Modification of Conventional Casting Techniques: The Adaptation of 'Lost-clay' Technique for Casting Metal Sculpture

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Abstract
Foundry technique in sculpture is not static but keeps developing to meet contemporary needs. The study aims at showcasing a metal casting technique which will serve as an addition to the conventional methods adopted in metal-casting by sculptors. The new casting technique called "Lost-Clay" which entails the use of clay in similar manner wax is used in cire perdue (Lost wax) technique. The theory of Material Substitution was adopted to explain the research. The main objective of the study is to introduce cheap casting technique with emphasis on its usefulness in casting metal sculpture, and to improve metallurgy. The study adopts a descriptive research approach. The information for the research was gathered from both primary and secondary sources. The primary sources are mainly oral while the secondary sources were written materials (published and unpublished). Clay is principal research material manipulated to obtain the mould used for casting. It was sourced locally and it was found to be cheaper than wax. At the end, metal sculptures were cast using the "Lost Clay" techniques to ascertain its material effectiveness and suitability. The study revealed that the technique is easy to handle, economical, and suitable for casting sculptures in metal. The researcher calls for more study in this area of study in line with Nigerian quest for innovation.

Keywords: Modification, Casting, Technique, Adaptation Lost-Clay, Metal Sculpture.

Introduction

The researchers like other foundry-men, had been using various casting techniques for over a decade and their interests have been to improve results with furnace, materials and techniques so as to achieve potentials and high productivity. Generally, art has been expressed through metal for more than five thousand years when the earliest craftsman in stone discovered and first exploited metal. Unlike stone, metal can be shaped by bending, beating or casting, (Frank, 1974). No one knows exactly when and where the first metal was found and used, but available sources pointed to Egypt as first to discover the use of metals where it was used to fashion articles of art, ornaments and daily needed usages (Clement, 1978).

Meanwhile, Mesopotamia was also said to have been advanced in metal technology simultaneously with Egypt. Other ancient centers of metal technology include Ur in Sumer, Middle East, around 2800 BC, and in Catal Hyuk, Anatolia. Shortly afterwards, it spread spasmodically to places like Indus valley in about 2500 BC, and progressed westwards towards Europe from about 2000BC. It was found in crude-"native copper" in China, where it was manipulated in an unprecedented level of sophistication produced excellent works. For instance some of the finest cast-bronze objects were produced in

about 1500BC during the Shang dynasty (15 - 11BC), (History of Metallurgy, 2015). Here in our country Nigeria to be precise, metallurgy has been an age long indigenous technology in places like Benin, Ife, Igbo-Ukwu, Nok, among many other areas. Nwanna (2014) states: "generally speaking, the origin of metal and its early uses are still shrouded in the obscurity of the prehistoric time, but it appears that discovery and uses of metal dated to the Neolithic man". Base on analytical studies, Nwanna concluded by saying that "There is no reliable evidence for one to know the exact date when man first discovered how to use metals, but we do know that copper had been used for as long as 5000 BC and gold were first used during the 4000BC".

Metal was defined by Oxford Advanced Learners Dictionary as: "a type of solid, mineral substance that is usually hard and shiny which heat and electricity can travel through, for example tin, iron, copper, aluminum or any alloy of these". Metal is the solid mineral substance that can be melted by heat to produce work of art, domestic needs as well as serving as electricity conductor. In early discovery of metals native metals are found in an un-reacted state. Such metal are gold, silver and copper in nugget form that naturally occur in a relatively pure state. The ancient man first discovered and began the use of them via the application of fire on a large scale (pyrotechnology) which marked the first truly industrial activity (Fire and metal-my geology 2015). Furthermore, the development of some basic processes of metallurgy was also discovered. The processes include smelting, melting, casting, annealing, embossing, and filigree.

The use of fire in foundry process makes it possible to achieve these developments of metallurgy primarily through smelting of mineral ores to extract metal, then melting and casting of metal. It is either cast as ornaments of art or as functional objects. Analysts have shown that most archaeological finding of the Neolithic era were metallurgies. Related to the sculpting process is metal casting, in which metals are shaped through melting using furnace process and poured into mould to cast an object. In this paper, the researchers aimed at introducing cheaper casting technique with emphasis on its usefulness in casting sculpture.

Metal casting has endured from the pre-historic period to present with some modifications, but there is need for cheap alternative method of metal casting that will be suitable for Nigerian art schools, and metal-casters. At this juncture, researchers mind were preoccupied with what would be the outcome of adapting the modified lost clay casting technique for casting sculpture. The development in this context involves not just the casting of sculptures, but also the unlocking of the individual potentials and adoptive ideas from this foundry practice. Adoption of the technique is hoped to satisfy the need for complementing techniques of metal casting for arts and other similar uses. It will also stimulate interest.

Objectives of the Study

The objectives of the study are as follows:

- To study the technique adapted for casting metal sculptures in terms of the effectiveness.
- To contribute to the existing corpus of literature on the subject.
- To encourage the development of cottage industries in Nigeria, that will be specialized in small scale foundry.

Literature review

Theoretical Framework: Theory of Substitution

This research is underscored by Theory of Substitution. This is identified to support the research on mould-making process where the existing material is replaced with another suitable material that is less expensive. Again, it conforms to the principle of casting in which existing material substitutes with other material for the reproduction.

William. S. Jevons, an Economist and Logician propounded the theory first in 1863 as "Marginal substitution" for Political Economics and Logic principle of "Substitution similar" in 1871. The development of Substitution is associated with scholars like Slusky,Alfred Masheal, John Stuart Mill among others. Substitution is a popular Economics term, applied in consumer's demand. It simply means replacement or change of a given competitive demand commodity with its substitutes, example margarine and butter. In this case each of the available good substitutes for another if need arise. That is when price of one increases, the price of the other remain stable, the consumer will shift to the one that is comparatively cheaper.

Later, William .J. Rankin in his book *Tre*atise *on Process Metallurgy: Industrial Processes (*2014), adopted the theory as Material substitution which explain that: "technological substitution: the substitution of services for materials or goods substitution of material for other materials and substitution of technologies by other technologies". Succinctly it is changing or replacement of one material for another material / good.

The notion for adopting theory of substitution in this study is based on the above act, the process or result of using a novel technique which substituted an existing material with unconventional material to produce same mould for the metal-casting. Substitution in this context based on the proposition of Rankin, which could be made possible through some technological innovations that make quintessence the driving force. Consequently, clay used in this technique (Lost clay) has the quality of being complementary and offering similar uses wax used for cire-perdue technique. The procedure begins after mould are released from the clay original model, then, thin layer of clay slabs laid on the mould cavity, pressed into the cast to obtain the core.

By this, the inner core investment is formed with core suspended with core pins, which connects the outer investment (mould). This foundry idea saves cost, improve product, avoid problems of model waxing and mould de-waxing. He also introduces new material and direction altering the conventional method. The ability of the researchers to explore this technique using clay as an alternative to wax is fundamental to the research.

Casting as an indirect means of sculpture production implies substitution technique. This involves first, replacement of impermanent material with permanent material to duplicate a cast. The casting entails duplicating the mould, and second, to change the material of the model to a permanent one. Therefore, substitution of material for another material and substitution of technologies by other technologies" here is clay used instead of wax as case of lost wax technique.

Studies on Modification

The eccentricity of inventive cultural propensity invests it with atmosphere of continuity and dynamism which are of course the appurtenances necessary for the sustenance of any culture. Okoye (2008) speaking on first Bronze casting and

Blacksmithing workshop, under the theme: *Metal Working in Nigeria: Continuity and Change*. He sees the need for change and modification of bronze casting technology and black-smith in Igboland, mainly by Awka metal-workers. He recommends to them the need to synthesize ideas to improve their profession. He points out that: Here they will have the opportunity of being exposed to fertilization of modern technological ideas in bronze casting; black-smithing, welding theories and practices, our traditional bronze casters, blacksmiths and welders will learn new ideas and improve on their age-old technological skill.

Akin to this study, brass casting is kept alive at Igun Street in Benin City. There, the researchers gained more insight into "lost wax" casting technique from one of the Benin casters named *Izihiriga*. The process begins with waxing over a core of clay admixed with cow dump. They meticulously designed models of bust with rods and slabs of wax sculpted into forms. Red earth sourced from anthill was used to invest model and later tied with wires and reinvest. When dried, the mould is fired and wax runs away leaving cavity where molten metal was poured into. The mould when cooled was destroyed. The cast is then finished to shine. However, similarities shared with the above idea are comparatively the same on invention. On other hand, there is material modification of present study with the conventional methods. Hence, both processes maintain the same principle of substitution.

Studies on Casting Technology

Casting is a manufacturing process by which some liquid material is usually poured into a mould which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified is known as casting which is ejected or broken out of the mould to reclaim the piece. (wikipedia, 2015). Casting materials are usually metals or clay and some other cold setting materials that came after mixing two or more components together; such as gelatin gel, epoxy, concrete, plaster of Paris, and polyester resin. Casting technique is indirect modeling that most involve use of mould as means. It is always a technique for substitution and reproduction of an original 3D model. The substitution employed here to exchange a medium in one material for a duplicate form in another. The substituted material then becomes permanent. In this study, molten metals are used to substitute the clay for reproducing the metal castings.

Metal casting offers several advantages over other methods of casting. These methods of casting are adoptable to intricate shapes as strength and rigidity that can be given to intricate part which is not often obtainable through some other casting method of sculpture.

Ebhigbo (2001) in his study etitled, *"Art of bronze casting in Nigeria: continuity and change,* attempted to address the art of bronze casting in Nigeria, using Benin traditional cire-perdue technique, which is the method that wax is modeled directly on predetermined core as a specimen. Here, it was observed that it is at the point of positive wax finishing that the cast mould process and the predetermined core meet. Every other process from this point is closely the same until the molten bronze is poured, chipped and chased. Hence, the researcher suggested for the methodology from what he observed that because the transposition from clay to bronze involved two moulds and two castings. Therefore, the name changed to modern cire-perdue technique to differentiate it from the conventional method of direct waxing on

predetermined core. Thus, both researches conform to the process of experiment and absolutely the same in material substitution principle with the study on Lost-clay technique.

Studies on Production of Metal Sculpture

Throughout the ages, history has proved that metal sculptures have continued to serve tangible evidences reflecting the nature of the prevailing civilization or culture of the peoples that made them (Okonofua, 2000). The above expression is tied to the fact that indigenous technology such as metal-work is among the specializations and cultural heritages of some localities in Igboland. It is through this prism that culture can be x-rayed. They tend to be more practically oriented in their living, for instance, due to their proficiency of metal casting, there is proof in Igbo adage : *(igwe niile gaje n"uzu)* ,to back it up. Which literarily means that all metals must be forged.

At this juncture, the researchers conclude with the following attestation that "the metal works of today show a significant degree of diversity, uniqueness of style, fine-craftsmanship, diversity of typology and innovations. Anything short of this would have been strange, given the great technological strides mankind has attained in metallurgy" (Egonwa, 2008). The review tries to establish that modification on casting technique existed in different forms and this assisted the researchers with required knowledge. The work fills a gap in the area of metal casting and development of metallurgy in Nigeria.

Research Methodology

The research adopted an exploratory method. It explored locally sourced materials like metal, clay, sand and Plaster of Paris, scraps of bronze and aluminum metal were also used The study was also supported with some data. The source for data includes; gathering of primary data like oral information, and secondary information from library, internet services, photographic documentation of visual exercises supported with unstructured oral interviews. Thus, opinions were sampled through interview to find out the views of some metallurgist /sculptors – lecturers, students and, foundry, from the selected locality

Metal Casting: Methods and Materials

Metal casting process generally involves melting and pouring into a mould the molten metal material, which solidifies and takes on the shape of the cavity. Melting temperature of metals used for castings range from 232 ^{oc} to 3370 ^{oc}. The mould could be made of cement concrete investment, or POP plaster. The researcher used the modified method that substitutes wax with clay. This approach is related to cire-perdue and is called the "Lost Clay" technique an alternative cheap technique.

"Lost Clay" Technique

This is a special method of casting, used for metal casting by the researchers to reproduce sculpture through use of clay slab to line on the cavity. Casting in metal is achieved by removing the clay sheets laid in between outer investment and the core to form the cavity of the mould. Lost clay technique is a substitution process that allows the sculptor to work freely with clay then, transform the expression into a more durable material like bronze which could reproduce one piece at times. It is employed depending

on the nature of the sculpture to be cast. It gives an extremely good result with surface texture like cire-perdue, depending on the outcome of the clay model.

To understand the lost clay process better without confusing it with cire-perdue, it is necessary to know how the mould is made and what factors and processes are important to produce a good casting. The principle factors/procedures are:

- Modeling process
- Mould making Procedure
- Core-pattern making
- Mould retouching, Reinvestment and baking
- Melting and casting /
- Cleaning and Finishing

The Modelling was done with pliable or soft material like clay or plasticine which permits easy release for the mould. The design can take any form, be it relief or 3-dimentional. For the clay model, detailing of form must be completed before proceeding to mould making. Because of peculiarity of the mould making process, either a relief or simple 3-dimensional piece is suitable due to how the runners will be fixed. The fixing of runners continues after mould investment, after which nails/pins are strategically inserted into the model before investment.

Plate 1: Showing Sample of Clay Model of a head for plaster Mould of Lost Clay Technique, Photo: Chimezie Egwuonwu.

Plate 2 : A Sample of Relief clay Model of an Intended Plaster Mould for Lost Clay Technique. Photo: Chimezie Egwuonwu.

Mould Making Procedure

Plaster mould-investment is the most common method that is used for making the mould. Plaster of Paris (P.O.P) was groged with sharp sand, as additive to increase the refractory capacity of the substance. Clay wall technique was used to partition the mould into piece mould. The reason was to reduce the space that could be formed by the seam in-between halves. While dividing, undercut(s) were manipulated in such a manner that would not give problems, the ones on the edge of the mould were specially considered. Then, the preparation of plaster to water ratio % is 5kg groged pop to 2-2.5 litres of water, then mixed thoroughly to pasty slurry. With less water, the mould will be harder and stronger. It gives best mould results. The mixture plaster was then invested on the model with hand and improvised trowel. At this moment, care had to be taken, not to push or shift the nails and the clay wall out of position. The investment had to go round the model at equal thickness of 2-2.5 inches, depending on the size of the work, and allowed to set, the mould is second part-halve was taken on as the clay wall removed. The seams lubricated, after the mould release from clay model and nails withdrawn. See plate 3 after mould have been released from the clay model.

Core-pattern Making

Some lumps of leather-hard clay were rolled into slab of 3 – 5mm thickness. Cut into sizes, laid accordingly as a layer inside the mould over the plains, and curves. The clay sheet/slab predetermines the cast thickness. It therefore, depends on the researcher choice to control it to achieve the desired thickness. The edge of the mould must be laid to the seam and trimmed. Again, the same process was also repeated on the remaining halve in a of 3-d piece. Then some greasy lubricant applied on the clay surfaces. Later, the nails/pins reinserted into the former positions on the moulds, with both mould aligned in position. Next, mould was carefully bond with wire to engage them as the core is being cast. Then, some creamy slurry mixture poured into the empty space of the mould to beam level. When the plaster sets, nails withdrawn and mould opened to release clay sheets from the both halves.

After which the core repositioned in the half moulds, holding with nails reinserted. Lastly the second halve fixed and the nails reinserted to suspend the core. At last the mould rebound, seam closed up with some plaster, see plate 6.

Mould Retouching, Re-investment and firing

In mould retouching and baking, another plaster was mixed and used to cover the seam and unwanted opens on the mould. At this point, the funnel has to be formed to connect the cavity. Also the vents created through the mould to the cavity, passages to ventilate gases and heats. Finally, the mould was placed on the fire and continuously turned to have all sides seasoned. When ready for cast, it would be checked if anything felled into the mould and if so must be cleared.

Melting and Casting

During this process some scraps of metal was packed in a crucible sourced from discarded refrigerator compressor. Then, placed in the hearth charged with hardwood – charcoal plus palm kernel char sprinkled with some mixed wasted engine oil and kerosene and it was ignited. The aluminum scraps melted at melting point of 930°c. The fluid was skimmed and slag was removed. Already the mould has been positioned unto the casting sand pit. Subsequently the dross was scooped and the crucible was carried out of fire to cast molten metal into the mould. When molten metal is poured into the mould there was free flow because of it was well seasoned. When the cast solidifies, the mould was broken. It was released by knocking out the mould with hammer, pneumatic chisel and drill. The investment core was also removed and the cast reclaimed.

Cleaning and Finishing

The cleaning and finishing involves cutting away of the vents, funnel and chasing of some unwanted spike on the cast. Later, some abrasive was used to polish the surface to shine. The clearing and finishing involve cutting away the vents, funnel and chasing of some spot unwanted on the cast. Later, some abrasives like sand-paper, scrubbing powder and wire brushes were used to clean and polish the surface to shine.

Plate 3: Showing Slabs of Clay and Process of obtaining the Core for the Pop Plaster Mould

Plate 4: Showing the researchers casting core of a mould used for lost clay technique

Plate 5: Showing in Pieces the two Half Halves and Core of the Mould

Plate 6: Showing the Last Plaster Coating after the Second Bind with Wire.

Plate 7: Showing a Cast Produced Using "Lost Clay"

Plate 8: Showing Some Bronze Casts using Lost Clay Technique

In summary, lost clay technique is efficient, economical and time saving. It shows a significant degree of diversity, uniqueness of style, fine craftsmanship and innovation. However, the technique used has its own implications, advantages and disadvantages. For example, it can only produce a cast at a time like the traditional cire-perdue technique.

Project Analysis, Evaluation and Discussion

Casting has being one of African's favorite methods for indigenous metal technology. The advanced cultures of Nok, Ife, Benin, and Igbo-Ukwu antiquity convey the practice of casting in lead, iron, copper and copper alloys (bronze and brass) with the complicated cire-perdue technique and solid casting to the present era. In the setting of indigenous metal founding, marvelous works were produced using style, materials and techniques: though struggled with the limited possibilities of their traditional tools to produce works. But this research advanced to provide necessary knowledge on the practices in use of methods and materials.

Materials like charcoal, palm kernel chars, brass, aluminum, flux, talc powder, red-earth, P.O.P, among others were materials used to carry out the casting processes. These materials employed increased artists understanding them, with their accompanying characteristics. Nature of some material was limited to this particular technique it was applied, and size of cast to be reproduced. Understanding these materials characteristics, the right tools to be used, and the techniques adopted do affect

outcome of the casting. For example, Plaster of Paris (PoP) exhibits outstanding properties like rapid setting, bounding and refractory ability. It withstands certain degree of thermal shock and heat temperature at maximum of 210$^{oc.}$ Therefore, it is capable of substituting red earth for mould-making. Furthermore, the procedures involved in reproducing the mould and the final sculpture presented some experimental task that demands careful observation.

The common distinctions of Lost clay technique are cost of mouldmaking, process of mould-making, size of the sculpture and desired surface finishing. By this reason, the casting technique was suitable techniques for all metals cast in course of the study. It is comparatively cheap.

The technique is suitable for simple detailed piece. The mould- making is easy and faster. From clay model (positive) plaster investment mould is achieved, released and substituted with sheets of clay which is cheaper means. However, use of mould cast from lost clay technique has benign health effects. It does not cause emission of mono-oxide or fume when cast. No turbulence in the mould because neither there was any elements of wax, nor moisture in the mould. And when piece is completed the surface has fine finishing as good as cast from cire-perdue method.

Conclusion

Without a good choice of research methodology the results of this study would not have been possible. This methodology helped in employing this clay medium, used in different forms in sculpture production to also fit in, in place of wax as in lost wax technique of casting. This study discussed the process of lost clay technique and its procedures. The clay material used in this project has been up graded from the level of material to modeling to that of wax in lost wax technique of casting. This study has made the materials, processes and ideas in casting unlimited. Excluding clay only for modeling during casting will be covering its expressive attribute. The study have revealed clay expressive, potentials and opened up more vistas in the area of metal casting.

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