EVALUATION OF BEES WAX AND CORE MATERIALS FOR TRADITIONAL LOST WAX CASTING

by

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DECLARATION

I hereby declare that this submission is my own work towards the MFA degree 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 made in the text.

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ABSTRACT

Cast hollow artefacts produced by Krofofrom metalsmiths are characterised by pinholes in the inner walls. This is due to the presence of cow dung in the core composition made up of charcoal and clay. Various materials were investigated and experimented upon to enhance the working properties of core and wax compositions. This is in order to improve the quality of cast hollow objects and also to use the findings of the research for educational purposes. Qualitative research design (descriptive and experimental) was used to gather data from a sample size of 25 professional craftsmen out of an accessible population of 50 metalsmiths operating at Krofofrom. Additional data was gathered from the experiments conducted. It was found that the application of saw dust and P.O.P in core production ensures easy disintegration of the core after casting and provides smooth inner walls for cast hollow objects. It was also found that there is a complete lack of knowledge on the use of P.O.P moulds for cast hollow patterns as well as the use of lacquer and kerosene as surface preservatives for cast objects. It is recommended that in producing cast hollow artefacts, metalsmiths at Krofofrom should adopt the use of saw dust and P.O.P as used in this research in order to avoid pinholes in the inner walls of cast hollow objects. The technique of using molten wax to produce hollow wax patterns in P.O.P moulds should be employed to ensure direct duplication of the original object without creating parting lines in the inner walls of the model. The application of either metal lacquer or kerosene should be adopted in the finishing of cast articles to protect the surface from tarnishing. Also periodic workshops should be organised for metalsmiths to help improve the production processes as well as the quality of the cast objects.

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TABLE OF CONTENTS

CHAPTER FOUR

ANALYSIS AND PRESENTATION OF DATA FINDINGS

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

LIST OF PLATES (photographs) **Pages**

LIST OF FIGURES

LIST OF TABLES

ABBRREVIATIONS

P.O.P – Plaster of Paris

KCS – Kissi Core Sample

KNUST – Kwame Nkrumah University of Science and Technology

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter deals with a brief background of the study, statement of the problem, objectives of the study, hypothesis, importance of the study, organisation of the text, limitation and delimitation.

1.2 Background of the study

Lost wax casting since prehistoric times, has been practised all over the world by various cultures. The basic technique is always the same although there might be slight changes either in the core materials, mould making or in how the cast pieces are finished. A recent improvement in the craft for modern industrial use is referred to as ‘investment casting’. In West Africa, lost wax casting is practised in countries such as Nigeria (Benin, Ife), Ghana (Ashanti Region) and La Cote d`Ivoire.

In Ghana, gold weights are associated with lost wax casting, just as the craft itself is associated with the Asante kingdom. Until the change of currency from gold dust to paper notes and metal coins the technique was used to produce gold weights which were used as counter-weights in weighing gold dust and regalia for the king and his sub chiefs. Many of the craftsmen, who practised the lost wax casting technique and dwelt at Adum Ensuasi a suburb of Kumasi, retired from active service after the demonetisation of gold dust.

The craft later took a different turn with regard to production when some of the metalsmiths relocated to Krofofrom, also a suburb of Kumasi

Krofofrom used to be a farming village until the introduction of lost wax casting by Nana Agyare who reportedly was a member of the Asante King's guild of metalsmiths at Adum. On retiring from active service, Nana Agyare is said to have imparted the knowledge of the technique to his son, nephew and all those who desired to learn the craft. The craft which began in Krofofrom as a family trade handed down from father to son has now become the main occupation of virtually the entire population of Krofofrom. Over the years the Krofofrom craftsmen have been producing mainly for the open market and their craft has attracted customers both local and foreign. It is for this increasing demand that several 'developments' have been made in the production processes in order to increase productivity. Initially, the core for example, was made from charcoal and clay. This core composition casts perfectly but does not disintegrate easily after casting. Later the craftsmen added fresh cow dung to the composition presumably to aid in the disintegration of the core after casting. Be that as it may, lost wax casting at Krofofrom cannot be compared to the cast objects produced in Adum in the 1700`s nor can it be compared to the present day cast objects made by the Asantehene`s metalsmith at Adum, in terms of fine finish. Despite the Krofofrom craftsmen's attempts to improve quality, hollow cast objects from Krofofrom are characterised by pin holes on the inner walls

1.3 Statement of the problem

Over the years, the traditional metal craftsmen or metalsmiths at Krofofrom, a satellite village of Kumasi in the Ashanti Region of Ghana have been using a core composition made up of cow dung, powdered charcoal and clay for cast hollow objects. This composition results in a very stable core which also disintegrates easily after casting. Unfortunately, castings made using this core composition develop defects in the form of pin holes in the inner walls of the casting, thereby ruining the finish. In many instances these pinholes are difficult if not impossible to remove or seal.

The study therefore, seeks to investigate and experiment with materials that could be used to create a new core composition to improve the existing cow dung core composition in terms of strength, disintegration and elimination of pin holes.

1.4 Objectives of the Study

The objectives of the study are:

1. To evaluate wax and refractory cores used for traditional lost wax casting.
2. To investigate and experiment with a variety of materials for the formulation of improved core and wax composition.
3. To document the findings of the research for educational purposes.

1.5 Justification of Objective

1. Investigation into waxes and refractory core materials that have been used and those being used for traditional lost wax casting will enable the researcher to find out the exact nature of these materials so that he will able to work out improvements..
2. Experimenting with bees wax and other wax additives as well as variety of core materials will enable the researcher to compose cores and wax bodies that have the needed properties for improved lost wax casting.
3. The research findings and procedures will be documented. The documentation can serve as teaching and research material in the Metal Product Design

Section as well as resource material for the training of traditional metalsmiths who specialise in lost wax casting.

1.6 Hypothesis

Pin holes on the inner walls of cast hollow objects made at Krofofrom are caused by inappropriate core composition. Improved core composition will eliminate formation of pinholes.

1.7 Delimitation

This research is centred on lost wax cast objects in brass at Krofofrom, a suburb of Kumasi in the Ashanti region.

1.8 Limitations

The following factors impacted the execution of this project negatively:

1. The difficulty in obtaining data from metalsmiths at Krofofrom.
2. Suspension of casting due to unfavourable weather conditions at certain times.
3. The absence of a suitable parting material for this project
4. Financial constraints prevented the development of objects beyond a certain size.
5. Lack of appropriate tools and equipment at the Metals Product Design studios.

1.9 Definition of Terms

Bees wax – is a fatty creamy substance produced by the honey bee during honey preparation.

Lost wax – is a technique of reproducing an item in metal by first making a wax model of the item and subsequently melting out this wax to create a mould cavity which is filled with molten metal.

Wax model – is a wax replica of what is intended to be produced in metal. It has the form, shape and surface condition of the expected metal cast.

Gate – is the entrance of the mould through which molten wax or metal is introduced into the mould cavity.

1.10 Importance of the study

1. The research is significant in that it will help improve the standard of traditional lost wax cast hollow items at Krofofrom in particular and Ghana in general.
2. It will help eradicate the negative assumptions made against lost wax cast hollow artefacts from Krofofrom.

1.11 Organisation of the text

Chapter One deals with the problem statement, objectives of the study and the importance of the study. Chapter Two reviews literature related to the study. Chapter Three discusses features of the methodology while Chapter Four gives detailed account of the analyses and presentation of the data collected for this project. Summary, conclusions and recommendations are in Chapter Five.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Overview

The previous chapter gave a brief introduction of the study and the problem statement. This chapter reviews the related literature under the following sub-headings; casting, lost wax casting, lost wax casting in Ashanti, lost wax casting in Krofofrom, evaluation of casting made in the 1700`s and that currently made at Krofofrom. Lost wax casting in India and some parts of West Africa (Benin, Ife and Baule) is also reviewed.

2.2 Casting

In general, the casting process is utilised in various fields of production such as architecture, bead making, glass production, sculpture and ceramics. This research however focuses on metal casting with emphasis on lost wax casting. Metal casting is a technique of metal manufacture that involves reproducing an item in metal by pouring molten metal into a mould and allowing the metal to solidify and then extracting it for use (www.tech-faq.com/casting, 2010). Casting is carried out in a foundry. According to the Advance Encyclopaedia (2003), a foundry may be defined as a commercial set-up for manufacturing castings.

Casting is one of the most ancient methods of metal forming. The art of foundry is ancient and extends to prehistoric times. As far back as 5000BC, metal objects in the form of knives, coins, arrows and household articles were being used. The casting process is said to have been practised in early historic times by the craftsmen of Greek and Roman civilizations. Copper and bronze were common in ancient times, but evidence also indicates that iron had been discovered and developed in the period around 2000BC. The use of iron was restricted to the making of arrow points, coins, knives and working tools. The moulds were made in stone or sand. Around 500BC religious upheavals are said to have become frequent among the Greeks and Romans. This era is said to have coincided with the emergence of cast bronze statues of gods and goddesses and the lost wax process is said to have made enormous impact in this period (Gupta, 1983).

Foundry practice of casting encompasses such basic production processes as melting of metal, manufacture of moulds, pouring of the metal into moulds, shake out and fettling of the castings. The principle is that molten metal is poured into a mould whose cavity conforms to the shape of the desired cast. The metal on solidification, crystallization and cooling acquires certain mechanical and physical service properties. The cast is removed and then subjected to other treatment if necessary. This principle works in almost all the known metal casting methods such as sand casting, permanent mould casting, centrifugal casting, plaster casting, pressure die casting, shell casting, malleable casting and lost wax casting (Victor, 1990).

2.3 Lost Wax Casting

Lost wax casting, also called Investment Casting, Precision Casting or 'Cire – Perdue' by the French, uses a pattern of an expendable material such as wax, frozen mercury, plastic, tin or polystyrene. The mould called the "investment" is prepared by surrounding the expendable pattern with refractory slurry that can set (solidify) at room temperature (Victor, 1990). According to Gupta (1983), there are two methods of investment application: these are solid investment and shell investment. In solid investment, a primary coat (pre-coating) is applied to the pattern which, complete with gating, is then placed in a metal flask and is then surrounded by refractory slurry usually composed of Plaster of Paris and conditioning additives. The shell investment also called “Ceramic shell” or “Cronning process” uses no flask. A shell investment mould is made by alternately coating the pattern with a thin ceramic slurry then adding a layer of ceramic sand, that is pre-coated then alternately dipping it in a coating slurry with granulated refractory sprinkling or by suspending it in a fluidized bed, until a shell is built up to the desired thickness. Each coating is air dried before applying the next. Grain sizes vary from 20 mesh to 100 mesh. A fine grain size is used for the pre-coating and coarse grains are used progressively for subsequent coats. The mould is placed over a heat source at a very low temperature so that the pattern or wax melts off or out (or if plastic volatilises) leaving a cavity of the pattern in the mould. The name “lost wax” came about because the wax pattern is melted out or is lost from the mould. Before pouring, the mould is further strengthened or hardened by heating to about 1600F (871 degrees Celsius) for copper alloys. This process of heating is called “firing”. Molten metal is then poured in to the mould cavity while the mould is still hot. When the casting solidifies, the mould is broken and the casting taken out. The lost wax casting method can produce a complex casting with great precision and with very smooth surface, with no parting line as found on sand casting made by the cope and drag methods. Further finishing treatment such as polishing, patina treatment or lacquering can be given to the casting if necessary.

2.4 Lost Wax Casting in Asante

According to Rattray (1923) the art of casting in brass and bronze did not reach any high state of development in Ashanti until after the foundation of the Ashanti kingdom.

The origin of brass casting at Ampabame Krofofrom coincided with the reign of Nana Prempeh I. It is however, still not known when exactly the art of lost wax casting began in Ashanti nor can it be certain that it was Ife, Benin or Egypt where the technique of lost wax casting was acquired. In spite of the lack of clear evidence as to the origin, brass casting is considered an ancient craft of the Asante (Rattray, 1923). According to Garrard (1980):

> The anthropologist Rattray considered that brass casting did not reach any high state of development in Ashanti until after 1700 when the best craftsmen from many parts of the country were settled at or near Kumasi to work for the Asantehene.

These craftsmen produced gold regalia for the Asantehene as well as other brass products such as gold weights, ritual vessels and sculptures using handmade equipment (Fox, 1988). Ross (1977) commented on the fineness of the gold weights, and other castings saying:

> They weigh between one half and one kilogram, but based on a comparison with other Akan gold work, their actual gold content is probably low (between six and ten carats). These hollow castings are relatively thin walled (0.3-1.5 centimetres) yet casting flaws are rare.

During the 1870`s, political upheavals in Asante began to affect the casting art. Sir Garnett Wolseley on behalf of the British colonial administration sacked Kumasi in 1884. This action initiated the decline of art and craft in Asante and in effect stopped trading in gold weights. The use of gold dust was banned as currency by the British in 1889. By 1900, the use of foreign English currency had replaced gold dust. Gold weights production ceased and this nearly destroyed the casting craft (Garrard, 1986). This action drove many of the craftsmen from active business leaving only a few to produce regalia for the Asantehene. Descendants of some of the remnants are still producing regalia for the Asantehene and are resident at Ensuasi in Adum, Kumasi.

2.5 Lost Wax casting at Krofofrom

As a result of the political upheaval during the 1870's, and the demonetisation of gold dust, most of the metalsmiths retired from active service, since most of the objects they produced, aside regalia and ornamental objects, were gold weights. The craftsman in traditional Asante was respected for his creative ability and his command over fire and metal and not necessarily for the money that accrued to him as a result of his profession as a metalsmith. Brass casting is the main livelihood of the people of Krofofrom. The history of this art cannot be narrated without mentioning the name of Nana Agyare. Nana Agyare was a prominent metalsmith and a member of Asantehene`s guild who lived at Ensuasi, Adum in Kumasi. When Nana Agyare retired from active service as a metalsmith specialising in brass casting, it was at Ampabame that he imparted all the skills acquired in the craft to his son, nephew and all those who desired to learn the art of brass casting.

The main occupation of the people of Krofofrom before the introduction of the casting craft was farming. Brass casting became their main occupation when demand for cast objects could not be met by the metalsmiths at Ensuasi Kumasi. They were encouraged by the surge in demand and set themselves up to satisfy this demand generated by the interest of foreigners in the gold weights since the metalsmiths of Eusuasi were mostly not working for commercial reward but for the Asantehene and his sub-chiefs. So booming was the work of Krofofrom metalsmiths that they began to attract the attention of the Ghana Tourist Board. They have ever since been producing for the tourist market and the artefacts tend not to be unique because they are produced according to the dictates of customers and not from the craftsmen`s creative imagination. Mass production has become the order of the day and their production is based on demand and supply (Waters, 1993). Currently, the craftsman of Krofofrom is respected for the money realised from his products and not for his creative ability. In order to meet demand, a new core composition comprising cow dung, charcoal powder and clay was introduced to improve the existing clay and charcoal powder composition in terms of easy disintegration. According to the Krofofrom metalsmiths, the old core composition (charcoal and clay) took a long time to disintegrate after casting. To them, in this era of "commercial" brass casting, time played a more important role than creativity and perfection.

2.6 Evaluation of castings made in the 1700`s and that of Krofofrom.

Castings produced at Krofofrom cannot be compared to those produced by the Asantehene`s guild of metalsmiths at Ensuasi during the 1700s. This is evident in the trial casting organised by Rattray in 1927 about which he commented:

> The metal workers who were collected around me to make the series of castings were sadly out of practice. Faulty castings were numerous and failures were costly; the results too were not comparable with the castings of the former times.

This opinion was also confirmed by Ehrlich (1989), who said:

> The precise workmanship and almost total lack of European inspired motifs in these early pieces are in line with late fine work from the Baule, these characteristics of high creativity and perfection are in sharp contrast to some very late nineteenth and early twentieth century Asante gold works.

The castings that were made in the 1700`s were characterised by high creativity and perfection. The craftsmen's means of production in the 1700`s was not in anyway near the mass production processes used by the current crop of metalsmiths. The current mode of production at Krofofrom is mass production which ensures that large numbers of similar objects are produced for the market. The very idea of producing these items for a larger market implies that production is driven by demand from their marketing agents. With regard to mass production, very similar articles are produced with very little to differentiate between them. The shift from a creative art to a customer-dictated mass production system has had profound effect on the items themselves. Proper finishing is not a priority of the Krofofrom metalsmiths; all that is important to them is getting the job done on time. The change in the core composition has also adversely affected the quality of work as well as the improper handling of wax thread for cast hollow objects. The mishandling of wax thread is confirmed by Ehrlich (1989) who opined that much of the wax thread work was blurred or was frequently smoothened away in nineteenth and twentieth century Ashanti brass work, indicating a recent lack of care in the handling of the wax components. The presence of pinholes has now become a primary characteristic of cast objects from Krofofrom.

Devising new ways to produce objects quickly is good but making a conscious effort to attain a standard matching that of the 1700's is obviously desirable. There is still the desire, among some craftsmen, to attain such a level of perfection in the Asante kingdom as exemplified by Ensuasi metalsmiths. That this desire is not out of reach is confirmed by Silverman (1990) who remarked that:

> Examples of contemporary West African metal work that are every bit as fine as those produced one or two hundred years ago exist.

Hopefully, the findings of this research can help improve the quality of casting under such a mass production system at Krofofrom.

2.7 LOST WAX CASTING IN SOME PARTS OF WEST AFRICA AND INDIA

2.7.1 Benin, Ife and Yoruba

It is of no doubt that lost wax casting dates as far back as prehistoric man. It is however not known exactly how lost wax casting was introduced or developed in Africa, as it was practised by West African brass sculptors centuries before the arrival of the first Portuguese explorers in the late 15th century, 1484. Some West African countries where lost wax casting is practised are Ghana, Nigeria and Cote d`Ivoire. The Yoruba speaking people currently occupy the south western corner of Nigeria along the Dahomey border. Some Yoruba settlements even extend into Dahomey. The Yoruba tribe populates cities and kingdoms such as Ife, Benin and Oyo. Ife was the first of all Yoruba cities and the traditions of the Yoruba people began here. The people at Benin also called Bini are descendants from Ife. Benin and Oyo are said to have been founded by Ife rulers or their descendants. The Yoruba Kingdom is remarkable for its brass and bronze lost wax casting. If sculpture is the physical manifestation of three dimensional form conceived in a sculptor`s mind, then the African continent has produced many of the greatest sculptors of all time, even though no single name has ever been passed down. According to Alice (2000), Benin derived its knowledge of brass casting directly from Ife and throughout the entire Yoruba speaking kingdom. The style of Benin and methods of casting are the same as those of Ife. Yoruba people are also known not only for solid and three dimensional hollow (full figure) forms but also for pictorial plaques which are also cast in either copper or brass. In casting hollow objects, the core is produced in clay with all the details and then wax is used to coat the core. Further working is done on the wax to bring out all the details. Fine clay and charcoal composition was used to coat the wax as the first coat to capture the details in the mould. Further coating of coarse composite of clay was applied. Sprueing was done and a crucible with brass, copper or bronze scraps was fixed on the gate of the mould. The mould and the crucible were then covered with coarse clay slurry and then left to dry. The entire mould was placed in a heath and fired until the metal melted; by then the wax would have already burnt out. The mould was then turned upside down so that the molten metal flowed to fill the mould cavity. The cast was then taken out and core removed.

2.7.2 Baule

The Baule tribe of Ivory Coast are well known for their lost wax casting techniques. They are famous for their bronze and brass bead castings. It is believed that the craft was introduced to Ivory Coast by some Akan goldsmiths from Ghana. According to Alice (2009):

> The art of making this jewellery was introduced to Cote d'Ivoire by the Akan goldsmiths from Ghana centuries ago.

These Akan goldsmiths worked for Nana Kofi Adinkra of Gyaman in Ivory Coast who was the chief of the Akan society in Cote d`Ivoire. All the working processes and procedures as well as motifs such as the crescent form, human heads, leopard and other symbols currently used in Baule cast objects are all said to be of Akan influence. The Baule make use of a core in their cast hollow objects. The composition of the core material is finely ground powdered charcoal and clay. Alice (2000) again mentioned that:

> Many of the brasses are actually a thin sculpture of hollow metal. In this case, the wax sculpture is formed over a clay core.

As is the case of the Krofofrom process, wax was formed over the core and the modelling tool was used over it to bring out desired details and effects. Fine clay slurry was then used to coat the work as the first coat to capture the detail in the wax, and the coarse clay layers were applied subsequently to provide strength. The two parts, that is, the core and the moulding materials over the wax were held together by means of spikes whose melting point was higher than the temperature for de-waxing as well as the melting point of the molten metal to be used. Solid castings did not make use of spikes. After the required thickness or layers of mould was acquired, the entire work was allowed to dry and then placed over a heat source to melt out the wax. After de-waxing of the mould, the temperature of the furnace was raised to release any wax residue. Subsequently molten metal was poured into the mould cavity.

2.7.3 India

The ancient art of lost wax casting is said to have begun in India around 2500BC in the Mohenjor Daro area. The Dhokra Damar tribe are the traditional metalsmiths of West Bengal and their technique of lost wax casting is named after their tribe, hence Dhokra metal casting. History reveals that years ago the Dhokra of central and eastern India travelled south as far as Kerala and north as far as Rajasthan, dominating the whole of India with their technique of lost wax casting. Dhokra casting is one of the oldest techniques of lost wax casting which has been used for over 4000 years and is still in use today. One of India's lost wax cast artefact is the Dancing Girl of the Mohenjor Daro, which dates to 2500BC.

As published by the University of Missouri's Museum of Anthropology (2011), there are two main processes of lost wax casting. The first: solid casting, which is predominant in the south of India, and the second: hollow casting, which is common in central and eastern India. Casting hollow objects is the most traditional method. In the Dhokra process cores were made of clay to the actual size of the work to be cast, taking into consideration shrinkage. The clay core was then covered with a layer composed of pure bees wax, resin from the *Damara orientalis* tree and nut oil. Clay slurry was applied to the wax to cover it. According to Norman (2007), finely ground clay with charred paddy husk mixed with cow dung was used by the metalsmiths in

South India for the first coat. Further clay slurries were applied subsequently in different grain sizes from fine to coarse. De-waxing was done over heat. Norman (2007), reports that the south Indians heated the completed mould in an open ground oven using cow dung cakes as fuel for the de-waxing. Molten metal was poured into the cavity thus created, and the metal on cooling was removed followed by other treatments such as cutting of the sprues and polishing.

In conclusion, the literature reveals that West African lost wax casting did not initially use cow dung as mould material in the past as was the case in parts of India. Even in the case of India, cow dung usage was more popular with the traditional birthplace of Indian casting that it is in eastern and central India. The use of cow dung in the first coat is said to be losing ground with the introduction of "ceramic shell" moulding method. A publication of the Precision Casting Company (2006), states that the fine mixtures of cow dung and clay was being substituted with silicaceous slurry to cover the work by dipping or pouring. Even though no apparent reasons were stated, it can be deduced that the core composition that included cow dung did not produce a desired outcome, hence a change to the silicaceous slurry.

Cow dung used in the production of cores for lost wax casting was not completely pulverized and as a result the amount of heat used in de-waxing and pre-heating was not able to combust cow dung completely. Total combustion of the cow dung rather occurred when molten metal which has a high temperature came into contact with it in the mould cavity. The high temperature of the molten metal, as it came into contact with the core, forced moisture in the cow dung to escape as super-heated water vapour. This water vapour was trapped on the surface of the inner wall of the casting thereby creating pinholes. This phenomenon is confirmed by a research undertaken by Kumar and Shende (2006) towards the development of a cow dung fuelled cooking stove. Their research revealed that cow dung comprised carbon, hydrogen, oxygen and small amounts of nitrogen, so that, if one took, say 20gm by weight of cow dung, the breakdown by percentage of the various components would be: carbon (31.6%), hydrogen (05.18%), oxygen (37.8%), nitrogen (06.12%) and ash (19.3%). On burning completely pulverised dry cow dung, the resultant by products was carbon dioxide, water vapour and ash. On burning say, 20gm cow dung, the total weight of carbon dioxide released would be 8gm and while the total weight of water vapour formed was 9gm. Air was preheated in the cooking stove to about 180˚C - 200˚C before it combined and fluidized simultaneously with the cow dung. From their research it was shown that efficient combustion took place by blowing in more air and by maximising the surface area of the cow dung by pulverising it. A study of the findings confirmed that during de-waxing and pre-heating of mould, the amount of heat that a mould was subjected to was only able to get out the wax and the excess wax film on the core; because the cow dung was not in powder form, total combustion was not possible. When the core was subjected to the high temperature of the molten metal, say brass, the cow dung in the core to burned further producing the by-products of carbon dioxide, water vapour and ash. The water vapour was trapped on the surface of the core, thereby forming pinholes in the cast work.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

The previous chapter dealt with some of the research approaches that have been taken by others and a comparison of lost wax techniques in Ashanti in the 1700`s with those currently in use at Krofofrom. This chapter seeks to outline the various processes of documenting data and acquiring the needed information for the research. In this chapter, descriptive research and experimental research are the two main research methods. Research tools used are observation and interview. The chapter gives account of the Krofofrom traditional metalsmiths working procedures which includes core production and outlines the researcher's experiments made into core materials and various compositions of beeswax.

3.2 Qualitative Research Design

According to Key (1997), qualitative research is a generic term for investigative methodologies which can be broken down further into the following sub-headings: naturalistic, field or observer research, ethnographic and anthropological research with emphasis on interaction between variables and detailed data gathering through open ended questions that provide direct answers.

This research is qualitative and uses both descriptive and experimental research methods.

3.3 Research Methodology

The two methodologies used in collecting data for this research project are:

Descriptive Research

Experimental Research

3.4 Justification of Research Methodology

According to Babbie (1989), descriptive research is the accurate and systematic description of data and characteristics about the population or phenomenon being studied.

The nature of the research topic demands that several casting centres be visited to allow the researcher examine, analyse and describe objects or articles that are produced using the lost wax casting method and other procedures, and document all the processes used.

Experimental Research is a systematic and scientific approach in which one or more variables are manipulated, controlled and tested to determine any change or effect on a dependant variable (Experiment_Resource.com, 2008).

Experimenting with various wax compositions and core composition materials will be carried out to find out the suitability or otherwise of such materials for the specified purpose and function.

3.5 Population for the study

The population for the study are the metalsmiths at Krofofrom a suburb of Kumasi in the Ashanti region of Ghana. Accessible population for this research investigation were 50 local metalsmiths residing at Krofofrom.

3.6 Sampling

Sampling is the process of selecting entities from which data is drawn from. Entities that makeup sample size include variety of people, objects, textual materials, audiovisual and electronic records from which data is drawn (Leedy, 2005). The researcher used purposive sampling that was based on the population for the study and the accessible population, the sample size for the research was 25 people who were all professional metalsmiths.

3.7 Research Tools

Research tools used for gathering data for the project are:

- Interview.
- Observation.

3.8 Justification of Research Tool

Interview: Semi-structured interviews were employed as a means of gathering data for this research. Face to face interaction was held with foundry men and resource persons so that the needed facts could be obtained and documented.

Observation: Working processes of lost wax casting were observed, such as: how bees wax was prepared for pattern making, preparation of mould and mould materials, preparation of core, gating, risering, firing and other casting processes. These processes were recorded and utilised appropriately.

3.9 Facilities available for the Research

1 KNUST Library

2 College of Art Library

3 School of Engineering Library

4 The World Wide Web (Internet)

5 Casting studios

6 Jewellery workshops

7 Resource persons

8 The Metal Products Design Section studios

3.10 PROJECT DEVELOPMENT PROCESS

This part of Chapter Three gives the systematic account of all the investigations and experiments conducted on core materials, beeswaxes and all processes of lost wax casting used by the researcher and metalsmiths in Krofofrom under the various sub-headings: idea development, preparation of materials, wax pattern and core production, casting and finishing.

3.10.1 IDEA DEVELOPMENT

TOOLS AND MATERIALS USED IN IDEA DEVELOPMENT

Below is a list of tools and materials used in developing and generating ideas.

- Pen, pencil and eraser
- Natural and artificial objects (for reference and inspiration)
- Magazines and journals (for references and inspiration)
- Computer.
- Printer.

In Krofofrom, metalsmiths developed ideas or took inspiration from natural and artificial objects, from myths, proverbs and daily activities. There were no preliminary sketches made. Whatever idea the metalsmith had was first tried out in wax as sample work. Designs brought in by customers to Krofofrom craftsmen for production were first modelled in wax for the customer's approval before execution.

The researcher on the other hand developed his ideas from artificial and natural objects such as snail shell, tree barks, maize, Adinkra symbols (Sankofa bird) and geometric forms. These were used to create preliminary sketches and further developments were carried out as shown in Figures 3.1 to 3.3. From the numerous sketches, the researcher selected one and developed it further by twisting, stretching or enlarging until a desired effect was achieved. It was then rendered using a computer aided design (CAD) programme, in this case Rhino and 3D Max, to bring out details in the selected design, as shown in Figures 3.4 to 3.6.

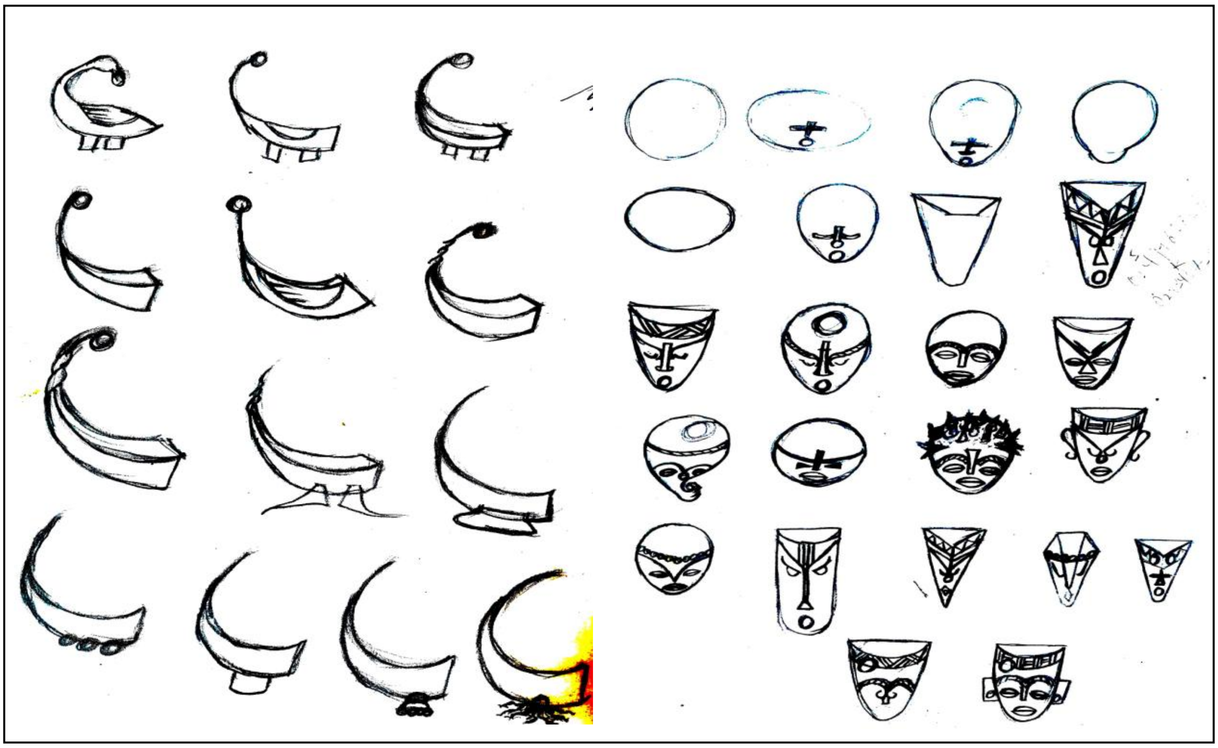

FIGURE 3.1: Idea developments from Sankofa and Akuaba

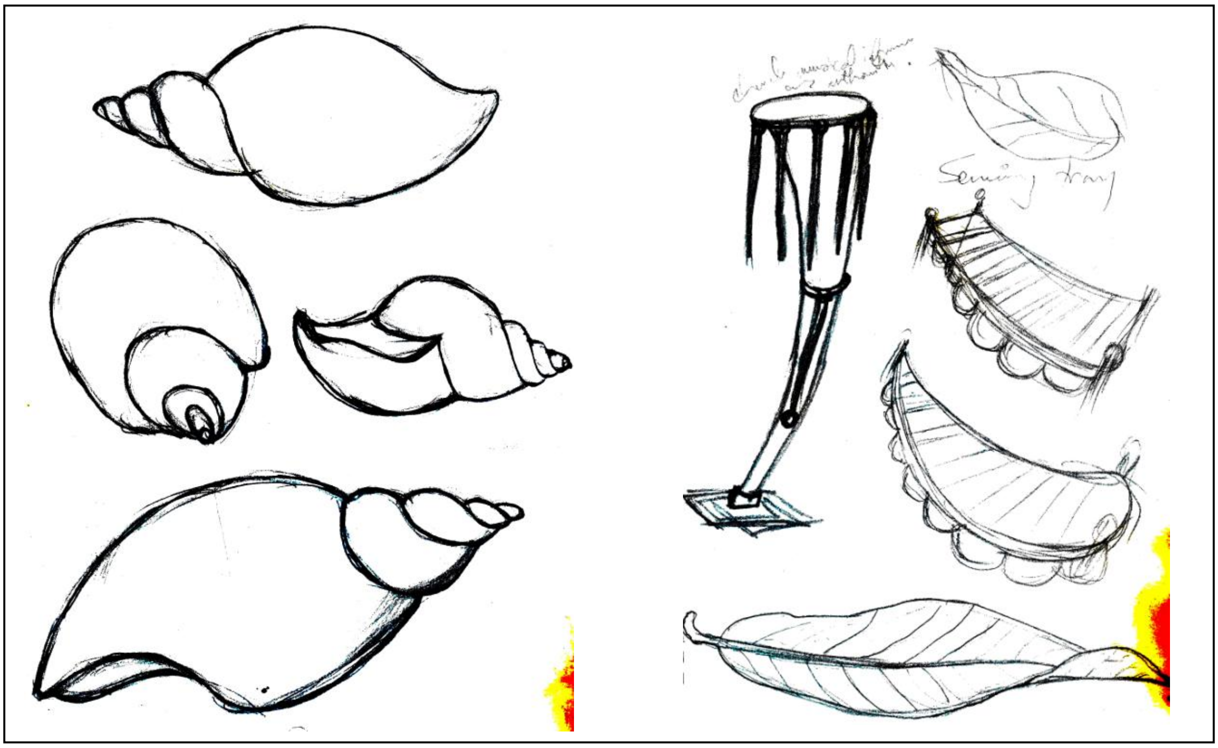

FIGURE 3.2: Idea developments from Natural Objects

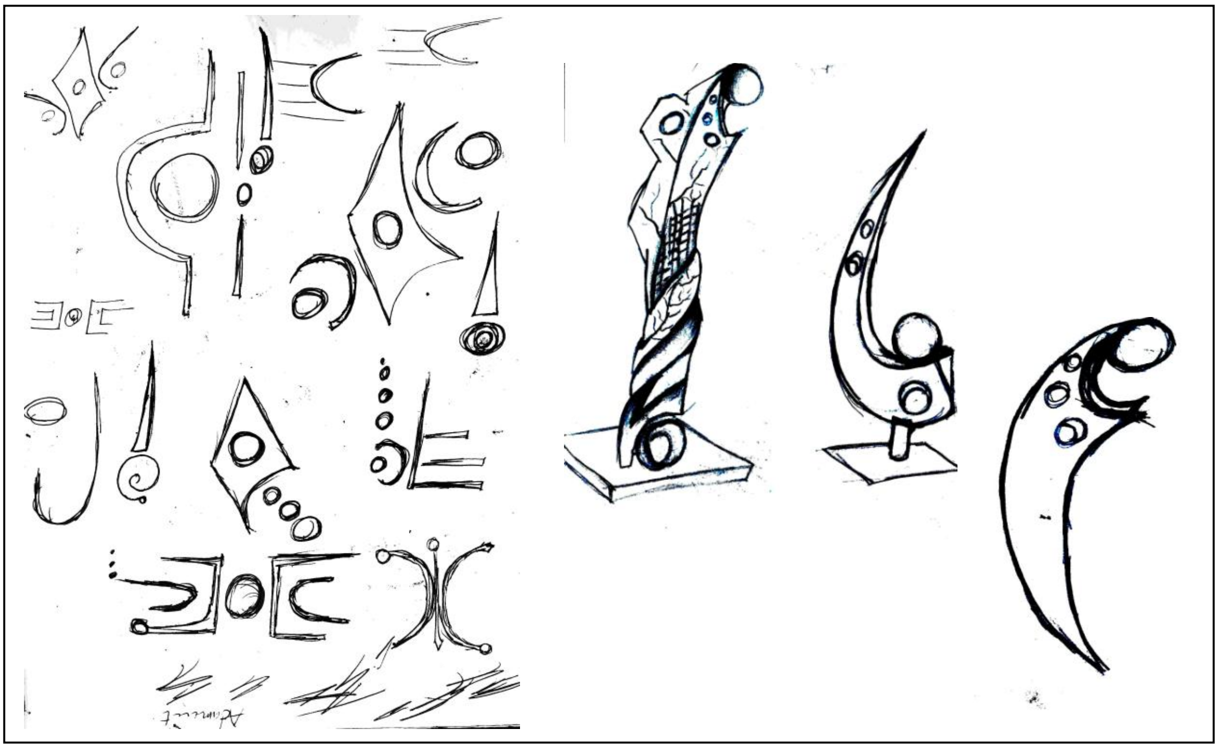

FIGURE 3.3: Idea developments from Geometric forms

FIGURE 3.4: *Front view (CAD) design*

FIGURE 3.5: *Side view of (CAD) design*

FIGURE 3.6: *Top view of (CAD) design*

3.10.2 PREPARATION OF MATERIALS

TOOLS AND MATERIALS USED FOR TESTS AND EXPERIMENTS

Below is a list of materials and some of the tools used by Krofofrom craftsmen and the researcher in preparing materials for this research:

- Weighing scale (digital)
- Metal mortar and pestle.
- Sieve.
- Plastic containers.
- Heat source.
- Wheel barrow and shovel.
- Aluminium container.
- Knife.

- Spoon.
- Beeswax, paraffin and candle wax)
- Clay.
- Charcoal.
- Sawdust.
- Plaster of Paris (P.O.P).
- Cow dung.
- Kerosene.

CORE MATERIAL PREPARATION BY KROFOFROM CRAFTSMEN AND THE RESEARCHER

These are the processes for the preparation of core materials and beeswax as practised by Krofofrom craftsmen and the researcher. Clay, charcoal and fresh cow dung are the three materials prepared and used by the Krofofrom metalsmiths for the production of cores. Clay and charcoal are used as moulding materials. Beeswax is used for producing wax patterns. The wax is drawn out either in wire or sheet form. Details of how each is processed are described later in this chapter.

Charcoal was pounded in a metal mortar with wooden pestle into powder (Plate 3.1). It was sieved with 120 mesh sieve when fine grains were required and 60-80 mesh sieves when coarse grains were required (Plate 3.2).

Clay was either prepared in powder form in the same way that charcoal was prepared or lumps of clay were soaked in water to produce clay slip. The clay slip was later sieved with 80 mesh sieve to remove stones and other debris that might be present

(Plate 3.3). Cow dung was collected using shovel and wheel barrow (Plate 3.4). Stones and sticks were then taken out of the cow dung.

PLATE 3.1: *Pounding of charcoal*

PLATE 3.2: *Sieving of charcoal*

PLATE 3.3: *Soaking clay for slip*

PLATE 3.4: *Collecting cow dung*

Beeswax usually contained sand particles due to improper handling by beeswax collectors. There are two ways of getting impurities out of beeswax; first, by keeping the lump of wax in the sun for about 15-30 minutes. A sharp knife was then used to skim the dirty surface away. The second method was to melt the wax over a heat source until it was completely melted. It was then poured through an 80 mesh sieve into a bowl full of water. The wax on cooling and hardening was kneaded for use.

The researcher made use of clay, charcoal, plaster of Paris and sawdust for the production of cores. Clay and charcoal were prepared and used as mould materials as done by the Krofofrom metalsmiths, but for this research, clay was used in the powder form as fine as 120 mesh. Sawdust with very small particle sizes (as fine as 80 mesh) were collected from the saw mill. Plaster of Paris did not go through any preparation process since its grain particle was already fine. Beeswax was used for making wax pattern. Various experiments were conducted to produce a variety of waxes from a combination of beeswax, paraffin, candle wax and kerosene. Details of these experiments are as follows:

3.10.2.1 WAX TYPES

Wax is expected to have low ash content, good hardness, tensile and impact strength in solid state, weldability, resistance to oxidation, adhesiveness, solubility in a specific solvent, resistance to chemical reaction when binders are used in the investment process, low shrinkage during solidification and enough strength to withstand fracture during carving. It is for these requirements that special wax (composition) had to be formulated for pattern making.

BEEWAX

Worker bees have eight wax-producing glands located on the inner sides of the sternites of the abdomen. The size of these wax glands depends on the age of the worker bee. They are at their largest when the bee is about 12 days old and declines steadily from the 18th day to 19th day until the end of its life. The bee masticates the wax scales produced by the glands with its mandibles and jaws and at the same time adds salivary secretions to help soften the wax. Once the wax is well kneaded, it is deposited on the comb under construction or used to seal honey cells (Bernard Leclarcq, 2008). Plate 3.5 shows a block of beeswax

PLATE 3.5: *Beeswax*

PARAFFIN WAX

In chemistry, paraffin is a term used synonymously with 'Alkane'. Paraffin (Plate 3.6) is a by-product from petroleum refining by de-waxing light lubricating oil stocks. It is a white, odourless, tasteless, waxy solid with a typical melting point between about 47 to 65 degrees Celsius, having a density of around 0.9g/cm3. It is insoluble in ether and certain esters. It is unaffected by most common chemical agents and burns readily.

PLATE 3.6: *Paraffin wax (source: wikipedia)*

CANDLE WAX

Candle wax (Plate 3.7) is made from beeswax and paraffin wax in different proportions. Candle wax melts around 46 to 68 degrees Celsius depending on the mixture of the candle. Paraffin plus beeswax candles tend to break when dropped from a height and are said not to be flexible.

PLATE 3.7: *Candle (source: wikipedia)*

KEROSENE

Kerosene, usually called paraffin oil, is a thin colourless liquid formed from hydrocarbons, with a density of around 0.78-0.81g/cm3. Kerosene is obtained from the fractional distillation of petroleum at temperatures between 150 to 275 degrees Celsius, resulting in a mixture of carbon atoms that typically contain between 6 to 16 carbon atoms per molecule. The flash point of kerosene is between 37 to 65 degrees Celsius (100 to 190 degrees F) and it is immiscible in water (cold or hot) but miscible in petroleum.

The various wax mixture samples were mixed together in their liquid state (molten state). Melting was done in an aluminium container and aluminium spoon was used to collect the molten waxes for weighing and mixed in a plastic container. Aluminium container and spoon were used because wax does not wet and stick to aluminium surface. Digital scale was used to weigh the molten waxes in grams. The wax mixture samples were labelled as group C (C1, C2, C3, and C4), comprising beeswax and candle. Group P (P1, P2, P3, and P4), comprised mixtures of beeswax and paraffin wax, while group K consisted of beeswax and kerosene. The last group CP1consisted of mixtures of beeswax, candle and paraffin wax.

A composition that contains paraffin wax takes much longer time to solidify when compared to either candle compositions or just beeswax. Candle wax solidifies faster than beeswax and therefore it is advisable to mix candle wax into beeswax and not beeswax into candle wax. Candle wax when molten is colourless and does not give out any smoke until it is introduced to excess heat which in most cases produces smoke. Paraffin when introduced to excess heat makes cracking noise and produces smoke. Beeswax when introduced to excess heat makes a cracking noise and sometimes catches fire. Molten beeswax produces a sweet smell and turns chocolate or brown colour when introduced to excess heat: discolouration occurs when beeswax is introduced to heat above 80-85 degrees Celsius.

The table below shows the reactions and physical characteristics of the various wax compositions.

TABLE 3.1: *Wax compositions and physical characteristics*

	Composition	**Solidification**	**Weldability**	**Hardness**	**Elasticity**	**Bending**
C1	6grams of beeswax to 1gram of candle wax.	Long time to solidify (10-18 min)	Good weld ability	Hard	Excellent	Excellent
C2	2grams beeswax to 1gram candle wax.	Solidifies easily (7-10 min)	Good weld ability	Hard	Excellent	Excellent
C3	2grams candle wax to 1gram beeswax.	Solidifies easily (7-10 min)	Good weld ability	Hard	Good	Poor
C4	3grams of candle wax to 3grams beeswax	Solidifies easily (7-10 min)	Good weld ability	Hard	Good	Good
P1	6grams beeswax to 1 gram paraffin wax.	Longer time to solidify (15-20 min)	Good weld ability	Hard	Very good	Excellent
P2	2grams beeswax to 1gram paraffin wax	Much longer time to solidify (20-25 min)	Poor weld ability	Very hard	Poor	Poor
P3	2grams paraffin to 1gram beeswax	Much longer time to solidify (20-25 min)	Poor weld ability	Very hard	Poor	Poor
CP1	2grams beeswax to 1gram paraffin wax to 1gram candle wax	Longer time to solidify (15-20 min)	Good weld ability	Hard	Very good	Poor
K1	3grams beeswax to	Longer time to solidify	Good weld ability	Soft	Breaks when	Breaks when

	1gram kerosene	(15-20 min)	property		stretched	bent

3.10.2.2 WAX PATTERN AND CORE PRODUCTION

Most moulds are made using a pattern that has a positive draft; such patterns can be withdrawn from the mould and the pattern reused. Investment moulding, however, uses patterns made from wax, rubber or frozen mercury. These patterns are removed from the mould by melting. The pattern does not need to have positive draft; any shape of casting can be made by investment or lost wax casting mould, including those with zero or negative draft.

Lawrence (1981) gives several ways of producing wax patterns. According to him, pattern making is the essential aspect of wax casting and the outcome of a pattern has much influence on the outcome of the cast object.

There are several methods of making patterns in wax. They can be produced from direct source: as print from either natural or man-made designs, by carving the design from a block of wax, by wax build up and by forming or wax build up around a core. There are two main types of wax patterns: hollow and solid.

The following are the procedures used by Krofofrom metalsmiths and the researcher in making such wax patterns:

First, a natural or an existing pattern was coated with soap solutions and then placed on a flat wooden or an aluminium surface. The design was then covered with cement mortar (mixture of cement and water).It was left overnight. The soap solution was used to coat the pattern to prevent the mortar from sticking to the surface. The design was removed from the cement leaving a negative imprint of the design in the cement mortar. Alternatively, P.O.P could be used in the same way. Thousands of designs could be produced in wax from the imprint in the cement mould. After the design was obtained in the cement mould, wax was softened using a heat source, the cavity in the mould was coated with soap solution and then the wax pressed into the design (Plate 3.8). A sharp knife was used for smoothening the back of the wax pattern. It was then removed from the cement mould (Plate 3.9). This method is used by majority of Krofofrom metalsmiths.

PLATE 3.8: *Wax pressed into mould*

PLATE 3.9: *Pattern after pressing*

In cases where the design to be reproduced was in the round, cement mortar was prepared in an enclosed space such as in a box whose four sides could be easily dismantled. The pattern, coated with the appropriate parting solution was set in cement mortar or P.O.P slurry half way of the model. The surface of the concrete after setting was covered with soap solution or oil; another mixture of concrete was used to cover the other half of the design. The solution used to coat the surface of the concrete prevented the two parts of the mould from sticking together. Gating was made in the mould (cement or P.O.P) if molten wax was to be used. In cases where sheet wax was used, gating was not always necessary. Plates 3.10 and 3.11 respectively, show a wax model and its P.O.P mould.

PLATE 3.10: *Wax model*

PLATE 3.11: *P.O.P mould*

In producing a wax pattern from molten wax using cement or P.O.P mould, the wax was heated to its melting point. It is advisable to melt wax in an aluminium saucepan. Wax does not wet and does not stubbornly stick to aluminium surface. The wax should not be heated beyond its melting temperature. Burning alters the consistency and introduces bubbles. The best way to prevent these catastrophes is to watch the melting constantly (Plate 3.12). One option is to cut the wax into smaller bits before melting, to ensure a homogenous melting of all the wax. According to Lawrence (1981), another way to be doubly sure of the melt is to check the temperature with a candy thermometer. The temperature should not exceed the flow point of the wax. The wax must be extremely fluid to run into all the crevices of the mould. Before pouring the molten wax into the P.O.P mould, the mould was first coated (Plate 3.13) with a parting solution comprising 70 grams of soap (say, key soap) dissolved in 30 grams of hot cooking oil; this solution, upon cooling turned into a cheese-like mass. After assembling the mould (Plate 3.14), molten wax was poured into it. If a hollow wax pattern was required, the molten wax was left to set for about 5-7 minutes. Setting of the wax could be checked by inspecting the gate of the mould for solidification (Plate 3.15). The mould was then turned upside down to drain out the excess wax in the centre of the pattern (Plate 3.16). If a solid wax pattern was desired, the wax was left for about 30-45 minutes. Wax close to the inner walls of the mould begins to solidify first. So when the mould was turned or flipped over after 5-7 minutes, only the unsolidified wax in the central portion came out through the gate, leaving the solidified wax against the wall of the mould. The wax and mould were left for another 15-20 minutes after which the mould was opened to remove the wax pattern carefully with a small metal rod (Plate 3.17). The wax pattern was later dressed and finished. Casting of the wax pattern should be done in the morning or at room temperature to avoid delay in wax solidification.

PLATE 3.12: *Melting of wax*

PLATE 3.13: *Coating of mould*

PLATE 3.14: *Assembling mould*

PLATE 3.15: *Wax ready for pouring*

PLATE 3.16: *Pouring wax from mould*

PLATE 3.17: *Model after casting*

Another method of a making wax pattern is by carving the design from a block of wax. This method of wax pattern-making was used only for solid patterns. The wax used for this form of pattern making should be strong enough to withstand cracking. Wax sample that contained paraffin or candle wax was ideal for this method of pattern-making and carved well at room temperature. The design to be carved was transferred to a block of wax. This could be done by drawing directly on the wax with a pointed tool or the design could be traced onto the wax by using a flat tool or coin to press the paper with the design onto the wax. With the artwork thus mounted onto the wax block, a pointed tool or say an empty ball-point pen was used to trace the design (Plate 3.18). After transferring the design, the paper was removed from the wax block leaving the transferred (pressed) design only on the wax. In cases where the design was to be pierced with a jewellers saw (Plate 3.19), piercing was done with the design mounted on the wax. Piercing was done by first inserting saw blade into a jewellers saw frame as usual with the teeth of the blade pointing downwards towards the handle of the frame and then tightened, piercing proper then began. the shape was carved out by cutting away excess wax with the aid of wax carving tools. Further refinement was done to bring out the desired details using wax modelling tools. Plates 3.20 and 3.21 shows carved and pierced wax models.

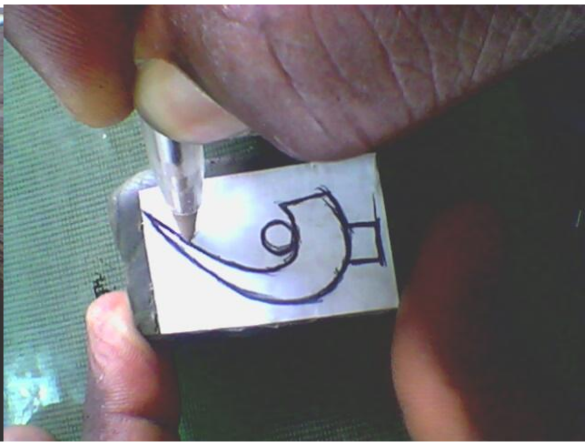

PLATE 3.18: *Piercing model* PLATE 3.19: *Transferring design unto wax*

PLATE 3.20: *Carved model* PLATE 3.21: *Pierced model*

Wax build up is another method of making patterns in wax. This method of pattern making makes use of natural wax without additives or with kerosene as additive. In this method, bits of wax were welded together to form a complete whole. The surface of the pattern was smoothened with pattern making tools and a heat source say, candle flame (Plate 3.22). This method could be used to produce both solid and hollow patterns as exemplified in Plate 3.23 and Plate 3.24.

PLATE 3.22: *Heating tool for wax build-up*

PLATE 3.23: *Built-up pattern*

PLATE 3.24: *Another built-up pattern*

Another method of wax pattern making is by forming either a wax sheet or wax wire around a core, the core in this case can either be just wax or refractory material. For the sample, the core (refractory material) was shaped to take the form of the object without any embellishment (Plate 3.25) then a wax pattern formed around it (Plate 3.26). In the case where wax was used as core, the wax was shaped into the core and then was coated with soap solution. Sheet wax was then formed around it; the wax sheet was cut open and the wax core taken out (Plate 3.27). Further detailing was done on the wax sheet (Plate 3.28).

PLATE 3.25: *Refractory core*

PLATE 3.26: *Model around core*

PLATE 3.27: *Cutting wax from core*

PLATE 3.28: *Modelling with tool*

FORMING OF WAX WIRE AND WAX SHEET

Wax wire can be formed by using any of the three methods described below. The first: soft wax is rolled on a flat surface such as on a wooden or glass surface which has been coated with a soap solution (Plate 3.29). The solution prevents the wax from sticking to the surface.

PLATE 3.29: *Rolling wax*

The second method is by softening the wax with heat and inserting the soft wax into a syringe (Plate 3.30). The wax was then extruded out of the syringe through its nozzle (Plate 3.31). Any size of wire can be produced by altering the diameter of the plastic nozzle which can be subjected to heat and then pressed to close to the desired size.

PLATE 3.30: *Inserting wax into syringe* PLATE 3.31: *Extruding wax wire*

The third method is the use of the wax extruding machine. The machine has two threaded parts but with one outlet, a cup and a handle. It works just like the syringe. The wax can be softened with a heat source, warm water or can be left in the sun for sometime. A thick bar of wax was formed from the softened wax. The cup side of the machine was opened and the bar of wax inserted into it (Plate 3.32). A hole corresponding to the desired size of the wire was drilled in a flat metal disc, that was then slotted into the cup (Plate 3.33). The cup was subsequently screwed onto the open end of the machine (Plate 3.34). The threaded plunger was turned by means of a handle to push the wax out through the orifice in the flat disc (Plate 3.35). A continuous perfect size of wax wire was produced by this method (Plate 3.36).

PLATE 3.32: *Wax inserted into machine*

PLATE 3.33: *Inserting metal sheet into cup*

PLATE 3.34: *Covering machine with cup*

PLATE 3.35: *Turning machine handle*

PLATE 3.36: *Extruded wire*

To produce sheet wax, the wax was first softened by heat. A flat surface such as wood or glass was coated with soap solution; a smooth surfaced bottle was also coated with soap solution (Plate 3.37). The wax placed on the flat surface was pressed down using glass bottle bottle as a roller until the required thickness of sheet wax was achieved (Plate 3.38).

PLATE 3.37: *Coating with soap solution*

PLATE 3.38: *Pressing to form sheet wax*

3.10.2.3 CORE MAKING

There is a variety of materials used in making cores in lost wax casting. In the 1700's, metalsmiths of the Asante kingdom used refractory materials such as 3 parts charcoal and 2 parts clay for cores. Although this composition cast perfectly, the core did not disintegrate easily after casting. Cow dung was added to the core material in an attempt to facilitate its disintegration.

Cow dung primarily, is the undigested residue of plant matter which has passed through the gut of cattle. The colour ranges from greenish to blackish, often darkening in colour as soon as it is exposed to the atmosphere. Cow dung in the charcoal, clay and water composition provides microscopic holes which facilitate disintegration of the core after casting. This core composition is used by the metalsmiths at Krofofrom and at the Centre for National Culture, Kumasi. The composition comprises 3 parts charcoal, 2 parts cow dung and 1 part clay. Water is added until the right consistency is reached. Charcoal helps in providing porosity to the core and prevents shrinkage. Old cow dung is not good for making cores because the fibre in the cow dung gets decomposed; fresh cow dung is used because of the fresh fibre in it. Cow dung helps in proper binding of all the constituent materials, facilitates the drying of the core and when burnt, leaves microscopic pores that contribute to the disintegration of the core. Clay in the composition strengthens and hardens the core when fired. Plates 3.39 and 3.40 show a composition containing cow dung and a core made out of it.

PLATE 3.39: *Mixed cow dung composition* PLATE 3.40: *Cow dung core*

The presence of cow dung in the core composition does not provide smooth inner walls for cast hollow objects. The addition of cow dung although serves the purpose of binding other components within the composition perfectly, yet retains water in the core even after de-waxing. This moisture in the core turns into vapour during casting. It is for this reason that a new core composition was experimented on to ensure it does not make use of cow dung and yet is very porous, binds perfectly, creates smooth inner walls of cast object and disintegrates easily after casting.

The researcher made use of clay, charcoal powder, sawdust and P.O.P in his experiments. Clay has these properties which include plasticity, shrinkage, fineness of grain, colour after firing, hardness, cohesion and capacity of the surface to take decoration. Clay often forms colloidal suspensions when immersed in water and becomes hard and lose its plasticity when subjected to heat. Clay in the composition provides strength and hardness to withstand heat and retain heat without collapsing. Burning wood in the absence of oxygen produces charcoal; a by-product of charcoal after it has been subjected to burning is ash. Charcoal in the composition helps in the burning of the core and minimizes shrinkage. Sawdust selected for this research was as fine as 80 mesh. Sawdust, a by-product of sawing and planing of wood product provides microscopic holes in the core which facilitates disintegration of the core after casting. Plaster of Paris (P.O.P) is prepared from gypsum (calcium sulphate dehydrate). When gypsum is heated to 120 degrees Celsius, it loses 75% water and crystallizes to form Plaster Of Paris. Gypsum is not recommended to be heated above 130 degrees Celsius, because the setting property of P.O.P will be destroyed. P.O.P when mixed with water forms a plastic mass which after half an hour forms a hard solid mass constituting interlaced gypsum crystals. The volume slightly expands (about 1%) during setting. Plaster of Paris in the core composition helps in drying of the core, prevents shrinkage and provides strength to withstand fracture.

First, four samples of the core were made and tested by subjecting them to heat up to the flowing point of brass. They were later used for casting sample work and the results were quite disappointing. The samples were labelled KCS (Kissi Core Sample) 1, 2, 3 and 4. The following are the details of the experiment:

The materials were weighed and dry mixed in a plastic bowl and water was then added. The amount of water used depended on the consistency of core or the kind of core the researcher wanted. The researcher mixed the core ingredients by hand in order to break the lumps that were formed and also to remove air pockets trapped in the mixture (Plate 3.41). Sample cores were made in flat biscuit shapes which were then weighed and measurement of 25mm marked on them (Plate 3.42). They were dried and then heated to the melting point of brass to test for shrinkage and ability to withstand heat. Table 3.2 below shows the component weights for the four core samples.

TABLE 3.2: *Component weights of core samples 1 to 4*

SAMPLE	CHARCOAL	P.O.P	SAWDUST	CLAY
KCS1	293.7g / 3parts	78.5g / 1part	18g / 1/2parts	52.4g / 1/2parts
KCS2	391.6g / 4parts	39.3g / 1/2parts	18g / 1/2parts	26.2g / 1/4part
KCS3	293.7g / 3parts	78.5g / 1part	18g / 1/2parts	104.7g / 1part
KCS4	293.7g / 3parts	39.3g / 1/2parts	18g / 1/2parts	52.4g / 1/2parts

The sample cores were then mixed and injected into each of the four (4) hollow wax models weighing 65 grams each. These models were all similar in size, shape, fineness and embellishment. Details of mould making and casting will be amplified later in this chapter. The amount of metal needed for casting an object is calculated by weighing the wax pattern with its sprues (without the core) and multiplying this weight by the specific gravity of the metal to be cast. Brass for example has a specific gravity of 8.56.

The casting result was undesirable. The cores got burnt and parts of the core filled with metal. All the sample cast objects had this deformity (Plates 3.43 to 3.47). This can probably be due to the cores not being able to withstand the pressure and high temperature of the molten metal as it solidified. When one considered the properties of the materials used for the sample cores, it would be observed that when clay, charcoal, sawdust and P.O.P are subjected to high temperature they with the exception of clay, lose strength and break down into ashes. Clay when subjected to high temperature loses plasticity but becomes very hard. A review of all the core samples, shows that although they disintegrated easily after casting and created smooth inner walls (Plate 3.48), yet they could not withstand the high temperature of brass during solidification. The core was very light, lacked strength and could not withstand the high temperature and pressure of molten brass as the molten brass solidified upon casting.

PLATE 3.41: *Mixing core materials*

PLATE 3.42: *Shrinkage test*

PLATE 3.43: *Core injected test samples*

PLATE 3.44: *Sample KCS1 after casting*

PLATE 3.45: *Sample KCS2 after casting*

PLATE 3.46: *Sample KCS3 after casting*

PLATE 3.47: *Sample KCS4 after casting* PLATE 3.48: *Inner wall of sample cast item*

There was the need to improve the strength of the cores. Further core development was done and labelled 1KCS3, 2KCS4 and KCS5. These new samples were developed from the previous core samples experimented upon. Sample 1KCS3 was an improvement of samples KCS1 and KCS3. Sample 2KCS4 was an improvement of samples KCS2 and KCS4. Table 3.3 below shows details of the sample composition. Biscuit size samples were made and tested for shrinkage, disintegration and strength just as was done with the first samples. After these tests, three similar wax patterns in weight, size and embellishment as those used for the previous experiment were also injected with the new core compositions and labelled 1KCS3, 2KCS4, and KCS5. The samples were later cast in brass and the results were quite encouraging (Plate 3.49 to 3.51). After these successful sample castings, other models were made from each of the successfully tested cores. The results of these subsequent sample castings were satisfactory (Plates 3.52 and 3.53). Detailed analysis of the various core samples are discussed in the next chapter.

TABLE 3.3: *Component weights of 'Improved' core samples*

SAMPLE	CHARCOAL	P.O.P	SAWDUST	CLAY
1KCS3	293.7g / 3parts	78.5g / 1part	18g / 1/2part	314.1g / 3parts
2KCS4	342.7g / 3 1/2parts	39.3g / 1/2parts	18g / 1/2parts	314.1g / 3parts
KCS5	293.7g / 3parts	39.3g / 1/2parts	35.9g / 1part	261.8g/ 2 1/2parts

PLATE 3.49: *Sample KCS5 after casting*

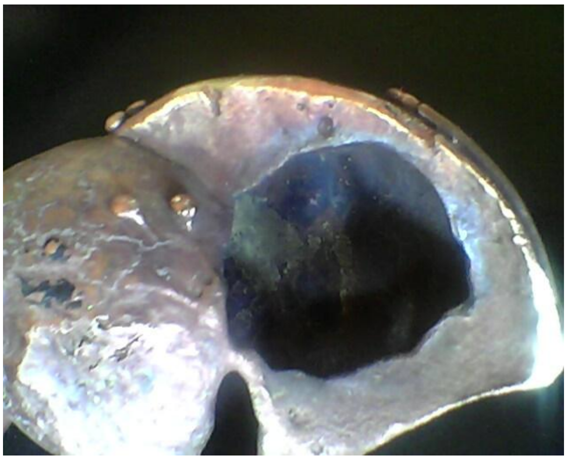

PLATE 3.50: *Sample 1KCS3 after casting*

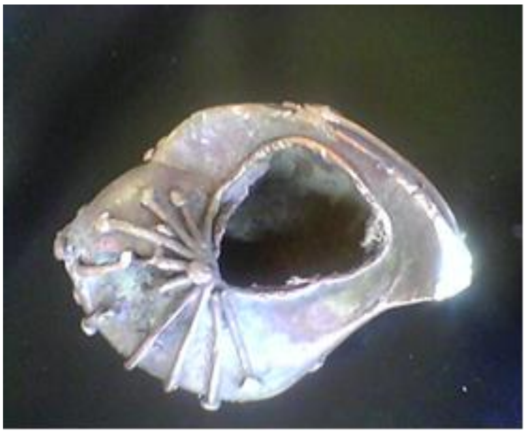

PLATE 3.51: *Sample 2KCS4 after casting*

PLATE 3.52: *Inner wall of "Growth"*

PLATE 3.53: *Inner wall of "Harmony"*

3.10.2.4 CASTING

Before the wax pattern is cast into metal, one of the first steps that the pattern goes through is spruing. According to Lawrence (1981), spruing is the process whereby wax rods or "sprues" ranging from say 1/8 of an inch up to more than 1/4 of an inch, depending on the size of the wax pattern to be cast, are permanently attached to the wax pattern. The wax sprues jutting out of the pattern converge to form a thick rod of wax which serves as gate from the reservoir (Plate 3.56). After wax burn-out, the sprues become conduits through which molten metal run to fill the cavity in the mould. Sprues can also be attached to the wax model after giving it a first coat of the mould material depending on the complexity of the design. Coating the wax model before attaching sprues strengthens and prevents possible fracture or deformation of the model. In the case of casting hollow works, the core can be pierced with spikes whose melting point is above that of the metal to be cast so as to hold the core within the mould even before attaching sprues.

Wax rods were formed and a metal spatula called 'hyihyibaa' by Krofofrom metalsmith as was heated and used for welding the sprues to the model. The models were given the first coat of refractory material made up of 3 parts fine charcoal powder (120 mesh) to 2 parts clay slip (Plates 3.54 and 3.55). Fine grades were used for the first coat to give the cast a smooth surface. After drying, sprues were attached by first scraping bare the contact point. The moulds were then given a second coat. The second coat provides additional strength and supports the first coat. This second coat was mixed in the same proportion but with coarser grains, of about 60 mesh. A third coat comprising a mixture of palm fibre and clay was applied to the second coat after it had dried (Plate 3.57). It also gives additional support and prevents the clay from cracking.

Sometimes a small crucible with brass scrap 9 times the weight of the wax pattern can be mounted on the gate of the already made mould and then coated again with the third coating material to assemble the crucible and the mould into one complete mould (Plate 3.58).

The mould was left to dry for about 6 to 8 days before de-waxing (Plate 3.59).

PLATE 3.54: *Coating with slurry* PLATE 3.55: *Items after coating*

PLATE 3.56: *Welding gate*

PLATE 3.57:*Mould with palm fibre coating*

PLATE 3.58: *Attaching crucible to mould*

PLATE 3.59: *Drying completed moulds*

De-waxing, also known as burn-out, is the process whereby wax is evacuated from the mould. To de-wax, the furnace was packed with fire wood and set alight. The moulds were then arranged in the furnace with the gates pointing downward (Plate 3.60). The temperature in the furnace was gradually raised by blowing in air until the wax inside the mould began to flow out. After the wax pattern in the mould had melted out, the temperature of the furnace was raised further so that any wax residue in the form of carbon still clinging to the walls of the mould cavity was completely burnt out. Some firewood was taken out of the furnace to reduce the temperature and ready the moulds to receive the molten metal.

PLATE 3.60: *De-waxing*

Melting of brass was done in a crucible lined with a refractory material. Brass was melted in a small furnace different from the one used for de-waxing (Plate 3.61). This furnace is fuelled by charcoal and the air blast was supplied by an electric blower (household mains or automobile battery). Having ascertained the weight of the metal needed, one-quarter of the metal by weight was added to it to make room for the reservoir and spills. The temperature of the furnace was then raised to be able to melt the brass. Once the temperature has risen to the flow point of the metal, the mould was removed from the other furnace with tongs (Plate 3.62). The mould was set in sand or wedged in-between stones with the gate upward. The melting crucible held with tongs was brought close to that part of the mould containing the reservoir and tilted to an angle of about 45 degrees for pouring (Plate 3.63). Within minutes, the molten metal would pass through the gate, travel through the network of sprues and completely fill the mould.

The brass solidifies gradually, from the walls inward. Solidification and cooling time of the brass depends on the volume of the cavity to be filled.

The mould was subsequently broken to remove the cast object (Plate 3.64). In the case of hollow objects, a metal rod was pushed into the core to break it loose from the cast object. The gate and sprues were trimmed off and the work polished.

PLATE 3.61: *Melting brass*

PLATE 3.62: *Removing mould*

PLATE 3.63: *Pouring molten metal into mould*

PLATE 3.64: *Cast item*

3.10.2.5 FINISHING

Finishing of cast objects goes through several stages. Finishing as carried out by Krofofrom craftsmen as well as that done by the researcher is discussed in this part of the Chapter Three. The cutting of sprues and gates using either hack saw or a pair of shears was the first step followed by grinding and filing off traces of sprues and other defects on the artefact (Plate 3.65). Metalsmiths at Krofofrom, after grinding and filing the artefacts, placed them in lime solution and left them overnight. The artefacts were thereafter brushed with a steel bristle brush. In cases where the cast objects were of smaller size, they were packed into a sack and rubbed against each other (Plate 3.66). Example of a finished work by Krofofrom craftsmen is shown in Plate 3.67. When necessary file marks were removed using emery papers. The researcher used pickle solution and bright dip solution for cleaning after using different grades of emery paper. Appendix 3 contains the chemical compositions. The artefacts were then polished with tripoli and then rouge on the polishing wheel, after which they were cleaned with kerosene using an ordinary tooth brush. Another finishing method that the researcher used was dipping in alum solution, (fifty grams of alum in half a litre of water). The artefact was immersed in the alum solution and boiled for some time. The amount of alum and water needed depends on the size and number of items to be polished. The artefact was polished using steel wool instead of emery papers (Plate 3.68). It was scratch-brushed (Plate 3.69), rinsed and dried. Finally, it was rouge polished, cleaned with kerosene and lacquered to prevent tarnishing (Plate 3.70).

PLATE 3.65: *Filing* PLATE 3.66: *Polishing in a sack*

PLATE 3.67: *Finished work from Krofofrom* PLATE 3.68: *Polishing with steel wool*

PLATE 3.69: *Scratch brushing*

PLATE 3.70: *Finished work*

CHAPTER FOUR

ANALYSIS AND PRESENTATION OF DATA FINDINGS

4.1 Overview

The previous chapter dealt with methodology used in data gathering for the research and gave a detailed account of the project investigation and experimental procedures used. Chapter Four does a detailed analysis and presents findings under the following sub-headings: Evaluation of core materials, Evaluation of beeswax, Pattern making and Finishes.

4.2 Evaluation of Core materials

This part of Chapter Four covers a comparative study of the cores used by the Asantehene`s metalsmiths in the 1700`s, those used at Krofofrom at present and the researcher's core compositions. It also provides an overview of objects made out of these experimental cores.

Cores used for lost wax casting by metalsmiths at Krofofrom have gone through several transformations even prior to this research work which aims primarily at improving the casting of hollow objects. In the 1700`s, metalsmiths of the Asante Kingdom were using a core whose composition was 3 parts charcoal powder (120 mesh) and 2 parts clay mixed with water to a consistency suitable for core modelling. This core composition is currently used by Asantehene`s metalsmiths at Ensuasi in Kumasi. Although this core casts very perfectly and gives fine inner walls to cast objects, it does not disintegrate easily after casting and tends to result in distorted and warped castings.

In this era of mass production as practised in Krofofrom, the metalsmith cannot afford to lose valuable cast objects through distortion and difficulty in core removal. The introduction of fresh cow dung to the composition of charcoal and clay was to improve upon the disintegration of the core after casting. Fresh cow dung is the undigested plant part that has passed through the animal`s alimentary canal. The fibre in the dung provides microscopic holes in the core which allows heat retention and improves the disintegration of core after casting. Although cow dung appears to help in the disintegration of core after casting, it nonetheless creates pinholes in the inner walls of cast hollow objects. According to Kumar and Shende (2006), effective combustion of cow dung takes place when the dung is pulverized. When cow dung is completely burnt its by-products are carbon dioxide, water vapour and ashes. Their research substantiates the point that the amount of heat that the core with the unpulverised dung is subjected to during de-waxing is not able to get the dung completely burnt. An experiment was conducted by this researcher whereby a core after routine de-waxing was immersed in water. The wet core retained its former "green" or natural characteristics of being sticky and pliable. Such cow dung core surfaces when in contact with the hot molten metal (e.g. brass) undergoes further combustion and the cow dung releases carbon dioxide, water vapour and ashes. "Micro blow holes" on the surface of the inner walls of the cast item which manifest themselves as pinholes are probably caused by this water vapour released from the combustion of cow dung.

The core composition of the 1700`s (3 part charcoal and 2 part clay) was altered to a ratio of 3 parts charcoal to 1 part clay. When this core composition was tested, it was found that it collapsed even before the molten metal solidified completely causing parts of the core to be filled with molten metal. This indicated that the composition lacked the strength to withstand the heat and pressure of the molten metal. One idea was to completely burn out the core before introducing molten metal into the mould. Another was to increase the amount of clay in the cow dung composition and then burn the core before covering it with wax. In both instances the outcome was unacceptable. Pre-heating the cow dung composition to completely burn the dung before introducing molten metal resulted in a weakened core unable to withstand the pressure of the molten metal.

The composition comprising 3 parts charcoal, 2 parts fresh cow dung and 1 part clay when tested showed that cow dung in the composition did not only help in the disintegration of the core but provided strength and acted as a binder for the other components. However, when this composition was pre-heated to completely burn out the cow dung the core lost strength and could not withstand the pressure and temperature that the molten metal entering the mould exerted. When the clay content was increased in the composition, the core showed signs of cracks during drying and sometimes during casting. Also when the core was subjected to a high temperature in order to completely burn out the cow dung in the composition before wax patterns were applied, it was discovered that erosion of parts of the core had occurred during de-waxing. Core erosion again occurred during pouring of the molten metal. The need to try different materials for producing cores that would have adequate strength, easy disintegration and pinhole-free casting became obvious.

The first four compositions labelled KCS1, KCS2, KCS3 and KCS4, (Table 3.2 of chapter three) were all a failure. Parts of the cores collapsed in the mould. This was possibly due to the fact that the composition of all four cores had less clay and thus could not probably have the strength to support the high temperature and pressure of molten brass during the pouring and solidification stage. Another experiment was conducted using the same core materials as in the previous four: charcoal, clay, P.O.P and sawdust but this time in different proportions other than those used for the four experimental cores. The second experiments were an improvement on the earlier experiments. The second experimental samples labelled 1KCS3, 2KCS4 and KCS5 were a success. Artefacts that were produced utilising these core compositions are presented below:

4.2.1 Artwork "KAE DABI" (to reminisce)

Core sample 1KCS3 was an improvement of cores KCS1 and KCS3. The compositions (KCS1 and KCS3) had the same amount of charcoal powder, P.O.P and sawdust but different proportion of clay. The result showed that of all the materials used in preparing the cores, it was the clay that imparted strength to the core and though it loses its plasticity when fired, it allowed the core to be easily disintegrated during removal. The artefact **"Kae Dabi"** (to reminisce), shown in Plates 4.1, 4.2 and 4.3 was moulded using core material 1KCS3.

PLATE 4.1: *Front view of Kae dabi*

PLATE 4.2: *Back view of Kae dabi*

PLATE 4.3: *Side view of Kae dabi*

Core 1KCS3 was used for this art work because out of the three core formulations investigated, this core, even though did not provide very smooth inner walls, did dry faster as compared to the other two sample cores. Its P.O.P content was higher than the rest of the samples and it supported and held applied details very well. For larger objects this core lent itself to being cut into segments and being joined together later with only P.O.P slip.

The artefact was named **"Kae Dabi"** (to reminisce) because its basic form was developed from the Sankofa bird which traditionally symbolises reaching back for old memories. It measures approximately 37cm tall and about 21cm at its widest point. The use of small wax wires is to demonstrate the feasibility of using such small sized wires seldom used by Krofofrom casters for large objects. The **"Kae Dabi"** art work can function as a decorative piece for holding flowers, as a bed-side lamp holder or can be used for any other purpose as desired by the user.

Symbolically, the form depicts the Sankofa bird and the wings on the sides are formed from a group of Adinkrahene symbols representing completion or closure which also can be extended to represent parental guidance. The back side in the form of woven net and the triangular shape at the bottom of the work represents the trinity and is intended to represent parental teachings on the fear and trust in God, transparency, truthfulness and hard work. This teaching on the fear of God is directly related to Proverbs chapter 1 verses 8 to 9 of the King James Version (1983), which says:

> My sons, hear the instruction of thy father, and forsake not the law of thy mother: for they shall be an ornament of grace unto thy head, and chains about thy neck.

The work is conical in shape, broader at the base and narrows as it goes up with leaves twirling around the top signifying growth. The twisted wire at the very top represents the struggles one goes through as one grows up from childhood to adulthood. The work also symbolises the realities one faces in decision making and the dreams and aspirations that are modified as one begins to encounter the vicissitudes of life. The gaps in-between the twisted parts of the work are intended to represent dubious or un-Godly ways that one may use to become successful in a short time. The three projecting wires signify the support of God through child hood to old age and all the successes granted by God through that period.

4.2.2 Artwork "HARMONY"

Out of the three core samples experimented on, core sample KCS5 took the longest time to dry. Drying time for the core sample tended to depend on the kind of core material components used and the size of the core and object. The temperature or ambient condition under which the core was produced also influenced the drying time. For instance, when three core samples in the form of balls of 20 grams each at room temperature were allowed to dry, it was found that the core sample 1KCS3 ball took 5 min to become leather hard, 2KCS4 ball took 13 min to become leather hard and KCS5 ball took 24 min. The higher the amount of P.O.P in the core, the shorter it`s drying time. Core sample 1KCS3 contained the highest quantity of P.O.P followed by core sample 2KCS4 whose content of P.O.P was slightly less and core sample KCS5 with the least P.O.P content. Because core sample KCS5 had the least P.O.P content and was slow in drying, it was suitable for making small cores for artefacts in which inner walls were part of their visible features because that sample enabled the creation of very fine inner walls and disintegrated easily.

The art work (Plate 4.4, 4.5, 4.6) is named "**Harmony"** because it was designed from two musical instruments; the xylophone and "Konon" which are commonly used by the Northern tribes of Ghana. "Harmony" measures approximately 18cm long, 15cm high and 9cm wide. The work was inspired by the recent instabilities in the northern part of Ghana. It was composed from two important local musical instruments which produce different sounds. Wood and calabash are the main materials used for these instruments. The two musical instruments have different shapes in terms of construction. The strings on the xylophone and that on the "Konon" perform different functions and produces different melodies. The two musical instruments, without the calabash, cannot produce the sweet melodies that characterise them. The two instruments together with the “Dondo” are the basic instruments whose sound are easily and readily associated with native Northern music just as the “Atumpan” traditional drum is easily identified with the Akan group of the South . No matter the difference in how these instruments are used, the skilful combination of the two is able to produce music that everyone appreciates. The variety of finish given to **“Harmony”** such as mirror finish against the textured surface, the matt natural brass colour against the patina treatment goes to emphasise the point that no matter the differences in our skin colour (dark or fair) or the differences in our ideas, unity can still prevail. The five smaller gem stones and the larger gem stone incorporated in the work signify foreign cultures and ideas which when properly blended with the local culture can still bring harmony. This work which can stand alone as a decorative piece can also be used as a receptacle for pens, pencils and small notes.

PLATE 4.4: *Front view of Harmony*

PLATE 4.5: *Back view of Harmony*

PLATE 4.6: *Harmony*

4.2.3 Artwork "GROWTH"

The art work named "GROWTH" (Plates 4.7and 4.8) is the outcome of core sample 2KCS4 which is an improvement of core samples KCS2 and KCS4. Core sample 2KCS4 was used for this size of work because out of the three core samples it is the second fast drying (after core 1KCS3). It allows for reshaping when dried, it enables the creation of smooth inner walls and withstands shock due to high metal temperatures and disintegrates easily after casting. Jewellers and metalsmiths use wire for producing filigree jewellery including metal beads which are strung with thread as bead jewellery. In Krofofrom, the latter is practised. The researcher produced artefacts using the jewellery technique of filigree in the closed and open format.

PLATE 4.7: *Front view of Growth* PLATE 4.8: *Back view of Growth*

The art work **“GROWTH”** was developed from the corn cob which as a symbol on linguist`s staff in Akan tradition symbolises ‘increase’ or to ‘multiply’. The work is approximately 20cm high and has a diameter of approximately 7cm at its widest part. The work shows part of the corn husk removed to show the ear kernels (represented by a net) on the corncob. The inner wall formed by the core is seen through the holes representing the grains in the net structure. As the saying goes, it is never healthy to destroy others to promote one`s self. An individual`s ability to appreciate the goodness in others has the tendency to reflect on how others will look at and appreciate that individual. Building a sustainable growth cannot be achieved by just showing what one is made of, but by also recognising what others can do and have done.

4.3 Evaluation of Beeswax

The mode of producing wax patterns by the metalsmiths at Krofofrom has not changed in generations. One wonders whether this is due to the fact that clients are dictating the production process or it is because the craftsmen themselves do not want to move away from the old method of doing things. Any of the assumptions may be true but the question can still be asked as to whether the metalsmiths are meeting the demand of customers or clients are accepting cast objects as they are because that is what the metalsmiths can produce? In the researcher`s discussions with some Krofofrom metalsmiths, it was found out that they have no skills of carving and piercing and the process of providing a good finish for their cast objects was not factored into the production process. The main techniques of making wax pattern are wax build-up and wax pressing. Some designs are such that when pierced with jewellers saw or carved with the proper wax carving tools, fine edges and an accurate duplicate of the original can be achieved. In this part of the research a series of patterns were developed, cast and finished in an attempt to demonstrate alternative methods of wax pattern making. Beeswax is not manufactured by some industrial or commercial process but is produced by the honey-bee and can be given further treatment to enhance its workability for any project intended. A honey-bee community consists of three different types of bees: the queen (reproductive female), the drone (male) and the worker (non reproductive female). Worker bees do not mate and therefore cannot produce fertile eggs. Occasionally they lay infertile eggs, which give rise to drones. Worker bees have eight wax-producing glands located on the inner sides of the sternites of the abdominal segments 4-7. The size of the gland is dependent on the age of the worker bee. Bees build their nest from wax secreted from glands in their abdomen. The hexagonal cells or compartment, constructed by the workers are arranged in a lattice work known as the comb or honey comb (Chambers, 2009). Beeswax is obtained from the honey comb of bees (Apis mellifera) after the removal of honey; the comb is melted with hot water, steam or solar heat. After removing impurities, the liquid wax is cast into cakes. The two main beeswaxes that are marketed are yellow beeswax and white beeswax. White beeswax is obtained by bleaching yellow beeswax with hydrogen peroxide, sulphuric acid or sunlight. Beeswax primarily consists of five component groups of a mixture of esters of fatty acids and fatty alcohols, paraffinic hydrocarbons, and free fatty acids; minor amount of fatty alcohols are also present. These five groups amplified below are: free fatty acids (typically 12-14%), most of which are saturated (Ca. 85%) and have a chain length of C24-C32. Secondly, free primary fatty alcohols (Ca. 1%) with a chain length of C28-C35. Thirdly, linear wax monoesters and hydroxyl monoesters (35-45%) with chain lengths generally of C40-C48. The esters are derived almost exclusively from palmitic acid, 15-hydroxypalmitic acid, and Oleic acid. Fourthly, complex wax esters (15-27%) containing 15-hydroxypalmitic acid which through their hydroxyl group are linked to another fatty-acid molecule. In addition to such di-esters, tri- and higher esters are also found. Lastly, odd-numbered straight chain hydrocarbons (12-16%) with a predominant chain length of C27-C33. The composition of beeswax is said to depend to some extent, on the subspecies of the bees, the age of the wax, and the climatic circumstances of its production. However, the variation in composition occurs mainly in the relative amounts of the different components present, rather than in their chemical identity (Aichholz and Lorbeer, 1996).

Various additives were mixed with beeswax in order to formulate different mixtures suitable for various kinds of designs as well as help give the wax compositions certain desirable properties (see Table3.1 for details) to facilitate wax working under various ambient temperatures. Below is a presentation of some of the artefacts created from the experimental waxes.

4.3.1 "AKUABA" (fertility doll) from wax containing Kerosene (K1)

Wax sample containing kerosene was used for the **"Akuaba"** (Plate 4.9 and 4.10) because of the desirable qualities of this composition. The sample (K1) is soft, has good weldability but tends to break when stretched or bent. The reason why it was used for a rounded form was due to its soft nature. The technique used was wax-build -up because it is very easy to build round forms with very soft wax. The wax was taken bit by bit with the modelling tool and was then welded onto each other bit by bit until a complete form was achieved. This wax formulation is not good for piercing and is best worked in cooler weather to facilitate hardening of the pattern/model. This wax sample provides an alternative when one intends to build up the wax pattern. It is workable in temperatures around 22-37 degrees Celsius or even less. Temperature conditions above 37 degrees Celsius might affect the hardening of the work

PLATE 4.9: *Front view of Akuaba*

PLATE 4.10: *Back view of Akuaba*

The **"AKUABA"** was inspired by the Akan fertility doll of the same name. This work measures approximately 13cm high. Both the Asantes and the Fantis have versions of the doll. The Asante version is characterised by a round or oval head, extended arms and rigid form while the Fanti version is characterised by its boxy headed shape. Features of the derived "AKUABA" include the typical feminine body captured in the roundness of its form. A depiction of movement is visible in this sculpture and which was also developed to show flexibility and dynamism of the feminine form. It is believed that the doll helps in child bearing and adult women who were childless have been known to carry such a doll on their backs in the past, hoping that the magical properties embodied in this doll would help them to conceive and have a child of their own. In contemporary Ghana, some young females may have found themselves childless due to the fact that they did not listen to parental advice and may have become sterile because of past sceptic abortions. The ears of the "Akuaba" art work were intentionally emphasised to allude to the adage: "she who has ears let her hear" to bring to the fore the need for young females to value the advice of parents. Patina treatment was given to the surface to bring out the true Ghanaian dark colour.

4.3.2 "NOISE" from wax sample containing Paraffin (P2)

Paraffin wax was mixed with beeswax to help obtain a wax that is very hard, crack resistant, easy to pierce or carve and suitable for working even in a warm environment. Natural beeswax is too soft and does not provide the properties or qualities stated above. This wax sample was used for "NOISE" (Plate 4.11) because of the very sharp corners desired of the work and the fact that sharp edged forms are best obtained either through carving or piercing.

PLATE 4.11: *Noise*

The art work, **"NOISE"** was inspired by cow horn. This art work mounted on a wooden pedestal measures approximately 12cm high. The cow horn is not known to produce as sharp a sound as the South African "vuvuzelar" due to probably the natural material and its round conical frame. But why should this art piece be compared to the "vuvuzelar"? This horn was designed to evoke the sharp sound of the "vuvuzelar", by the sharp edge of its corners. This work was designed as a symbol to mark the historic event on the African soil, specifically the FIFA world cup played in South Africa in 2008. In this event, Africa introduced another way of supporting football by producing that sharp and unusual sound from the "vuvuzelar" trumpet. The round ball (called Jambolani, in a South African dialect) also depicts football that was used for the game. Patina treatment was given to parts of the metal pedestal to depict the colour of the people.

4.3.3 "THE METALSMITH" from the wax sample (C3) containing Candle wax

After mixing paraffin and beeswax, it was found that although the composition served its purpose of withstanding cracks and was suitable for carving and piercing, there was the need for a wax that possessed similar characteristics in addition to being able to support the modelling of some curved shapes which the paraffin wax did do. Candle wax was mixed with beeswax to obtain the desired characteristic as outlined above.

The art work was named **"THE METALSMITH"** (Plate 4.12) because its form was designed from a series of image portraying work activities of metalsmiths. The art work which is about 13cm high shows a metalsmith whose head is represented by a faceted diamond, working with fire. The work was carved from a block of wax which served as an alternative to paraffin wax composition. Having spent seven years at KNUST, the researcher in a position to observe that even though all sections of the Department of Industrial Art need upgrading, it is the Metal Product Design Section that urgently needs this upgrading and also the section that has not been able promote itself. During 2008/ 2009 academic year, the researcher took pictures of his works fabricated at the section to banks and other corporate institutions in Kumasi and surprisingly most of the workers did not know much about the section. In order to promote the section the researcher during his final year and together with his team members erected the first outdoor metal sculpture on campus.

This cast brass object, inspired by the final year outdoor sculpture can serve as a trophy. The art work, triangular in cross section depicts all three sections of the department. The three holes also represent the three sections and the faceted diamond shape set on top of this form represents the researcher`s opinion that the Metal Section can yet become the “money making machine” and the “eye” of the Department of Industrial Art.

PLATE 4.12: *The Metalsmith*

4.3.4 "BALL GECKO" from wax sample (CP1) containing paraffin and candle

The experiments resulted in sample waxes that were pliable and could be worked on in hot and cold weather, good for piercing and carvings as well as others that were suitable for wax build-up modelling. It was very important to develop waxes possessing working properties that are better than those of natural wax; that is to say, a type of wax that can be worked with in both warm and cold ambient temperatures. A sizable amount of paraffin and candle were mixed with beeswax as can be seen in Table 3.1.

The art work was named "**Ball Gecko"** (Plate 4.13) because it was formed from wax balls and inspired by the lizard wall gecko. The Gecko is a member of a family of small, harmless lizards, found mainly in tropical regions. Certain species of this family make a loud clicking noise that sounds like "gecko". Geckos are said to be the only lizards that make any sound other than hissing. Geckos are often seen at night running upside down on the ceilings of houses. Some geckos have a disk on each of their toes composed of scales with much minute brush like projections. The special size and shape of the projections allow these geckos to cling to and move across smooth surfaces using van der Waals forces (Encarta, 2009). In Akan communities, Geckos are seen as sacred animals that protect humans at night from bad spirits and are not to be killed hence the name "Efie wura". Also because of their harmless nature they are seen as a sign of good luck or hope, for instance, if Gecko falls on a woman unawares, it is believed that the woman will get pregnant. Due to intercultural marriages and different religious beliefs, Geckos which were seen as sacred animals are now believed by some to be evil without any credible fact, even to the extent that cats and other animals are now perceived as demonic. This work was made to counteract this negative belief. Also, the Gecko was made in wax balls because the technique is mostly used in jewellery and almost all the metalsmiths at Krofofrom do not employ the use of wax balls technique in executing their metal art works.

PLATE 4.13: *Ball Gecko*

4.4 Pattern Making and Finishes

This part of Chapter Four provides an analytical study of most of the known wax pattern making techniques used at Krofofrom and the improvements that this research has brought about.

The subheading, Wax Pattern and Core Making of Chapter Three of this research work speaks expressly on the entire pattern making methods that are used at Krofofrom and those utilised by the researcher. Over the years, it has been known that soap water solution and oil are the parting liquids for wax to cement, wax to clay and wax to P.O.P operation. Most of the methods for making wax patterns or wax models do not make use of molten wax in P.O.P moulds. This researcher for this reason undertook it as a challenge. Although there are other ways of casting molten wax models in metal (aluminium) moulds, because wax does not strongly stick to aluminium surface, the use of P.O.P for mould is not practised at Krofofrom. Metalsmiths in the Asante Kingdom around 1700`s and at present have not and do not cast molten wax in P.O.P moulds. This may be due to the fact that several unrecorded attempts might have failed. When the researcher took the challenge of casting a hollow wax pattern from a P.O.P mould, a study of how hollow ceramic objects are cast in P.O.P mould was undertaken. A review of several parting materials and those used for existing pattern making methods were made. In getting the negative of the model in the P.O.P to create a mould for the pattern, the technique of coating the model with oil and then coating it with P.O.P as used for ceramic castings is also applicable in making the P.O.P mould for the wax pattern. The challenge was removing the wax model from the P.O.P mould, because in this case the wax does not shrink and a good pattern material is required to facilitate an easier separation of wax model from P.O.P mould. A possible suggested method would have been, rolling a sheet of wax and then pressing it in the P.O.P mould which has been coated with oil and then welding the two wax halves together. This is not possible with a mould that is made up of several parts. This is because the smoothness of the inner wall of the wax model cannot be guaranteed due to the parting line that would be created in the inner wall of the cast object. In casting molten wax in P.O.P, the mould does not behave in the same way as casting with ceramic slurry where the P.O.P mould absorbs the liquid (water) in the slurry but the principle of solidifying first from the wall is the same in both cases. In casting molten wax, the mould surface provides a cold envelop around the wax and causes the wax closer to the inner wall of the mould to solidify first. The mould was then turned upside down to allow unsolidified wax to flow out. There is the need to use parting material which will aid in the removal of the model without destroying the mould. When soap water solution was applied in the mould, the solution was absorbed by the P.O.P and did not work. When oil was applied, the hot molten wax mixed with the parting oil and this also did not work. A new parting solution was needed: 70 grams of soap (key soap) was dissolved in 30grams of hot oil (cooking oil). This solution solidifies when cooled. Its application to the mould and further working details are seen in chapter three. The artefact “Nwheso” (Plate 4.14) was created using this new parting solution.

PLATE 4.14: *Nwheso (to Preserve)*

“Nwheso” is an Akan word which literally means “to Preserve”. It can also mean “an Example”.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview

The previous chapter dealt with the analysis and presentation of data findings. This chapter summarises the findings made, draws conclusions and proffers recommendations.

5.2 Summary

Cast hollow artefacts produced by Krofofrom metalsmiths are characterised by pinholes in their inner walls. This is as a result of the presence of cow dung in the core composition of charcoal and clay.

Various materials were investigated and experimented upon to enhance the working properties of core and wax compositions in order to improve the quality of cast hollow objects and also to use the findings of the research for educational purposes.

Qualitative research design was used, descriptive and experimental research techniques were employed in gathering data from a sample size of 25 professional craftsmen out of an accessible population of 50 metalsmiths of Krofofrom. Data from the experiments conducted was also utilised

Findings obtained from data gathered are:

- The application of saw dust and P.O.P in core production ensures easy disintegration of core after casting. This composition creates smooth inner walls of cast hollow objects.
- The technique of wax piercing and wax carving for making wax patterns is not practised by the casters.
- There is no knowledge of how hollow patterns are cast using molten wax in P.O.P moulds.
- In place of emery paper, steel wool can be used to improve on the final finish.
- There is complete lack of knowledge of the use of lacquer and kerosene to preserve surfaces after polishing.

5.3 Conclusions

- Without the application of P.O.P and saw dust in the production of the core material, inner walls of cast hollow objects made at Krofofrom will still be characterised by pinholes.
- Piercing and carving are useful for creating quality wax pattern.
- A better hollow wax pattern can be produced by using the molten-wax-in-P.O.P-method.
- The application of steel wool can in some situations erase file marks and scratches to improve the final surface finish.
- Without the use of metal lacquer and kerosene as surface preservatives, cast brass articles will succumb to the atmospheric effect of tarnishing.

5.4 Recommendations

Based on the research findings and conclusion, it is recommended that:

- In producing cast hollow artefacts, metalsmiths at Krofofrom should adopt the use of saw dust and P.O.P for moulding as was used in this research in order to eliminate pinholes in the inner walls of their cast objects.
- Piercing and carving ought to be utilised for wax pattern production to provide a variety of visual forms that are only possible through these two stated methods of pattern making.
- Molten-wax-in-P.O.P-mould method should be employed to ensure direct duplication of the original object without parting lines.
- Steel wool should be used in erasing superficial file marks and other scratches to improve upon the finish of cast items from Krofofrom.
- The application of either metal lacquer or kerosene should be adopted in the finishing of cast articles to prevent them from tarnishing.
- A workshop should be built at Krofofrom in order to have a venue for disseminating research findings for the benefit of craftsmen. It is hoped that this workshop would be sponsored by the Ghana Tourist Board, Export Promotion Council as well as other donor agencies and stakeholders who may be interested in upgrading the skills of Ghanaian artisans.

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APPENDIX 1 – CHEMICAL COMPOSITIONS USED IN THIS RESEARCH

BRASS BRIGHT DIP

Nitric Acid – 25%

Sulphuric Acid – 60%

Hydrchloric Acid – 0.2%

Remaining percentage is Water

(Neutralize in a detergent solution)

BRASS PICKLE SOLUTION

Sulphuric Acid – 1 part by volume

Water – 9 parts by volume

BRASS PATINA SOLUTION (BLUE BLACK)

Copper Carbonate – ¼ of a pound

Ammonia – 1 part

Water – 2 ½ parts

(Temperature 79 degrees Celsius)

ALTERNATIVE (BRASS PATINA)

Coat Brass Article with Copper by immersing the object in a copper pickle which contains Iron (concrete nails); Iron in the solution forces copper particle in the solution to deposit on the Brass object. The object is scratch-brushed and rinsed in water. The Brass object coated with Copper can then be given Copper patina, made of 1 part Caustic soda to 2 parts Sulphure.