions were developed based on the relationships that existed between wood and metal (deductive logic) and the findings based on the observation of series of events that took place during the research (inductive logic). In summary, both the deductive and the inductive reasoning, critical thinking and collaboration with others were all keys to the project.

3.4.5 Language

The researchers' proficiency in English, Twi and Ewe was highly instrumental in the communication with different people from different parts of the country.

3.5 Population and Sampling

This has to do with the totality and the selection of elements upon which to project was based.

3.5.1 Population for the study

This is the totality of elements upon which the study was based. These are as follows:

3.5.1.1 Literature on wood and/or metals

This is approximately 391, comprising Engineering papers, books on structures, art history books, books on metals and related information, and books on wood and its related information.

3.5.1.2 Relevant agencies in and around the Kumasi metropolis

The relevant agencies studied in and around the Kumasi Metropolis include about 1242 made up of 350 metal agencies, 22 wood processing firms and 870 furniture and wood products agencies.

3.5.1.3 Wood and Metal production techniques

This comprises the countless forming, construction, decorative, and finishing techniques employed both by students and professionals.

3.5.1.4 Metals and alloys easily obtainable in Ghana

Under this category the researcher found 10 metals, these are: Aluminum, Copper, brass, Lead, Iron, Steel, Tin, Zinc, Gold and Silver.

3.5.1.5 African timbers and alternative wood species from Ghana.

This is a countless population woody tree products obtained in Ghana.

3.5.1.6 Wood and metal workers in Ghana

This is a countless population of both registered and nonregistered wood and metal producers in Ghana.

3.5.2 Target population

Since it was not feasible for the researcher to reach out to the whole population, the targeted population are summarised in table 3.1.

Table 3.1: Targeted population for the research

Target population	*Sub population*	*Total*
Literature relevant to wood and metal integration	30 literature on wood, 30 on metal and 40 on both metal and wood	100
Relevant agencies whose activities are relevant to the study.	Metal and Wood=30, wood processing firms=10, furniture and wood products = 60	100
Metal and wood working techniques easily produced.	Wood sculpture and metal jewellery techniques.	50
Ferrous and non ferrous metals obtainable as scraps.	Aluminium (fcc) Copper (fcc) Brass (fcc) Iron (fcc/bcc) Steel (fcc/bcc) Tin (fcc) Zinc (hcp)	7
Timber obtainable from Kumasi timber markets and some alternative wood species	19 timber, 2 bamboo, and 3 palms	24
Students and workers in wood and metal art in Kumasi	30 wood workers, 30 metal workers and 40 wood and metal workers	100

3.5.3 Accessible population

This is a fraction of the target population based on the fact that not all targeted were within the reachable range of the researcher, which totalled 381. Table 3.2 spells out the distribution of the accessible population.

Table 3.2: Accessible population

Accessible population	Sub population	Total
Literature relevant to wood and metal integration	30 literature on wood, 30 on metal and 40 on both metal and wood	100
Agencies whose activities are relevant to the study.	20 Metals workshops, 2-wood processing firms, and 25 furniture and wood products firms	47
Metal and wood working techniques easily produced.	Wood sculpture and metal jewelry techniques practicable on knust campus.	50
Ferrous and non ferrous metals obtainable as scraps.	Aluminium, Copper, brass, Iron, Steel, Tin, Zinc	7
Timber obtainable from Kumasi timber markets and some alternative wood specie	19 timber, 1 bamboo specie, and 2 palms species	21
Students and workers in wood and metal art in Kumasi	30 wood workers,30 metal workers and 40 wood and metal workers	100

3.5.4 Sampling

The sampling is based on Leedy and Ormrod's perspective that puts sampling under two headings. These are nonprobability and probability sampling techniques which are both employed in the study.

3.5.4.1 Nonprobability

This sampling technique has no way of guaranteeing that each member of the population will be represented in the sample. The nonprobability sampling techniques employed include:

i. *A synthesis of the convenience and purposive sampling*

In this respect, literature relevant to wood and metal integration and Agencies whose activities are relevant to the study have been selected based on those readily available and also for the important roles or specific purpose they could serve in the research.

ii. *Purposive sampling*

As the name implies, specific items are chosen for particular purposes. The purpose could be that the sample represents diverse perspectives of an issue. In this case: under metal and wood working techniques, metal jewellery and wood sculptural techniques have been chosen for the fact that they represent almost if not the totality of wood and metal production techniques.

iii. *Convenient sampling*

This method of sampling is also known as accidental sampling. It makes no pretence of indentifying a representative subset of a population. It takes units that are readily available. This has been adopted for the selection of timber easily available in Kumasi and also the ferrous and non ferrous metals easily obtainable as scraps.

3.5.4.2 Probability

In this sampling design the researcher can specify in advance that each segment of the population will be represented in the sample. This is the characteristic that sets it apart from the nonprobability sampling. Under this the simple random sampling and the stratified random sampling have been used.

i. Simple random sampling

This method of sampling is the least sophisticated of all the sampling designs. The sample is chosen randomly selection where every member of the population stands an equal chance of being selected. This has been employed in selecting the jewellery and wood sculptural techniques.

ii. Stratified random sampling

This is a random sampling technique employed in the case of a stratified population (a population with more than one category or layer - stratum) of different types of individuals. This method of sampling has been adopted for the sampling of students and workers in wood and metal art in Kumasi to ensure the representation of each stratum

3.6 The Samples

These of the representatives of the population based on which the data has been collected for the study. These are 187, based on the six strata of the population which constitutes 49.08% of the target population. These are as follows:

3.6.1 Literature relevant to wood and metal integration

The researcher thought of all the diverse aspect of the two materials in question and for that matter made sure that, the selection of books cut across. This is summarised in table 3.3 below.

Table 3.3: The sample of literature relevant to wood and metal integration

Wood		***Metal***	
literature on the growth of tree and how they influence the resultant wood	2	Metal forms	2
literature on structure, properties and usage of wood	2	literature on structure, properties and usage of metal	2
literature on usage of wood	5	Literature on metal production	5
literature on general information on wood	1	Literature on general information on metal	1
literature on finishing	2	Literature on finishing	2
Total	*12*	*Total*	*12*

3.6.2 Relevant agencies whose activities are relevant to the study

Under this the researcher is of the view that the various activities surrounding the two materials are important factors to the pros and cons of their integration. This has necessitated the choosing of samples from almost all the aspects as shown in table 3.4.

Table 3.4: The sample of agencies that were visited during the research

Category	***Population***
Metals workshops,	10
wood processing firms	1
furniture and wood products firms	10
Others	5
Total	*26*

3.6.3 Wood sculpture and metal jewellery techniques practicable on KNUST campus

The sample was considered with reference to four important production stages: these are decorative, forming, construction and finishing techniques as summarised in table 3.5.

Table 3.5: The strata of wood and metal techniques

Categories	***Techniques***	***Sample***
Decorative,	Chasing, scorching, inlaying, incision, etching and piercing.	6
Forming,	Casting, embossing, chasing, carving and etching.	5
Construction	Joining, Fastening, Hinging, weaving and adhesion.	5
Finishing	Polishing, painting, burnishing, and lamination	4
Total		*20*

3.6.4 Ferrous and non ferrous metals obtainable as scraps

This is a conscious effort by the researcher to contribute to effective waste management through art production. The researcher has therefore focused mainly on the metals obtained as by-products of other activities. These are aluminium from aluminium constructors, fabricators and high tension electricity workers; copper from motor rewinders, fridge and air-conditioners workers and repairers; brass from condemned plumbing and automobile spare parts and steel and iron from steel benders and other steel manufactures. This is shown in table 3.6.

Table 3.6: Summary of sampled metals for the study

Metals	total
Aluminium, Copper, brass, Iron, Steel	5

3.6.5 Timber obtainable from Kumasi timber markets and some alternative wood species

The focus of this has been on timber easily obtainable from the research environment. The sample therefore included some research samples from KNUST (ache, wawabema, palm wood and bamboo) and other 8 species.

Table 3.7: The sample of timber wood species used in the research

Wood species	Sample
Timber species	10
Bamboo specie	1
palm wood specie	1
Total	12

3.6.6 Students and workers in wood and metal art in Kumasi

Under this the researcher had three strata from which equal numbers were ensured between those who work with only one of the materials. More quota has been give to those who combined the two materials because they matter most to the research. These are presented in table 3.8.

Table 3.8: Sample of workers involved in the study

Categories	Samples
wood workers,	30
metal workers	30
wood and metal workers	40
Total	100

3.7 Research Experiments

Certain experiments were conducted in order to ascertain certain behaviours of the materials relevant to the integration. Because metal is most of the time stable and predictable, more of the experiments were concentrated on wood than on metal. These include: the movement test of wood as influenced by the harmattan weather; and secondly, test of possible roles of adhesives, cements and binders in wood and metal integration.

3.7.1 The movement test of wood as influenced by the harmattan weather

Wood metal integration often rely on the drying shrinkage of wood often at fibre saturation point at which the timber stops shrinking. But more often than not the peculiar dry harmattan weather experienced at north coast of the Gulf of Guinea causes an extra shrinkage in wood that sometimes separate wood and metal. This is a structural occurrence usually experienced on the wood's surface. Therefore this test bas been purposefully adopted in order to factor this into the calculations that would make wood metal integration more successful.

This test was initiated to ascertain factors that could be adopted to curtail the negative influence of the harmattan weather on wood and metal integrations. Wood surfaces in wood art especially carved pieces come in many variations than in other engineering applications. Due to this wood surface were selected at random from 12 wood species in order to ascertain an average consideration during the application of metal on wood. The samples were taken at the time the researcher describes as the stable weather: when it was neither humid nor dry in early December 2008. During this the sample sizes were targeted at 4 x 4 x 1 inches (expressed in centimeters as 10.16 x 10.16 x 2.54). However, since the research focuses only on the facial changes in dimensions, the measurements were concentrated on the length and breadth dimensions (10.16 x 10.16). Moreover due to the imprecise nature of the tool used in the cutting of the samples, the removal of excess fibres through abrasion to ensure accurate measurement and the inevitable shrinkage of the specimens in the process, the resultant dimensions were different but not a deterrent to the research.

Again due to the anisotropic nature of wood, the number of samples per specie could not be restricted to one but was decided on three from which the average was taken in every step of the experiment. These are summarised in table 3.9.

Table 3.9: Summary of samples for the harmattan shrinkage test

Names and botanical names of selected species	Number of sample pieces	Targeted dimension		Resulted dimensions	
		Length (cm)	Breadth (cm)	Length (cm)	Breadth (cm)
Akye white female *(Blighia sapida)*	3	10.16	10.16	9.94	9.95
Laminated bamboo (Bambusa vulgaris)	3	10.16	10.16	10.240	9.770
Mansonia (Mansonia aitssima)	3	10.16	10.16	10.200	9.820
Odum (Milicia excelsa)	3	10.16	10.16	10.000	9.90
Asanfena (Aningeria altissima)	3	10.16	10.16	10.050	9.50
Mahogany *(Khaya ivorensis)*	3	10.16	10.16	10.201	9.780
Akye -red male {Blighia sapida)	3	10.16	10.16	10.000	10.000
Denya (Cylicodiscus gabunensis)	3	10.16	10.16	10.440	9.630
Wawabema (Sterculia rhinopetala)	3	10.16	10.16	10.170	10.320
Hyedua (Guibourtia ehie)	3	10.16	10.16	10.260	9.920
Teak (Tectona grandis)	3	10.16	10.16	9.960	9.780
Coconut wood (Bactris gasipaes)	3	10.16	10.16	10.563	10.51

NOTE: length = the end to end dimension and breath = the edge to edge in the case of tangential and radial sawn wood and in some special cases one side was taken for the length and the other for the breath.

3.7.2 Test of possible roles of adhesives in wood and metal integration

The individual usages of both materials (wood and metal) sometimes require the use of respective adhesives. Due to this it was also necessary for the researcher to look at how some of these adhesives could still hold between the two materials. Some of these are not defined as adhesive or binders by their manufacture but are adopted as adhesives and binders by virtue of their ability to adhere to the surfaces of the two materials (wood and metal). The sample for the study is summarised in table 3.10.

Table 3.10: Selected adhesives and solvents and their purposes for the study

Adhesives/binders		Purpose	Selected solvent and test	
Scientific name	Common name		Solvent	Purpose in research
Polyvinyl acetate (PVA)	White glue or carpenters' glue	Wood and paper	Water	Woomeint particle binding test
Epoxy	Araldite / Metal glue	Multi-purpose	Thinner	Woomeint adhesion and binding test
Contact cement (dissolved neoprene)	Contact glue	Leather or textile and wood	Thinner	Woomeint adhesion test
Cyanoacrylate	Super glue	Multi-purpose adhesive especially for plastics and rubbers	Ready to use	Woomeint adhesion and binding test
Polysiloxane sealant	Silicone	Multi-purpose sealant	Thinner	Sealing and flexing test
acrylics	Acrylics	Multi-purpose adhesive and finish.	Water	binding and adhesion test
polyurethanes	Auto clear	Multi-purpose finish for rigid bodies	Thinner	Binding and adhesion test
Pigmented drying oil	Oil paint	Multi-purpose finish	Thinner	Binding and adhesion test
Cellulose lacquer (Rhus Vernicifera sap)	Lacquer/ varnish	Multi-purpose finish	Thinner	Binding and adhesion test

The samples of adhesives collected are composed of different chemicals for different purposes and therefore vary in properties, behaviour and cost. In view of this they were neither seen nor treated the same. They were tested in five different ways considering their purposes and capabilities, these are:

i. surface adhesion tested for metal

ii. surface adhesion test for wood

iii. particle binding test for metals

iv. particle binding test for wood

v. particle binding test for mixture of wood and metal

vi. inter surface adhesion test for wood and metal

In each of these tests, the respective adhesive/binder was also diluted and tested to ascertain its curing time and strength under diffusion using selected solvents. This was to expand the adhesive when larger quantities are required to save cost and also to facilitate their use when required in thinner consistency. Under this, brass powder and aluminium sheets were adopted for the test. This is so because they and easily obtainable and unlike ferrous metal, they would not rust to disintegrate the joints or bond. This formed the basis for the other adhesion tests. See table 3.11.

Table 3.11: Specimens for the surface adhesion test

ADHERSIVE/BINDERS AND SOLVENT		RATIO OF ADHERSIVE TO SOLVENT				SURFACE AREA	CHOSEN METALS
Scientific Name	Solvent	Ratio1	Ratio 2	Ratio 3	Ratio 4	(CM)	Aluminium sheet
Polyvinyl Acetate (PVA)	Water	Factory Ratio	3:1	2:1	1:1	2 X 2	Aluminium sheet
Contact Cement (Dissolved Neoprene)	Thinner	Factory Ratio	3:`1	2:1	1:1	2 X 2	Aluminium sheet
Cyanoacrylate	-	Factory Ratio	-	-		2 X 2	Aluminium sheet
Polysiloxane	Thinner	Factory Ratio	3:1	2:1	1:1	2 X 2	Aluminium sheet
Acrylics	Water	Factory Ratio	3:1	2:1	1:1	2 X 2	Aluminium sheet
Polyurethanes	Thinner	4:1	3:1	2:1	1:1	2 X 2	Aluminium sheet
Epoxy	Thinner	4:1	3:1	2:1	1:1	2 X 2	Aluminium sheet
Cellulose Lacquer (Rhus Vernicifera Sap)	Thinner	Factory Ratio	3:1	2:1	1:1	2 X 2	Aluminium sheet

3.8 Data Collection Instruments

The instruments for data collection included, Observation guide, Reading guide, Checklist, Interview questionnaire, Opinionnaire or Comment sheets and Wood and metal working and measuring tools. These were chosen in respect to the research designs and the data collection method used. This is summarised in table 3.12 below.

Table 3.12: Research design and data collection instruments

Research design	Data collection method	Data collection instruments
Content analysis	• Identification and sampling of specific materials that are relevant to the study • Coding the material based on a predefined characteristic.	• Reading guide • Checklist
Collective case study	• Observation • Interviews	• Observation guide • Interview questionnaire
Grounded theory study	• Interview • exhibitions	• Interview questionnaire • Opinionnaire or Comment sheets
Experimental	Definition and measurements of materials' variables	Wood and metal working and measuring tools and also the kinaesthetic sense of the hand.
Descriptive Quantitative research	• Observation • Interviews	• Observation guide • Interview questionnaires

3.9 Validity of Instruments

The data collection instruments were carefully selected in order to obtain correct data. In the case of measuring the wood samples, the researcher chose an electronic calliper over the manual for a more accurate dimension. The interview, reading and observation guides were chosen to keep the researcher in focus in order to seek nothing but answers to the research questions. Opinionnaire or comments sheets were adopted in order to also obtain the views of people who the interview could not cover especially during the exhibition situation notwithstanding the checklist adopted for the categorisation and monitoring of the data.

3.10 Data Collection Procedures

These are the means by which the relevant information and variables were collected to serve as the bases of the findings. These were collected in accordance with the objectives that aimed at answering the research questions.

3.10.1 Objective one of the study

Objective one of the study was to establish factors that must be considered prior to the integration of wood and metals notwithstanding the identification of possible means by which metal and wood are or could be integrated. Under this the researcher identified relevant works that had been done and still ongoing in the field of metal and wood that bear information that could be tapped and creatively considered to make wood and metal integration more successful. Secondly the researcher embarked on consultation, interviewing of experienced personalities and informal discussions. Lastly, the researcher also performed some experimental tests on some relevant materials and the result recorded. These constituted two categories of data: the primary data and the secondary data.

3.10.1.1 Secondary data collection

The researcher had to conduct the secondary data collection first in order to develop a strong theoretical base for the primary data collection. In this, the research questions (what factors are needed to be considered prior to the integration of wood and metals? and, by what means could wood and metal be integrated?) were broken into sub question as follows:

- Why are wood and metal integrated?

- What aspects of the two materials are or could be integrated?
- How could the nature of wood affect wood and metal integration and vice versa?
- What properties have wood that would accommodate metal?
- What factors usually affect metal on wood pieces?
- What function of wood could attract the incorporation of metal?
- What mutual benefits do or could wood and metal derive from each other when put together?
- What benefit do users derive from wood metal integrated products?

Based on the above, a reading list/checklist was prepared as presented in the appendix 7. Literature was then carefully selected according to compilations done by wood scientist, wood technologist and engineers, wood researchers and other stakeholders. Such books were read and carefully monitored by an answer guide that was prepared using the sub questions above with space for the answer for each question provided below. This is presented in appendix 8. This was to ensure that the questions being answered alongside the reading. A guide was allotted to each book that was selected and had space for the title of the book and the author's name and content.

3.10.1.2 Collection of primary data

These are the data collected by the researcher from his surrounding environment as well as experimental tests that were conducted on the materials during the research.

Environmental data

This had to do with the interviewing of experts in the field, visiting and observing relevant operation from relevant agencies and analysing works relevant to the field of study. During the exercise, 30 wood workers were interviewed, among them were wood engineers, carpenters, wood carvers and/or finishers and workshop instructors. Information sought from them include the rationale behind the use of wood, the challenges the material posses, strategies adopted for handling the unpredictable material among others. After that 30 metal workers which included goldsmiths, metal fabricators, blacksmith, lecturers and technicians were interviewed on the behaviour of metal, working method, complementary materials among others. The people interviewed next were those who consciously use both materials (wood and metal), these included graduates of the Integrated Rural Art and Industry who specialised in wood-metal integration, sculpture teachers, structural engineers and wood finishers, all of which numbered 40. The essence of the interview was to ascertain from the interviewees the rationale behind their creation in wood and metal, their motivation, challenges and others discussed in detail in the subsequent chapter. The overall number of people interviewed was 100. The interview questionnaire contained questions derived by a further break down of the sub questions for the research questions one and two. This was to make them easier to answer by the respondents (see appendix 1). This was used for all the hundred respondents, though not all questions were applicable to all of them. It was also a means to test the knowledge of the respondents on the related subject.

Also, 26 relevant agencies in Kumasi and Accra were visited to observe the ground wood and metal working procedures, materials and tools notwithstanding the related state of the art technologies, most of which were carried out in conjunction with the interviews. Under these ten (10) metal workshops were visited comprising engineering shops, jewellery shops, blacksmith shops and a fabrication pool. A wood processing firm was also visited to observe activities related to wood processing. The observation continued with 10 furniture and wood product agencies and 5 others which included wood metal furniture firms, wood and metal research and learning institutions.

Also different wood-metal works encountered were also studied to ascertain useful information related to them that were considered in the course of the study. Some of these were fastening mechanisms, the contradicting shrinkage of wood in contrast with the stability of metal, finishing among others.

Experimental test

According Chapman and Peace (2001), the experience gained from working and testing a range of different materials will help to reinforce the ability to make successful decision. They further say that it is a useful means of exploring the limitations such as strength of unusual material combination. These experiments previously mentioned in this chapter were in two phases.

<u>Experiment one: The movement test of wood with emphasis on influence posed by the harmattan weather</u>

In the quest for extra shrinkage posed by the harmattan weather, the researcher, from the artists point of view realised that apart from the usual tangential, radial and transverse surfaces of wood, the wood artist especially the carver, deals with variety of surfaces that resulted from random cutting angle of tools to the direction of flow of the wood grains that resulted from the movement of the wood in different ways during growth. In the same way, integrating metal into wood art also encounters different situations time after time due to factors such as the unpredictable nature of wood; unlimited form produced by the wood artist; unlimited joining techniques and sometimes the use of more than one species of wood in a single work.

In view of this, three samples of wood pieces taken at random from each of the species were coded with the initials of their botanical names. These were arranged in an airy environment and their movements in response to the changes in the weather were observed by periodic measurement of their surface area. The summary of the species and their respective samples are spelt out in table 3.13.

Plate 3.1: Wood specimens after sawing and abrasion

Table 3.13: Outline of wood sample for the harmattan shrinkage test

SPECIES	CODE	SAMPLE 1	SAMPLE 2	SAMPLE 3
Akye white female *(Blighia sapida)*	BSF	BSF-1	BSF-2	BSF-3
Laminated bamboo (Bambusa vulgaris)	BV	BV-1	BV-2	BV-3

Mansonia (Mansonia atissima)	MA	MA-1	MA-2	MA-3
Odum (Milicia excelsa)	ME	ME-1	ME-2	ME-3
Asanfena (Aningeria altissima)	AA	AA-1	AA-2	AA-3
Mahogany *(Khaya ivorensis)*	KI	KI-1	KI-2	KI-3
Akye -red male {Blighia sapida)	BSM	BSM-1	BSM-2	BSM-3
Denya (Cylicodiscus gabunensis)	CG	CG-1	CG-2	CG-3
Wawabema (Sterculia rhinopetala)	SR	SR-1	SR-2	SR-3
Hyedua (Guibourtia ehie)	GE	GE-1	GE-2	GE-3
Teak (Tectona grandis)	TG	TG-1	TG-2	TG-3
Palm wood (Bactris gasipaes)	BG	BG-1	BG-2	BG-3

In each period the three samples for each of the species were measured length and breadth or "edge to edge and end to end" by the use of an electronic veneer calliper and the average measurements calculated and recorded. This was the addition of the three lengths divided by three and the addition of the three breadths divided by three. Example, in the case of Tectona Grandis (teak) the average measurement is mathematically presented as follows:

$$AL:TG = \frac{\text{L:TG} - 1 + \text{L:TG} - 2 + \text{L:TG} - 3}{3}$$

Where AL = average length of teak, L:TG-1=length of teak sample one, L:TG-2=length of teak sample two and L:TG-3=length of teak sample three. The same was done with the breath:

$$AB:TG = \frac{\text{B:TG} - 1 + \text{B:TG} - 2 + \text{B:TG} - 3}{3}$$

Where AB = average breath of teak, B:TG-1= breath of teak sample one, B:TG-2= breath of teak sample two and B:TG-3= breath of teak sample three. In view of these the average area: average length multiplied by the average breath was calculated as:

$$AA = \left(\frac{L{:}TG-1 + L{:}TG-2 + L{:}TG-3}{3}\right) \times \left(\frac{B{:}TG-1 + B{:}TG-2 + B{:}TG-3}{3}\right)$$

Where AA=average area, and what is within the brackets represents average length and average breath respectively.

Plate 3.2: Specimens coded and arranged in an airy environment.

Plate 3.3: Measurement of specimen

Experiment two: experimental test of some available adhesives and binders on wood and metal to determine their possible applications

These relevant tests conducted on the selected adhesive in order to determine their applicability were divided into three; these are dilution test, adhesion test and binding test.

Dilution test: Due to the nature of the intended application of the adhesives, the selections that are not traditionally diluted were sent through a preliminary dilution test. See plate 3.4. These included the contact glue, the cyanoacrylate, epoxy and the polysiloxine sealant. All of them responded to thinner except cynoacrylate. The adhesives were then mixed in different proportions as earlier illustrated in table 3.11 of this chapter: in the process they were applied to thoroughly cleaned wood and metal (aluminium) with surface dimension 2cm x 2cm. This excluded those for the bending test. Those for the bending the diluted ones were applied in strokes side by side with their original undiluted ones on metal stripes. After this they were comparatively observed after curing; followed by thumbnail scratching test to determine their strength; the nature of their appearance after curing was also observed; and lastly, their behaviour in terms of elasticity and stickiness were observed by touching and bending test, all in relative terms with the originals.

Plate 3.4: (a) Diluted polysiloxane and (b) epoxy on test plate

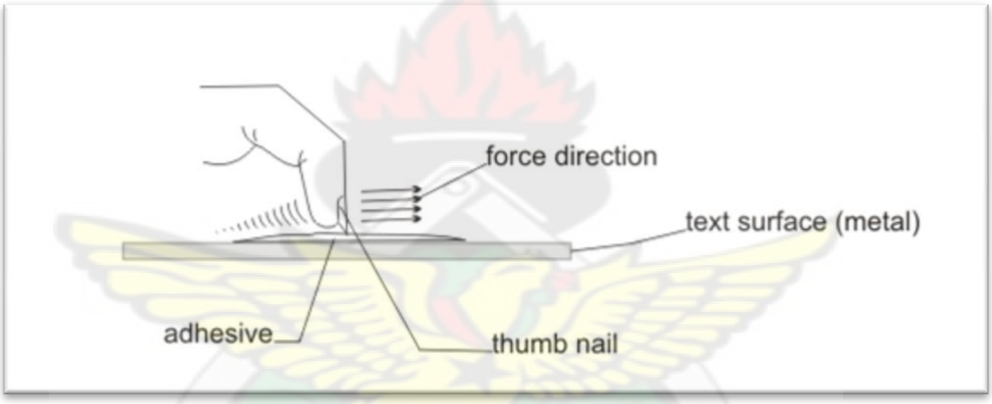


Figure 3.1: Scratch text setup

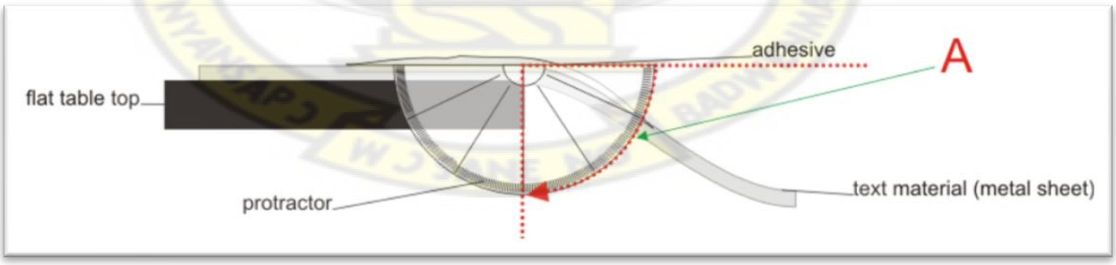


Figure 3.2: Elasticity test setup

Adhesion test: This was to test the adhesives' ability to hold two pieces together. The adhesives in their respective proportions were applied between wood and metal using the same surface dimension of 2cm x 2cm to ascertain their adhesion strength by thumbnail and chisel lifting.

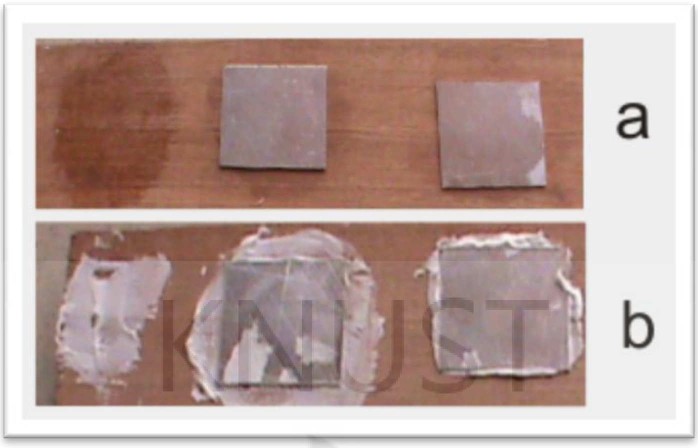


Plate 3.5: Adhesion specimens of (a) contact glue and (b) polysiloxane

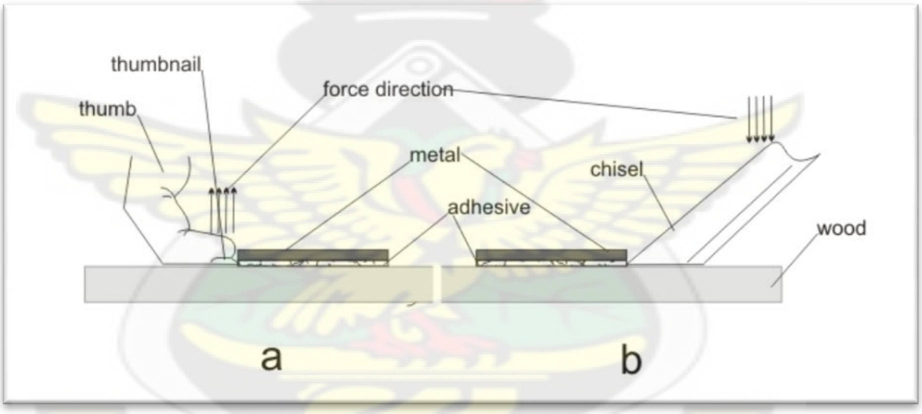


Figure 3.3: Lifting test (a) with thumb nail (b) the chisel edge

Binding test: This was to find out the abilities of the adhesives to hold particle such as wood and metal grits or chippings for useful wood metal integration ventures. This was also considered as part of the quest to contribute to the maximum wood utilisation to curtail the increasing wastage of the material. In this, filings of brass and wood saw dust were employed in three different combinations: wood dust combined with adhesive, metal filing combined with adhesives and a combination of the two materials with adhesives.

The ratios of the adhesives mixtures were useful here in relative terms with the grit sizes. This was so because certain sizes could not mix readily with the viscous nature of the adhesives except the cynoacrylate. Generally, for the purpose of the study the wood dust produced by sawing was used, and in the case of the metals from sawing and filing. On these, preliminary tests were performed to ascertain a suitable proportion for the particle. With reference to the nature and application of the adhesives the researcher thought of three modes of application, thus dump binding (DB), moist binding (MB) and cured binding (CB) taking into consideration their setting time. These were carried out with a checklist as presented in table 3.14 below.

Table 3.14: The checklist for the conduction of the binding test

Adhersive/Binders and Solvent			***Mode of application***			***Particles***	***Time***	
Scientific Name	Solvent	Ratio	DB	MB	CB	Wood, Metal or Combined	Cast time	Setting time
Polyvinyl Acetate (PVA)	Water	2:1	Yes	-	-	Wood, Metal or Combined		
Contact Cement (Dissolved Neoprene)	Thinner	2:1	-	-	Yes	Wood, Metal or Combined		
Cyanoacrylate	-	-	Yes	-	-	Wood, Metal or Combined		
Polysiloxane	Thinner	2:1	Yes	-	-	Wood, Metal or Combined		
Acrylics	Water	2:1	-	Yes	-	Wood, Metal or Combined		
Polyurethanes	Thinner	3:1	-	Yes	-	Wood, Metal or Combined		
Epoxy	Thinner	2:1	Yes	-	-	Wood metal and combined		
Pigmented drying oil	Thinner	2:1	-	Yes	-	Wood, Metal or Combined		
Cellulose Lacquer (Rhus Vernicifera Sap)	Thinner	2:1	-	Yes	-	Wood, Metal or Combined		

NOTE: "DB" stands for dump binding in which the adhesive content of the mixture is enough to drip; "MB" represents moist binding in which the adhesive's consistency stayed within the particles such that they could not drip; and "CB" represents cure binding in which the adhesive in question sticks properly when it dries (therefore it is mixed and allowed to dry before the mixture is pressed together).

Plate 3.6: Composition of mixtures

The set up for the casting was such that the wood dust was first bound followed by the metal dust and then a mixture of the two. These were cast into wooden slots and also pressed into free forms and timed to cure. Their behaviours were studied after curing.

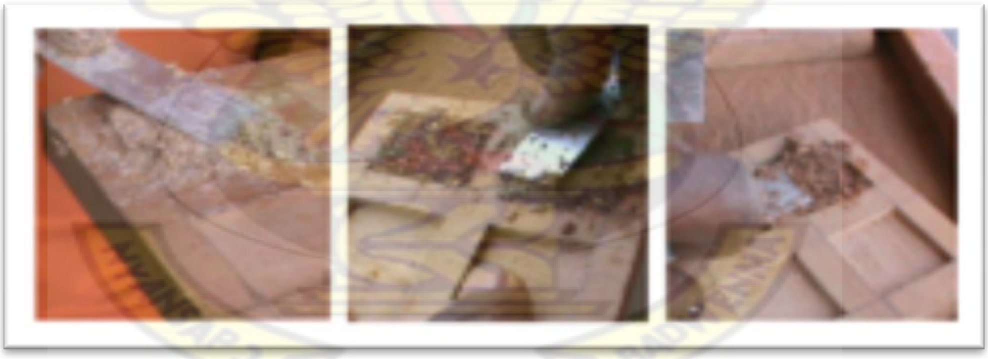


Plate 3.7: Casting of adhesive into wooding slots

Plate 3.8: Production of free form

Plate 3.9: A sample mixture (contact glue and wood saw dust) spread to dry before being pressed together

Plate 3.10: The mixture of the contact glue and the wood saw dust being hammered into wooden slot after curing

However, in the case of cure bonding if a space is to be filled as in the case of wood slots, adhesive was first applied in the slot in order to facilitate contact with the bond. After the casting the specimens were tested in four ways. These were:

i) Abrasion test by the use of abrasive surface (emery and glass papers) to ascertain their response and reaction to abrasion. This was rated with a rating scale of very poor to excellent.

Plate 3.11: Some dry bond ready for abrasion test

Plate 3.12: Abrasion being done on the abrasion board

ii) *Surface compression test* by pressing hard with the thumb and also the thumbnail after abrasion to a flat surface to ascertain their sinking and denting resistance.

Plate 3.13: Compression test with the thumb and thumbnail

iii) Corrosion reaction test by immersion and coating with acid and the reactions observed.

Plate 3.14: A sample in acid (nitric acid)

3.10.1.3 Other materials considered

The researcher believes in the durability of the two materials in question and for that matter taught of other durable materials that could link wood and metals. One of such materials the researcher found was natural leather which also has a long tradition with metal in the making of belts, footwear, wallets, bags, cloths among others. This was also creatively experimented with the two materials

Secondly, the researcher also taught of wax as a form rendering material in the modelling of composites that would not readily stand at the beginning. The wax is idea due to its ability to leach or melt under low heat.

3.10.2 Objective two of the study

The second objective of the study was to produce wood and metal specimens that would be kept in the library as a reference material. This objective aimed at answering the third research question: “by what possibilities could wood and metal integration pieces be kept as reference materials?" to answer this, the following sub questions were generated:

- What reference items are found in the library?
- By what means are reference material kept in the library?
- What are the normal sizes of material kept in our libraries in relative terms with the shelves on which they are kept?
- In what form and size could wood and metal integration specimen be kept in the library?

In view of these questions the researcher conducted an observation of record keeping and cataloguing in the library notwithstanding the sizes of works kept in the library. This was done alongside the library research which also entailed some review of literature in relation to cataloguing, shelving and general nature of documents kept in the library.

Secondly, the researcher relied on both primary and secondary data related to wood and metal production techniques, materials, and applications as a creative foundation upon which ideas were developed for the creation of the integration ideas and techniques. Data sources included selected relevant literature on wood and metal integration; and selected agencies whose activities are relevant to the study. However the researcher paid particular attention to wood sculpture and metal jewellery techniques practicable on the KNUST campus to ensure that the outcome of the project is teachable.

3.10.3 Objective three of the study

Objective three of the study aims at making the project communicable and for that matter teachable through the generation of technical jargon for the processes and techniques involved in the production of wood and metal integrated art -“woomeint”. Under this pursuit the sub questions under the fourth research question are as follows:

- What are jargons?
- How are jargons generated?
- How do the people in the field (experts) of wood and/or metal describe the processes and techniques they undertake?
- What is new about the coming together of the two materials, techniques or processes?
- How do/would laymen describe or appreciate what they see (wood metal artworks)?

These involved the collection of information on etymology (the origin of words) and how they are adopted and used by other languages from available literature. This was followed by review of literature compiled by experts including direct comments from other workers through on the job interviews, which helped to ascertain how they describe similar situations encountered by the researcher. The next consideration for the jargons was the characteristics of the new ideas that were generated by the researcher in the study. This was done through intrapersonal communication by the researcher and also through exhibition of the result. The exhibition granted the researcher the opportunity to receive first hand information from experts and laymen on what they feel about what they see. These were collected through informal discussions and opinionnaires or comment sheets (appendix 9) provided for attendants of the exhibition. The comment sheet served as a guide to the attendants who were able to submit well organised comments on the exhibits to the researcher. Based on these, further enquiries were made as and when it became necessary.

3.10.4 Data analyses plan

The data was subjected to logical analysis. Due to the mixed method design employed, both the inductive and the deductive reasoning were used. The researcher therefore drew logical conclusion from theoretical and practical premises set by the data coupled with inferences drawn about general phenomenon based on the observations made.

Under the quantitative approach the researcher reduced data to simpler forms such as mean and summarising statistics. This was mixed with interpretative narratives from the data that aimed at capturing the details of the phenomena under study.

3.11 Conclusion

These methods and tests were adopted to integrate theory and practice as an adequate precedence upon which wood and metal could be integrated in art. This was not only for their intended functional purposes but also for the whole utilisation of the materials for their effective management. Moreover the methodology of the production of specimens as reference materials would be a means of perpetuating the ideas unlike the project situation where the ideas might not be readily perceived due to various juxtapositions. Lastly, the method made the work teachable through the step by step procedure booklets designed for the specimens. Thus, the methodology was strategically adopted to achieve the three set objectives.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF FINDINGS

4.1 Introduction

This chapter is the presentation and analyses of data gathered from both the primary and the secondary sources. The data have been presented, analysed and discussed in accordance with the objectives of the study. Under each objective are research questions and sub questions geared towards the satisfaction of their respective objectives as elaborated in chapter three.

4.2 Objective One

The objective one was to establish factors that must be considered prior to the integration of wood and metals and also to identity possible means by which wood and metal are or could be integrated. This objective was to answer two of the research questions (1 and 2) in chapter one under the respective sub questions also listed in chapter three. The primary and secondary data gathered through the content analyses and the administration of the questions are presented and interpreted as follows:

4.2.1 The outcome of the content analyses (secondary data)

This entails the data got from the analyses of relevant literature on areas outlined in table 3.3 gathered by the answer guide in appendix 8.

4.2.1.1 Why wood and metal are integrated

From the information gathered during the review of related literature, metal and wood integration is a long tradition. And since there is nothing that happens without a cause, it was necessary to find out the reasons why artists use the two materials.

Wood and metal are two different materials: organic from living trees and inorganic from non-living minerals respectively. Wood is one of the main materials since the prehistoric era before metal was discovered. The early metals (copper and gold) were more useful for ornamental purposes, this was so because they were too soft to be used as tools used by the prehistoric man for constructions and hunting expeditions. This explains the continuation of the Stone Age after the discovery of metals. In this age stones were attached to wooden handles and used as striking tools (one of the earliest material integrations). According to Holt, Rinehart and Winston (2005), the discovery of bronze as early as 5000 years ago was the end of the Stone Age. This was so because bronze is a harder metal and able to be formed into more usable forms than the flint stones. Unlike the tying of stone at the end of a piece of wood to produce an axe, metal was also more accommodative because its formability provided room for the incorporation of components like handle to an axe without much problem.

In view of this it could be said that metal and wood are integrated because one is a better substitute to a component in the art form of the other.

According to Chudly and Greeno (2005), metal frames do not shrink or warp, they could be fixed in similar manner as timber frames which could receive a rust free treatment as in the case of non-ferrous metals. In their recommendations of fasteners also produced similar applications for wood and metal (example wood dowels and metal dowels). These statements were made in the discussion of ideal door, door frames and lining.

Based on this it could be stated clearly that wood and metal are also integrated for the fact that metal could be conditioned to bare certain advantages of wood and vice versa and also because of the similarities in their application.

Adams (2002) and Prisant (1999) give account on art works in wood covered in metal through a process known as gilding. Chudly and Greeno (2005), accounts on construction also mention an opposite situation: the use of wood veneer as a finish for metal partition. This is an evidence that the two materials can be reversed in their uses. In this case it also confirms that metal and wood could have common uses.

In can therefore be said that, the integrations of the two materials are also for the fact that they complement each other.

Emmitt and Gorse (2007), illustrate the uses of metals in construction. These illustrations include sheet metal (lead) coverings to timber roofs in which lead is mentioned as having the properties of resistance to weathering agent example mild acid in rainwater including its high level malleability, comparatively heavy weight and achievability of complicated shapes without damage to the metal. These properties were sufficient to provide: protection for wood roofs from the adverse effects of weather; weight to the roofing structure to withstand the wind; and shape that is in conformity with the roof style. However the lead, because of its weight and high flexibility cannot be used solely for the roof without the support of the wood.

In view of this it could be said that metal and wood are also integrated because they are mutual solution to each other's problem.

A brief interview with a Ugandan Artist, Ben Bukenya presented on www.africannet.com reveals two important works done by the artist in wood and metal. Bukenya has creatively used the two materials to achieve the theme: live strong like a lion, live wise like a fox. In answering the interview question: "how do you describe your creative aspiration?" He answers: "as a contemporary sculptor, my works lie in the core confidence of compassion and durability". This statement explains why he chose metal over all other materials for his wood sculptures. This is indication that both materials are durable. See plate 4.1 and 4.2.

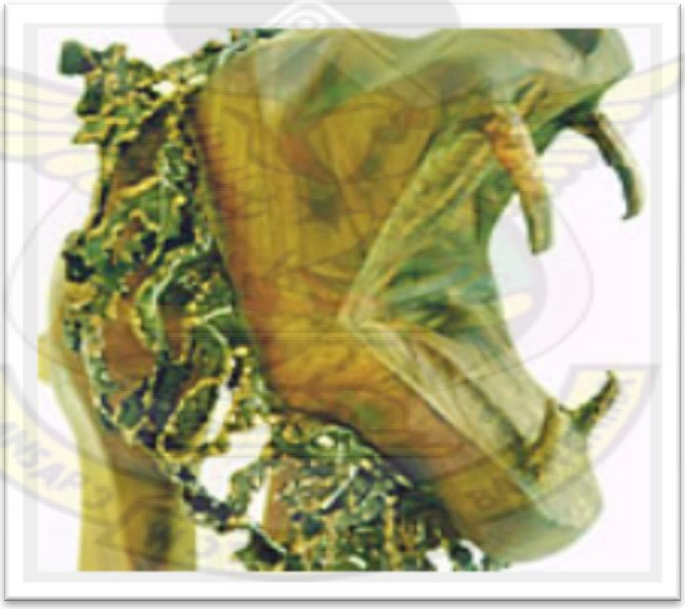


Plate 4.1: The lion in wood with its hair treated in metal by Ben Bukenya

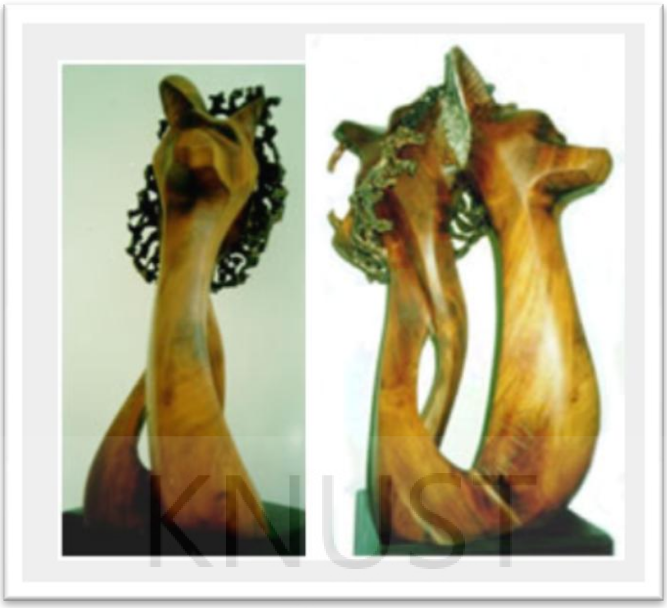


Plate 4.2: Two views of the fox in wood and metal by Ben Bukenya

It could also be said that the two materials are compatible because they both have the quality of executing lasting impression (works of both are durable).

From the content of the review wood and metal are integrated because the solitary usage of the two materials are associated with aesthetic and constructional problems either in the structure, function, look and durability that could undermine the success of a product's competition on the market. This is so because singularly, they may not satisfy their intended users.

4.2.1.2 The aspects of wood and metal that are or could be integrated

From the theories of integration presented in chapter two of this study, integration involves the combination of various aspects of the integrant to achieve a common unit. This has necessitated the investigation into aspects of the materials that are of interest to those who have had various experiences with the materials.

Works done in metal technology by Bray (2003), Tracy (1971), Ard et al (1981), McGrath (1995) and (1997) McCreight (1991), and in wood technology by Bridgewater A and Bridgewater G (2007), Mitchell (1993), Simpson (2008), Duginske et al (1992) Engler (1990), Cass (2006), Allen (2006) and others reveal common processes in wood and metal technology. These include forming techniques such as sawing, drilling, lathing, casting, carving, shearing and bending; constructional techniques such as screwing, riveting, adhering and jointing; and also finishing treatments such as surface scouring, filing, polishing and painting. Others include heat treatments and renovation treatments. The researcher also realises the uncountable common articles that both materials could produce under furniture, structures, containers, clothing, toys and decorations.

Moreover the two materials are applicable in similar ways: subtractive methods-carving, parts assembling-construction, shape transformation-modelling, replication in mould-casting and in combination use with other materials-assemblage. The researcher also realises the unique appearance in the contrast showed by the combination of wood and metal notwithstanding the varieties they create with their numerous textures and colours.

Van Vlack (1973) a material technologist also elaborates on properties of metal and wood which include mechanical properties (elasticity, plasticity, hardness and toughness), thermal properties (thermal expansion and conductivity) and electrical properties (electrical resistivity and conductivity). The measure of these however varies from one metal to the other and from one wood to the other. These account for the various behaviours (stability, collapse, etc) of the materials under different situations.

Furthermore, Adams (2002) and other authors on wood and metal art, elaborate that various cultures like the Egyptians and the Greeks chose metals for what they represented. For them gold represents royalties and for that matter wood sculptures recorded as retrieved from the royal setting including the spiritual temple where the gods were also considered as spiritual kings, were mostly embellished in gold dominated fashion or sometimes combined with silver in certain cases. Though metals such as copper and bronze had been discovered they were mostly employed for purposes such as utensils and weapons. But today bronze has gained recognition as the third metal ranking from gold. In other words gold stands first, silver second and bronze third.

Woods on the other hand are grouped according to their utilisation status and conservation classifications. Under utilisation status, they are grouped into premium, commercial, lesser used and lesser known species. Under conservation classification, they are put under critically endangered (CE), endangered (E), vulnerable (V), lower risk near threatened (LRNT) and lower risk least concerned (LRLC). Therefore wood or metal chosen for a particular production may represent an idea and or philosophy that sends the message To Whom It May Concern. This could cause a product to be rejected or accepted by people based on their believes and values.

Other aspects with reference to the wood and metal structure is that, the pattern of the crystal formation and the movement in the filaments of the wood structure and their disposition by knots and other natural obstacles are good impressions that are considerable in their production. This is so because their misapplication could disturb the look and performance of a product.

From the above the researcher deduces the following as aspects of wood and metal that are integrated or could be integrated:

Processibility: the ability of the two materials to be processed into similar forms like sheets, powder, poles etc. notwithstanding their similar processing means previously discussed, make their joint application very promising.

Representation: the representative nature of both materials could be creatively improved to making their collaborative use more communicative and useful in appreciation and marketing.

Applicability: this is the capability or suitability of the materials to be useful in the way and manner the designer would wish to handle them. In view of this the common applicability of both materials could be integrated or used as complements to each other. Secondly the unique applicability of each of them could also serve as supplements to each other.

Stability: the property of the materials that causes them to develop forces or moments that restore their original condition when disturbed from a steady mode. This quality could be either better in wood or in metal depending on their conversion status. This is also as an aspect that would need integration in order that the strong material would be used to stand in for the weak one. This is to make it possible for the designer to be able to achieve effects and responses that could otherwise not be achieved.

Kinaesthetics: this is the sensory experience of the materials derived from kinaesthesia. In the case of real life, not all products are required to be heavy, light or bare the natural weight of wood or metal. In other words it may be required to trim or increase the weight of either of the materials or emphasise the weight of the other at different times in product design for specific purposes. Therefore the kinaesthetics of the materials is also an important aspect that could be integrated.

Aesthetics: aesthetics in this sense is the pleasantness of the materials to the senses. The researcher believes that users must enjoy the products they patronise. This enjoyment has to do with how the senses react and feel about the product. In this situation the wood or metal could have the tendency of a good smooth feel, texture or smell or vice versa that could also be an aspect of integration between the two materials.

Contrast: wood and metal have distinctive characteristics that set them apart. These include their colour, texture and structure. These are also aspects of the two materials that could be integrated because the juxtaposition of dissimilar elements in a work of art creates pleasing and variety of effects in the creative adventure.

Mechanisms: these are the fundamental processes in the materials responsible for an action, reaction, or other natural phenomenon. In other words they are factors such as the arrangement of the constituents of the material that cause action and reaction movements such as expansion and contraction in the presence of heat or moisture; corrosion in the presence of acids; fading in the presence of sunlight and other responses to mechanical action that also vary from one material to the other. These are also aspects of the materials that could carefully be studied to improve on their role in “woomeint”.

Properties: these are the qualities or traits peculiar to the individual materials. Properties such as porosity, strength and lustre could be integrated with density, weakness and matt respectively to create pleasing effects. Since the materials possess numerous natural and artificially induced properties, they could also be considered as aspect for integration.

4.2.1.3 How the nature of wood affects wood and metal integration

With regards to the accounts of Tsoumis (1991), among other wood researchers, the nature of wood as a result of the organic development from their optical and lateral meristems under the influence of environmental factors renders the basic chemical composition that vary from one wood to the other as discussed in the literature review. The organic components and other cellular components notwithstanding the various conversion methods discussed in sections 2.3.4 and 2.3.11 respectively in the literature review renders the wood, certain mechanisms (eg. movement by swelling ,shrinkage and warping); reaction to external factors (eg. its reaction to the weather, water and chemicals) and mechanical status (eg. Strength, toughness, porosity) that could either affect "woomeint" negatively or positively.

Effects of wood mechanism: integration of metal into wood also includes the planting, piercing, inserting, and embedding of forms of metal into the wood including lapping and fastening. These sometimes produce negative results due to the inevitable movements that occur in wood. Some of these negative results are:

- Disintegration of the combination or the reduction of its life span through excessive tension on the metal in place or vice versa as a result of shrinkage. In this situation, the metal could resist the movement of the wood and cause it to crack, on the contrary, the wood could also overcome the metal either by crumpling it or forcing it out depending on the one with the upper hand.

- Shortage in intended dimensions and alteration in the intended form of the wood through warping. This could negate the success of integration by not fulfilling its requirements if it is not checked through proper conversion practices and more calculative and pre informed integration procedures.

- The splitting of the wood as a result of working at the wrong grain side. For example nailing of wood at the edges of a face of a piece could cause it to split though it might be required.

On the contrary “wherever there is a will there is a way” therefore the same situation could become advantages to a creative adventure. Some of these are:

- Employing crooking, cupping and bowing effects of wood in figure 2.15 in a “woomeint” curved joint that would otherwise require heat bending of the wood members to save energy.

- The twisting effects could also be adopted as a free original form for the creation of “woomeint” art

- The shrinkage factor could also be employed positively through calculative application as reinforcement for studs, nails and screws.

Effects of reaction to external factors: wood as a natural composite of lignified fibres are either made better or destroyed by external factors depending on whether those factors are tolerable or intolerable to its composition. Some intolerable factors include acid rains that corrode and weather wood; excessive humidity that would weaken the interconnecting lignin that may cause collapse of the structure. The factors may however not affect the metal existing in integration with the wood because that alone is not a guarantee for the sustenance of the integration. For that matter the vulnerability of natural wood may affect the design of the applications of metal in integration to ensure its protection. In other situations the chemical that may be used to treat metal may also be harmful to wood. This may also affect the production procedure due to the peculiar treatments that may be required by the individual materials. So far as art is concerned the researcher believes that some of the defects by the intolerable factors could also be adopted and used as artistic effects.

Effects of the mechanical status: mechanical conditions such as hardness, toughness and elasticity of wood as described by Tsoumis (1991) vary from one wood to the other. The degree of these in wood often dictates their working procedure and method. Example, very hard wood like "ache" may not permit nailing, so instead of just nailing with hammer, the worker may be required to drill first which may slow down the production. A too porous wood may also absorb excessive moisture that may cause steel fasteners to rust. In view of these wood may not be easily manipulated as in the case of metal, and for that matter, it is easier for metal to flow around wood than the contrary. However much will depend on the creative abilities of the worker because "impossibility is in the mind of the less favoured".

It could therefore be said that the nature of wood could either affect wood and metal integration positively or negatively depending on the design upon which the integration is based and secondly the expertise of the artist in question.

4.2.1.4 How the nature of metal affect wood and metal integration

The nature of Metal as described by McCreight (1991) and others is crystalline chemical element characterised by numerous properties. Metal is versatile because of its endless forming and sizing capabilities and moreover vast in types and varieties that make it super multi-purpose. It is therefore a key to endlessness in wood production. Some of these are: ability to provide wood with a means of conducting heat and electricity; rendering of strength to wood sizes that are otherwise not easily usable for certain application due to their weakness; addition of value to wood base on its value and as check to wood movements based on its stability. "Take what you can use and let the rest go by", says Ken Kesey as cited in McCreight (1991).

4.2.1.5 Properties of wood that would accommodate metal

Bray (2003), McGrath (1995) and McCreight (1991) all expound that metals may be in many forms, colours and sizes with different properties and behaviours. In application of metals to wood, any of the vast variations of sizes, forms and colours may be required by an artist. With the fixing of metal forms to wood as described by Simpson (2008) ranges from screws to bolts and nuts. However it is certain characteristic properties of the wood that make these processes possible. Some of these deduced by the researcher and buttressed by Negi (1997), Tsoumis (1991) and others are:

Colour: this is the most common physical property of wood that varies considerably in different species of wood. The aesthetic appeal that metal creates on wood is noticeable by the arrangement of colours (also known as texture) of the wood. In view of this, particular metals due to their colours may be accommodated by particular wood species based on the artistic impression the artist intends to create (it could be a blend or contrast, each of which is determinant by the colour of the accommodating wood). Cass (2006) and Allen (2006) also add that natural colour of wood does not always matter because they are sometimes artificially induced by varied means.

Density: this is the dry mass contained in unit volume of a wood. This would be in a good position to accommodate metal forms that must be formed around a wood form without disturbing the structure of the wood. This is also a factor that prevents excessive water from entering wood which may protect inherent iron from rusting.

Shrinkage: it is the reduction of the dimension of wood due to change of its moisture content. This could be a disadvantage to "woomeint", but to the researcher it is also a factor that promotes strength in joint if carefully managed. Shrinkage may resist the puling of fasteners from wood in order to make the joint stronger.

Permeability: it is the ability of wood to allow water and other liquids into it. This property is essential to the application of liquid substance to the wood in the form of finishes or preservation treatments notwithstanding adhesives. These are able to penetrate the wood in order to fulfill their purpose. Permeability in wood is also of great essence to "woomeint" because metal technology also involves liquid substances.

Acoustics: acoustical properties of wood refer to two phenomena of wood: the productions of sounds by direct striking of the wood and secondly, the behaviour of wood to sounds produced by other source transmitted through the air. This is the property of wood employed in the making of xylophone. This property is also a room for accommodating the musical or sound design aspect of "woomeint".

Wood working qualities: these are qualities of wood by virtue of which it can be worked or finished into various end products. They are not directly physical properties but they are of vital importance in deciding the end use to which particular species of wood could be put. Some of the qualities as Anon (1970) supports is that wood has certain working properties in common with metal under both hand and machine working operations. This is also an accommodating situation where woodworking could involve the use of metal without much obstacles.

Defects: These undesirable characteristics of wood could form a basis for wood metal integration. Example, a nice metal effect could fill a knot or a worm hole to add colour to wood. In this sense the defect becomes an accommodating factor.

Thermal reaction capacity: this has to do with the response of wood to heat. This reaction often enables wood to be in simultaneous thermal expansion and contraction with metal to accommodate the metal to sustain the integration.

Electrical resistance: this is a condition that exists in well seasoned wood that prevents electricity from passing through it. This is the basis for the accommodation of metal meant for an electrical process in "woomeint" to control the limit of the flow of current.

4.2.1.6 Factors that usually affect metal on wood pieces

From the numerous readings, the researcher deduces certain factors of wood in relative terms with metal as factors that affect the well being of metal on wood pieces. These are swelling and shrinkage, finishing and oxidation.

Swelling and shrinkage: this factor discussed earlier causes changes in the dimension of wood thereby causing metal fixes on it to lose their definite position. The shifting of metal on wood as a result of swelling and shrinkage may result in the failure of the integration which could be in the function or structure of the integration.

Finishing: this is normally the rendering of wood surfaces their final look. These come in various ways. Cass (2006) and Allen (2006) describe various material and means by which wood is rendered its final finish. Some of these include wax application, varnishes and paints. However, some of these materials like oil paint may also serve the same purpose for metals but others like wax may not. Some like acrylics may do for both but would not last on metals as in the case of wood. Therefore wood finishes that are incidentally applied to metal may therefore fail the metal while the wood is still intact (a failure of the integration).

Oxidation: this occurs when metal is exposed to air and dampness. Sulphur content that is present in the air discolours and blackens the metal. Metal for certain purposes are repolished periodically to maintain their lustre. Though oxidation could also be done artificially or adopted as a desirable effect, it is a factor that may disturb metal in integration with wood. This is so because metal fixed into wood is not always detachable and the non detachables could hardly be repolished without affecting the wood surface. This situation is even worse if the original finishing of the metal involved acids.

4.2.1.7 Functions of wood that could attract the incorporation of metal

Designing always starts with a problem that leads to the organisation of elements or materials to that effect. The purpose of the design is a solution to the problem within which each of the elements or materials perform a function that contributes to the success of the design.

From the literature on wood utilisation by Allen, Simpson, Bridgewater A. and Bridgewater G. among others, the researcher deduced that at one point or the other, the wood that is used performs one of the following functions within the purpose for which it was made: Strength, Value, Decoration, Communication, Connection, Mechanisms and Durability.

Strength: members in wood projects most of the time require strength to withstand tension, compression and shear stress. This function largely depends on the size of wood and the conversion of the wood. So far as the artist is concerned wood may lose its strength at certain points in time that may require the reinforcement to ensure its function. Tsoumis (1991) buttresses this assertion also.

Value: it is also noticed that some wood are more valuable than others. Oteng-Amoako et al (2002), even agree that wood is divided into four utilisation or demand categories, these are premium species, commercial species, Lesser Used Species LUS) and Lesser Known Species (LKS). Each of these categories has a value placed on it. Premium species are running out and for that matter most valuable and expensive. Commercial species have a greater demand and are widely used and since their demand is higher they are more expensive. LUS is less used and for the matter not well known in terms of performance which makes it less valuable to its users. In the case of LKS, they of are less value because they are not known as species that could serve very important purposes. Prisan (1999) adds that, the value of a piece is based on six factors. These are: rarity, provenance, quality, finish, colour and condition.

The value of a wooden product would also depend on the value of the wood used. Wood used in a product could be rare, have a good history of ownership, quality, have a good finish, beautiful colour, and be in a very good or favourable condition, either of which could be a function wood could perform in a product. These functions could however be enhanced or protected by the introduction of metal. This is so because metals have similar values with wood and sometimes more superior values that could supplement that of wood.

Decoration: wood is also chosen over other materials because of its long lasting decorative effects that are possible through its numerous forming capabilities. Besides, it also has a beautiful figure that becomes very obvious when polished. Wood therefore, functions as an element of decoration that could attract enhancements by more capable decorative materials such as metal.

Communication: traditionally wood species are used to communicate ideas. One may communicate a natural phenomenon through wood carvings. These same carvings may be abstract communication of ideas representing groups of people as in totems; status in societies sometimes represented by stool and chairs in various cultures. Metal on the other hand is very representative of statuses in society. In most societies gold is not seen on common people except the affluent and royals in society, for that matter it stands and is associated with issues of high profile. The communication aspect of wood is therefore an important function that could attract the incorporation of metal for the elaboration of details or placing of emphases.

Mechanisms: wood species at certain points in time are required to perform certain mechanisms such as Security and Jointing with dissimilar materials. An example is the use of wood in the manufacture of doors and gates and also the use of wood as support for roofing systems that require the wood to joint a material such as cement which it is not compatible with. In these cases wood would function to the fullest by attracting the use of a more appropriate material such as metal in the jointing, hinging and locking system of the door in the case of the security mechanism. And the application of a connector that is both connectible to wood and cement like metal to connect the two in the case of the roofing system. Therefore metal is also usable in the case where wood is not hundred percent capable of being executed into certain mechanisms.

Durability: comparatively metal may be more durable than wood but wood piece are sometimes require to last for generations unborn. Adams (2002) accede to the fact that, across times, art presents wood carvings covered with metal such as bronze, silver and gold that have lasted times before Christ was born to date. Examples already presented in the literature review are the reliquary statue of Saint Foy and the stag at the archeological museum, Ufa. However Prisan's account (1999) claims that some wood antiques with metals have had their metal components replaced. This means that they were fashioned in iron and could not stand the test of time. The durability function of wood therefore would embrace precisely nonferrous metal that would not rust or deteriorate.

4.2.1.8 Mutual benefit that occur or could occur between wood and metal

From the literature on wood and metal it has been realised that wood and metal have similar properties that promote their compatibility and dissimilar properties that necessitated their coming together because they complement each other. Table 4.1 below illustrates some identified dissimilarities and how they benefit both materials.

Table 4.1: Summary of mutual benefits between wood and metal

Metal	*Wood*	*Benefit*
More conductive of Heat electricity	Less conductive of heat electricity	• The ability of integration to exhibit both properties as and when it becomes necessary
Biodegradable and combustible	Permanent except for iron base metals.	• Metal as a protective cover for wood against degrading agents. • Wood as temporal material for giving form to metal and later taken by exposure to degrading agents. • Wood could change chemically through combustion as an added effect on metal.
Swelling and shrinkage	More stable	• Metal as movement check on wood
Less lustre	Lustrous	• Metal and a reflective material on wood to make it more noticeable.
Figured	Plain	• Plain metal as a contrasting material on wood and vice versa in "woomeint" designing.
Malleable	Breakable/rigid	• Malleable metal as means of giving intricate form to breakable wood. • Rigid wood as an armature to make thin metals stable
Not recyclable	Recyclable	• Metals' ability to regain their structure after disintegration is an advantage one can capitalised on for effective waste management in "woomeint". This could be done by the introduction of metal at points that excessive trimming is needed in order to minimise waste from the non recyclable wood.
renewable	Non renewable	• A form could be maintained for posterity using metal. But due to the fact that metal is non-renewable but highly demanded, its usage could be minimised through the incorporation of replaceable wood components that could be renewed and acquired from time to time.
Relatively light in weight	Relatively heavy in weight	• Heavy metal could be employed to induce weight into a light wood that require extra weight. • Wood on the other hand is also a good material employable as a weight reduction material in metal
Fibrous	Not fibrous (crystalline in	• The fibrous nature of wood makes it susceptible to most cheep adhesives and

	nature)	finishes that could also affect metal positively when creatively put together. • The crystalline nature of metal also make it susceptible to thermal fusion and magnetic finishes that could be advantageous to wood when creatively considered.

Secondly, the similarities that have been identified include debatable and non debatable properties as follows:

Heat formability: the ability of both materials to alter in shape under the influence of heat. This is also the bases of their thermal expansion and contraction movements that benefit the structural well being of both materials.

Alternative working technique: both materials have various forming, constructional and finishing techniques that enable them to fit into numerous situations. This similarity benefits both materials because at any point in time there are alternatives from which a suitable working technique could be selected to satisfy a situation.

Colour variety: another aspect where wood and metal benefit from each other is the fact that both materials come in various colours. These colours are as a result of the various species from which wood is acquired notwithstanding the artificial means by which colours are also induced into wood. But in the case of metal, different metals have their colours based on their chemical make-up. However, these colours are limitless with regard to alloying (the endless formation of other metal through the mixing of the base metals) that changes their chemistry.

Cost effectiveness (debatable): any of the two materials could be cheaper and expensive depending on the type or form of the metal or wood involved. Some forms or types of metal could be cheaper than wood and vice versa. Both materials may therefore enjoy under exploitation when in mutual integration.

4.2.1.9 Benefits users derive from wood and metal integrated products.

From the study wood and metal integration always has a purpose that determines its quality (the ability of the product to serve every aspect of its purpose correctly). Quality includes elements that could be listed under functional, aesthetic and environmental purposes. In this respect wood metal integration may be friendly to its users; aesthetically appealing to its users; valuable to its users; duly serve the purpose for which it was acquired and above all wood metal integration may not be a nuisance to the environment of it users because wood is capable of returning to the soil and the metal could be recycled and reused for same or other purposes. This is also to say that with wood and metal integration a patron would always have a booty that could be sold or invested after the use of the product.

4.2.2 Outcome of the interview of experts in the field (primary data)

This section deals with the responses that were given by interviewees in respect to the question designed for relevant workers in the field. Answers received by the researcher were different but similar in most cases. The results were therefore merged and summarised under the various categories of respondents and their respective questions as follows:

4.2.2.1 Sub question one

The first sub question was inquest for why the two materials are integrated. The respondents responded to the following questions as follows:

- *Do you at certain points in your production use wood and metal together?*

The answers given were rated from "not at all" to "always". In this respect each of the categories fell under more than one of the responses on the scale as distributed in figure 4.1.

Figure 4.1: Points at which workers use wood and metals together

Some woodworkers were of the realization that though they have not conditioned themselves to work in wood and metal, they almost always use metals and confessed that though they are not metal workers they do not easily do without the introduction of metal. This category was almost all woodworkers except some carvers who do not have any business with the finishing of the pieces they carve who answered "not at all". Even under the category, some confessed that they sometime nailed glued joints of broken piece of their carvings together. Based on this it could be said that most wood workers are liable to the use of metals

Some metal workers like goldsmiths, fabricators, auto body workers, and late turners to mention but a few actually have nothing to do with wood and for that matter fell under the "not at all" category. Though most of the blacksmiths do not have anything to do with wood, at least some use wood as handles for certain work or tools they forge and for that matter fell under the ‘sometimes’ category. Jewellers provided very important information that has to do with the mixing of wood dust with resins as colourants on metal pieces, and because it is not the only source of colour for their work it was put under the “when it becomes necessary” group.

The third category of experts who are associated with both materials sometimes have some members working in only one of the materials. This may be for the sake of variety which put them under “always” and “sometimes”.

- *What do you use them for?*

Under this question the researcher wanted to know the kind of products that necessitates the use of the two materials. To this they responded as follows:

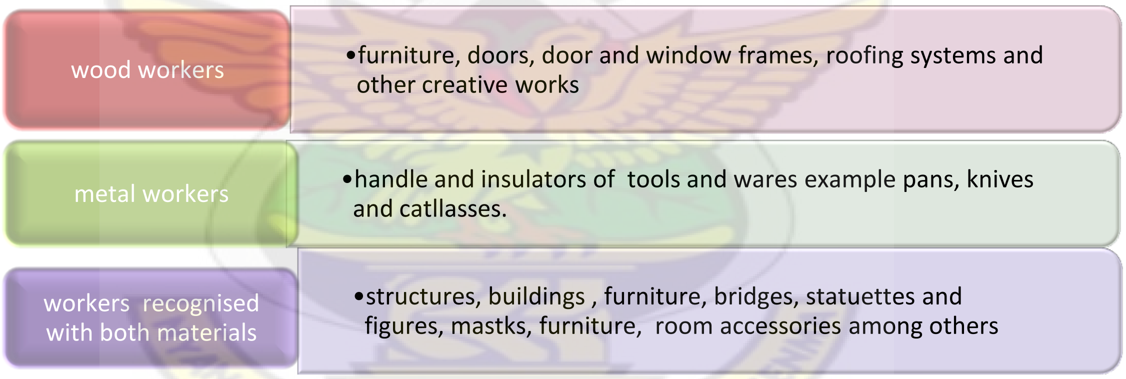


Figure 4.2: Responses on products to which wood and metal are associated.

The result was numerous and similar for that matter only few important ones were presented. However the result presents certain similarities between the first category and the last: examples are the recurrence of furniture and the components of buildings. It is a sign of the long tradition of wood and metal joint applications. One may think that the wood workers do not shape metal, but the point is no one straightens nails for the wood worker when they are bent neither do they send them to the metal worker when they want them shorter. This is a humble metalworking beginning by woodworker that could be improved upon. In view of this it could also be said that wood metal integration is often done because artisans are already used to it.

- *Why neither wood nor metal alone?*

Respondents under this section explained the essence of metal in their works and vice versa. These are summarised in table 4.2 as follows:

Table 4.2: Reasons why workers prefer the use of wood and metal to the use of only one at a time.

Woodworkers
• It is cheaper and easier adopting metal than making everything wooden. Example it is easier to nail wood than to make dowels and drill hole for the joining of wood pieces. • There are many metal pieces on the market design to fit woodwork designs like doors and furniture. For that matter it is not necessary indulging in the time and wood wasting activity of doing everything in wood
Metal worker
• Sole metal equipment are not always handy • Metal that must come into contact with electricity or fire certainly needs insulation
Those associated with both materials
• Metals make the woodworks more beautiful. • Metals are able to improve the strength properties of wood that boosts the durability of structures. Examples given are shear strength, tensional strength and compression strength notwithstanding the strength of joints.

Based on the above it could be said that wood and metal are integrated because: It is easier and cheaper; metals are easily obtainable, both material complement each other and also because some workers were trained with it and for that matter already accustomed to it.

4.2.2.2 Sub question two

The second section that deals with the aspects of wood and metal that are integrated were responded to as summarised under their respective questions as follows:

- *At what instances do you put together the two materials?*

Table 4.3: Instances where workers put wood and metals together

Stratum	Summary of Answers
Woodworkers	• When prepared wood pieces or members must be jointed together. • When there is need to provide mechanisms such as a lock and a hinge. • When there is need to embellish a piece of work. • When there is need for a reinforcement in a piece
Metalworkers	➢ When there is the need to protect the user ➢ When there is the need to prevent the metal from making contact with things that they may be destroyed. ➢ As colourant for filling recesses on jewellery components.
Associates with both materials	• Anytime I feel like it. • I hardly do with one without the other • When I really want to show contrast, example between a sculpture and its pedestal • Sometimes when I feel like creating an unusual effect • When I want to do wood dust modelling. • When I feel like doing mix media • Upon request by clients

From table 4.3 above it could be said that the instances the two materials are put together are based on three factors: demands of the materials, demands of the clients and creative instincts of the artist in question.

- *What aspects of your production require the integration of the two materials?*

To this question, the respondents mentioned specific aspect of their working processes in wich they introduce wood or metals. These are presented in table 4.4.

Table 4.4: The points at which the production of the workers require the incorporation of wood or metal

Workers	The points of production
Woodworkers	• Assembling: at the stage when members are to be put together in which metal come in as connectors, fasteners and decorations that comes before the finishing. • Final finish: this is when woodwork is finally polished or sprayed; the metal components then may come as fixes and appendages.
Metalworkers	• The finishing aspect such as the fixing of handle or wood component after forging that may or may not be followed by any heat treatment.
Associates with both materials	• Making of armature: making of framework for modelling and construction. • Finishing and Decoration: finishing of woodwork by the introduction of metal as a form of decoration or embellishment. • Assembling of wood members in construction • When there is the need to put certain details on metal work which is otherwise difficult or expensive to execute in metal.

From Table 4.4, the aspects of production of the three groups that involve both materials include the forming, construction and finishing excluding materials conversion and processing. Also workers apply metal to wood more than wood is applied to metals.

It is obvious that there is always something found in one material the other lacks which constitutes their unique individual properties. It could therefore be said that the aspects of wood and metal that are integrated is their properties: that constitutes the overall behaviour and characteristics of the materials. These are grouped under physical, mechanical, electrical and thermal properties as already discussed in chapter two.

4.2.2.3 Sub question three

The third aspect demanded the nature of wood and metal ever encountered by the workers that challenge them in their integration adventure. The workers responses under the sub questions are as follows:

- *What problem do you encounter with wood?*

Table 4.5: Problems workers encounter with wood

Workers	**Problems encountered with wood**
Woodworkers	• Surface denting when fixing the metal pieces • Inability to sometimes receive nails due to its nature or defects • Inability to hold fasteners caused by defects
Metal workers	➢ Splitting in the process ➢ Getting stained and losing its nice look after work
Associates with both materials	• Delicate surfaces easily dents that curtails excellent finish • Its different properties sometimes make it finishing in combination with metal time consuming. • Fastening is not always easy • Shrinking and warping of the wood that renders supposed fitting forms and sizes inappropriate to the task.

From the responses tabled above it is obvious that the problems often posed by wood are dependent on the working procedure. This is so because it would certainly be easy to nail a hard wood when the nailing is preceded by the drilling of an appropriate hole. Also the careful seasoning and timely application of wood could alleviate or bring to the barest minimum the impact of shrinkage and warping.

- *What problems do you encounter with the metal?*

Table 4.6: Problems encountered with metals

Workers	Problems encountered with metals
Woodworkers	• It is difficult to acquire certain sizes of metal fittings or fasteners. • Discolouring of the metal
Metals workers	• Cutting of intricate shapes in the case of certain metals are difficult. • It is quite uneasy to give an excellent finish to some metal works except with the help of certain non-metallic materials like fillers and primers. • Certain size, forms and types of metal are difficult to work with.
Associates with both materials	• Metal sheets easily get crumpled during certain applications • Metal sometimes get discoloured that curtails the beauty of the work especially when fixed on wood such that it cannot be repolished • It take so much time to finish some metals • Certain forms become difficult to acquire which limits the scope of creativity.

The problems presented in table 4.6 are partly the limitations on the equipment or technology used by the workers and partly the failure to acquire the right metal form or size for the job at hand. With reference to the properties of metals, their applications are almost endless. These problems could only be attributed to the lack of appropriate technology and insufficient communication between metal producers or manufacturers and its users. Answers to the next questions however explain how they go around the problems.

- *How do you overcome these problems?*

Table 4.7: How workers overcome their problems with the materials

Workers	**How workers overcome their problems with the materials**
Woodworkers	• Sometimes series of drilling would have to be applied to make nailing possible • Stains on wood are covered with wood stains in order not to show them • Metal fittings are acquired before production or the production is based on the fitting available. • Discoloured metals are adopted as desirable effects or sometimes camouflaged by heat colouring. • Protecting of metal surfaces by painting in the case of ferrous metals • Coating of wood metal integrated surfaces with an amalgam and abrading to show metal through. In this remedy the metal ends and fasteners that have problems are relegated.
Metals workers	• Forgetting about intricate shapes that may make the works more appealing and resorting to simpler ones • Adaptation of resulted metal textures as effects • Sacrificing the metallic exclusiveness by adopting certain non-metallic material like fillers and primers to render it a smooth finish. • Working within the means of what is available
Associates with both materials	• Thick sheets are sometimes adopted to replace the lighter ones that easily gets crumpled during certain applications • Metals that get discoloured easily as a result of tarnishes and rust are often painted over. • Some tarnishes are adopted as desirable effects • Metals that demand much time to polish are textured to make their application easier. • Designing is consciously done to ensure that impossibilities are not included

The line of actions to the problems mentioned in table 4.7 may be due to certain factors such as: Lack of demands for wood and metal works with a natural finish; the failure of clients to see the value in the natural presentation of the two materials and lack of certain relevant logistics to that effect. “It is good to be creative, but creativity is not always the act of running away from realities”.

- *By what logistics do you embark on this adventure (wood metal combination)?*

Table 4.8: Resources available to the workers for the incorporation of metal into wood

Workers	**Logistics**
Woodworkers	• By the traditional wood worker, simple tools like shears, scissors, and metal matting tools, pair of pincers, punches, hammers and brushes were mentioned. Abraders like abrasive papers, improvised scraper and files were also mentioned. • Apart from those mentioned above, others mentioned are wood saws, chisels, screw drivers, hand and machine drill, hand and machine planes and machine sanders. Sophisticated machines such as the Percussion drill, compressor and its accessories such as the nail guns and spraying guns. • Finishes such as oil paints, lacquers, potassium, wax polishes and locally composes amalgams were also mentioned. • Adhesives mentioned are PVA and super glues.
Metals workers	• Anvil, hammers, hand grinders, drills and bits.
Associates with both materials	• To this category all the above situations were applicable • In addition to the adhesive was the Epoxy

This table is a clue to show how interrelated the technologies for the three groups are. The limitation of a member of a group may be based on the independent nature of that member. Also these logistics, though manageable, could be improved since they contribute to the problems faced with the materials by the workers.

From the answer of the four categories of questions it could safely be said that the nature of the two materials that affect the integration are their chemical (example tarnishing of metal as a means of protecting its surface) and strength properties (example hardness and toughness), that are often beyond the logistics of the worker.

4.2.2.4 Sub questions four

The fourth aspect was the quest to know what is good about the wood they use that supports the incorporation of metals.

- *What type of wood do you use?*

Table 4.9: Types of wood used by workers

Working groups	Name of wood
woodworker	Mahogany, Odum, Emire, Asanfena, Mansonia, Teak, Cindrela, Avodire, Sapele, Danta, Koto, Walnut, Wawa, Ofram and Sese
Metal worker	Dahoma, Kusia, Apro, Denya and dead pestle
Associates of the two materials	Teak, Mansonia, Asanfena, Sese, Ache, Wawabima . Odum, Dahoma, Kusia and Denya.

From the outcome above, it is obvious that the woodworkers group use more species than the others. Moreover, the species are not very much related in their behaviour (physical properties) because of the wide scope of products they do. In the case of metalworkers, they are choosy in the type of wood species they use. This is partly due to the compressive procedures required in their fixing to the metal and partly due to the vigorous purposes they may serve in their use. The last group of workers are more conscious in the choice of their wood than the first group. This is so because they focus simultaneously on both material and joint processes than the first group which focuses more on the wood than on the metals.

- *How does the wood behave in the process of adding metals?*

This question was really answered by the first and second categories of workers and the results are as follows:

- Sometimes it is easy to fasten and at other times difficult except with drilling
- Drilling is sometimes difficult leading to the burning of the wood by the friction that occurs between the drill bit and the wood.
- Some of the wood or parts are extremely hard that makes the wood not easy to work with or finish.

The above discussion explains that wood-metal integration is not just done because it is always enjoyable, but much motivation depends on the outcome than the processes involved.

- *How do you connect the two materials together?*

Table 4.10: Means by which workers connect the two materials together

Woodworkers	Nailing, screwing, riveting, and bolting.
Metalworkers	Riveting, bolting and the pushing of the metal into the wood to grip it.
Associates of both materials	Nailing, screwing, riveting, adhering and bolting.

For the results, group one and three had everything in common except for the adhesion applied by the third group in obscure situations. All the connection materials are a third factor to the holding of metal and wood pieces together except a situation by the second group where only metal and wood are connected without any material medium.

- *What is the final outcome of the wood after the whole process?*

Table 4.11: The outcome of wood after the incorporation of metal

Woodworkers	Strong, durable and different outlook
Metalworkers	Gorgeous and original look.
Associates of both materials	Appealing, strong, contrasting

The summary of results above reveals the purpose for which the workers execute the integration of the two materials. Answers from the first and the third group reveal how the strength and outlook of wood could be enhanced by the incorporation of metal. However, the overall answers expressed a change in the look of wood in association with metal. This could be the result of the unique contrast established between them as mentioned by the third group.

From the analyses made on table 4.11, it could be said that the respective wood used by the three groups are characterised by certain properties such as beauty, strength, texture, weight and friendliness that support the working procedures of the workers, the look of the product as well as the final use of their products. For example, the wood the metalworkers uses is due to the fact that besides having good finish and being friendly to the user they also respond positively to hammering that may occur in the course of riveting. It neither breaks nor splits notwithstanding its ability to withstand the usage of the product.

4.2.2.5 Sub questions five

The fifth aspect on factors that affect metals on wood pieces were responded to as follows:

- *Have you ever experienced something happening to the metal after the work had been done?*

Table 4.12: Problems seen on metal during/after incorporation with wood

Woodworkers	Changes in colour, rusting
Metalworkers	No, change in colour,
Associates of both materials	Change in form, Crumpling, rusting

The responses in table 4.12 indicate that the usual problem of metal on wood is the change in its colour and form. This discolouring may be caused by stains, oxidation and corrosion whereas the deformation may be as a result of the shrinkage and swelling movement in the wood that has a capacity over the metal. This deformation may cause a wood metal chair to deviate from standing well after having passed a standing test or even cause a flexible sheet of metal on a wood surface to lose its original form. Discolouring on the other hand may cost the beauty of the work which may be difficult to reverse depending on the mode of metal incorporation. Some members of the second group use protected metals like anodised aluminium that, they fit to well seasoned wooden frames. Because the metals are protected and their positions on wood lack further movements, their answer was "no" to the question indicating that, they have never encountered such an experience.

- *What kind of finishing treatments do you give to the work after the integration?*

This required the final finish giving to final "woomeint". It has however been realised that also individual components are given these finishes before the final assembling. These finishes are presented in table 4.13 below.

Table 4.13: Finishing treatments given the works after integration

Working groups	Wood finish	metal finish	Dual purpose finish
Woodworkers	Wax polishing,		painting lacquering or varnishing
Metalworkers		Plating and Polishing	Painting, lacquering, Painting and oiling
Associates of both materials		plating	Lacquering, Painting and wax polishing,

The above therefore represents the finishing treatments giving "woomeint". All the finishes (wood, metal and multi finishes) run through except polishing, oiling and plating. The metal is polished by the use of abrasives and buffers to give the metal its lustrous natural feel which makes it different from wax polishing. However it is found that there are problems with some of the finishing on some of the metal that result in the problems found with metals on wood surfaces.

- *Do you do any preliminary treatment to the materials before they are brought together?*

This was to seek for information on the preliminary treatment given to the materials or products prior to the final finish that takes place before or after assembly.

Table 4.14: Preliminary treatments given to wood and metal prior to integration

Working groups	Wood treatment	metal treatment	Dual purpose treatment
Woodworkers	Staining, build up coating of charcoal mixed with PVA, preservation, scorching and texturing.		Painting, Smoking, abrasion
Metalworkers		Plating, polishing, smoking and pickling.	Painting, Abrading
Associates of both materials	Staining, scorching and preservation	Plating, polishing, smoking and	Painting, Smoking, abrasion, texturing

		pickling	

From table 4.14, it is obvious that it is not the woodworker's priority to go an extra mile to treat the metal neither is it the priority of the metalworker to treat the wood unless the multipurpose treatments that are already within their means. They explain respectively that the metal pieces are already made and ready for use. For the treatment of the wood some of the workers explained that it is not necessary due to the purposes they may serve. But all the parties do some amount of preliminary treatments which prepare the surface for the final finish; some protect the materials and others form part of the final finish.

4.2.2.6 Sub question six

The sixth part was to find out the specific demands, expectation or functions regarding wood that demands the incorporation of metals.

Though this question gives the impression that it is not likely to be answered by the second group of workers, their stake in the activities enabled them also to make meaningful contributions. These are as follows:

- *What specific demands necessitate the introduction of metal into wood?*

Table 4.15: Demands that necessitate the introduction of metals into wood

Woodworkers	• General assembling of wood members in projects • Decoration of wood projects • The need for appendages • The need to have variations in wood products
Metalworkers	• The need to reinforce wood products • The need to provide mechanisms in wood products. • The need to provide strong joint for giant wood pieces

Associates of both materials	• The need to protect wood surface • The need to provide light looking pedestals to wood forms • The need to provide good contrast among parts of a product • The need to reinforce wood products • Joining or linking of wood pieces together • The need to provide mechanisms in wood products. • Demands of the market

All the above indicate that the incorporation of metal in wood is basically the demands of the design in question that may be based on one or more of the following:

The stereotype application of metal pieces and mechanisms, for example locks, nail, handle and the rest.

The shortcomings of wood, for example strength limitation, limitations on forming techniques, the wastage as a result of certain application etc. that may demand metal as a reinforcement, decoration, strengthening and protection material for the wood.

The demands of clients: users of wood product may commission wood producer with specific metal component. Or if the designer realized that clients have began expressing dissatisfaction or boredom with a product and there is need to effect new changes.

- *What roles do metal play in the function of your wood works?*

For this question, table 4.16 summarises the responses.

Table 4.16: The role of metal in wood works

Woodworkers	• As a hold on joint • As an integral part of the product • As decoration on the wood product
Metalworkers	• As a reinforcement in wood • As a wood joint connector

	• As a mechanism in a wood product eg. Movement or locking mechanism
Associates of both materials	• As an integral material in wood production • As an integral part of the product • As a wood joint connector • As a hold on joint • As a mechanism • As decoration in wood production • As a protection for wooden parts • As frame works for wood and/or metal application • As a reinforcement in wooden parts

From table 4.16, the third group's application of metal is the total of the others. In summary, these could be grouped under three applications as follows:

i. Integral material: in cases where the two materials are used for the production of the components of a product.

ii. Integral component: in a case where each of the materials stands as complete components in the integrated product. An example is The Peace Pole in plate 2.19 where the metal components are separable from the wooden components.

iii. As a wood aid: this aspect becomes valid when metal's substitutable weaknesses occur in the design of a wooden component. An example is a timber bridge for vehicles where a whole wooden beam is either replaced or supported by a metal or steel beam to sustain its use.

- *What metal do you patronise on the markets?*

For this question metal patronised by the workers were in two categories, those that were processed into finished product and ready for use (processed metal) and those ones that must be processed by the worker. These are summarised in table 4.17:

Table 4.17: Metal components patronised by workers on the market

Working groups	Processed metal	Raw, converted or scrap metal
Woodworkers	Hinges, locks, screws, general nails, louver frames, ceiling fun hangers, roofing sheets, doors and drawer handles. Springs, window stoppers, drawer sides and runners, bed hooks, catches, knockers	Metal sheets (zinc and brass)
Metalworkers	Screws, bolt and knots, rivets and lockets	Rods (iron, steel, copper, aluminium and brass), steel pipes and bars, aluminium (sheet, pipes and frames; copper, brass, silver and gold in various and sometimes unpredictable forms.
Associates of both materials	Hinges, locks, screws, nails and roofing sheets.	Copper sheet, pipe and scraps; brass sheet and scraps; aluminium sheets, iron and steels rods, pipes and bars.

In table 4.17 are the respective materials that the workers obtain from the market. The woodworkers group has the greatest number of processed metals. This could be so because their main motivation for the usage of metal is its availability of the ready to use metal products on the market. On the contrary the metalworkers are more into the processing of the metals and for that matter patronise the raw or converted metals which they process into finished product that are also patronised by the other groups. The third group however is an intersection of the two groups, they process the metal and also purchase the already processed ones when it becomes necessary.

From the analyses above one may wander why wood is requested even beyond its capabilities, but as discussed in the previous chapters, it is a material of choice for good reasons. Due to this the workers look for avenues within and outside the material to make their dreams come true notwithstanding the application of metal. It could therefore be said that the demands, applications and functions of wood that necessitate the incorporation of metal are situations that are beyond the natural capabilities of the material. In other words: these are situations where the limits of the material are reached. These limits could be strength limits, decoration limits, durability limits, processing limits or functional limits.

4.2.2.7 Sub question seven

In this seventh section the interviewees were to provide mutual benefits they have noticed between the two materials

- *How do wood and metal look in integration?*

For this question, table 4.18 summarises the responses.

Table 4.18: How wood and metal integrated works look

Woodworkers	Strong, appealing, original, durable and different
Metalworkers	Friendly, colourful and original
Associates of both materials	Vivid, nice, colourful, Strong, appealing, original, durable and friendly.

From table 4.18, the woodworkers concentrated more on the impact of the metal: how metals strengthen wood and make them more appealing; how metals facilitate imitations and make work look original; how they prolong the life span of wood and how they give woodworks different looks. The metalworkers are also of the view that, wood adds colour to metal works to make them more inviting. Quite apart from that they are also of the view that metal integrated with wood look friendlier because some metals may not be friendly to hold at all times. The last group however, share common views with the other groups with the exception of two points that were made: they are of the view that, the look of both materials gets improved when they are together which they describe as vivid and nice.

- *How different does wood behave in togetherness with metal and vice versa?*

The quest for the mutual benefit continued with investigation into how different the materials behave in integration with each other apart from the visual impressions. The outcomes are as follows:

Table 4.19: How wood and metal behave differently when they are together

Woodworkers	Strong, appealing, original, durable and different
Metalworkers	Friendly, colourful and original
Associates of both materials	Vivid, nice, colourful, Strong, appealing, original, durable and friendly.

According to the woodworkers wood with metal always behaves as a host to metal since they are either fixed on or planted on or into the wood. They are also of the view that most of the time wood puts up a stronger behaviour in conjunction with metal. The metalworker also submits that wood behaves as a lighter material on metal works that performs its purpose without adding much to the weight of the product. According to the associates of both materials wood becomes endless in it capabilities (versatile) apart from the other two behaviours mentioned by the other groups.

Secondly, the woodworkers see metal as facilitator in wood than when alone: for example, metal can be a fastener in metal work but may not be able to nail metal pieces together as in wood. This is to say, metals become more useful with wood. Also when thinned out, metal becomes very weak but becomes very stable in conjunction with wood. Moreover, its strength is more felt in most cases with wood because of their dissimilar nature in strength and weight under various conditions.

The metalworker is also of the view that metal is more handy with wood. Unlike the all metal situation where its non-porous nature may cause one to sweat in the palm at the grip which sometimes causes it to slip resulting in accidents. The second point is that wood helps to reduce the weight which makes it lighter to carry. However the third category of workers sees eye to eye with the other groups and concludes that both mterials become more versatile with each other.

It could therefore be said that so far as creativity is concerned the weakness of none of the two materials could be raised above the other. This could be attributed to the fact that woods come from various species of trees with different properties; metal on the other hand has over seventy base metals with countless alloys with countless varieties of properties and behaviours. Also until a particular design of metal and wood are at hand one can hardly tell which has an advantage over the other. Mutual benefits in "woomeint" could therefore be said to be very high and may exist in the physical, chemical, mechanical, electrical and/or thermal properties of the materials.

4.2.2.8 Sub question eight

The respondents had to express how beneficial their wood-metal products are to their users.

Two sub questions were also posed from which answers to this question were deducted. These are as follows:

- *How do wood metal products serve their purpose better than wooden product?*

Table 4.20: The advantages of wood metal integrated products over wooden products

Woodworkers	• Metal renders products with different appearances and feel that helps to curb boredom about the same product. • Metal gives a wood product its actual function: for example without fittings like hinges and locks on a door; it would hardly be easy to use, and at the same time be weak in its security feature.
Metalworkers	• Wood may not be strong enough to function in all situations • Also, certain products in wood would hardly be achieved without metals
Associates of both materials	• Metal may make wooden works stronger and more durable. • Metal on wood may carry more details that may better communicate intended information than it may be in only wood. • Wood metal products could be more aesthetically appealing in relative terms than wood works.

From table 4.20, all the suggestions given are related to how metal improve the looks and functions of wood. It could therefore be said that metal incorporation into wood could look satisfying to its users and also boost the users confidence in the usage of the product as being strong, durable or worthy of possession.

4.2.3 Outcome of the observation of activities in relevant agencies (primary data)

The observations came up with common technologies, forms of materials, projects, and debris that could serve as a good premise for "woomeint".

4.2.3.1 Technologies

The technologies observed could be classified into five: these are processing, forming, construction, decoration and finishing technologies. These are outlined in table 4.21.

Table 4.21: Observed technologies employed in the industry

Category	Method	Metal	Wood
processing	Grit bonding	Cold casting	Chip board casting
	Sheet bonding	Mokume	Ply bonding
	Strip or buttons bonding	Mokume	Lamination and kerfing
	Sponge making	Iron sponge	Dish and tooth sponge
Forming	Lathing	Metal lathing	Wood lathing
	Chiselling	cold chiselling /carving	Chiselling/carving
	Heat forming	Forging	Hot bending or steam bending
	Casting	Hot and cold casting	Dust casting
	Shearing	Sheet shearing	Veneer shearing
	Sawing	Sawing /piercing	Sawing/coping
	Planing	Milling	Planing
	Filling	Filling	Rasping
	Drilling	Drilling	Drilling
Construction	Creation of joints	Jointing	Jointing
	Fastening of joints	Riveting, screwing and bolting.	Riveting, screwing and bolting.
	Adhering of surfaces	Cold bonding (eg. Use of epoxies)	Gluing (eg. Use of PVA)
	Mechanising	Hinging	Hinging
Decoration	Texturing	Matting or stamping	Stamping /texturing
	Sheet laying	Marquetry/ parquetry and Inlaying	Marquetry/ parquetry, lamination and Inlaying
	Reliefing	Engraving, embossing/repoussé	Engraving, intaglio, and embossing
	Colouring	Painting, incision and heat colouring	Painting, incision and heat colouring
	Hole sawing	Piercing	Coping
	Heat colouring	Oxidation	Scorching
Finishing	Buffing	Mechanical and hand buffing with polishing compounds	Mechanical and hand buffing with polishing compounds
	Painting	Brushing and spraying	Brushing and spraying
	Abrading	Scraping and abrasion	Scraping and abrasion
	Varnishing	Clare finishing and staining	Clear finishing and staining

Some of these common technologies are factors that facilitate the integration of both materials without much problem. This is so because the common technologies have direct link with common tools and materials that could be used to deal with both materials for effective time management and cost effectiveness.

4.2.3.2 Forms

These are the various appearances of the materials used by the agencies visited. These were found in four groups, they are flat forms, bars, fibres and particles as spelt out in table 4.22.

Table 4.22: Common metal and wood material forms observed in the industry

Type	**Metal**	**Wood**
Flat forms	Sheet	Veneer
	Plate	Slicer boards and engineered boards
	Strip	Strip
Bars	Rodes(hexagonal, square, rectangular and round) of various sizes	Poles, buttons, beams and wood mouldings of various sizes.
Fibrous	Steel wool	Wooden fibre sponge
Particles and dust	Saw dust	Fillings and saw grit
	Abrasion dust (wood powder)	Metal powder
	Wood chipping	Metal chippings

The common forms also account for the common application of wood and metal. These are basis for common application of the two materials for common projects notwithstanding it rich source of project ideas.

4.2.3.3 Projects

The researcher also noticed some common projects between the scope of production of the two areas (woodworking and metalworking). These were found under containers, furniture, demarcations, room accessories, decorations, clothing and accessories as presented in table 4.23.

Tables 4.23: Observed common products of wood and metal

Type	Metal	Wood
container	Trunk	Chop box
	Purse	Purse
	Jewellery box	Jewellery box
	Trays	trays
	Handbag	Handbag
Furniture	Cabinet and shelves	Cabinets and shelves
	Chairs, stools and tables	Chairs, stools and tables
	Doors and gates	Doors and gates
Demarcations	Fence	Fence
	Partition	Partition
	Bars	bars
Room accessories	Curtains	Curtains
	Vases	vases
	Candle and lamp stands	Candle and lamp stands
Decorations	Frames (for pictures and mirrors)	Frames (for pictures and mirrors)
	Sculpture (in the round and reliefs)	Sculpture (in the round and reliefs)
Clothing and accessories	Fasteners	fasteners
	Jewelleries	Jewelleries
	Belts	Belts

The existent articles of same kinds in both areas are enough motivation and clue to the merging of the two materials in the same products. That could also serve as a basis for the development of other products subsequently or simultaneously.

4.2.3.4 Debris

The researcher also discovered that the by-products of the activities involved in processing both materials are similar. Some of these are mapped in table 4.24 below:

Table 4.24: Similarities in wood and metal debris

Debris / Material	***Dust***	***Shaves***	***Particles***	***Chippings***	***Off cuts***
Metal	From abrasion	From lathing	From sawing, grinding and filling.	From Drilling, shearing and milling	From sawing and piercing
Wood	From abrasion	from planing	From sawing and rasping	From drilling and shearing	From sawing and copping

4.2.4 The outcome of studies of "woomeint" works

The outcome of these studies was not too far from the deductions from the information gathered. However, other relevant information were found out. These are in the areas of fastening of joints, types of joints, decoration of wood with metal and finishing.

4.2.4.1 Fastening of joints

Wood and metal are held together with fasteners than adhesives. These fasteners are mostly screws, bolt and knots, nails, studs and rivets. The adhesive used are epoxy and cyanoacrylate both of which are multipurpose adhesives.

4.2.4.2 Types of joints

It was also noticed that the joints employed in joining wood and metal are mostly *lapping joints* made by overlapping two ends or edges and fastening them together, and *pierced joints* made by pushing one material into the other preceded by drilling or not. These joint are grouped into four by the researcher as Lap joint (A), multi- lap joint (B), Closed lap joint (A) and Pierced joint (D) as illustrated in figure 4.3. It was also observed that they are the basic joints upon which more complex joints are based.

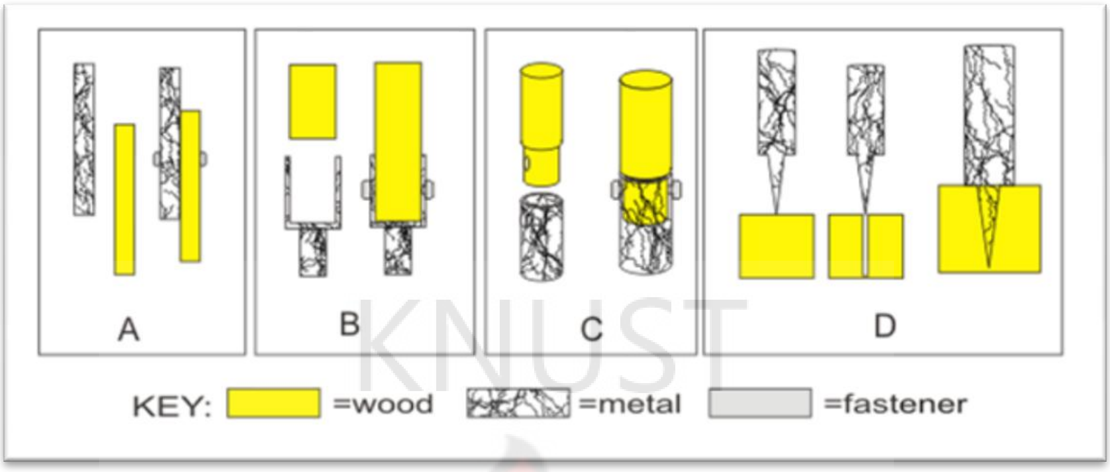


Figure 4.3: Lap joint (A), multi- lap joint (B), Closed lap joint (C) and Pierced joint (D)

The following are some examples of joints under each of the categories tagged in their respective A, B, C and D codes.

4.2.4.2.1 Lap joints

These joints are applied in different ways on varieties of wood metal forms. In A1 ("woomeint" sankofa clock) the joint is applied between the neck of the bird and the clock and also between the beak of the bird and the egg. This is followed by A2 (the garden chair). In these, the joints are found between the metal slabs and the wood slabs found on the seat and the seat back. In A3 (a lock on a cupboard) the joint is found between the base of the locks and the cupboard's surface. The last is the door locks handle fastened on the door in A4. See plate 4.3.

Plate 4.3: Examples of lap joint held with fastener

4.2.4.2.2 Multi-lap joints

This is mostly applied to shoulder an edge or end face and two or more perpendicular surfaces depending on the forms at hand as illustrated in figure 4.3.

Figure 4.4, B1 represents a saw fitted to its handle in that fashion, B2: a jack-knife fitted to its handle in the same fashion and B3: a structural pole joint to a metal connector in the same fashion (a counter change of B1 and B2).

Plate 4.4: Samples of multi-lap joint

4.2.4.2.3 Closed lap

In this case one of the materials (mostly metal) produces a fitting slot into which the other is inserted and sometimes fastened. Some examples illustrated in fig 4.3C are the base of the piece pole (C1), C2 ("woomeint" candle chandelier) and the adze's blade and handle (C3).

Plate 4.5: Examples of closed lap joints

4.2.4.2.4 Pierced joints

These joints, though could be fastened, are normally not fastened joints. It is the principle based on which fasteners are applied to hold other members in place because they themselves are fast in their positions by the grips of the wood. These are therefore multi-purpose because they are joints and at the same time supplements of joints (fasteners). Some of these are shown in plate 4.6: D1 (a chisel to its handle) and the wood part of the chandelier to its hang (D2).

Plate 4.6: Examples of pierced joint

4.2.4.3 Decoration of wood with metal

Decoration of wood pieces with metal is surface oriented and mostly involves sheets and occasionally wires of metals. The challenges in this area include the shrinkage factor of wood especially in the harmattan season that causes metal decorations to lose contact with wood surfaces, crumpling or deforming on the surfaces. An example is the problem with the decorated wooden chair shown in figure 4.7 below.

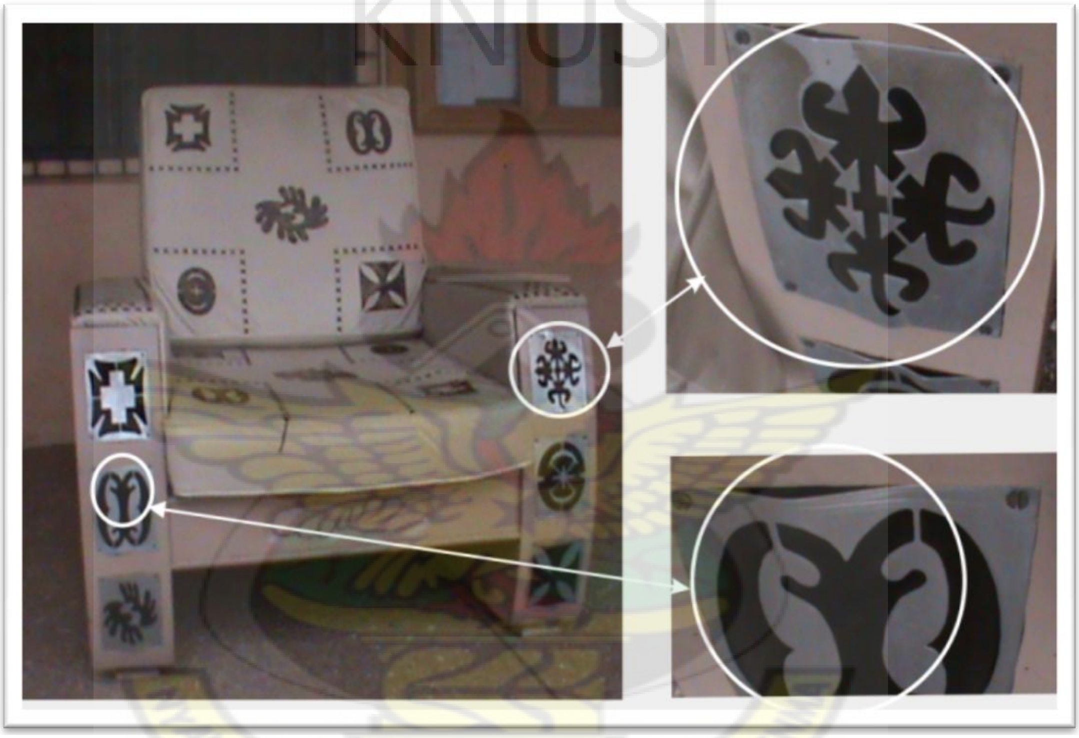


Plate 4.7: Crumpled metal decoration on wood surface.

Based on the swelling and shrinkage behaviour of wood discussed in the previous chapters this behaviour of the wood could not be prevented. The impact destroys impressions created by sheet metal laying applications than in others. This is so because most sheet metals as in nonferrous metals are less strong in resistance than the force impacted during shrinkage.

4.2.4.4 Finishing

In this aspect finishing is either done for each material separately or a combination of both. This depends on the type of finish required; the type of finishing agent in question and the effect of the finish on each material. These are obvious in the pictures of works shown above in plates 4.3 to 4.7.

4.2.5 Outcome of experimental tests

These are the results and findings got from the experiments

4.2.5.1 Experiment one: The movement test of wood with emphasis on influence posed by the harmattan weather

4.1.5.1.1 Recorded results:

The average shrinkage and swelling results were attained over the period as presented in appendix 6, from which the areas were also generated (table 4.25) as specified in the chapter three of this dissertation.

Table 4.25: Average areas of wood specimens after the season

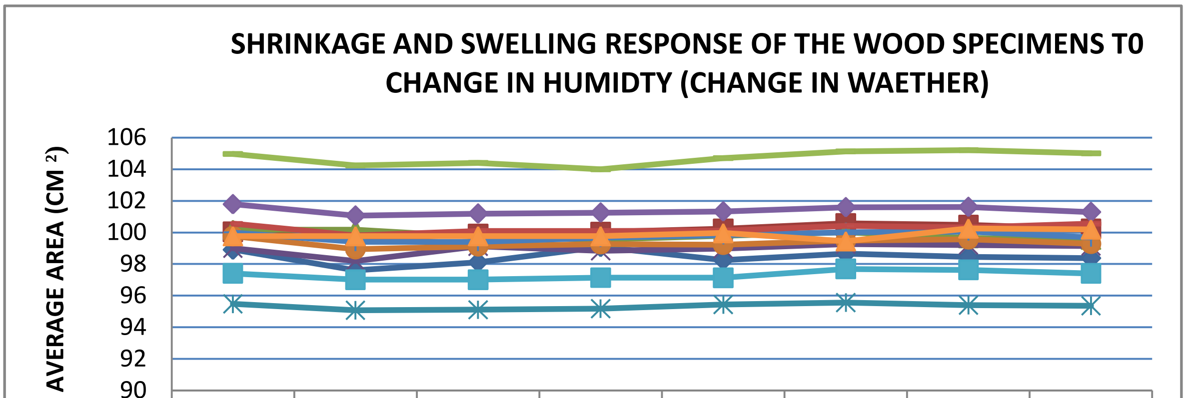
WEATHER CONDITION OF THE MEASUREMENT	STABLE WEATHER (SW)	PEAK OF HAMATAN (POH)	EARLY RAIN SEASON (ERS)	LEAN RAIN SEASON (LRS)	IRREGULAR RAINS (IR)	HEAVY RAIN SEASON (HRS)	CONSTANT HUMIDITY (CH)	AFTER THE RAINY SEASON (FRS)
DATE OF MEASUREMENT	28/12/2009	13/2/2010	9/3/2010	16/4/2010	23/5/2010	31/5/2010	16/6/2010	10/12/2010
AVERAGE AREA IN CENTIMETERS	AA(cm)	AA(cm)	AA(cm)	AA(cm)	AA(cm)	AA(cm)	AA(cm)	AA(cm)
SPECIES								
BSF	98.903	97.6117	98.11677	99.07214	98.24666	98.65414	98.445355	98.37594
BV	100.0448	99.5328	99.917	100.0309	100.2402	100.5765	100.475242	100.2309
MA	100.164	100.164	99.717	99.54611	99.77786	100.0049	99.638484	99.54136

ME	99	98.2	99.13205	98.84547	98.97503	99.26278	99.20524	99.14516
AA	95.475	95.073	95.10374	95.1735	95.44813	95.56327	95.394041	95.36501
KI	99.76578	98.94	99.113	99.26733	99.2256	99.4899	99.560428	99.27613
BSM	100	99.4	99.39938	99.65939	99.82952	100.0197	100.059909	99.68986
CG	100.5372	99.8151	100.090	100.0925	100.1083	100.4086	100.310007	100.546
SR	104.9544	104.2425	104.3957	103.9944	104.6907	105.1195	105.200273	104.9957
GE	101.7792	101.061	101.1886	101.2503	101.323	101.5889	101.609088	101.2879
TG	97.4088	97.0104	97.01148	97.14128	97.13282	97.69283	97.624945	97.40862
BG	99.76754	99.7675	99.76754	99.76754	99.95767	99.43893	100.25236	100.1911
TOTAL	1197.8	1190.818	1189.967	1193.841	1194.955	1197.82	1177.821372	1206.255
AVERAGE	99.81664	99.23483	99.41269	99.48674	99.57962	99.81833	99.81461	99.67114

NOTE: Species abbreviations are referenced to Table 3.13

4.2.5.1.2 The instability of wood surface area

The above recorded figures on table 4.25 are analysed below in figures 4.4 and 4.6, the undulating nature of the lines indicates the fluctuating nature of wood surface areas. However some of the curves are more undulating than others: a signal of more shrinkage and swelling in some of the species than others. The figures (average area in cm^2) below the chart in figure 4.4 are also corresponding to their respective points (seasons) on each line also in accordance with each species with their respective abbreviations and colours on the right.



	SW	POH	ERS	LRS	IR	HRS	CH	FRS
BSF	98.903	97.6117	98.11677	99.07214	98.24666	98.65414	98.44535	98.37594
BV	100.0448	99.5328	99.917	100.0309	100.2402	100.5765	100.4752	100.2309
MA	100.164	100.164	99.717	99.54611	99.77786	100.0049	99.63848	99.54136
ME	99	98.2	99.13205	98.84547	98.97503	99.26278	99.20524	99.14516
AA	95.475	95.073	95.10374	95.1735	95.44813	95.56327	95.39404	95.36501
KI	99.76578	98.94	99.113	99.26733	99.2256	99.4899	99.56042	99.27613
BSM	100	99.4	99.39938	99.65939	99.82952	100.0197	100.0599	99.68986
CG	100.5372	99.8151	100.09	100.0925	100.1083	100.4086	100.3100	100.546
SR	104.9544	104.2425	104.3957	103.9944	104.6907	105.1195	105.2002	104.9957
GE	101.7792	101.061	101.1886	101.2503	101.323	101.5889	101.6090	101.2879
TG	97.4088	97.0104	97.01148	97.14128	97.13282	97.69283	97.62494	97.40862
BG	99.76754	99.7675	99.76754	99.76754	99.95767	99.43893	100.2523	100.1911

Figure 4.4: Changes in the area dimensions of the wood samples over the period of the study (key: table 4.25)

4.1.5.1.3 The scope of change in surface area

The scope of surface area changes is expressed as the difference of the lowest recorded values (yellow boxes) and the highest recorded value (red boxes) shown in figure 4.5. This is also shown on the chart as the lowest and the highest points on each line (figure 4.6). This difference was calculated and expressed in percentages of the initial area sizes (SW) which represent the percentage the scope of movement provided by the following formula to table 4.27.

$$\left(\frac{D}{SW}\right) \times 100$$

Where D is the difference of the maximum recorded swelling (MAX) and the minimum recorded shrinkage (MIN) or MAX minus MIN. SW represents initial size at stable weather. The result for all the species are spelt out in table 4.27.

	SW	POH	ERS	LRS	IR	HRS	CH	FRS
BSF	98.903	97.6117	98.1167	99.0721	98.2466	98.6541	98.4453	98.3759
BV	100.044	99.5328	99.917	100.030	100.240	100.576	100.475	100.230
MA	100.164	100.164	99.717	99.5461	99.7778	100.004	99.6384	99.5413
ME	99	98.2	99.1320	98.8454	98.9750	99.2627	99.2052	99.1451
AA	95.475	95.073	95.1037	95.1735	95.4481	95.5632	95.3940	95.3650
KI	99.7657	98.94	99.113	99.2673	99.2256	99.4899	99.5604	99.2761
BSM	100	99.4	99.3993	99.6593	99.8295	100.019	100.059	99.6898
CG	100.537	99.8151	100.09	100.092	100.108	100.408	100.31	100.546
SR	104.954	104.242	104.395	103.994	104.690	105.119	105.200	104.995
GE	101.779	101.061	101.188	101.250	101.323	101.588	101.609	101.287
TG	97.4088	97.0104	97.0114	97.1412	97.1328	97.6928	97.6249	97.4086
BG	99.7675	99.7675	99.7675	99.7675	99.9576	99.4389	100.252	100.191

KEY: LOWEST RECORDED FIGURE HIGHEST RECORDED FIGURE

Figure 4.5: The scope of movements of species

Table 4.26: Scope of movement of specimens

SPECIES	MAX.	MIN.	DIFFERENCE MIN. & MAX.	PERCENTAGE (%) OF MOVEMENT SCOPE
BSW	99.07214	97.6117	1.46044	1.476639
BV	100.5765	99.5328	1.0437	1.043233
MA	100.164	99.54136	0.62264	0.621621
ME	99.26278	98.2	1.06278	1.073515
AA	95.56327	95.073	0.49027	0.513506

KI	99.76578	98.94	0.82578	0.827719
BSM	100.0599	99.39938	0.660529	0.660529
CG	100.546	99.8151	0.7309	0.726995
SR	105.2003	103.9944	1.205873	1.148949
GE	101.7792	101.061	0.7182	0.705645
TG	97.69283	97.0104	0.68243	0.700584
BG	100.2524	99.43893	0.81343	0.815325
AVERAGE	99.99459	99.13484	0.859747667	0.859522

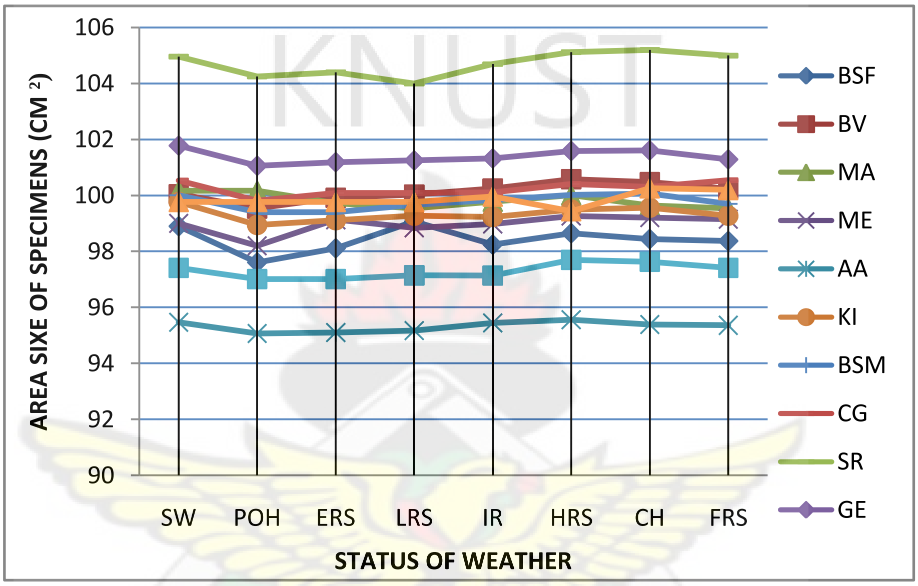


Figure 4.6: Chart of the shrinkage and swelling movement of species

4.1.5.1.4 Observations

It was observed that species thought to be of high shrinkage during seasoning could become more stable when well seasoned. For example: among the light coloured samples, Asanfena (AA) comparably records the least surface area scope of movement (0.513506 %): table 4.26. Though it is observed by most woodworkers as a wood with greater shrinkage percentage, it has proven to be a good wood after seasoning so far as shrinkage is concerned. However among the dark wood, Mansonia (MA) proved more stable with 0.621621 % which is below average. This is followed by Hyedua (0.705645 %) and then red Ache (BSM) 0.660529 % from the red wood group that are below the average mark (0.859522). These are better options for "woomeint" than others because of the risk involved in excessive shrinkage. See table 4.26.

With reference to figure 4.7 it was observed that wood generally experiences drastic surface contraction at the Peak Of the Harmattan (POH) and gradually retracts from the Early Rain Season (ERS) to the High Rain Season (HRS). This approximately remains constant at the Constant Humidity (CH) and then begins to contract again at Falling Rain Season (FRS) when the rains begin to subside. Wood is therefore never stable so long as the weather keeps changing.

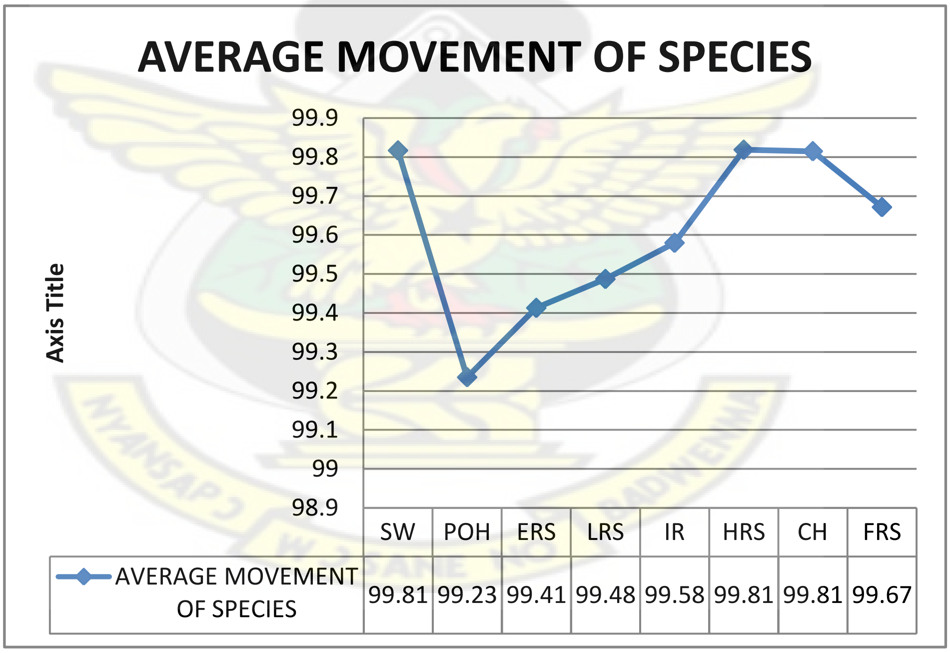


Figure 4.7: Chart of average shrinkage and swelling movement of species

4.2.5.2 Experiment two: experimental test of some available adhesives and binders on wood and metal to determine their possible applications.

4.2.5.2.1 Outcome of dilution test:

After the curing of the adhesives it was realised that: their appearances were almost like the originals. Moreover none: not even the contact cements and Polysiloxane was sticky after curing. The summary of their scratch and peal resistivity, elastic limits and behaviours are summarised in tables 4.27 and 4.28 respectively.

Table 4.27: Outcome of the scratch and peal test

ADHERSIVES	SCRATCH RESISTANCE	PEAL RESISTIVITY ON WOOD AND METAL	
		METAL	WOOD
Polyvinyl Acetate	Good	Poor	Excellent
Contact Cement	Very good	Excellent	Excellent
Cyanoacrylate	Excellent	Excellent	Excellent
Polysiloxane	Very poor	Very Poor	Poor
Acrylics	Poor	Good	Very good
Polyurethanes	Excellent	Excellent	Excellent
Epoxy	Excellent	Excellent	Excellent
Pigmented drying oil	Good	Very good	Excellent
Cellulose Lacquer	Good	Excellent	Excellent

Some of the adhesives responded one sided (acrylic and PVA) and performed better on wood than on metal. However the general performances of the adhesives are wood biased because of its porous nature. Obviously not all adhesive can serve a purpose in metal but the slightest adhesive on metal could help in one way or the other depending on the purpose of application (the artist's mind). The excellent scratch resistance group provides a glassy surface to the wood. The very good group were characterised by lost of lustre at their path of scratch. The good group experienced minor scratches followed by poor that scratches completely. The very poor is also characterised by pealing apart from the scratching.

Plate 4.8: Side by side strokes of diluted (up) and non diluted (down) adhesives

The elasticity test also resulted in all passing (elastic above 180 degrees) except three (cyanoacrylate, epoxy and polyurethanes). Some of which were reversible without problem. Others recorded wrinkles as recorded in table 4.28.

Table 4.28: Outcome of elasticity test between diluted and concentrated adhesives

ADHERSIVES	ANGLE OF FAILURE BETWEEN CONCENTRATED (C) AND DILUTED (D) ADHESIVE		REMARKS AFTER BENDING		REMARKS AFTER REVERSING	
	D	C	D	C	C	D
Polyvinyl Acetate	< 180°	< 180°	INTACT	INTACT	LESS WRINKLE	LESS WRINKLE
Contact Cement	< 180°	< 180°	INTACT	INTACT	NO WRINKLE	NO WRINKLE
Cyanoacrylate	20°		BREAK		NO WRINKLE	NO WRINKLE
Polysiloxane	< 180°	< 180°	INTACT	INTACT	NO WRINKLE	NO WRINKLE
Acrylics	< 180°	< 180°	INTACT	INTACT	WRINKLE	WRINKLE
Polyurethanes	60°	80°	CRACK	CRACK	NO WRINKLE	NO WRINKLE

Epoxy	80^o	145^o	CRACK	BREAK	WRINKLE	WRINKLE
Pigmented drying oil	$< 180^o$	$< 180^o$	INTACT	INTACT	NO WRINKLE	NO WRINKLE
Cellulose Lacquer	$< 180^o$	$< 180^o$	INTACT	INTACT	LESS WRINKLE	LESS WRINKLE

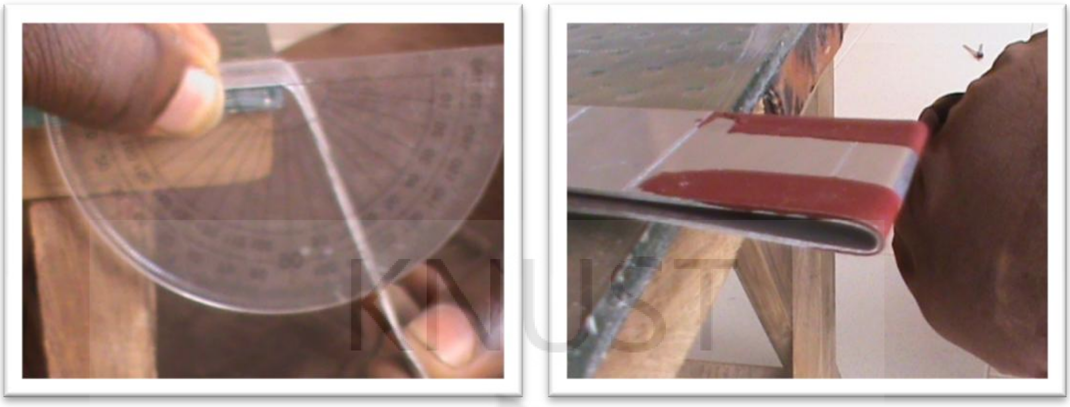


Plate 4.9: Elasticity test: angel below 180^o (left) and angle above 180^o (right)

4.1.5.2.2 Outcome of the adhesion test:

The rating scale for each of these is ranged from very poor to excellent (table 4.29), thus their ability to hold fast. Some fall off after drying (poor) others had very strong permanent joints after curing (excellent). Between these are those that are less strong than excellent (very good) and those that are also judged less strong than the very good (good). The lifting test was generally positive with the finger nail lifting except for the PVA. On the other hand with the chisel lifting some recorded just edge lifting without coming off (very good), some came off but with much effort (good), others required less and least efforts to get them off (poor and very poor respectively).

Table 4.29: Outcome of the rating of adhesion and separation resistivity

ADHERSIVES	**ABILITY TO HOLD AFTER CURING**	**LIFTING RESISTIVITY BETWEEN WOOD AND METAL**	
		Finger nail	Chisel
Polyvinyl Acetate	Poor	Poor	Very poor
Contact Cement	Excellent	Excellent	Very good
Cyanoacrylate	Excellent	Excellent	Very good

Polysiloxane	Good	Very good	Poor
Acrylics	Good	Very good	Good
Polyurethanes	Very good	Excellent	Very good
Epoxy	Excellent	Excellent	Very good
Pigmented drying oil	Good	Very good	Good
Cellulose Lacquer	Very good	Excellent	Good

4.2.5.2.3 Outcome of binding test:

The outcome of the binding test was generally successful. Though the behaviour of some of the adhesives with respect to their response to the tests conducted may seem undesirable but could be adopted in creative ways. These are summarised in table 4. 30.

Table 4.30: Outcome of binding test

Type of bond	approximate Curing/ setting time (minutes)	Abrasion response	thumb compression resistivity
Polyvinyl Acetate	2880	Good	Very good
Contact Cement	15	Poor	Very good
Cyanoacrylate	3	Excellent	Excellent
Polysiloxane	4320	Very poor	Poor
Acrylics	2880	Good	Very good
Polyurethanes	1440	Good	Very good
Epoxy	30	Good	Very good
Pigmented drying oil	4320	Poor	Good
Cellulose Lacquer	2880	Good	Very good

The binding test was generally successful with the exception of certain disadvantages recorded with some of them (table 4.31). These are excessive drying rate; poor abrasion properties: filling of the grits of abrasive and rendering them inefficient due to their moist nature unlike the dry ones that produced dry fine dust during abrasion; and sinking response to compression as spelt out in the table.

The finger nail denting test for hardness was also positive. The adhesives were generally hard except silicon. Based on visual judgement, the order of hardness was distributed on a ration scale: rating from very hard to very soft as illustrated in figure 4.8.

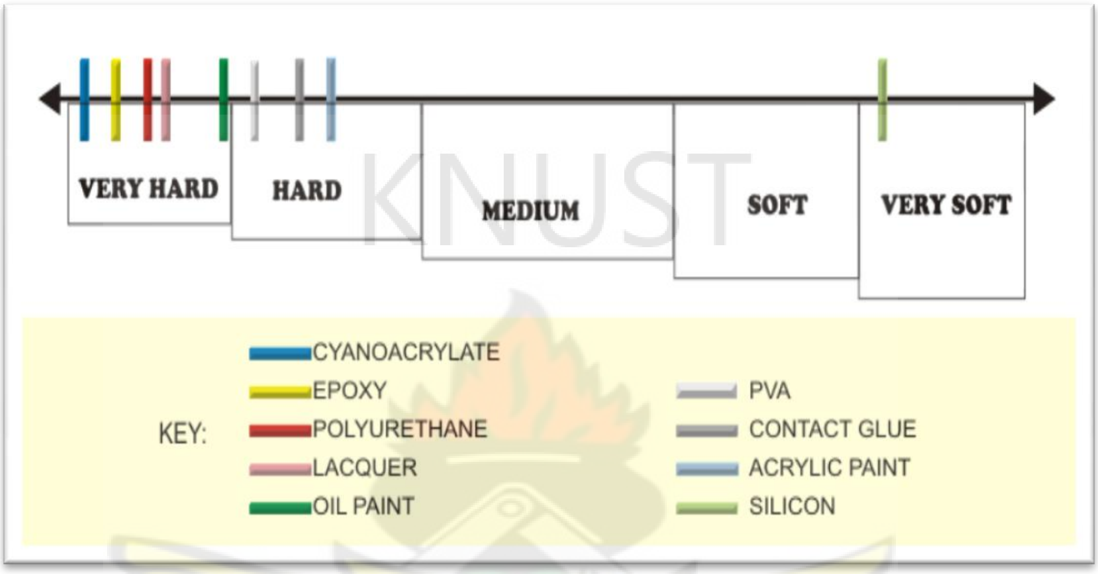


Figure 4.8: Thumbnail denting results for the binding test.

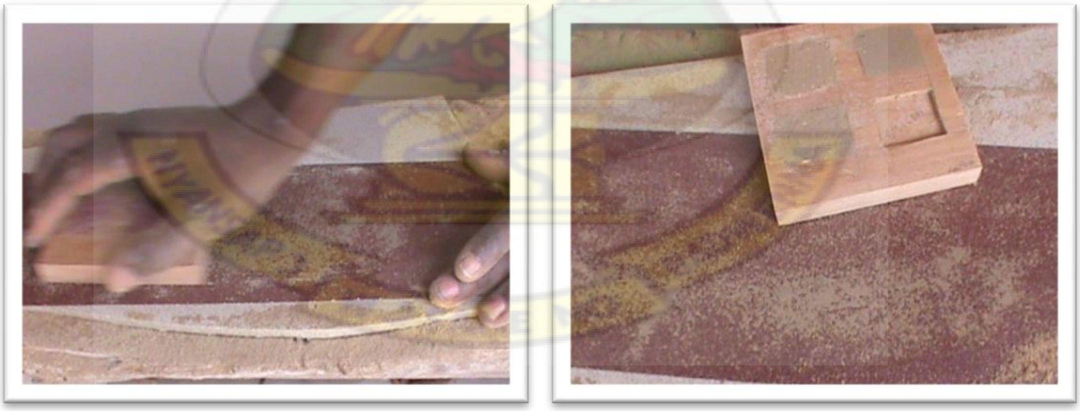


Plate 4.10: Abrasion failure of silicon bond particles

4.2.5.2.4 Outcome of the acid immersion test:

Bonded particles and wood immersed in nitric acid became pale. The black *hyedua* that was immersed lost its colour for a pale colour like *odum*. The only shortcoming was the weakening of the fibres, however it could be employed for restricted purposes in wood metal art.

4.2.6 Summary of objective one

The data collected for this objective is substantial. It covers various aspects of acquisition, nature/behaviour, processing, utilisations and complementary materials logistics base on which creative consideration were made to generate factors worth to "woomeint" to ensure its certainty and success. This knowledge also propelled the researcher to come up with the various integration methods discussed in chapter 5.

4.3 Objective Two of the study

This objective was to produce wood and metal integration specimens that will be assessed as reference materials to enhance the teaching and learning of the subject. To this effect, knowledge and experience acquired from content analyses and observation led the researcher to the following: Reference items found in the library; Means by which the items are kept in the library; Sizes of materials kept in the library; and Form and size of "woomeint" that fits the library situation.

4.3.1 Reference items found in the library

Reference items observed by the researcher found in the library are generally books, pamphlets, news papers (loose and bound), journals, magazines and other paper products. The researcher also observed that sculptures in the form of plaques and busts are also kept in the library for references relating to achievements of distinguished personalities.

4.3.2 Means by which the items are kept in the library

Information kept in library are generally shelved and properly coded or inscribed with their names or descriptions. These are catalogued on the computer and in the form of books with respect to their respective shelve numbers or codes that make them easy to trace. The observed sculptures on the other hand are placed at vantage points in the library (example the entrances to the library) to make them easily noticed.

4.3.3 Sizes of materials kept in the library.

Materials kept in the library range from very big (comparable to bound news papers) to small (comparable to children story books). However some of the big sizes in relative terms with the library table space to chair ratio might be a border when the library is filled to capacity.

4.3.4 Form and size of "woomeint" that fits the library situation

Considering the weight of the materials and the possible avenues related to their integration, the researcher settled on specimen sizes of approximately 4 inches by 4 inches (4" x 4") to check weight and also facilitate effective space management. Secondly, the researcher was of the view that, not all students could readily comprehend what they see and for that matter each specimen was considered to be accompanied by the specimen production procedure booklets which also contain recommended application for each of the specimens.

Due to the facts that librarians may not have the requisite knowhow to maintain the specimen they were put in protective boxes to lessen their chances of necessitating maintenance, and also facilitate their easy arrangement as in the case of books. These are well presented in chapter 5.

4.4 Objective three of the study

This objective was to generate technical jargons related to the project in order to facilitate easy communication and appreciation of the paradigm. Under this the researcher notices that jargons are generally derived from similar situations to the condition or situation in question. Often found in our dictionaries, this similar situation may even be outside the subject matter or language under discussion. For example plane used in wood technology as a verb and a noun to mean the flattening of wood surface and also the device used for such operation respectively, come from a *latin* word *planum* meaning *level ground*. In this case *ground* is far from *wood* but it is obvious that the adaptation was based on the idea *"level"*.

According to Robins (2008) communication has neither restriction nor barrier. The most important issue becomes how new ideas can be shared conveniently among animals. He said:

> Against every known mode of animal communication, is its infinite productivity and creativity. Human beings are unrestricted in what they can talk about; no area of experience is accepted as necessarily incommunicable, though it may be necessary to adapt one's language in order to cope with new discoveries or new modes of thought.

He continues by proving the power given to man by God to name and for that matter communicates what he creates by quoting (Gen. 2:19).

> So out of the ground the Lord God formed every beast of the field and every bird of the air, and brought them to the man to see what he

> would call them; and whatever the man called every living creature, that was its name.

Robins further opines that jargons are propounded to make communication easy among a group of people and also for the ennoblement of their group (example tribe or groups of professionals). He continues that:

> "Professions whose members value their standing in society and are eager to render their services to the public foster their own vocabulary and usage, partly to enhance the dignity of their profession and the skills they represent but partly also to increase their efficiency. An example of this is the language of the law and of lawyers"

Also, other sources including reference books and dictionaries present words that are formed from acronyms of phrases and clauses. From these, the researcher realises that formulation of jargons has to do with the circumstances surrounding the subject matter, the authority of the stakeholders and the language that best describes the situation. Based on this the suggestions of the stakeholders were jointly considered by the researcher with similar circumstances that exist in the areas of wood and metal to arrive at the jargons and names of specimens as presented in the chapter five.

4.5 Conclusion of the discussions

Wood and metal are different and similar materials. This is so because they differ in certain functions and applications but are also similar in other functions and applications. The advantage of one over the other depends on the mind of the user, the nature of the wood and metal at hand and thirdly the project to be undertaken. Methods of integrating wood and metal involve the individual methods of production of the two materials and other superior methods that come with both materials.

Factors that affect the nature of wood and metal integration depend more on the wood conversion and processing method than on metal. This is so because metal can easily be reorganised or recycled into any form that becomes necessary, but wood on the other hand is limited in its remedy. Its susceptibility to impacts of bad harvesting and processing method renders it a dictating factor in wood metal integration.

Factors that must be considered prior to the integration of wood and metal entail all aspects of the two materials discussed in this chapter. However these could be put under five categories, these are:

- The purpose of the integration
- The nature and behaviour of main materials (wood and metal) and complementary materials
- Available technology
- Ergonomics and
- Environmental factors

The above are all geared towards the addressing of problems that may exist between the wood and metal in integration, therefore a careful and creative consideration of the five steps should result in a successful integration.

CHAPTER FIVE

THE PROCEDURES IN THE EXECUTION OF THE PROJECT

(PRACTICAL DEMOSTRATION OF FINDINGS)

5.1 Introduction

This chapter is a presentation of the creative integrated wood and metal specimens generated by the researcher to bring to light the creative means by which the two materials could be integrated. This also entails the generation of the jargons and how the specimens could be presented as reference materials in the library. This chapter is therefore divided into three sections as follows: *means by which metal could be integrated into wood; Jargons for the integration procedure* and lastly *metal integration into wood as reference materials for the library and their respective Jargons*.

5.2 Metal Integration into Wood

Based on the data collected, the researcher deduced that metal application to wood is essential in four fundamental ways and the integration of two or more of the ways. In view of this the researcher categorised metal integration into wood under five main methods, based on which the specimens have been developed. These are: *Textural integration, Structural integration, Jointing integration, Mechanising* and *Assemblage integration.*

5.2.1 Textural integration

This is the integration of metal into wood by way of affecting or enhancing the surface appearance of wood art forms. This process is divided into three fundamental approaches; these are *sinking*, *flashing* and *reliefing* of the metal on/in the wood surfaces based on which all the design are made. The metal forms employed include sheet, plates, wires and particles.

5.2.1.1 Sinking

As represented by A in figure 5.1, is a method of fixing, laying or casting a form of metal below the wood surface level. As a fundamental approach the metal is either fastened, adhered or planted. Since it involves cutting into the wood that makes the metal liable to the shrinkage effect of the wood, a shrinkage allowance is required based on the expected percentage shrinkage of the chosen specie of wood. The shrinkage allowance is not left open but filled with durable flexural material as illustrated in figure 5.2.

5.2.1.2 Flashing

Unlike the sinking technique this method is such that the metal flashes with the wood surface as represented by B in table 5.1. Apart from this difference all other procedures are the same between the flashing and the sinking technique. However the researcher also thought of making this allowance invisible by developing a diagonal recess that opens below the surface as illustrated below in figure 5.3.

5.2.1.3 Reliefing

There are two processes involved under this technique. The first; laying or mounting of the metal piece over the wood surface and the second: the planting of the metal piece where part of the metal sinks into the wood as illustrated in C-1 and C-2 respectively in figure 5.1. However the shrinkage allowance technique again is applicable in two ways. For C-2 the techniques in both figures 5.2 and 5.3 are applicable. But in the case of C-1 the allowance is determined by the flexibility of the adhesive in the case of adhesion and secondly, in the case of fastening, it is given in the fastening holes of the metal as illustrated in figure 4.5.

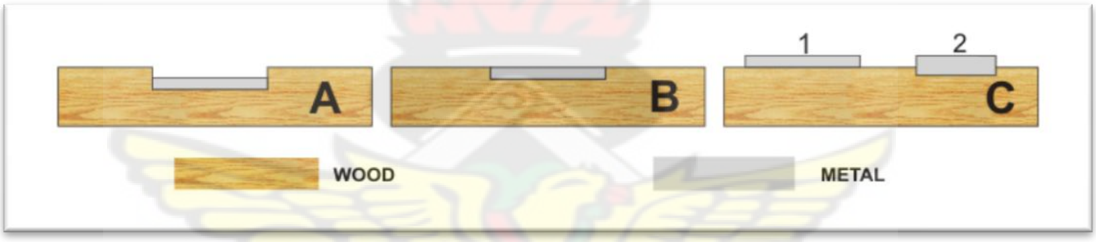


Figure 5.1: Cross-section of fundamental textural integration techniques (A-sinking, B-flashing and C-reliefing).

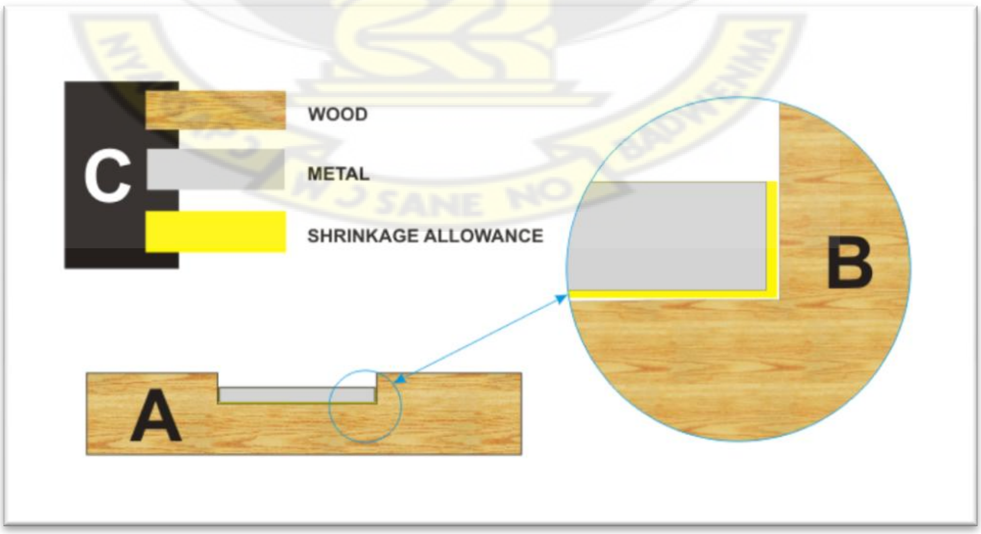


Figure 5.2: Cross-section of sinking technique (A) showing vertical shrinkage allowance (B)

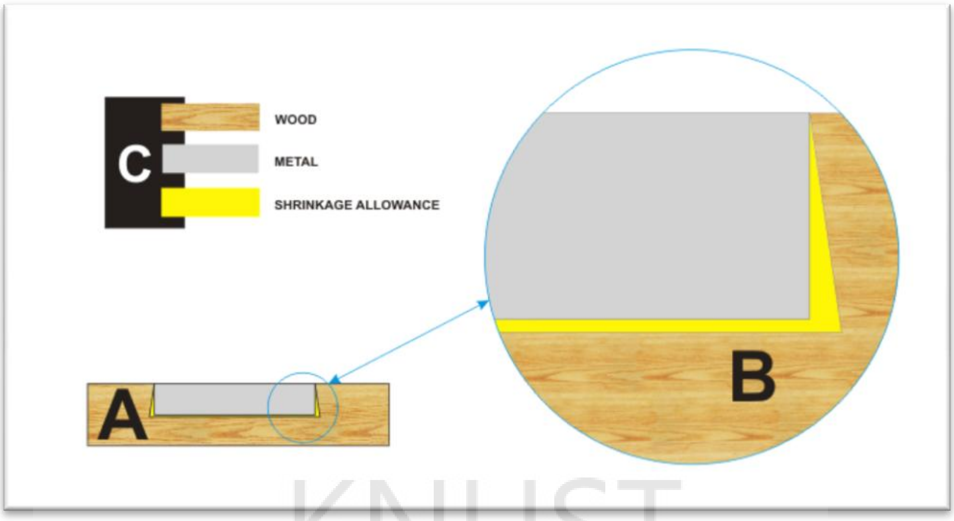


Figure 5.3 Cross-section of flashing technique (A) showing diagonal shrinkage allowance (B)

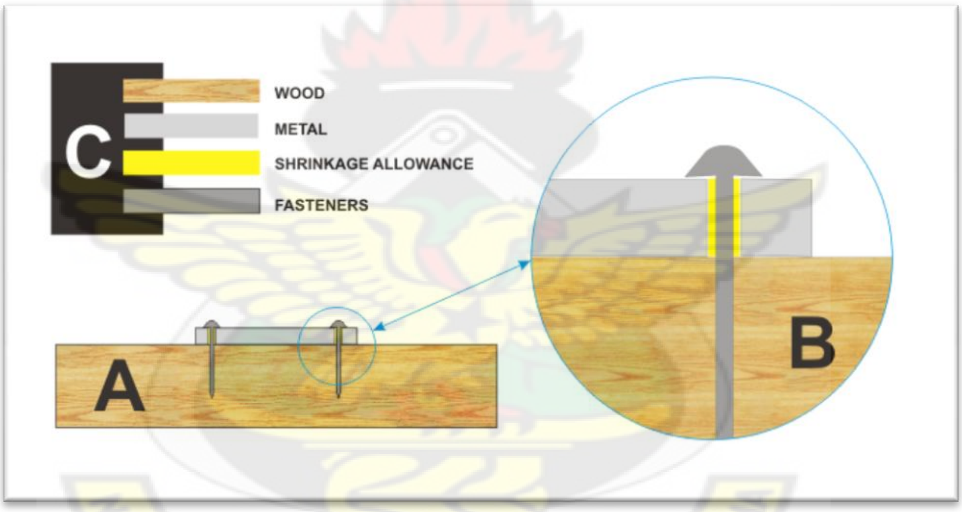


Figure 5.4: Cross-section of fastened relief technique (A) showing shrinkage allowance in metal (B)

5.2.2 Structural integration

This method has to do with composite generation techniques that focus on the material (wood) than its use. This is a process of affecting the structural flow of wood such that the wood and metal are seen as mixed in composition of various degrees and ratios, also in varied constituent sizes and forms. This was also categorised by the researcher into five. These are *insertion*, *interlaying*, *intra-laying*, *basketry* and *particle binding*.

5.2.2.1 Insertion

This is a method of slotting metal through a conforming pierced hole in wood and the ends abraded to flash with the wood surface. This is either inserted halfway to flash with one surface (insertion) or inserted through to appear on both surfaces (through insertions) as illustrated in figure 5.5. The metal is held in place by adhesion and the contractive nature of the wood. This technique is capable of creating thrilling effects by decorative repetition.

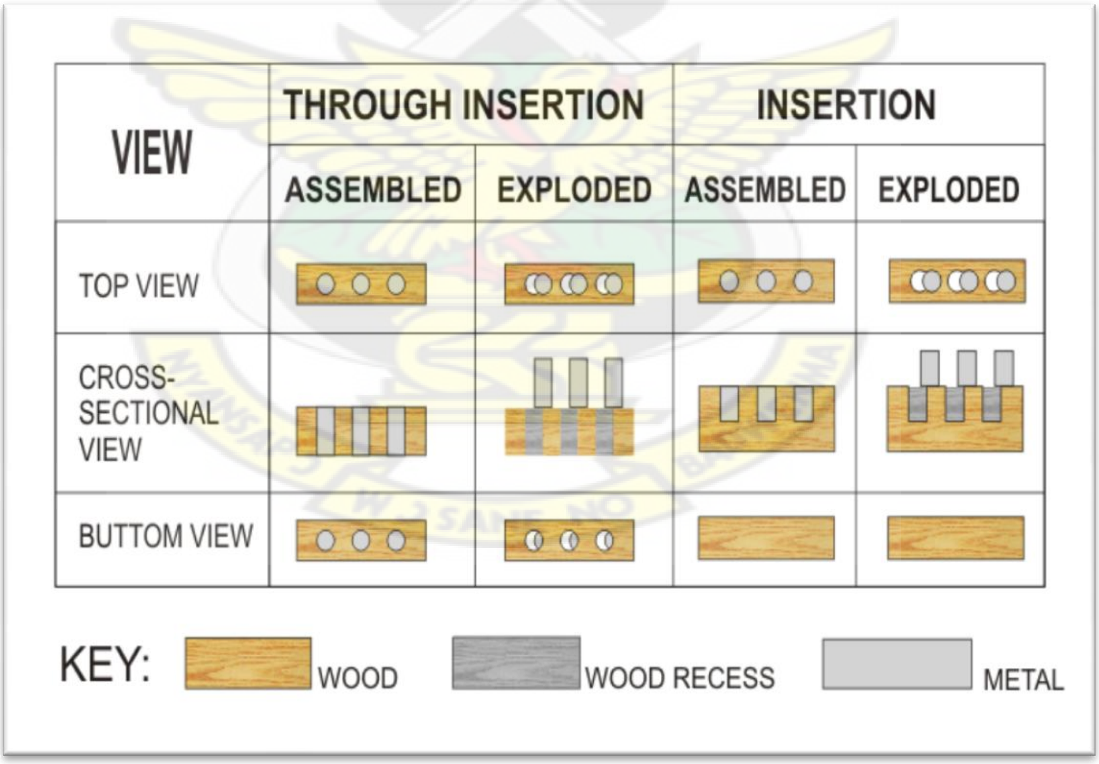


Figure 5. 5: Insertion technique layout

5.2.2.2 Intra-laying

This is a method of laying plates sheets between two opposite surfaces of the same wood piece as illustrated in figure 5.6. This is stronger when applied along the grain of the wood. The intra-lay is held in place by wood to wood dowelling across the inter-lay. Adhesives may be applied as filler for unnecessary spaces or gaps that may occur. The repetition or cross application of this technique could create wonderful effects.

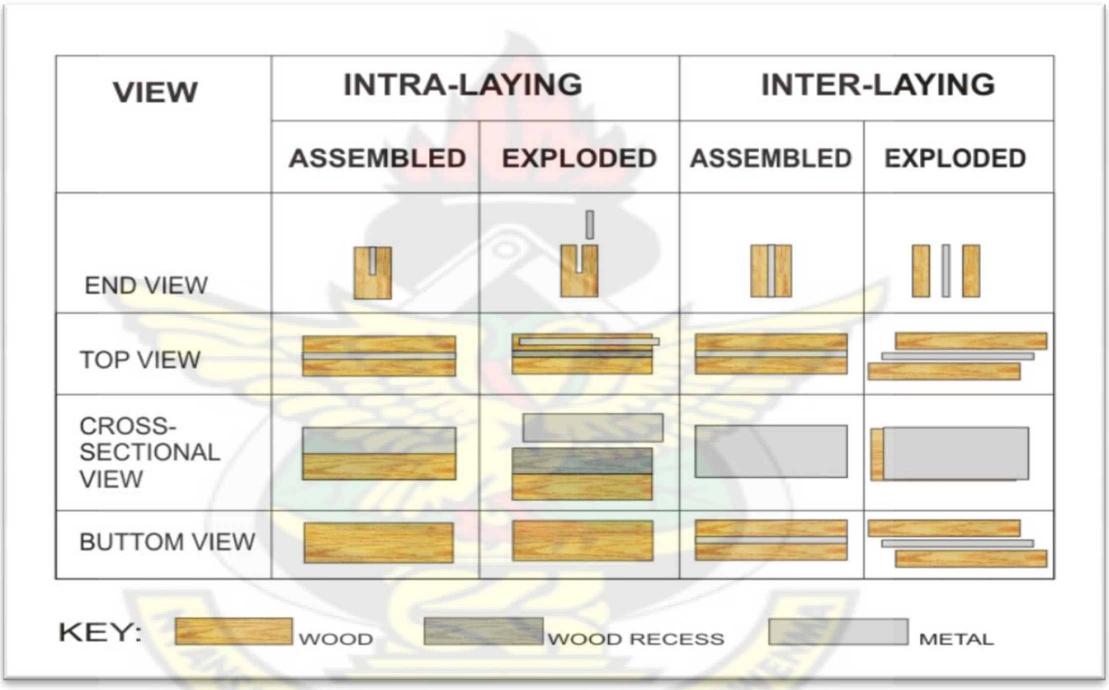


Figure 5. 6: Interlaying and intra- laying layout

5.2.2.3 Interlaying

Unlike intra-laying, this technique lays the metal sheet or plate between two separate pieces. This is done in three fundamental ways, these are: the allowance of the visibility of all edges of the metal (interlaying) as in figure 5.6; the hiding of some edges of the metal (shouldered interlaying) and the hiding of all ends of the metal (blind interlaying) represented respectively in figure 5.7. The inter-lays are held together by strong adhesive like contact glue or through the process of cross dowelling that may be supported by adhesive as filler for unwanted gaps. The gap filler may also serve as protection to the bond.

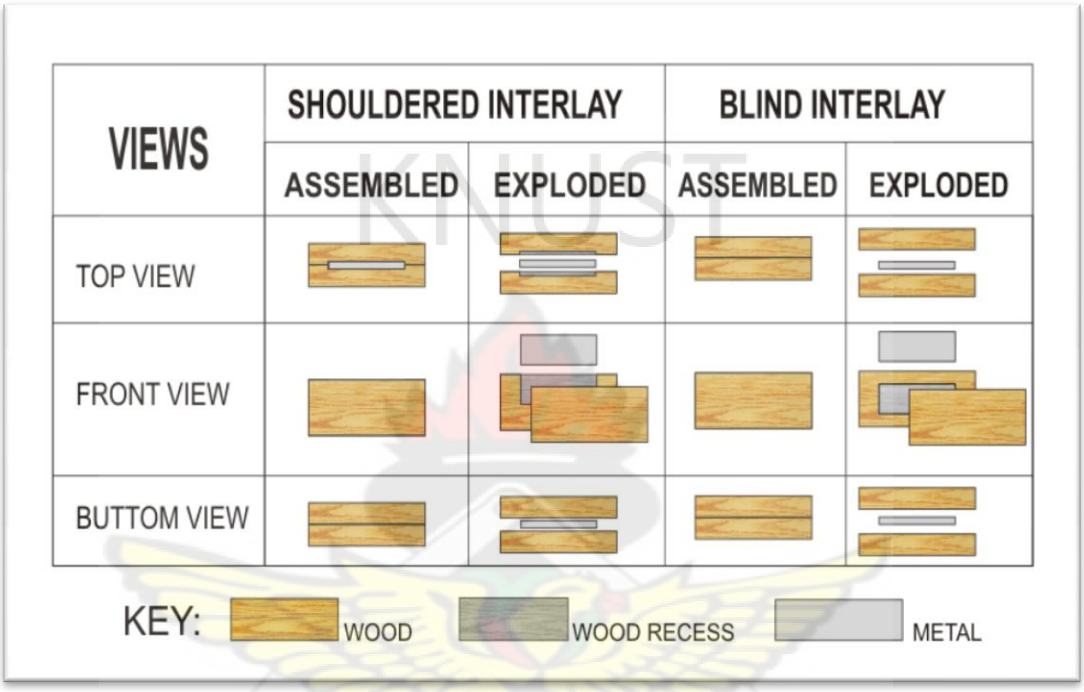


Figure 5.7: The layout of the shouldered and the blind interlaying techniques

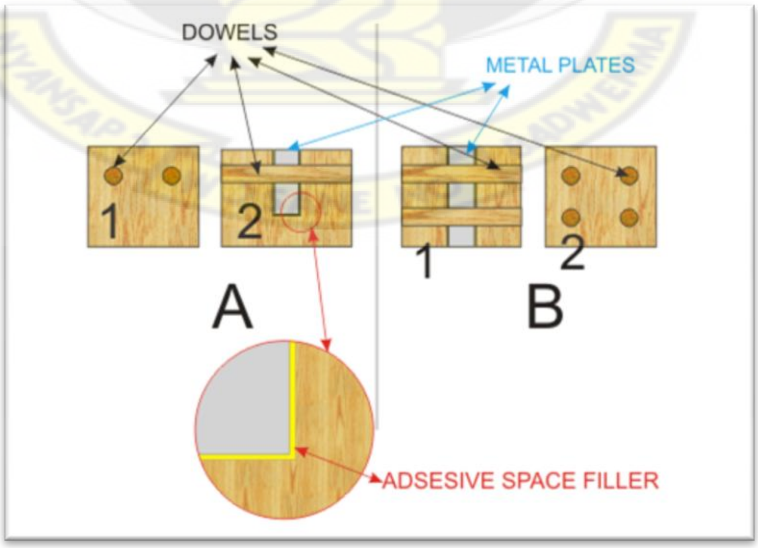


Figure 5.8: Cross dowelled intra-laid (A) and inter-laid (B) metals with adhesive gab filler

5.2.2.4 Basketry

This technique is simply the interlacing of wood sticks with metal strips. This technique is based on the basketry and other weaving techniques as in textile. It is therefore as unlimited as the weaving techniques notwithstanding the various possibilities in metal and wood that could be channelled into its enhancement. Applicable metal forms include rods, wires and strips. The ends of the metal weaver are ended with metal seaming and fastening techniques like cupping and riveting. Example of this is illustrated in figure 5.9.

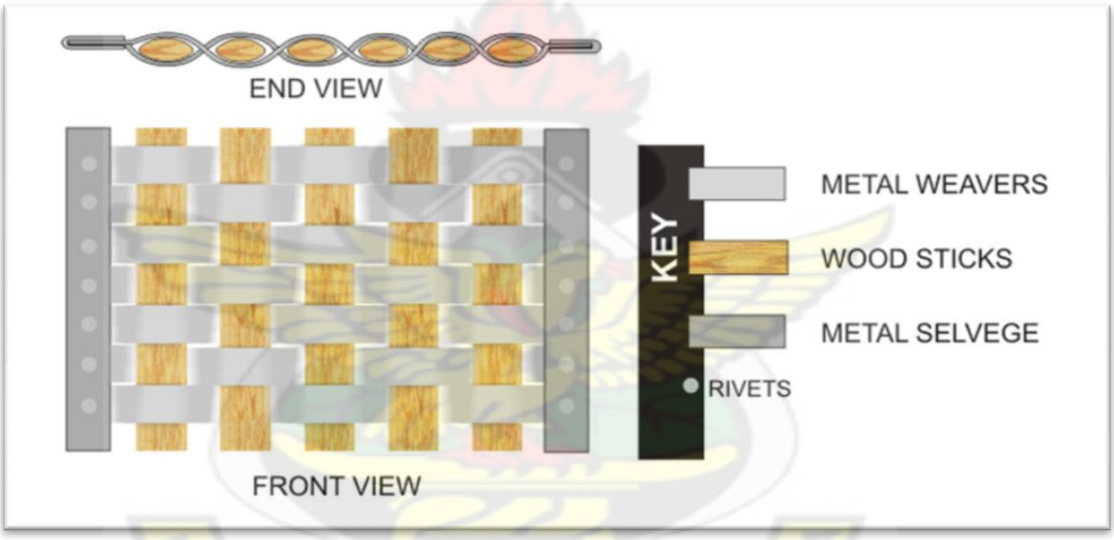


Figure 5.9: A sample of the basketry techniques

5.2.2.5 Particle binding

This is the casting of wood particle in amalgamation with metal particles and a binder. This result is abraded after curing or drying to reveal wonderful textures as shown in plate 5.1. Most applicable binders are those that also respond positively to abrasion.

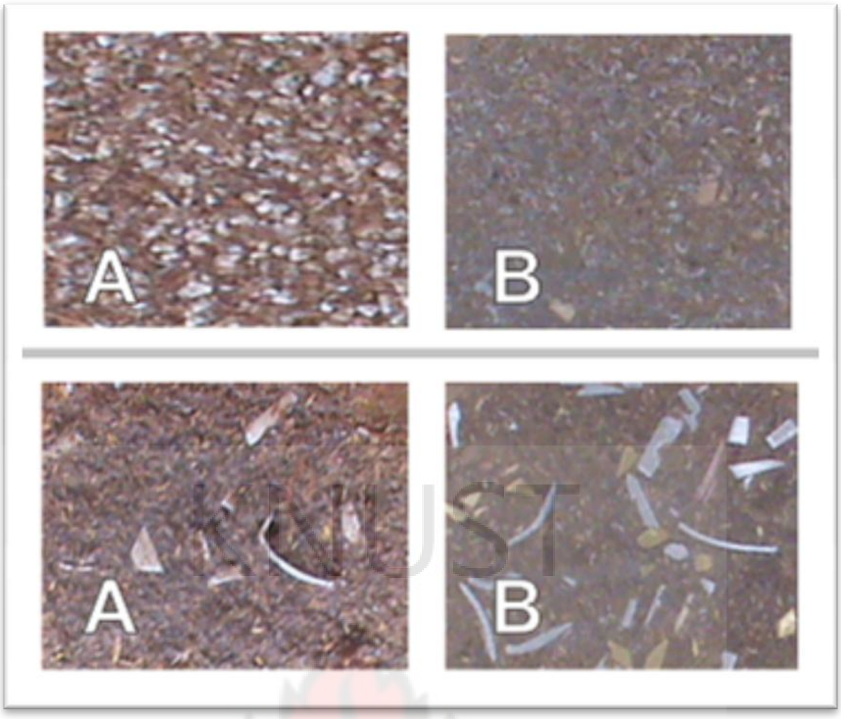


Plate 5.1: particle bond textures before abrasion (A) and after abrasion (B)

5.2.3 Jointing integration

This category has to do with the use of metal as joints maker for wood pieces. In this situation the wood joint is actualised with metal. This is categorised into two groups as fastening and connecting.

5.2.3.1 Fastening

Unlike the usual nails, screws and rivets, this is the designing of special fasteners for the joining of wood pieces that could also serve other purposes as decoration and protection apart from just holding the pieces in place. This may be removable for temporal joints and non- removable for permanent joints.

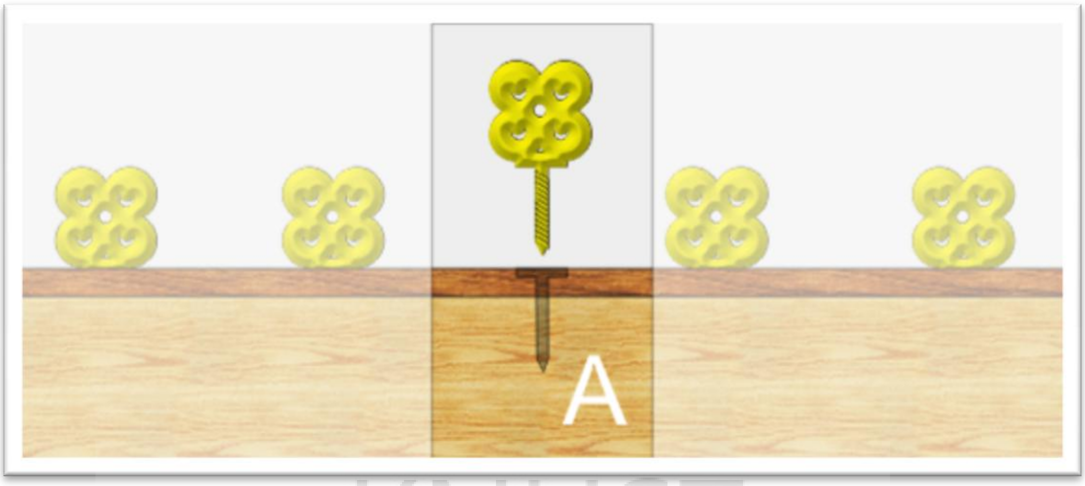


Figure 5.10: Removable fasteners (threaded) on temporal joints

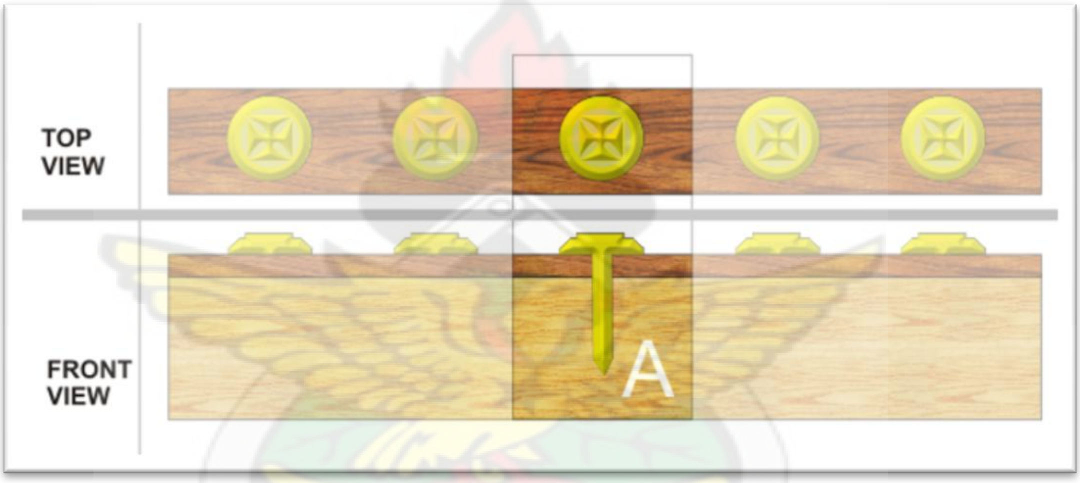


Figure 5.11: Non-removable fasteners hammered on permanent joints

5.2.3.2 Connecting

This technique has to do with the unification of two wood pieces with a metal fabricated jointer or connector. The study categorises the connectors into two groups: fixed connectors (figure 5.12) that may be used in rigid structures and movable connectors (figure 5.13) for flexible or knockdown structures. In each situation either the wood or the metal may receive the other.

Figure 5.12: Fix connections with closed connectors (up) and open connectors (down)

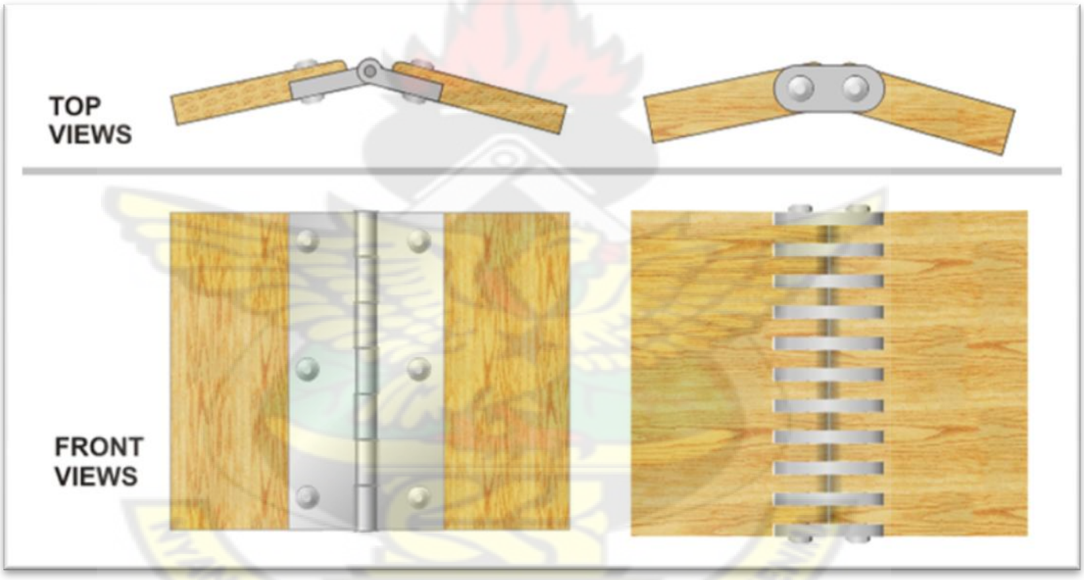


Figure 5.13: Moveable connections

5.2.4 Mechanising integration

This aspect involves the use of metal for mechanisms or automata in woodworks to enhance or facilitate their uses. Already existing examples are locks and automated hinges. This is a way of boosting efficiency in some woodwork. Others may include swivel and springing mechanisms.

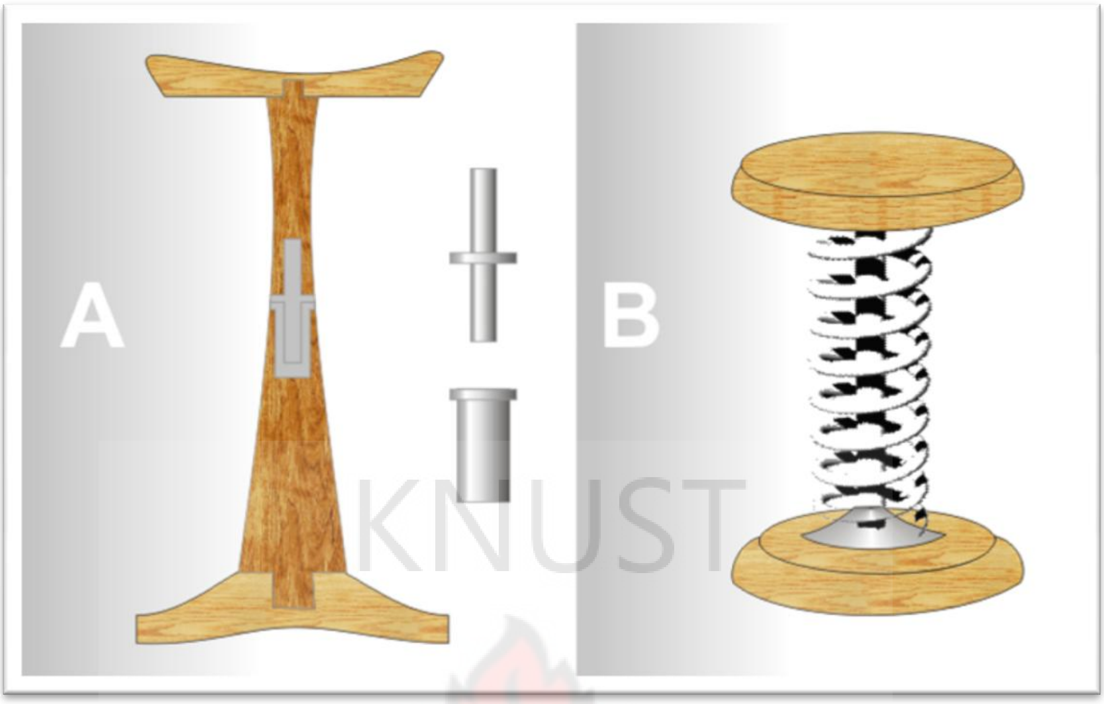


Figure 5.14: Cross section of a wood stool (A) with a swivel mechanism and B- a wooden stool with a spring mechanism.

5.2.5 Assemblage integration

Unlike the other integration techniques that target specific aspects of a production, this technique may target more than one aspect of the products. It is a technique that involves the integration of the other techniques or the repetition of a technique in which case the two materials become more of mixed together. Therefore it could be defined as mixed or repetitive method of metal integration into wood. Examples are figure 5.15 showing the reliefing technique (A) and the inter-laying technique in a security door design (B). And figure 5.16 showing the reliefing technique (A); the flashing technique (B); the mechanising (C) and the jointing technique (D) integrated into a wooden door.

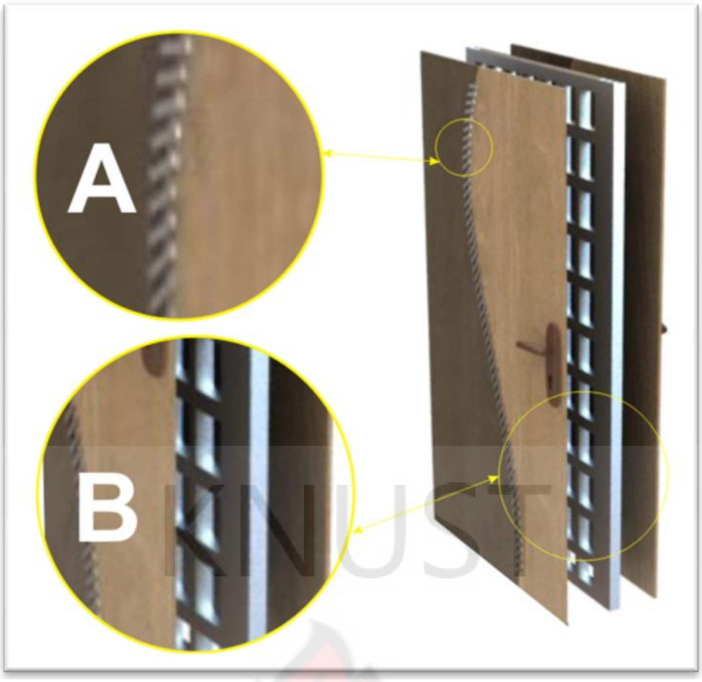


Figure 5.15: A burglar-proved door design (an assemblage of three structural, mechanism and textural integration)

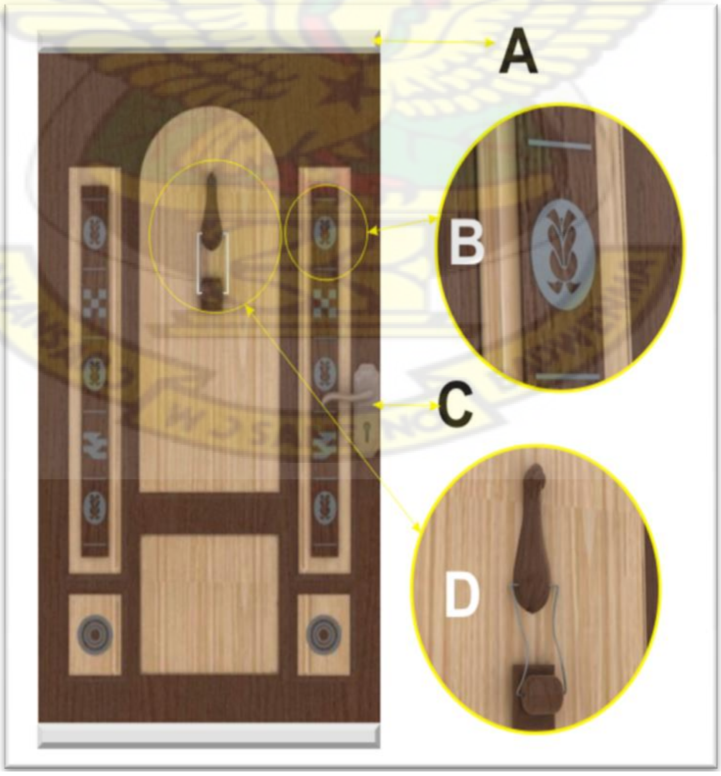


Figure 5.16: A door design exhibiting example of all the integration techniques

Assemblage integration which constitutes the integration of the other metal and wood integration techniques marks the end of metal integration into wood art forms. Anything more may result in the integration of wood into metal art forms

5.3 Jargons for the Integration Techniques

This section deals with two aspects: the general area of study (*wood and metal integration*) and the specialised area of study (*metal integration into wood*)

5.3.1 Wood and metal integration

The researcher realises that wood metal integration could be done in either of two ways at a time: the integration of wood into metal or the integration of metal into wood. In view of this, three jargons have formed acronymically in conjunction with other suffixes to ensure that they cover the similar scope of jargons found in dictionaries: *Art, Practise or occupation, Artist, Modus operandi or technique, Scientist in the area and Place of work of the artist.*

Art: The original jargon generated could only describe the art work that results from the operations. These are as follows:

"***Woomeint***" \'wü'mēnt\ n\ for wood and metal integration or wood and metal integrated art.

"***Woodinmet***" \'wü'din'met\ n\ for wood integration into metal art

"***Metinwood***" \'met'in'wüd\ n\ for metal integration into wood art

Practise: this aspect is the art of performing the tasks related to the arts. To this the suffix –ry (which refers to the practice of an activity) was adopted. These are as follows:

"***Woomeintry***" \'wü'mēntrē \ n\--the art of integrating wood and metal

"***Woodinmetry***" \'wü'din'metrē \ n\--the art of integrating wood into metal art

"***Metinwoodry***" \'met'in'wüdrē \ n\ --the art of integrating metal into wood art

Artist: the artist who specialises in the respective areas. To this the suffix –ist (which refers to one that performs a specified action) was also adopted as follows:

Woomeintist" \'wü'mēntist \ n\--one who practises the general art of integrating wood and metals

"***Woodinmetist***" \'wü'din'metist \ n\-- one who practises the art of integrating wood into metal art

"***Metinwoodist***" \'met'in'wüdist \ n\ -- one who practises the art of integrating metal into wood art

Modus operandi or study: this is the art of dealing with wood and metal in "woomientry". To this the suffix –urgy (technique or art of dealing or working with such as a product, matter, or tool) was adopted.

"Woomeinturgy" \'wü'mēnt ər-jē \ n\--the technique of working and dealing with wood and metal

Scientist: the scientist who specialises in "woomeinturgy". To this the suffix –ist was againd adopted.

"Woomeinturgist" \'wü'mēnt ər-jist \ n\-- a person learned in the knowledge or system of knowledge covering general truths or the operation of general laws of wood metal integration, especially as obtained and tested through scientific method

Place of work: this is the workshop designed for "woomeintry". To the work studio (a place for the study of an art) was adopted in addition to "woomeint".

"Woomeint studio" \'wü'mēnt 'stü-dē-ō\ a shop equipped with both wood and metal tools and other specialised tools, where wood and metal could be integrated.

5.3.2 Metal integration into wood ("Metinwood")

As discussed earlier, these are in five categories, which are *Textural integration, Structural integration*, *Jointing integration*, *Mechanising* and *Assemblage integration.* As illustrated in table 5.1, each category is represented by its initials, followed by the divisions that are coded by convenience: by initials when the members of the group have different initials as in the TI (Textural Integration) group and by a combination of part of words as in LOM (**lo**cking **m**echanism).

Again, for the sake of future developments and for that matter possible ambiguities the codes of the basic techniques and that of the division are conjoined. Apart from that the researcher also deems it essential for easy classification of the techniques and others that may emanate in future. Therefore the jargons under "*metinwood"* come in three stages:

i. *family name* (basic techniques): example TI (textural integration)

ii. *variety name* (divisions): example R (reliefing)

iii. *joint name* (deducted jargons) that determines their family and variety at the same time: example TIR (textural integration reliefing)

As also presented earlier in this chapter and in table 5.1, the right pronunciations (phonetic sounds) of the jargons are not left out in order to prevent sound ambiguities. Also in view of the fact that "*metinwood*" could counter changed to "*woodinmet*", it becomes a must to precede each jargon with its subject name or code in order to also avoid ambiguities in the areas of study ("woomeint"). In this research the researcher proposes MW for "metinwood" and WM for "woodinmet" which could be referred to as "woomeint" codes.

Therefore in the case of "woomeint" the communication jargons are presented as follows:

Woomeint code HYPHENE(-) joint name = woomeint name

Example in "metinwood"(MW), the name for insertion (INSERT) under structural integration (SI) is given as :

MW -(SI + INSERT) = woomeint name

woomeint name = MW - SIINSERT

Lastly, AI representing the integration of VARIETIES of basic techniques or REPETITION of a technique depends on the varieties of techniques employed or the technique repeted . This is given as:

Woomeint code HYPHENE(-) AI *first technique\second technique\ third…………..* for varieties of techniques and

Woomeint code HYPHENE(-) AI *the technique(s)*®

Where ® stands for repetition. Example:

MW – AI SIINSERT\ TIR\ JIC\ SIPAB

The above means that the metinwood (metal integrated wood art) is an integration of reliefing textural integration, connecting jointing integration and particle binding structural integration.

Table 5.1: Jargon generation table

Basic Techniques	Initials /Codes	Divisions	Codes	Source of jargons	Deducted Jargons	Phonetic Sounds
Textural integration	TI	Reliefing	R	Sculpture	TIR	Tē \'ī\ är
		Flashing	F	joinery	TIF	Tē \'ī\ef
		Sinking	S	sculpture	TIS	Tē \'ī\es
Structural integration	SI	Insertion	INSERT	Literal meaning English	SIINSERT	Sēn sərt
		interlaying	INTER	Literal meaning English	SIINTER	Sēn tər
		intra-laying	INTRA	Literal meaning English	SIINTRA	Sēn trā
		Basketry	B	Weave art	SIB	sib
		particle binding	PAB	Wood processing	SIPAB	sip'ab\
Jointing integration	JI	Fastening	F	Wood and metal technologies	JIF	jif
		Connecting	C	Structural engineering	JIC	jik
Mechanising Integration	MI	locking mechanism	LOM	Wood technology	MILOM	mil 'əm

		Movement mechanism	MOM	Wood technology	MIMOM	mim əm
Assemblage integration	AI	This depends on the theme or intention of the artist	This depends on the varieties of basic techniques employed	Mixed media Sculpture	AI	ā\ī

5.3.3 Conclusion

The above jargons do not limit the description or appreciation of a "metinwood" by the artist. This means that so long as the wood and metal techniques remain in their respective areas of specialisation, their terminologies and conditions are still relevant in the detail description of a "woomeint". Therefore "woomeint" jargons are designed to make communication easier and faster among the professionals, and they must be placed before the main idea behind the work or the actual name of what the artist means to produce: example table top, pillar, partition et cetera.

5.4 "Metinwood" reference materials for the library and their respective jargons

With reference to information gathered from the libraries relatively, the inflow of books may be slower than the production of metinwood speimens. In view of this the researcher has resorted to miniature sizes for effective space management. Under this the resercher came up with 50 specimens. But for the pupose of this report only 20 are presented under the integration method except for the MI method.

5.4.1 "Metinwood" specimens

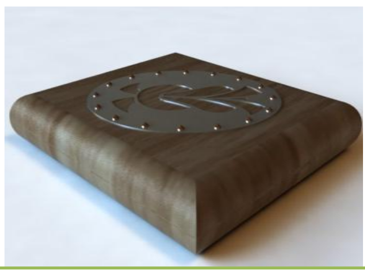
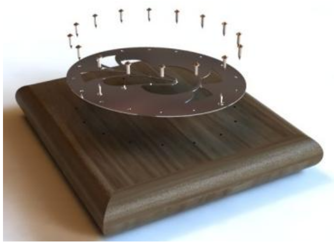
These are the application of the basic integration techniques in conjunction with possibilities in wood and metal such as carving, piercing, embossing and casting. These specimens are "metinwood" basic ideas upon which more complex works or other ideas could be based. Apart from that, the specimens are designed based on specific purpose as discussed earlier.

The sizes of these are approximated around 4 inches by 4 inches under each category. For the sake of good contrast the researcher has used the two dark wood species (Mansonia and Hyedua) among the less shrinking group from the result of the experiment in chapter 4.

However, for the purpose of this presentation twenty specimens are presented out of fifty. Three illustrations are presented for each specimen: the 3-D design, detail of 3-D design and the photograph of the actual specimen under each category. Attached to these also are their descriptions and recommended uses. These are as follows.

5.4.1.1 TI (textural integration)

Table 5.2: MW- TIR: Overlay

MW- TIR: Overlay		
3-D design	Design details	Photograph of actual work
		

Description: A pierced metal piece tacked with decorative nails onto the wood surface **Recommended use:** For surface decoration and inscription. As decorative butt joint reinforcement.

Table 5.3: MW- TIR: Chased on

MW- TIR: Chased on		
3-D design	Design details	Photograph of actual work
		
Description: A carved cocoa half pod covered with metal leaving the stock and implanted into a wood surface. **Recommended use:** For wood surface protection and enhancement. As finishing technique, decorative and colouring technique for wood.		

Table 5.4: MW- TIR: Surface cold casting

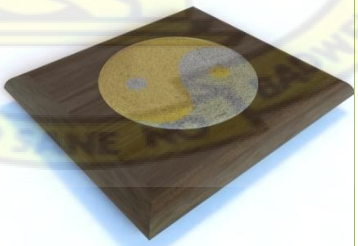
MW- TIR: Surface cold casting		
3-D design	Design details	Photograph of actual work
		
Description: aluminium dust in contrast cold cast with brass dust on wood surface. The binder employed is cyanoacrylate (super glue) **Recommended use:** rendering of metallic finish to wood; could also be employed as colouring and texturing technique for woodwork.		

Table 5.5: MW- TIR: Mock Stitching

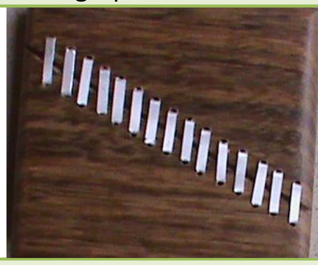
MW- TIR: Mock Stitching		
3-D design	Design details	Photograph of actual work
		
Description: A sawn wood surface with parallel holes at either side of the saw line. The opposite holes are connected with strips of metal across the sawn line to appear as if it was stitched. **Recommended use:** As a decorative technique and as means of creating illusion woodwork.		

Table 5.6: MW- TIR: Flash Inlaying

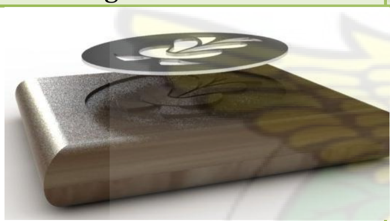
MW- TIR: Flash Inlaying		
3-D design	Design details	Photograph of actual work
		
Description: A pierced metal sunk into a conforming recess in wood to flash with it surface. **Recommended use:** For surface decoration and inscription. And also for colouring wood.		

Table 5.7: MW- TIF: In cold casting

MW- TIF: In cold casting		
3-D design	Design details	Photograph of actual work
		

Description: Metal dust mixed with PVA adhesive cast into a sunk design. This was abraded after drying to reveal the wonderful textures. **Recommended use:** For surface enhancements and inscription

Table 5.8: MW- TIS: Mock weaving

MW- TIS: Mock weaving		
3-D design	Design details	Photograph of actual work
		
Description: This is the carving of wood surface in the weaving fashion showing warps and weft. The warp or weft if replaced or covered with metal, the fashion to appear like interwoven in wood and metal. **Recommended use:** For surface texturing and decoration.		

5.4.1.2 SI (Structural integration)

Table 5.9: MW- SIINTER: Pierced interlay

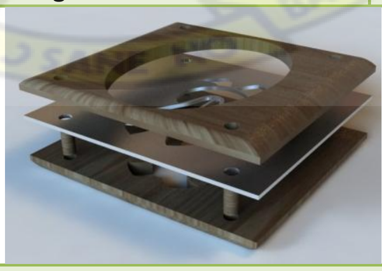
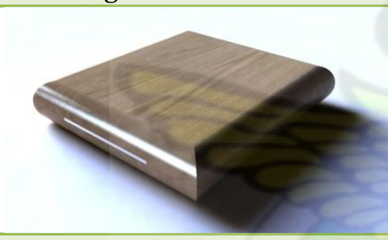
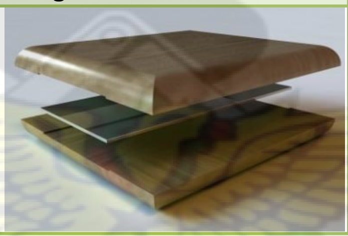
MW- SIINTER: Pierced interlay		
3-D design	Design details	Photograph of actual work
		
Description: A pierced metal interlaid between two pierces wood to reveal the metal design **Recommended use:** For ventilation and decoration of woodworks and at the same time strengthening it.		

Table 5.10: MW- SIINTER: Pierced Blind Interlay

<table>
<tr><th colspan="3">MW- SIINTER: Pierced Blind Interlay</th></tr>
<tr><td>3-D design</td><td>Design details</td><td>Photograph of actual work</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Description: An inter-lay between two recessed wood pieces to hide the ends of the metal between.

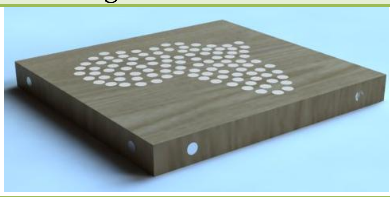
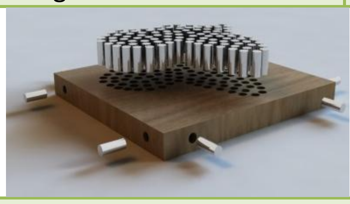
Recommended use: for surface decoration, a decorative reinforcement and also for mini framing purposes.</td></tr>
</table>

Table 5.11: MW- SIINTER: Shouldered Interlay

<table>
<tr><th colspan="3">MW- SIINTER: Shouldered Interlay</th></tr>
<tr><td>3-D design</td><td>Design details</td><td>Photograph of actual work</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Description: This interlay falls between the interlay and the blind interlay with only two opposite ends of the metal showing

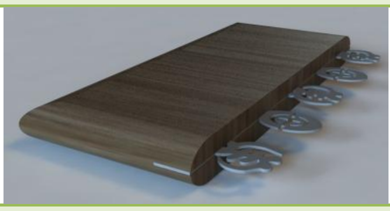
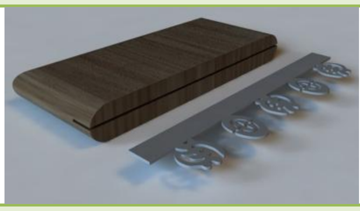
Recommended use: For the restriction of excessive bending in wood. It could also be adopted for the elongation of wood pieces.</td></tr>
</table>

Table 5.12: MW- SIINSERT: Motif Weight Inducing

<table>
<tr><th colspan="3">MW- SIINSERT: Motif Weight Inducing</th></tr>
<tr><td>3-D design</td><td>Design details</td><td>Photograph of actual work</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Description: This is the pushing or rods into their corresponding holes in wood surface to create a pattern and at the same time make the wood heavier in weight.

Recommended use: For the induction of weight into wood pieces for weight demanding purposes and also for the creation of textures on wood surfaces.</td></tr>
</table>

Table 5.13: MW- SIINTRA: Edge Guarding

MW- SIINTRA: Edge Guarding		
		
Description: This is a purposefully pierces metal intra-laid at the edge of the wood pieces to serve as an edge guard. **Recommended use:** This could be adopted for security purpose on wooden fences and for other decorative purposes.		

5.4.1.3 JI (Jointing Integration)

Table 5.14: MW- JIC: Sheet Widening

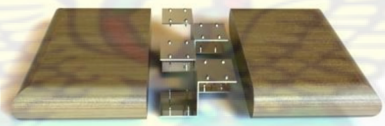
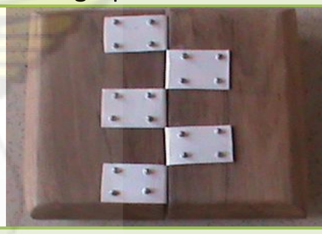
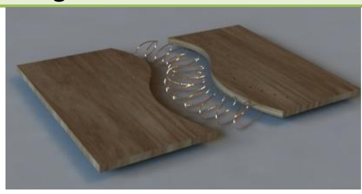
MW- JIC: Sheet Widening		
3-D design	Design details	Photograph of actual work
		
Description: This is the use of a metal fabricated sheet as a connector between two pieces for the purpose of widening it and at the same time rendering it with a unique impression. **Recommended use:** For the widening of wood sheets and also a means of creating decorative joints.		

Table 5.15: MW- JIF: Wire Stitching

MW- JIF: Wire Stitching		
3-D design	Design details	Photograph of actual work
		
Description: This is the use of wire to stitch two wood pieces together preceded by the		

drilling of respective holes. **Recommended use:** For the fastening of wood pieces together and also for the creation of decorative effects in woodwork.

Table 5.16: MW- JIC: Open rod widening

MW- JIC: Open rod widening		
3-D design	Design details	Photograph of actual work
		
Description: This is a serial connection of the two wood pieces with rods to create a see through opening between them. **Recommended use:** This could be use for caging and decorative or ventilated widening joints in between pieces of wood		

5.4.1.4 AI (Assemblage Integration)

Table 5.17: MW- AI TIR\SIINTER: Sun Flower

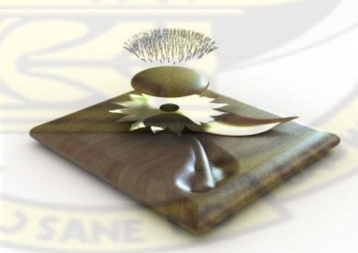
MW- AI TIR\SIINTER: Sun Flower		
3-D design	Design details	Photograph of actual work
		
Description: this is a creative combination of the reliefing (the application of the petals, seeds and the leaf) and interlaying (of the metal pieces between the base and the top wood) techniques dowelled together to form a sun flower. **Recommended use:** this technique could be employed in many ways as far as contrast between the object in the composition is concerned.		

Table 5.18: MW- AI SIINTER®: Dowelled Lamination

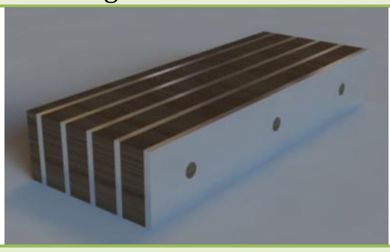
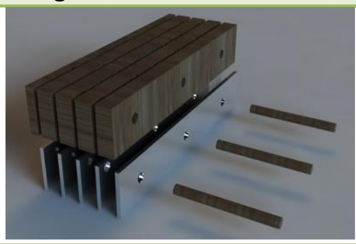
MW- AI SIINTER®: Dowelled Lamination		
3-D design	Design details	Photograph of actual work
		
Description: This is the repetition of the inter-laying technique dowelled together to form a wide piece. **Recommended use:** For high class panels and furniture tops.		

Table 5.19: MW- AI SIINTER®: Bonded Lamination

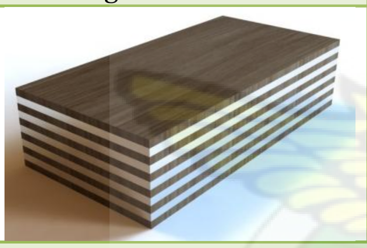
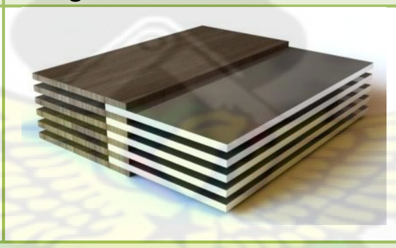
MW- AI SIINTER®: Bonded Lamination		
3-D design	Design details	Photograph of actual work
		
Description: This is another repletion of the inter-laying technique bonded together with contact glue **Recommended use:** For high class panels and furniture tops.		

Table 5.20: MW- AI SIINTER®\JIF: Rod Beading

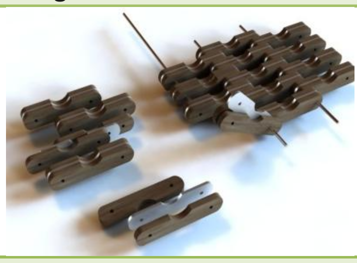
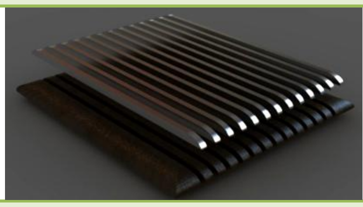
MW- AI SIINTER®\JIF: Rod Beading		
3-D design	Design details	Photograph of actual work
		
Description: This is a series of interlay, inter-beaded on a long fastener to hold them together to spread like a mat. **Recommended use:** This is employable in the making of floor cover and also for decorative furniture		

Table 5.21: MW- AI SIINTRA®: Mock Lamination

MW- AI SIINTRA®: Mock Lamination		
3-D design	Design details	Photograph of actual work
		
Description: This is the repetition of the intra-laying technique over a wood surface to appear from the front as if it was laminated. **Recommended use:** For the surface reinforcement and decoration		

5.4.2 The form and layout of booklets

The booklets of the specimens are meant to be temporary in order to make room for future addition of ideas. Due to this, permanent jackets have been made for them that bare the permanent information for their respective specimens. The cross section of the booklets is shown in figure 5.17, followed by the design of the jacket in fiqure 5.19.

Figure 5.17: The cross-sectional layout of the reference booklets

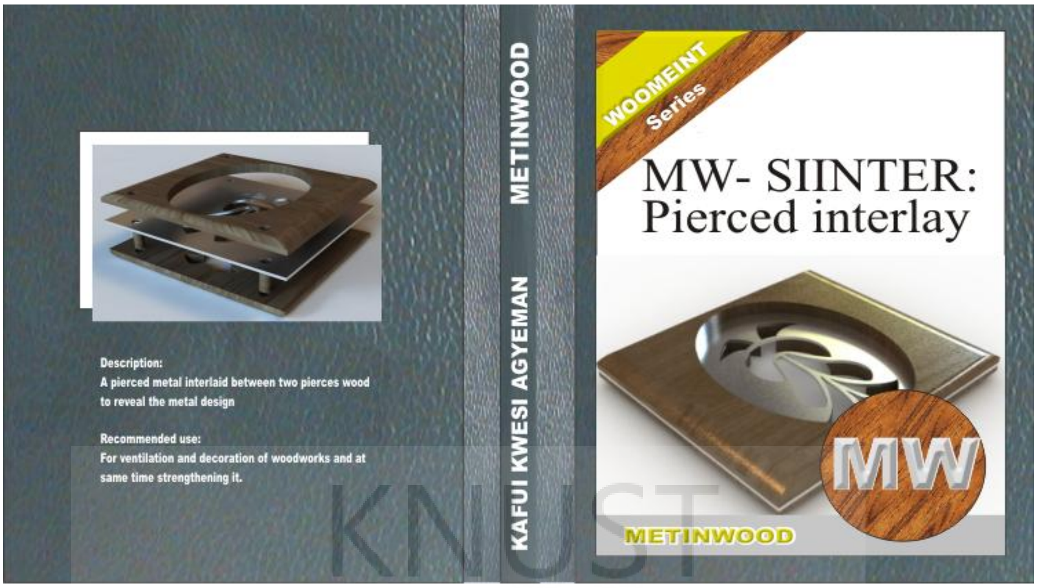


Figure 5.18: A sample design of the reference booklet jacket (for the inter-laying technique).

Each booklet contains the purpose and the step by step procedure in the execution of its respective specimens. For the purpose of this dissertation the content of only one (the inter-laying technique) booklet is presented as follows from figure 5.20 to figure 5.28.

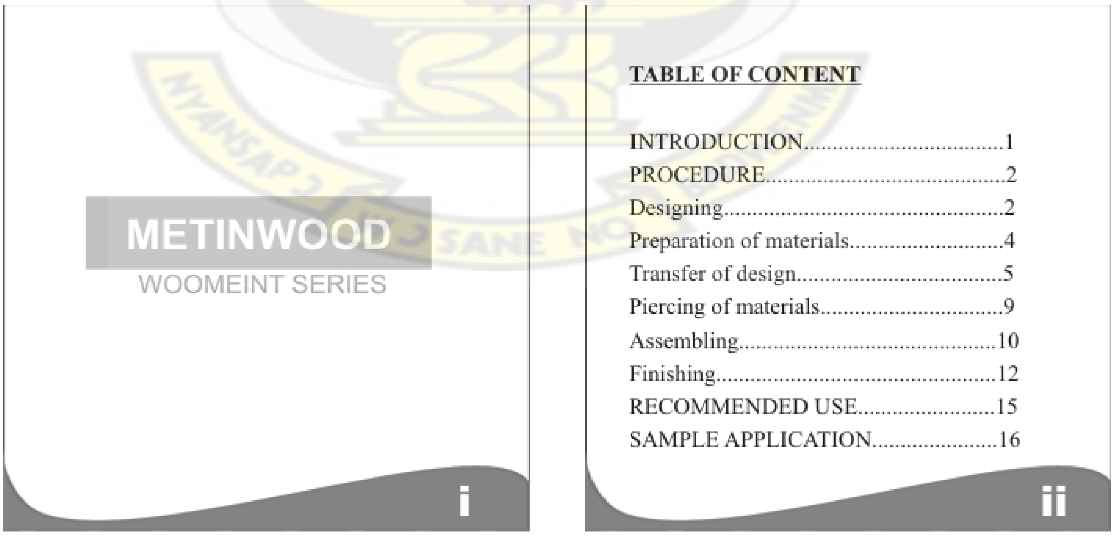
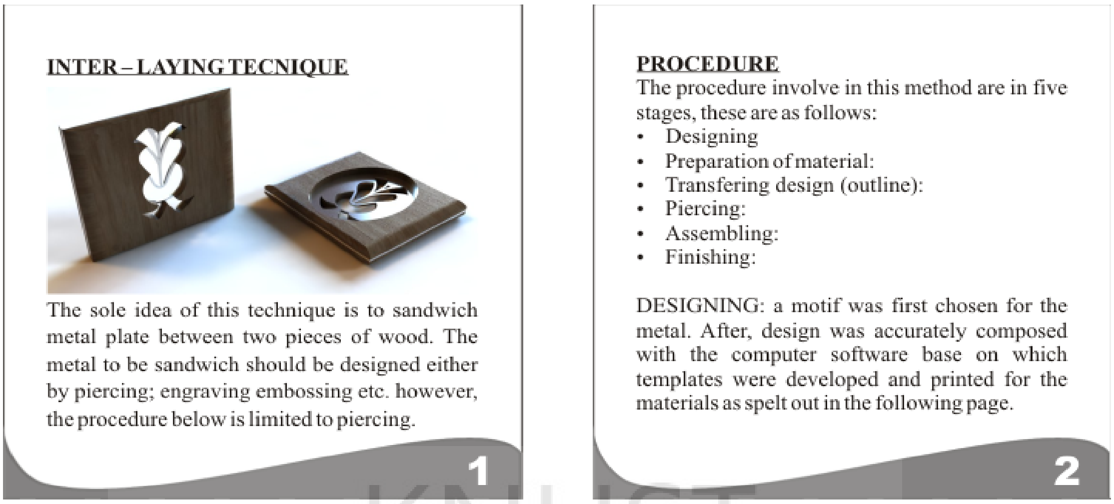


Figure 5.19: Booklet preliminary pages (i & ii)


INTER – LAYING TECNIQUE

The sole idea of this technique is to sandwich metal plate between two pieces of wood. The metal to be sandwich should be designed either by piercing; engraving embossing etc. however, the procedure below is limited to piercing.

1

PROCEDURE

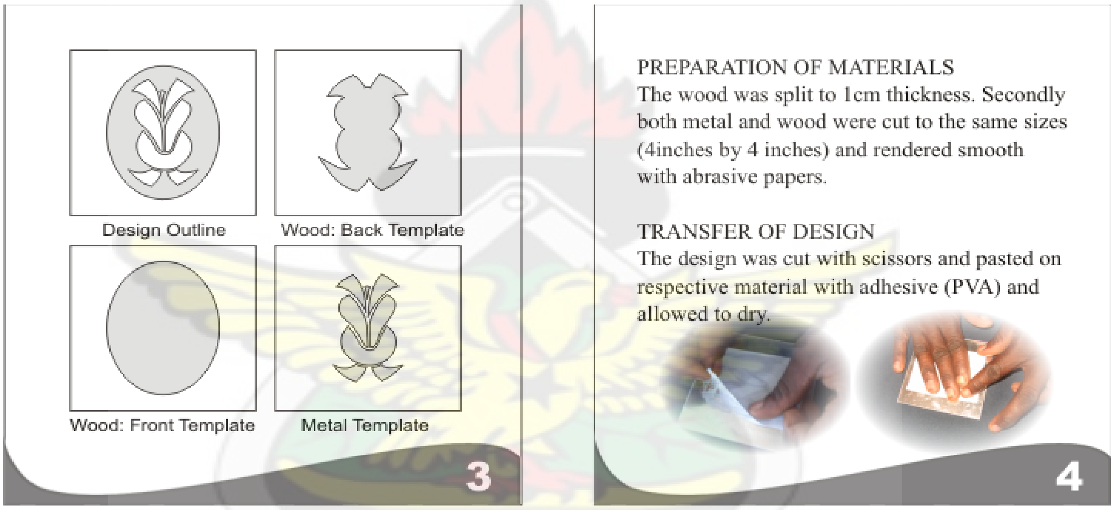
The procedure involve in this method are in five stages, these are as follows:

- Designing
- Preparation of material:
- Transfering design (outline):
- Piercing:
- Assembling:
- Finishing:

DESIGNING: a motif was first chosen for the metal. After, design was accurately composed with the computer software base on which templates were developed and printed for the materials as spelt out in the following page.

2

Figure 5.20: Booklet pages one and two



PREPARATION OF MATERIALS

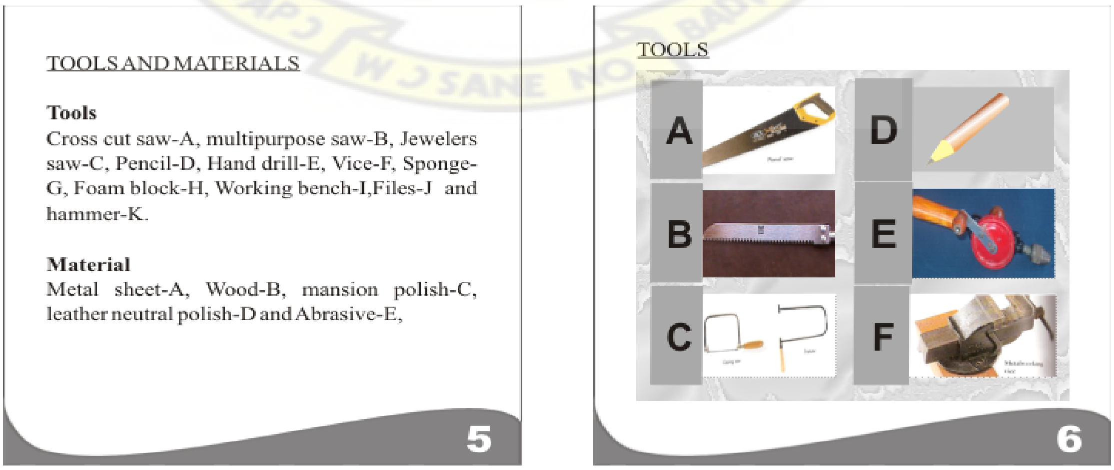
The wood was split to 1cm thickness. Secondly both metal and wood were cut to the same sizes (4inches by 4 inches) and rendered smooth with abrasive papers.

TRANSFER OF DESIGN

The design was cut with scissors and pasted on respective material with adhesive (PVA) and allowed to dry.

4

Figure 5.21: Booklet pages three and four


TOOLS AND MATERIALS

Tools

Cross cut saw-A, multipurpose saw-B, Jewelers saw-C, Pencil-D, Hand drill-E, Vice-F, Sponge-G, Foam block-H, Working bench-I,Files-J and hammer-K.

Material

Metal sheet-A, Wood-B, mansion polish-C, leather neutral polish-D and Abrasive-E,

5

TOOLS

Figure 5.22: Booklet pages five and six

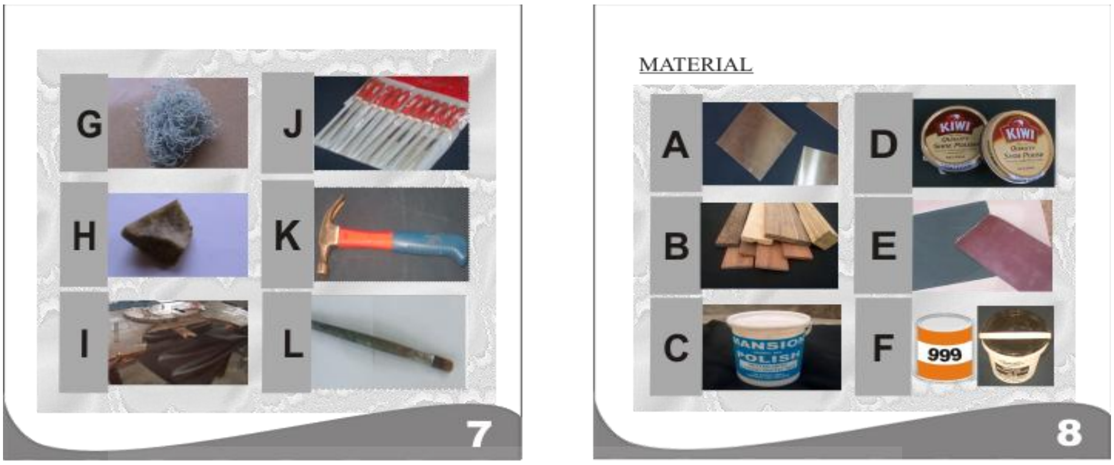


Figure 5.23: Booklet pages seven and eight

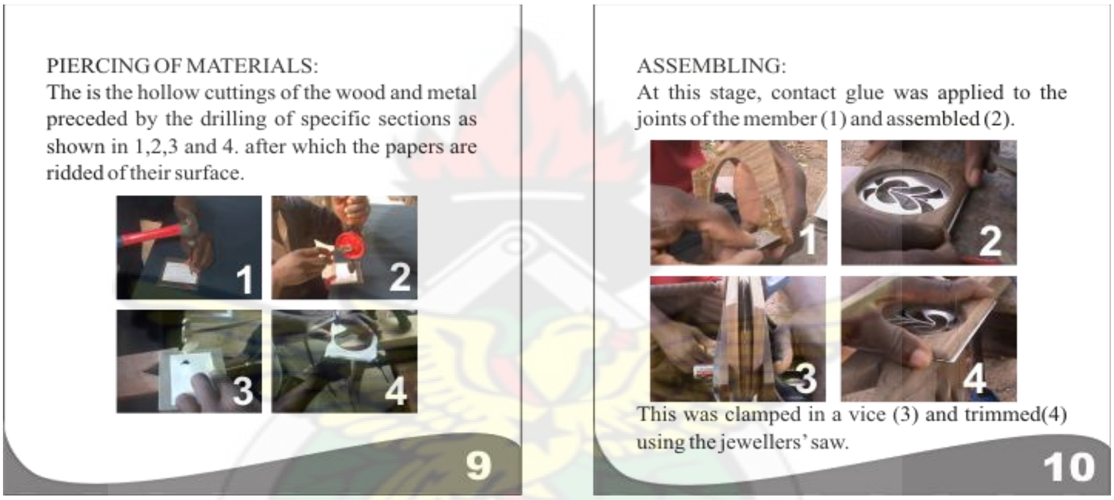


Figure 5.24: Booklet pages nine and ten

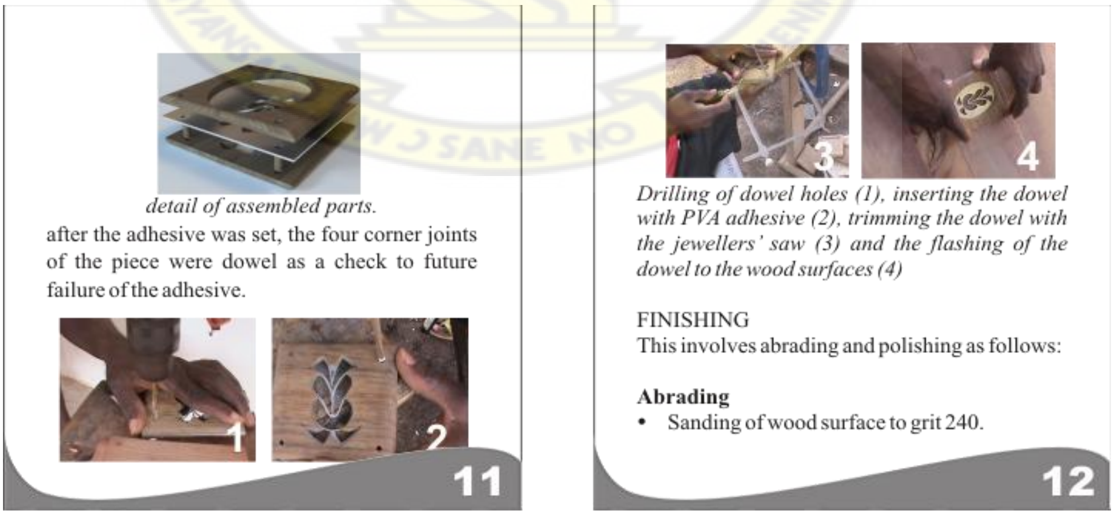


Figure 5.25: Booklet pages eleven and twelve

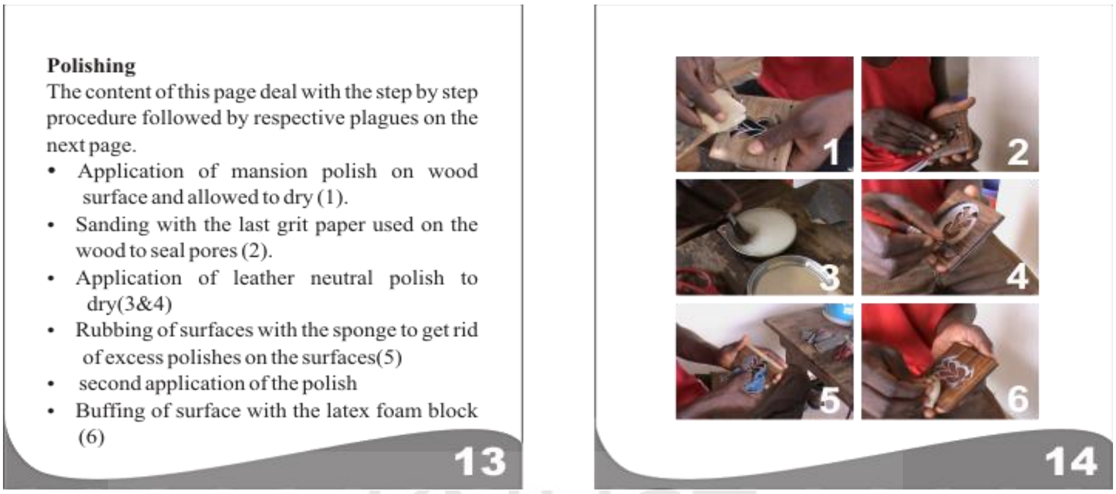


Figure 5.26: Booklet pages thirteen and fourteen

Figure 5.27: Booklet pages fifteen and sixteen

This is intended to properly document and make the concept comprehensible to students who may use them.

5.4.3 The specimen boxes

This is the protective case for the specimen. This was constructed with the rebate butt joint that provided enough surfaces for gluing to make it strong and durable. The design as shown in figure 5.28 has a buckling section that keeps the specimens under lock in the box. It also has the label section that is covered with fibre glass: this area is to contain a clear label of the content for easy identification of the specimens.

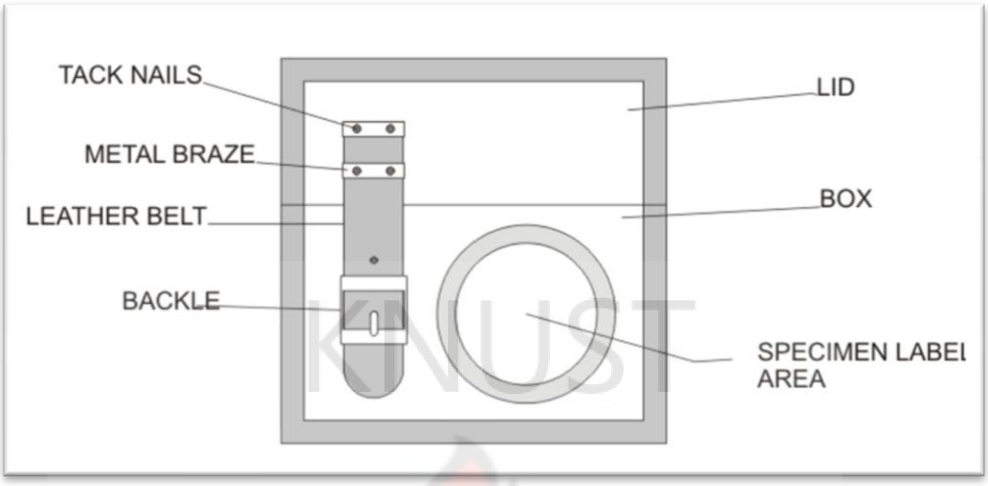


Figure 5.28: The design layout of the specimens' box

5.4.3.1 The construction of the box

The researcher realised the need to reduce the weight of the box to the barest minimum. Considering the size of the tack nails that were used, the thickness of the wall and for that matter the thickness of the wood that was used was given the dimension to 0.7 cm. After the preparation of the parts as shown in appendix 10, they were formed (A), followed by the fixing of the hinges between the supposed lid and the main body (B) before the splitting of the lid from the body (C) to ensure proper alignment of the two parts as illustrated in figure 5.29.

This was finished by the lining of its edge with an amalgam of clay and PVA proceeded by the coating the intended surface with diluted PVA to facilitate adhesion. After it had dried, it was coated with acrylic paint to create the intended impression as presented by the design in figure 5.30.

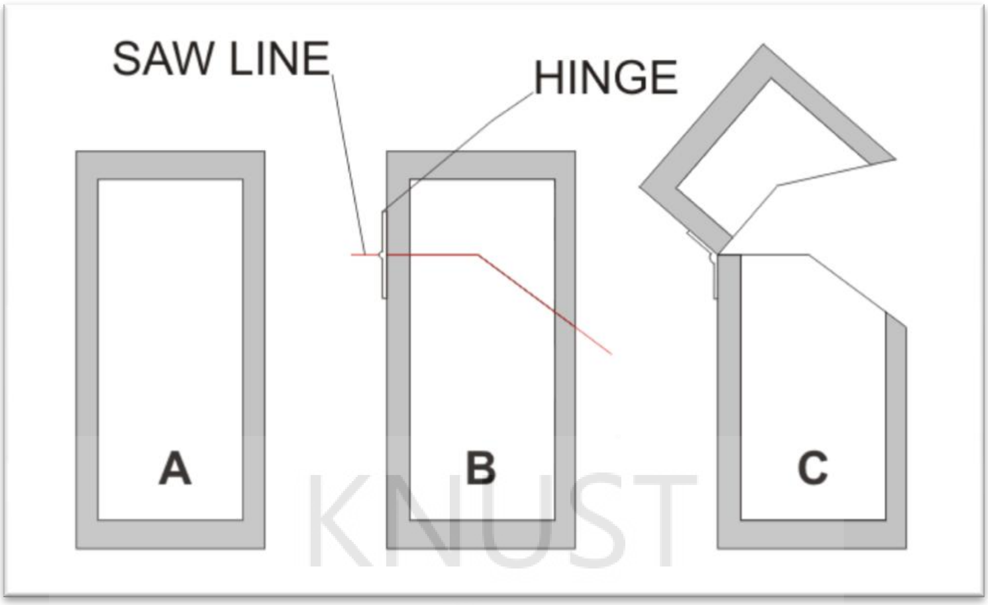


Figure 5.29: The construction plane of the specimen box

Figure 5.30: The three dimensional rendition and explosion of the design

The leather belt and buckles that had been formed were affixed to them and then polished with wax on the buffing wheel. The labels as prescribed for each specimen were printed in bright colours and fixed in their respective position (plate 5.2) for easy identification.

Plate 5.2: The finished boxes

5.4.4 Library arrangement set up of specimens

This was designed to sit on the shelves in the library. Two arrangements are intended by the researcher as shown in A and B in figure 5.33 and 5.34.

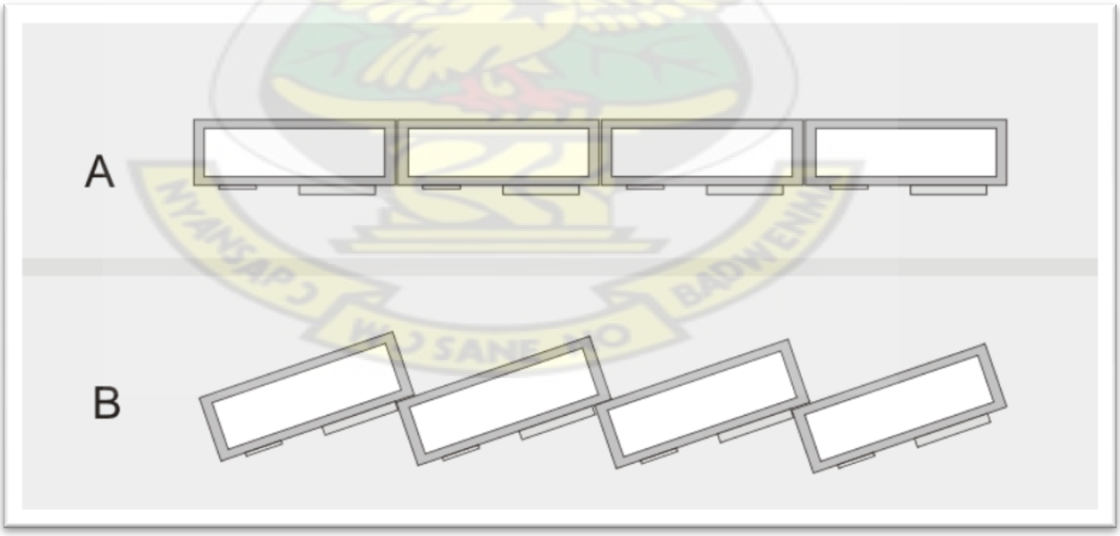


Figure 5.31: The plan of the shelve arrangement of the specimens' boxes

Plate 5.3: Actual sample arrangement of the specimens' boxes

Each specimen is tagged with a number based on which a directory is made for easy tracing on the shelves. In view of these the boxes are suppose to be arranged in the sequence of their numbers as demonstrated from 1 to 4 in figure 5.34.

5.5 Conclusion

This is an innovation based on the natural behaviour of wood and metal. "An innovation without proper documentation is as good as an idea in the mind of an individual, it yields less if it does not benefit the bearer and society". This creative approach is meant to move the study of art a step further towards a hopeful future. According to Sir James Hopwood Jeans, an English physicist and mathematician, "to travel hopefully is better than to arrive". This is to say that this innovation is not an end but a beginning and a hope for greater things by both the researcher and others who may indulge in it. As Phillpotts, a British novelist, poet, and dramatist says, “the world is full of magical things patiently waiting for our wits to grow sharper”.

According to Robert Irwin, “art exists not in objects but in a way of seeing”. This attempt to expose this innovation through a set of reference materials (plate 5.4) is also intended to bring out the art in it through how people would see and comment on it. Since “a man who makes not mistakes does not usually make anything”, this being the first time may have certain shortcomings that would be addressed later based on comments from its users and stakeholders and that is the more reason why the booklets are temporary. “Art has no end”.

Plate 5.4: The complete library set.

CHAPTER SIX

PRESENTATION AND DESCRIPTION OF TWO METINWOODS FROM THE RESEARCH

6.1 Introduction

This chapter presents two works that are based on the findings of the research. The works are based on the following themes:

i. A spider in a web and

ii. Stool light fountain

These are described based on the terminologies or jargons developed in the previous chapter, and for that matter their description is limited to the "woomeint" than their functional aspects. Various aspects related to the integration techniques are highlighted as follows.

6.2 A Spider in a Web

The spider in the web as shown in Plate 6.1 is an *Assemblage integration* of three out of the four "metinwood" methods: *Textural integration, Structural integration* and *jointing integration.* It entails a wooden spider embellished with metal in a metal web formed within a supposed opening in a wall with the bricks in wood connected with metal sheets. The entire work is mounted in a wooden frame with metal attachments of domes and adinkra symbols on it. The details under the metinwood method are discussed as follows:

Plate 6.1: A metinwood: A spider in a wed.

6.2.1 Textural integration

As shown in Plate 6.2, *MW- TIR: fixings of adinkra symbols and domes* are made on the wooden frame members with a black background to make it vivid. This also gives the frame a classical finish. Secondly, the *MW- TIR: wire planting and sheet overlay* are employed for the spider's hairy body and body patches respectively .This makes it appear more real as if there is life in it (Plate 6.3). Lastly the *MW- TIR: wire binding* is employed at the legs to make it solid and also provide an extended hook for the gripping of the web (network of chains)

Plate 6.2: The wooden frame with MW- TIR: fixings of adinkra symbols and domes

Plate 6.3: The spider with *MW- TIR: wire planting and sheet overlay* for the hairy body and body patches respectively.

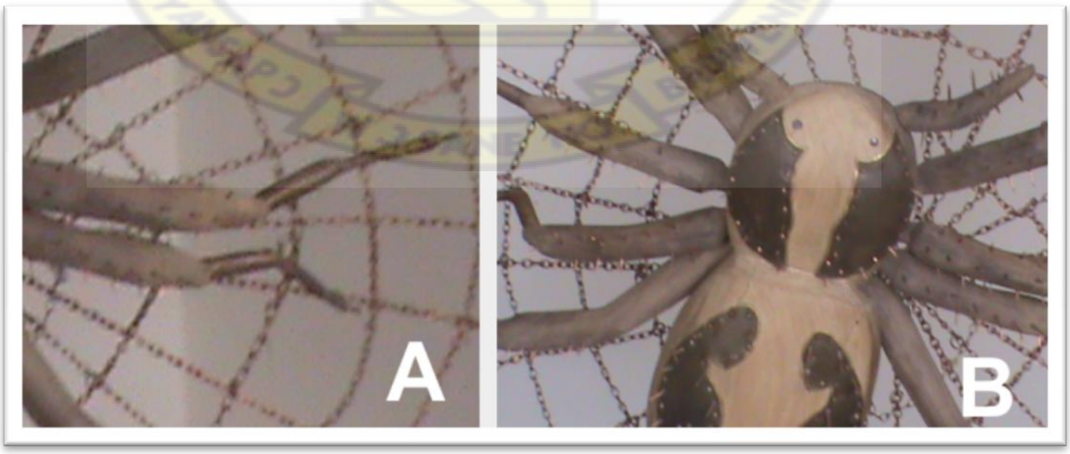


Plate 6.4: The spider with *MW- TIR: wire binding* for the legs

6.2.2 Structural integration

Under this method the *MW- SIINSERT: wire texturing* are employed to give the wooden bricks the natural terracotta effect apart from the colours of the chosen woods. In this respect copper and aluminium mires are employed.

Plate 6.5: The *MW- SIINSERT: wire texturing* techniques showing as bright dots of the wood surfaces.

6.2.3 Jointing integration

Under this, only one technique: the *MW- JIC: Open sheet interconnection* is employed for the linking of the bricks. This has been done with aluminium sheet to render the composition the natural feel of cement connection between bricks as shown in plate 6.6.

Plate 6.6: The *MW- JIC: Open sheet interconnection* showing between the wooden bricks

6.3 Stool Light Fountain

The light fountain is also a “metinwood” assemblage integration of *Textural integration, Structural integration* and *jointing integration* methods. This constitutes a stool on its pedestal with the integration of metal at important points as shown in plate 6.7. The details follow.

Plate 6.7: Metinwood light fountain

6.3.1 Jointing Integration

Under this the *MW- JIC: pierced sheet interconnection* has been employed for the light chamber to provide vents for the light rays in order to accomplish its purpose. These interconnections are among the wooden angles of the light chamber as shown in plate 6.8.

Plate 6.8: The light chamber of the stool composed with The *MW- JIC: pierced sheet interconnection*

6.3.2 Textural Integration

As captured in plates 6.9 and 6.10: two techniques of this method are employed. These are the *MW- TIR: Mock Stitching* and the MW- *TIR: pierced holes capping.* The *MW- TIR: Mock Stitching* has been employed over cracks in the base of the stool (A&C) and also for the base of the pedestal. This has made the cracks though glued, appear more secured notwithstanding its decorative effect. The other on the base of the pedestal (B) has improved the look by making it more elegant.

The MW- *TIR: pierced hole capping* on the other hand as in plate 6.10 has been employed on the hole on top of the stool and sides of the pedestal to shoot decorative light rays onto the surrounding walls of where the fountain may be.

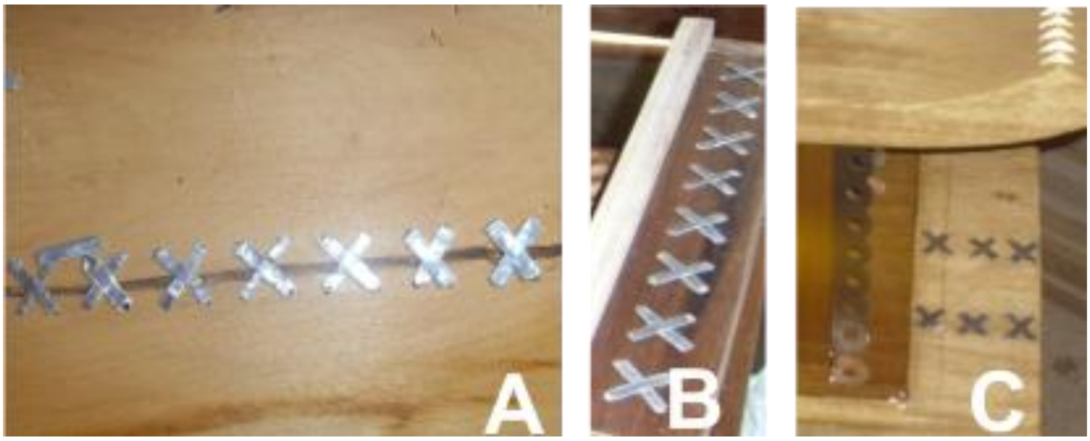


Plate 6.9: The *MW- TIR: Mock Stitching* on the cracks of the base (A&C) and on the base of the pedestal (B)

Plate 6.10: The MW- *TIR: pierced hole capping* employed on the holes on top of the stool (A) and the holes on the pedestal (B)

6.3.3 Structural Integration

Under this method only one technique has been employed: the *MW- SIINTRA: Edge Guarding*. This as shown in plate 6.11 is to, render the stool its iindigenous symbolism or look, and the metal contrast is also to improve the looks of the pillars.

Plate 6.11: The *MW- SIINTRA: Edge Guarding* employed for the four pillars of the stool.

6.4 Conclusion

As obvious in the works discussed above, it could be said that their description is easier with the developed jargons. Though in fewer words, they may carry deeper understanding for the edification of those who may learn and understand them. Though the jargons are quite precise in their discretion they give enough room for creativity. In view of this they are more of clues to possibilities than instructions to facilitate creative activities and easy communication in this field of study.

CHAPTER SEVEN

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter outlines the summery of this dissertation with highlights on pertinent findings, conclusions and offers recommendations.

7.2 Summary

Wood and metal integration dwells on two categories of factors: factors related to the structure of the metal affected by the chemical component, heat treatments, alloying and chemical treatment. Secondly those structural and chemical compositions of wood are affected by the type and characteristics of species, growth environment, harvesting, conversion and treatment.

Wood and metal has a long tradition owing to the fact that one is a better substitute to a component in the art form of the other; both materials could be conditioned to bare certain advantages for each other; they have application similarities; they complement each other; they are mutual solution to each other's problem; and they both have the quality of executing lasting impression (works of both are durable). Moreover, there are so many other areas related to their Processibility, Representation, Applicability, Stability, Kinaesthetics, Aesthetics, Contrast, Mechanisms and Properties that are influenced by internal and external factors that could be explored and integrated. Also, changes due to expansion and contraction do take place in metal, but it is more significant in wood due to their structural differences.

Moreover, the two materials have tremendous common technique and material related to production and processing notwithstanding their difference in techniques that becomes a scope booster to the endless creativity in woomeint. Therefore wood and metal integration were carefully investigated in this project based on the purpose of the integration; nature and behaviour of the materials (wood and metal); nature and behaviour of their complementary materials; available technology related to both areas; ergonomics of users and the prevalent environmental factors. Storage for future referencing and improvement and lastly Communication are not left out due their integral nature. This is so because "when an idea is wanting, a word could always be found to take its place".

7.3 Conclusions

The researcher is of the following conclusion based on the findings of the study as the basis for wood and metal integration and further research.

The anisotropic nature of wood species are based on internal factors (example structural formation and growth deformities) and external factors like variation in environmental and weather conditions notwithstanding other chemical sources, example acid rain. It is therefore important to study the environments of wood production and use it in order to use wood appropriately. Also, same species may differ from one variety to the other even between the male and female of the same variety as in the case of the movement results of male ache and the female in chapter four in this dissertation that recorded considerable differences between the two.

Defects in wood are inevitable and for that matter form part of the wood structure. It is a relevant feature of wood that could suggest the application and movement of metal on wood art forms. Example of this is tracing the wood grains movement with metal wires to create a sensational effect.

One can use metal and wood better when their structures are well understood. The structures of wood and metal affect their behaviour and responses to working or application. For example, a knotty wood would definitely lack relative strength to normal wood. Also a tangentially sawn wood would certainly warp towards the inside of the circle. Metal on the other would break easily across its grains than along the grain.

The behaviour of wood can never be the same everywhere since the climatic conditions vary from one place to the other. Wood responses such as swelling and shrinkage, expansion and contraction that affect the standing of metal may vary from one location to the other.

The shrinkage percentage of wood in relation to moisture loss in a green sawn wood is not a basis for the judgment of the shrinkage of same piece below fibre saturation point. This was evident in this project by the results of Asanfena a known specie of comparatively high shrinkage recording 0.513506 % of movement scope against Mansonia 0.621621 % known to be more stable. In view of this it could be postulated that some species are stable after thorough drying irrespective of their shrinkage percentage from their green state.

The flexural properties, scratch resistance and transparent curing properties of *contact glue* and *Cellulose Lacquer* on both metal and wood make them good candidates for the finishing of "woomeint" and also as a base for the composition of woomeint colourants. Others that could also be employed include polyurethane and epoxy that would only suit a stiff surface since they cannot flex appreciably.

The corrosive effect of acid that cleans metals in pickling solutions are also employable as a bleach in wood. This is due to the fact that, the black *hyedua* in acid immersion test produced the colour of *odum* which is yellowish. Acids could therefore be employed as agents for special effects in “woomeint”

Woomeint may have unlimited purposes, it is therefore impossible to discard a material or process as inappropriate. Whether appropriate or inappropriate, it may depend on the artist, the resources available and what is intended. “Out of what seems foolish in the eyes of some men proceeds wonder to the eyes of the wise”.

Factors that must be considered prior to the integration of wood and metal are those factors that influence the structure, properties and unitization of the materials, or the state of the material. These are the structure, properties and utilisation.

Above all, wood metal integration Wood metal integration thrives on four fundamental dictates that must be considered. These are:

i. The dictates of **M**aterials

ii. The dictates of the **E**nvironment

iii. The dictates of the **I**ntegration

iv. The dictates of the **U**ser

This is captured by the researcher as the **MEIU THEORY OF WOOD METAL INTEGRATION:** That states the one **M**ust **E**ver **I**nsist **U**ntil the problems within the coming together of the two materials are addressed. Therefore the Integration of wood and metal is never successful until the problems within their coming together are addressed.

7.4 Recommendations

Based on the conclusions, the researcher recommends the following:

1. Of the two materials: wood and metal, metal is more flexible and more consistent in its behaviour than wood. Therefore wood and metal integration experiments must focus more on wood such that its behaviour could be understood or predicted in its application with metal.

2. Wood must not be studied in isolation of the environmental conditions that it is meant for. This will help ascertain ground realities that will ensure the success of its application.

3. According to the theories, no two wood pieces even from the same tree are the same let alone wood pieces of different varieties of the same species. Therefore, correlation study of even wood of the same species must not be taken for granted since they may yield unexpected result even in some "woomeints".

4. Defects of wood may be a fruitful research area that could be studied and creatively employed in wood metal integration. Since their forms are hardly predicted, the originality of works that may emanate from them cannot be underestimated.

5. The structure of wood and metal must be studied and understood by woomeintists in order to be able to use them more effectively. In view of this there must be the organisation of syllabus based on set objectives for the study of the materials' structural formation and behaviour toward a well informed adventure in wood metal integrated art.

6. In order to gradually select wood species that would be good for wood and metal integration, it is recommended that further harmattan shrinkage study is conducted on other common species.

7. In the area of effective waste management, it is also recommended that further research is conducted in relation to how wood metal integration could make use of the waste that are related to the industry.

8. Research must also be directed to the areas of materials in complementary use with wood and/or metals for the improvement of their application and also experimentation into their alternative use for the development of the paradigm.

9. The specimen referencing is recommended for art institutions for the perpetuation of creative ideas and also as an aid to teaching and learning.

10. Further research should be conducted into the essence of integration in art education by artists, scientists and art historians for the developments of other areas of art through the integration of materials.

11. Research must be conducted in the other side of the coin: "woodinmet" to provide information for a more correlative study for the development of the

entire coin ("woomeint"). This is better between an artist and a scientist to bring out both the artistic and the scientific details to ensure its success.

12. "Woomeinturgical" research must cover the four dictates (MEIU) enumerated in the recommendations for sustainable development of the paradigm.

13. Professionals and stakeholders in the field of wood metal integration must form an organization towards the exchange of applicable ideas to make wood and metal integration a reality.

14. Lastly, this project is recommended to be taught in schools as an art subject.

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APPENDICES

APPENDIX 1

INTERVIEW QUESTIONNAIRE FOR THE COLLECTION OF RELEVANT INFORMATION FROM EXPERTS WHO ARE STAKEHOLDERS ON WOOD AND METAL INTEGRATION

Why are wood and metal integrated?

- Do you at certain point in your production use wood and metal together?
- What do you use them for?
- Why not neither wood nor metal alone?

What aspects of the two materials are or could be integrated?

- At what instances do you put together the two materials?
- What aspects of your production require the integration of the two materials?

How could the nature of wood affect wood and metal integration and vice versa?

- What problem do you encounter with wood?
- What problems to do encounter with the metal?
- How do you overcome these problems?

- By what logistics do you embark on this adventure?

What properties have wood that would accommodate metal?

- What type of wood do you use?
- How does the wood behave in the process of adding metals?
- How do you connect the two materials together?
- What is the final outcome of the wood after the whole process?

What factors usually affect metals on wood pieces?

- Have you ever experienced something happening to the metal after the work has been done?
- What kind of finishing treatments do you give to the work after the integration?
- Do you do any preliminary treatment to the materials before they are brought together?

What functions of wood attract the incorporation of metal?

- What specific demands necessitate the introduction of metal into wood?
- What roles do metal play in the function of your wood works?
- What metal do you patronize on the markets?

What mutual benefits do or could wood and metal derive from each other when put together?

- How do wood and metal look in integration?
- How different does wood behave in togetherness with metal and vice versa?

What benefit do users derive from wood metal integrated products?

- How do wood with metal products serve their purpose better than wooden product?

APPENDIX 2

OBSERVATION GUIDE FOR THE COLLECTION OF DATA FROM SELECTED AGENCIES RELEVANT TO WOOD AND METAL INTEGRATION

Agency………………………………………………………………………………

Products

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Materials involved

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Activities and production methods

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Technology involved

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APPENDIX 3: CHECKLIST FOR THE ADMINISTRATION OF THE SHRINKAGE EXPERIMANTAL TEST

NAME OF WOOD	SIZE AT STABLE WEATHER		SIZE AT THE PEAK OF HAMATAN		SIZE AT EARLY RAIN SEASON		SIZE AT LEAN RAIN SEASON		SIZE AT IRREGULAR RAINS		SIZE AT HEAVY RAIN SEASON		SIZE AT CONSTANT HUMIDITY		SIZE AT STABLE WEATHER AFTER THE RAINY SEASON	
DATE OF MEASUREMENT																
Dimension	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**
Akye white female *(Blighia sapida)*																
Laminated bamboo (Bambusa vulgaris)																
Mansonia (Mansonia aitssima)																
Odum *(Milicia excelsa)*																
Asanfena *(Aningeria altissima)*																
Mahogany *(Khaya ivorensis)*																
Akye red male *{Blighia sapida)*																
Denya *(Cylicodiscus gabunensis)*																
Wawabema (Sterculia rhinopetala)																
Hyedua *(Guibourtia ehie)*																
Teak *(Tectona grandis)*																
Coconut wood *(Bactris gasipaes)*																

NOTE: AL= Average Length and AB= Average Breadth

APPENDIX 4

ASSESSMENT GUIDE FOR THE EVALUATION OF WOOD AND METAL WORKS

Is the main material wood or metal? ……………………………………………..

What is the theme? ……………………………………………………………….

What about wood and metal is being integrated?

What are the characteristics of the metal components?

By what means are the two materials connected?

What role is metal playing in the integration?

How is the wood benefiting from the integration?

What other materials are found apart from the two material?

How well is the works serving its purpose?

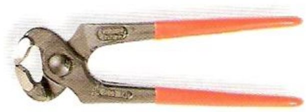
APPENDIX 5

APPARATUS AND MATRIALS FOR THE STUDY

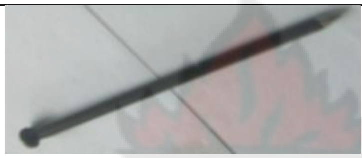
Hand tools

<u>Wood hand tools</u>

Tool	*Plate*	*Uses in the project*
Saws		These were used for various wood sectional cuts in the project.
Multi-purpose saw		This was employed for minor cutting of wood pieces.
'G' clamp		For holding pieces in place during work and also the holding of piece together to set is the case of adhesion.
Planes		These were used for the smoothening of the wood surfaces to make piece neat and precise.
Spoke shave		This was use for planning curves surface.
Chisels and gouges		These are flat cutting tools (chisels and curves edge cutting tool(gouges) employed for minor cutting and carving of the wood pieces.

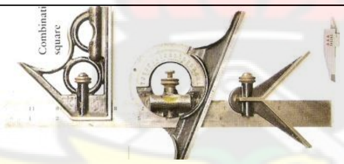
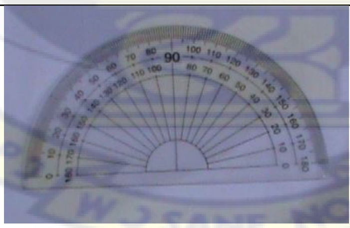
Adze		This is a traditional carving tool that was also employed the facilitate carving when it became necessary.
Pincers		This was used for cutting studs and nails that were too long into specific size and also drawing them back in the case of a mistake.

Metal hand tools or equipment

Tool	Plate	Uses in the project
Scribers		This was used in the making of inscription on metal surfaces as a guide for various operations.
Pliers		These usually come in set and single. These were user for the creation of intricate from in the metal wire and sheets.
Shears		This was very instrument in the cutting of the metal sheets.
Files	 	These also come in set and single. They are face cutting tools that were employed for precision cut that could not be accomplished by the say or shears.
Hacksaw		This is mend for more heavy duty cutting on metals. This was used in the cutting of thicker iron and steel rode.

Blow torch		This is firing equipment that was used for the heat treatment of the metals.

<u>Common hands tools</u>

Tool	*Plate*	*Uses in the project*
Metal tape measure		This was use for the taking and transferring of measurements.
Combination square		This was use the monitoring and transferring of smaller measurement and also for the marking of precise 90 and 45 degrees angles.
Electronic veneer calliper		This was very instrumental in the taking of precise measurement from the wood specimens.
Protractor		This was use the monitoring of angle in bending proceeding.
Punch		This was use for the marking the starting point of drilling operations.
Coping saw/jewellers' saw		This was employed

Hammer		This was the main driver for nails, studs and punchers in the various operations.
Rubber mallet		This was use in dent free operations that involved the planishing of metal sheet surface and also in other forming operations.
Screw drivers		These were used in the driving of screws into position.
Wooden mallet		This was the main driver of chisels and gouges.
Hand vice		This used to hold smaller pieces to be grinded, filled or sewed in place to avoid the risk of using the hand.
Hand drill		This was used in conjunction with the bit for the drill of hole for screwing nailing and dowelling.
Riveter		This was used for fixing blind rivets.

Power tools

Portable power tools

<u>Metal portable power tools</u>

Tool	*Plate*	*Uses in the project*
Engraver		For the cleaning and texturing intricacies.

<u>Wood portable power tools</u>

Tool	*Plate*	*Uses in the project*
Router		This was use in the precision recession of wood surfaces and mould and rebating of edges.
Jigsaw		This was used for the of curves sawing of curvatures.

Common portable power tools

Tool	*Plate*	*Uses in the project*
Percussion drill		This was used in free style drilling operations.
Belt sander		This was used in conjunction with an abrasive belt cloth for the execution of smooth flat surfaces.

Stationary power tools

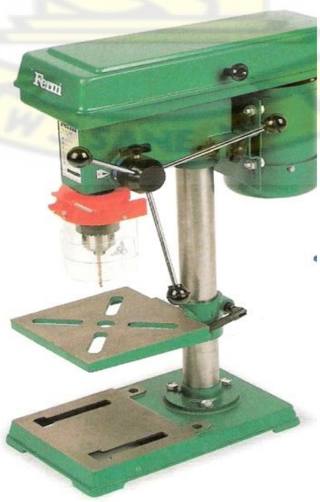
Wood stationary tools or equipment

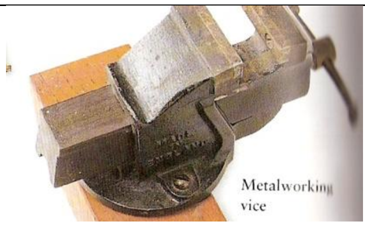
Tool	*Plate*	*Uses in the project*
The bench		This is the main working surface for the wood operations
Radial-arm saw		This was employed a more precision cross cutting of the wood specimens.

Metal stationary tools or equipment

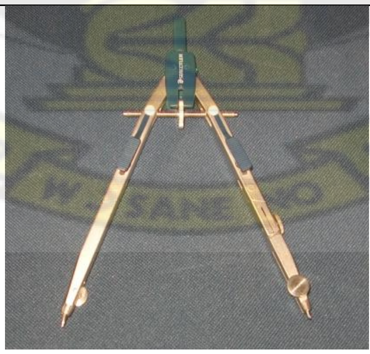
Tool	*Plate*	*Uses in the project*
The grinding machine		This was used for the trimming of metals into specific forms.
Anvils and stakes		These were the surfaces on which various hammering operations were done
The metal table		The main working surface for the metal operation.

Common stationary tools or equipment

Tool	*Plate*	*Uses in the project*
Pillar drill		This was employed for precision angle drilling operations due to is adjustable characteristics.

The bench vice		This was used in the holding of metal pieces in place for other operations such as drilling, bending and sewing.

Miscellaneous tools

Tools	*Plate*	*Uses in the project*
Camcorder		This was used in video and photographic documentation of the project proceedings. this assisted the researcher in the recollection of procedure and illustration of the project report.
Scissors		This was used in the cutting of paper templates that were transferred onto the metals and scribed in certain cases for precision cuts.
Brush		This was use in the application of adhesives.
Compass		Was used for drawing circle and transferring measurements.
Improvised miniature chisels		These were fashioned out of concrete nails to specification that are not easily found on the market for the cutting of smaller areas.

Goggles		This was worn by the researcher to protect the eyes when dangerous particle and chemicals were involved.
Ear plugs		This was use by the researcher in plugging the ears in order to protect the ear drum un the mist of excessive noise.
Round drive punch		This was use in the punching of holes in the leather use in the project.

Material

Wood Material

Material	*Uses*	*Use in the project*
PVA	This a white milky adhesive use in holding wood pieces together.	• This was used as the main adhesive the positioning id paper design on the wood and metal surfaces • For the gluing of wood pieces together • Thought it is not fast to metal, it was use as joint filler that make the joint more compact and strong. • It was one of the main materials explored as particles binder in both wood and metal
Acrylics	This is a form of paint used in coating wood surfaces as a finishing treatment.	This was also used as joint filler and a particle binder

Metal materials

Material	Uses	Use in the project
Epoxy	This is in two main parts: the resin and the hardener. These are mixed in equal proportion	This was used as a wood metal adhesive and also a binder for woo and metal particles.

	and for holding metal pieces together and also as a sealant in metal work.	
Acids	This is a corrosive liquid that at use as etching and pickling materials in metallurgy.	This was use as a metal cleaning agent and also as bleach for the modification of wood textures.

Common materials

Material	*Uses*	*Use in the project*
Cellulose lacquer	This is a natural wood finishing material obtained from the varnish tree used the coating of wood and metal surfaces as a finishing treatment.	This was uses as a metal and wood particles binder ans alo as a finishing material.
Hardener and clear	This is another varnishlike liquid that also comes in two components: hardener and clear.	This was use as finisher and also as particles binder of both materials.
Cynoacrylate	This is a fast setting adhesive sold mostly under the trade name super glue use for a more general purpose such as gluing metal, wood, ceramics, plastics and even skin and leather pieces together.	To was use as an adhesive and as well a particle binder.
Silicon sealant	This is a multipurpose sealant used for the rendering of minor spaces water proof in contraction and fixing of fixtures.	This was experimented as a joint filler and as a flexible particles binder.
Oil paint	This is diluted with thinner when necessary and brushed or sprayed as a finishing coat on a variety of materials.	This was also a employed as a joint filler and a particles binder

Miscellaneous materials

Material	*Uses*	*Use in the project*
Contact glue	This is use to hold leather pieces together. It is applied	This was successful as a wood and metal bonding medium

	and first on both joints and allowed to dry. The joint are then assembled and compressed to establish it.	and also a particle binder.
Fasteners	These are the nails and rivet used in the fixing of wood and metal pieces together respectively.	These were use in the project as wood metal fasteners.
Abrasive sheets	These come in the glass, sand and emery on papers and cloths in various grits. These are used for the smoothing of surfaces.	These were employed for the wearing of surfaces and materials and bonds to reveal their intended effects.
Metal dust	This is metal grinded into fine dust. The are normally mixed with paint and varnishes that are sprayed as finishing materials.	These were mixed with lacquers and employed as a finish on both wood and metal
Metal fillings and chippings	These are the byproducts of filling and drilling operation normally recycled by melting and casting.	This formed one the strong bases for the experiment that resulted in the creation of some effects in wood through bonding.
Saw dusts	These are the byproducts of sawing operations in woodwork.	This was also bonded this abrased to produce varied effects.
A4 bond sheets	The are white paper that ate normally printed on by the digital printer.	These were the main medium for the printing and transferring of designs from the computer on the metal and wood surfaces.
Pencils	This is a lead rod embedded in a wooded stick used for drawing and markings.	The was the main marking tool for the study because of its ability to clean easily

APPENDIX 6: DIMENSION SHRINKAGE AND SWELLING RESULTS OF THE SELECTED SPECIES

NAME OF WOOD	SIZE AT STABLE WEATHER		SIZE AT THE PEAK OF HAMATAN		SIZE AT EARLY RAIN SEASON		SIZE AT LEAN RAIN SEASON		SIZE AT IRREGULAR RAINS		SIZE AT HEAVY RAIN SEASON		SIZE AT CONSTANT HUMIDITY		SIZE AT STABLE WEATHER AFTER THE RAINY SEASON	
DATE OF MEASUREMENT	28/12/2009		13/2/2010		9/3/2010		16/4/2010		23/5/2010		31/5/2010		16/6/2010		10/12/2010	
Dimension	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**	**AL**	**AB**
Akye white female *(Blighia sapida)*	9.940	9.950	9.93	9.830	9.952	9.859	9.949	9.958	9.945	9.879	9.953	9.912	9.949	9.895	9.945	9.892
Laminated bamboo (Bambusa vulgaris)	10.240	9.770	10.24	9.720	10.25	9.748	10.268	9.742	10.260	9.770	10.265	9.798	10.262	9.791	10.258	9.771
Mansonia (Mansonia aitssima)	10.200	9.820	10.200	9.820	10.219	9.758	10.190	9.769	10.220	9.763	10.215	9.790	10.212	9.757	10.201	9.758
Odum *(Milicia excelsa)*	10.000	9.900	10.000	9.820	10.056	9.858	10.031	9.854	10.036	9.862	10.056	9.871	10.040	9.881	10.039	9.876
Asanfena *(Aningeria altissima)*	10.050	9.500	10.050	9.460	10.049	9.464	10.05	9.470	10.062	9.486	10.054	9.505	10.051	9.491	10.049	9.490
Mahogany *(Khaya ivorensis)*	10.201	9.780	10.200	9.700	10.200	9.717	10.198	9.734	10.200	9.728	10.202	9.752	10.204	9.757	10.201	9.732
Akye red male *{Blighia sapida)*	10.000	10.000	10.000	9.940	10.009	9.931	10.013	9.953	10.015	9.968	10.017	9.985	10.013	9.993	10.004	9.965
Denya *(Cylicodiscus gabunensis)*	10.440	9.630	10.430	9.570	10.437	9.590	10.435	9.592	10.441	9.588	10.444	9.614	10.437	9.611	10.442	9.629
Wawabema (Sterculia rhinopetala)	10.170	10.320	10.170	10.250	10.177	10.258	10.129	10.267	10.176	10.288	10.186	10.320	10.181	10.333	10.174	10.320
Hyedua *(Guibourtia ehie)*	10.260	9.920	10.260	9.850	10.274	9.849	10.274	9.855	10.272	9.864	10.275	9.887	10.276	9.888	10.257	9.875
Teak *(Tectona grandis)*	9.960	9.780	9.960	9.740	9.955	9.745	9.953	9.760	9.945	9.767	9.987	9.782	9.977	7.785	9.961	9.779
Coconut wood *(Bactris gasipaes)*	10.563	9.445	10.563	9.445	10.563	9.445	10.563	9.445	10.563	9.463	10.564	9.413	10.564	9.490	10.562	9.486

NOTE: AL= Average Length and AB= Average Breadth

APPENDIX 7

SECONDARY DATA COLLECTION READING GUIDE/CHECKLIST FOR OBJECTIVE ONE

WOOD INFORMATION	DONE	METAL INFORMATION	DONE
NATURE OF WOOD		NATURE OF METAL	
RELEVANT PROPERTIES OF WOOD		RELEVANT PROPERTIES OF METAL	
UNTILISATION OF WOOD		RELEVANT APPLICATION OF METAL	
ASSESSORIES IN WOOD WORK		METAL APPLICATION ON WOOD	
COMPLEMENTARY MATERIAL OF WOOD		COMPLIMETARY MATERIALS OF METAL	
BENEFITS OF WOOD ON ITS USER		RELEVANT METALWORKS WITH WOOD CONPONET	

APPENDIX 8

ANSWER GUIDE OR RECORD SHEETS FOR THE COLLECTION OF RELEVANT ANSWERS FROM THE SECONDARY DATA SOURCES:

- TITTLE OF BOOK OR LITERATURE

  ……………………………………………………………………………………

  ……………………………………………………………………………………

- AUTHOR:

  ……………………………………………………………………………………

  ……………………………………………………………………………………

- CONTENT………………………………………………………………………

  ……………………………………………………………………………………

SUB QUESTIONS FOR OBJECTIVE ONE:

a) Why is wood and metal integrated?

b) What aspects of the two materials are or could be integrated?

c) How could the nature of wood affect wood and metal integration and vice versa?

d) What properties have wood that would accommodate metal?

e) What factors usually affect metal on wood pieces?

f) What function of wood could attract the incorporation of metal?

g) Are all materials applied to wood also applicable to metal?

h) What mutual benefits do wood and metal derive from each other when put together?

i) What benefit do users derive from wood metal integrated products?

APPENDIX 9

COMMENT SHEETS FOR THE GENERATION OF IDEAS FOR THE NAMIMG OF “WOOMEINT” SPECIMENTS

NAME:……………………………………………………………………………………

……………………………..........................……………………………………….

AREA OF SPECIALISATION

…………………………………………………………………………………………

………………………………

PROPOSE A NAME FOR THE FOLLOWING SPECIMENS ON THE STAND:

SPECIMEN 1	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 2	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 3	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 4	

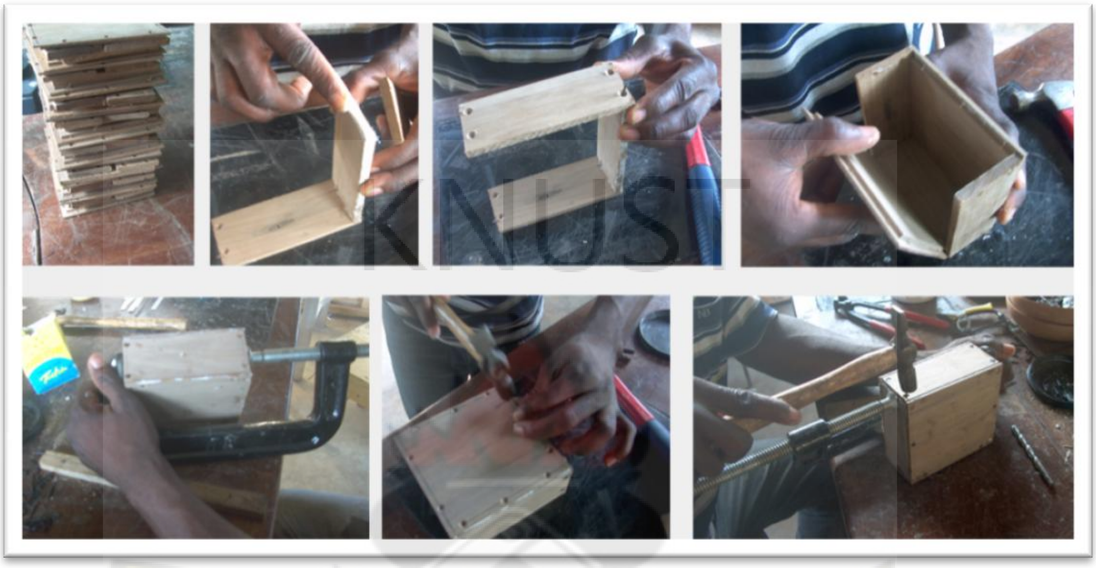
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 5	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 6	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 7	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 8	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 9	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 10	

TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 11	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 12	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 13	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 14	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 15	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 16	

TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 17	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 18	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 19	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	
SPECIMEN 20	
TECHNIQUE	
PROCESS	
REASON(S) FOR THE PROPOSE NAME	

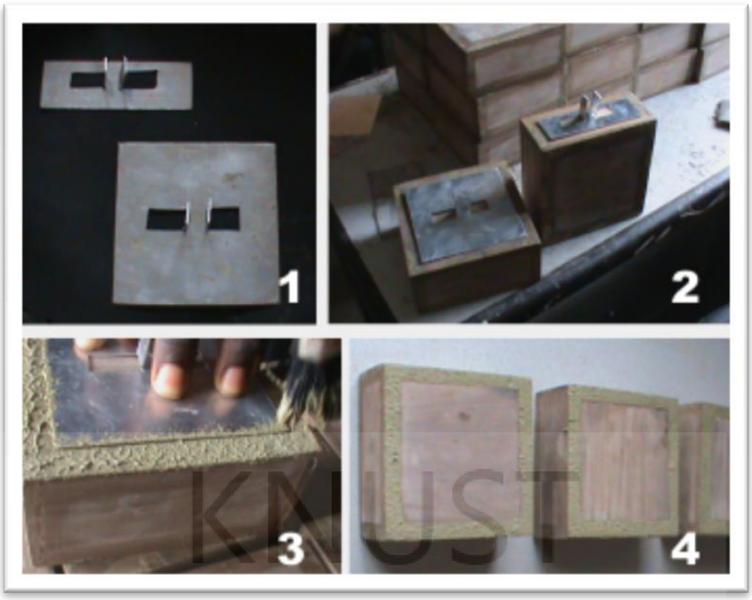
APPENDIX 10

ECEPTS OF PROCEDURE INVOLVED IN THE EXECUTION OF THE SPECIMENS BOXES.



The assembling procedure of the box

Puttying and abrasion of boxes



Dubbing of textures on the edges of the box

Staining of edges

Fixing of parts and polishing