PRODUCTION OF PORTABLE FURNACE USING LOCALLY SOURCED MATERIALS FOR FOUNDRY PRACTICE IN ART SCHOOLS IN SOUTH EASTERN NIGERIA

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Abstract
A furnace is the primary source of heat for melting and processing of metal used for casting metal sculptures. The insufficiency of furnaces for foundry in the art schools in the Southeastern states of Nigeria caused mainly by the exorbitant cost of foreign-made furnaces impelled the researcher to carry out this study. In view of the problem, the researcher explored the possibilities of up-cycling to fabricate a portable furnace from waste and locally sourced materials. Theory of heat was adopted to guide the research. The aim of the research is to explore waste and locally sourced materials for manufacturing a portable and energy-efficient furnace fired with used engine oil and charcoal. The study is studio-based research hence a mixed research approach was employed. The study employed quantitative and qualitative methods. Data for the study were gathered through Primary sources mainly sources such as interviews, observation and group focus Discussions while secondary sources are written materials, published and unpublished, such as magazines, books, lecture notes and internet sources. The study also used questionnaires to elicit information from respondents' instruments were scaled with 5-point Likert's scale of rating with 50% as the cut-off point. The practical project entailed the use of clay materials, fibreglass, Sheet metal and junk for the furnace construction. Also, an electric motor was used to fabricate a blower powered by electricity, which supplys oxygen to combust the used engine oil, and charcoal used for firing. During the test to cast sculpture, heat energy produced was estimated up to 1400^{o}**c** with minimal monoxide emission. It was observed that the furnace is easy to operate, repair with a low cost of maintenance. The study reveals that through exploration of these waste materials, cost of manufacturing was reduced considerably. The research also proved the possibility of using locally sourced materials such as used metal for the fabrication; charcoal, and used engine oil for operating portable furnace. It was also observed that the portability of the furnace offers significant assistance in decongestion of studio because of the movable wheels. Furthermore, it will ultimately lead to achieving efficient teaching of foundry techniques in art schools in Southeastern Nigeria. This furnace is suitable for medium and small foundry workshops. The use of such foundry in the cottage foundry industry will increase returns and improve the economy. The study recommends that Art schools should work to construct their furnaces using locally sourced materials for enhanced teaching and learning.

Keywords: Portable furnace, locally sourced materials used engine oil, charcoal, foundry, cast metal sculpture.

INTRODUCTION

Development of furnace started with the early man when he advanced from the use of stone tools to fashioning tools out of smelted ore - bronze and iron (particularly in the period between 500BC and 700BC). In Nigeria, Nok was reported as the earliest culture associated with metal works from early 400 BC because there was a tin mine at Taruga near Abuja

where many iron smelting furnace were found. Furnace assumes great importance as a means of manufacturing metal sculpture and a bedrock for engineering production. One of the earliest furnaces was the primitive type which functioned mostly with natural draught or type of air blast with bellow. This is a very simple one where charcoal, coal or coke combust with supply of the draught. However, these days the winds of inventions bring change to assorted class of furnaces. As a result, they are identified by the energy they use as well as their operational modes or capacities which are modified.

Indeed, furnace is the main equipment used for foundary of tools, artifacts and machine parts. The use of metal casting technology in recent times represents an under-exploited though has a competitive cost advantage to manufacturers. Liquid metal manufacturing offers lower-cost parts in connection with their ability to cost complex configurations in near-achieved forms that in some cases are unattainable by other manufacturing processes, (Eljack 2005). For ages, a furnace has been useful metallurgy equipment for processing and smelting metal. Adikwanduaba (2005) posits that: melting is changing metal material from a solid to a liquid state by application of heat energy from the furnace, hence, the melting caused by heat collapses the crystalline structure of metal or glass as the case may be, so that particles liquefy and flow freely". Secondly, when it is employed to fire or process non-metallic material like refractory clay substances the state of the substance changes. However, the control and application of fire is of course is one of the things that interest man to manipulate technologically and would in turn greatly assist developments. So, there is a continuous search to control and manipulate fire for the advantage through the use of furnace. As a result, the application of fire on a large scale (pyro-technology) marked the first truly industrial activity, (Fire and Metal My Geology, 2015).

Furnace is a versatile piece of equipment with a field of application that is widely employed in various forms of metal works in Arts and Engineering. Foundry practice hangs on the availability and efficient use of furnaces to produce metal works and process or transform materials from one state to another by producing heat used for the soldering, smithing, forging and founding. Heat is usually applied to the furnace either by combustion of fuel, solar energy or by electric resistance heating, (Manabhanjan, Ivan, & Dipt 2015). It is equipment that produces thermal energy used to affect the breakdown of molecules in material placed within it. Certainly, it is crucial in foundry practice.

Against this background, the use of furnaces in foundry also as teaching aids in schools delivers a fulcrum balance between practical research and theoretical knowledge so as to enhance teaching and learning in higher education in other to achieve expected goals. Unfortunately, the researcher observed that furnace unavailability in the studios of most Art schools is a hindrance to study and practice to a large extent. The educational institution is a place where teaching and learning impart relatively permanent changes in behaviour or capabilities resulting from the learning experience. Therefore, technological advancement in this area is requisite to enhance development because the purpose of education is not mere intellectual development but the ability to put the intellect to work in practical terms. This has been the missing link in educational efforts or perhaps it is waning, (Udu, 2016).

From the researcher's experience during his undergraduate and postgraduate studies, lessons on foundry technique were based on theory, in rare cases, casting was done outside the school with folk furnace to melt non-ferrous metal. The researcher observed that the unavailability of a furnace in most art schools is the major problem militating against students in foundry practice. This problem spurred the researcher to embark on providing a cheaper/ more convenient alternative. Golorunnishola, Ojaomo, and Onibon (2019), reported that: "There are about 160 foundries in Nigeria at various levels of life and death conditions".

In other words, the cost of acquiring imported furnaces hampers practice. Besides, the designs of some of these imported furnaces do not hold out for proper use in teaching and learning. Again, the size and operation are not suitable for sculpture specifications and use in the small-scale foundry practice in Art schools. Momoh (2005), as cited in Ogundu, Morgan and Ibeawuchi (2015), rightly stated that: "the school workshops, laboratories and the environment where vocational education is given must be adequately equipped to reflect the actual working environment". So, studying or teaching in a studio/workshop without a functional furnace challenges the ingenuity of the teacher and makes learning defective.

Absence of furnaces in sculpture studios as a teaching aid is not proper for art schools. Furnace is required in art schools for effective teaching and learning, in both public and private institutions of higher learning. This idea is in line with Nigeria's National Policy on Education (2004) which seeks among other things, to create and promote self-realization, better human relationship, individual and national efficiency, effective citizenship, national consciousness, national unity, as well as or cultural economic, political, scientific and technological advancement.

Statement of the Problem

Certainly, furnace has been the fulcrum around which every other foundry practice hangs. Unfortunately, coming to the area of sculpture there is a lack of the required equipment for foundry practice in most institutions of higher learning in Nigeria. This problem was caused mainly by the unavailability of a furnace. Again, most of the modern furnaces are imported into the country from overseas of which some are unsuitable for casting metal sculptures. Looking at the imported furnaces, their sizes, source of energy used and mode of operations do not hold out proper use for small-scale studio practice in sculpture. Given this problem, the researcher embarked on the design and fabrication of a portable furnace with an emphasis on locally sourced materials in order to reduce the cost of production and increase its availability, affordability and efficiency.

Aim and Objectives of the Study

The aim of the study is to use locally sourced materials in the construction of a portable furnace operated with used engine oil and charcoal, and suitable for metal casting in Nigerian Art schools.

Objectives of the Study

The study set out some objectives which include;

1. To use locally sourced materials such as scraps of metal, used engine oil, wood and clay in constructing an affordable furnace powered with cheap energy such as waste engine oil and charcoal.
2. To ascertain the potentials inherent in used engine oil and charcoal as energy sources with low cost of operation and maintenance.
3. To identify strategies for improving the use of locally produced furnaces in teaching and learning sculpture.

Research Questions

- What is the possibility of using locally sourced materials such as scraps of metal and clay and energy sources such as used engine oil and charcoal for operating a portable furnace?
- What are the potentials inherent in used engine oil and charcoal as energy sources with low cost of operation and maintenance?

- What are the strategies for improving locally produced furnaces to meet the challenges of teaching and learning metal sculpture in Nigerian art schools?

Review of Related Literature and Knowledge

Concept of Furnace

Metal to be cast has to be in a molten or fluid state before pouring into the mold and a furnace is used to melt metals, (Khanna, 2015). A metallic substance is first heated in the furnace until it becomes molten, and it is then poured into a suitable negative mould. Furnace states that: "they are devices used to provide heat for an industrial process, typically higher than 400^{o}c They are used to provide heat for a process or can serve as reactor which provides heat of reaction". In the words of Rajiv (2006), "A furnace is an equipment used to melt metals or glass for casting or to heat materials to change their shape or properties (heat treatment)". In this regard, a furnace is a device in which the chemical energy of fuel or electrical, even solar energy is converted into heat which is then used to raise the temperature of materials called burden, charge or stock placed within it for the purpose, (Gupta 2010). Surely, the most distinctive innovation of man to harness materials is through the metallurgical furnace.

Every type of metal melting furnace fires on the same principle of releasing heat energy at a higher degree, although it has classes depending on fuel types, mode of operation, material handling system, structural form and construction. Furnaces operating at low temperatures are Oven and Stove. The Oven usually function as an apparatus for baking while Stove go for soldering and other functions. On this note, Peter & Barric (2014), affirm that: " The principle objective of a furnace is to attain a higher processing temperature that can be achieved in the open air". Again, the process of metal melting and blending into soluble or solid matter is uncommon with other heating devices like the kiln, oven and stove because melting requires immense heat compared to these other devices. Furnace is the most commonly used device for higher temperature and industrial processing. On the whole, a furnace can be fired with different types of fuel such as liquid, gaseous, solid fuel and electricity. Few operate with fuels usually aided with forced draughts powered by low shaft of mechanical energy from a motor fan.

The study is focused on crucible furnace, it is one of the oldest and simplest types of melting furnace in foundry practice. In a crucible furnace, the metal charge is placed and melted in a crucible. A crucible is made up of silicon carbide, graphite or other refractory materials and it can withstand high temperatures. A crucible furnace is though mainly used for melting of non-ferrous metals and (low melting point) alloys; it has been and is being used for melting cast iron and steel also. A crucible furnace consists of a steel shell provided with refractory (firebrick) lining from inside the pot. (Elijack 2005).

This project is a bale-out/ lift out crucible furnaces in which crucible can be lift out using long tongs. Principally, it is economical for melting small quantities of non- ferrous metals. Adikwanduaba (2018) noted that "for small foundries, the crucible furnaces are very convenient because the operation is intermittent and various alloys are handled in small quantities". Hammed, Amosun, Adebesin, Aikuele and Kaffo (2021), note that: "the main reason why oil-fired furnace is commonly used is that they are not expensive, easy to operate, melting of small batches of different alloys which are melt directly in the furnace and the maintenance ability is economical friendly". Therefore, its size and function of the produced by the researcher makes it appropriate and for small scale casting for teaching and learning purposes.

Theoretical Framework

This study is underpinned by two – prong theories. They are theories of heat and formalism. Theory of heat was applied in the analysis of the energy reaction in the study. It is germane to the design and constrution of the furnace as system used for heating objects. Second, formalism theory offers elaborate structural description of the furnace in respect to how materials are employed to manufacture every component.

The project employs Theory of heat as thermal energy perceived to be the basis of the furnace and foundry activity. Foundry depends on energy to heat and process materials. In this regard, heat, chemical, mechanical and electrical are the forms of energy required for the transformation or processing from one stage to another.

In 18th Century Caloric theory was proposed in 1789 by French Chemist Antoine Lavoisier. The theory explained heat as fluid-like substance. It was assumed to be invisible and weightless fluid substance that could neither be created nor destroyed. The temperature increases or decreases when flowed in or out of a body. Hence the theory contrasted with the idea of mechanical theory of heat. But modern scientists hold the microscopic view of heat. Later, the theory of heat or mechanical theory of heat was introduced in 1798 by Sir, Benjamin Thompson. He rejected Caloric theory and correctly guessed that heat was in form of energy that could be produced by mechanical means. The Theory was further developed by other scientists.

The heat transfer of the energy in form of heat is used to melt the charge placed in the crucible for cast. Adopting the theory of heat or mechanical theory of heat is consequential to the energy interaction between this furnace, and the components. This specifically explains the function of blower (electric fan) and energy activated in the hearth in form kinetic energy.

Consequently, Theory of Heat is the principal theoretical framework adopted in this study. Adaptation of the Theory underpins the significance of heat energy transfer in the furnace and functions in other foundry processes. The reaction is between matter (materials) and heat energy; this action causes a reaction which produces the effect, as heat liberated from fuel used. Hence, the change produced by reaction is mainly essence of the theory.

Formalism theory

This is one of the oldest theories of aesthetics; it dates back to the time of Plato, Aristotle and Kant. Philosopher Plato was the first to develop a theory of forms that based on appearance, (The Art Story, 2021). It is called Imitation Theory which states that art is imitation of nature. Later, Immanuel Kant further developed the modern form of the question of aesthetic formalism.

Reason for considering formalism theory here is because of significance to structural analysis whereby attention is giving to the structural arrangement, style and element of design. This can be explained by the structure and elements combined to form the expressive idea.

Research Design

The study employed survey design meant for collecting, analyzing, and measuring of the varibles observed in the research problem. Mixed research method (qualitative and quantitative)research designs were adopted because of nature of the study that involved material exploration and describing data collected.

Study Area

The study area comprises the five South-eastern states of Nigeria made up of Igbo speaking culture; the geo-political region comprised the following states namely, Abia,

Anambra, Ebonyi, Enugu and Imo States. It is located within latitudes 4° 47‟ 35‟‟N and 7° 7‟ 44‟‟‟N, and longitudes 7° 54‟ 26‟‟E and 8° 27‟ 10‟‟E in the tropical rain forest zone of Nigeria, with mean maximum temperature of 27oC, and total annual rainfall exceeding 2500mm (Ezemonye and Emeribe, 2012). There are a good number of educational institutions both public and private in the area. The study was carried out in the federal and states owned tertiary institutions which comprise of fifteen (15) federal and States tertiary institutions (Universities, Colleges of Education and Polytechnics) that are offering Fine and Applied Arts as areas of specialization.

Map 1: Map of the Southeast Geo-political Zone of Nigeria Showing the Five Component States
Source: Ezemonye and Emeribe, (2012)

Population of the Study

The population of study consists of 203 lecturers, instructors, technologists and Sculpture and Ceramics students in their third and fourth year of study from the 15 (fifteen) tertiary institutions that have Department of Fine and Applied Arts in the 5 South-eastern States of Nigeria. The population is made up of lecturers, instructors, and technologists in Universities 30, Polytechnics 14 and Colleges of Education 32, a total of 78 teaching staff and 125 students. They comprised 9 (nine) federal tertiary institutions (Universities, Colleges of Education and Polytechnics), and 6 (six) state Universities, Colleges of Education and Polytechnics.

The purposive sampling method was used – where those respondents interviewees were considered to possess the required attributes or information in which specific elements that satisfy some predetermined criteria are selected. Nine Art schools were selected (Department of Fine and Applied Arts) with options from Sculpture and Ceramics namely: Nnamdi Azikiwe University, Awka; Alex Ekwueme University, Abakilike; Imo State University, Owerri; Federal Polytechnic Nekede, Owerri; Federal Polytechnic Oko, Federal College of Education, Ehamufu, Abia State University, Uturu, Alvan Ikoku University of Education, Owerri, and Nwafor Orizu College of Education, Nsugbe.

Among these Art schools selected, respondents sampled bring the total to 86 comprising 26 lecturers, instructors, technologists, technologists and 60 students under Sculpture, and Ceramics resulting in about 51% of the total population selected.

Instrument for Data Collection

A structured oral interview was used to elicit responses from respondents. Instrument in the questionnaire consists of two sections, A - is designed for personal data of respondents. Section B has 22 – items in all developed from the three sets of questionnaires from data of the research questions. The twenty-two (22) items structured questionnaire developed by the researcher is based on the three research questions: "Production of furnace for casting metal sculpture in Art schools" (PFCMAS) was used to collect data. The instruments developed consist of compound instruments developed on multiple variables. Items of the instrument will be answered on a five (5) point Likert- type rating scale of Strongly Agree =(SA), Agree =(A), Undecided =(U), Disagree =(D), and =Strondly Disagree (SD) was used to develop the instrument of the research 1, 2 and 3. In research questions, the respondents were required to respond to a question by ticking the appropriate spaces. Later, it was collected and analysed using percentages.

Method of Data Analysis

In this study, the researcher analysed data obtained from respondents using quantitative and qualitative data analysis. The data collected were analysed using Percentage and the 5 – Likert scale of rating instrument with a 50% cut–off point. Items scored 50% and above were accepted; while scores below 50% were rejected.

Production of the Furnace

Several activities involved in the process of constructing components of the furnace included; collection of scrap, arrangement, forging of patterns, welding, clay-body preparation / lining, and finishing. The fabrication entails using tools such as a hammer, hack- saw, G-clamp, chisels, scriber, brushes, vice, arc welding, drilling machine, and rubber mallet, measuring tape, rule tape, painting brush, bending table and angle drilling machine, to manipulate the locally sourced materials for the construction. These materials include:- selected automobile metal junks, metal junks, pipes, electrodes, clay materials, and fiberglass among many others. In this case, it is the service which objects deliver that ascribes value to them, (Ashworth as cited in Vines 2005). Upcycling the materials not only saves money but also reveals the ingenuity of the sculptor in exploring the potential of waste materials. It also reduced the hazards it could cause to the environment. Consequently, the approach is in line with the idea of engaging waste materials as significant economic resources. The design consists of three main components (the shell, blower, and oil tank) that work together as the furnace.

3.9.1 Source of Tools and Materials

Plate 1: Picture of some Materials (junks) used for the Construction of the Furnace

Source: Photograph taken by the Reseacher.

Plate 2: Showing Source of Oil used in Operation of the Furnace. Source: the researcher (2023)

Stage One: Design Development

Designing of the furnace component was first put into free hand sketch and drawingexploredwith the three basic forms, the sphere, cube and cone (to reality). In this aspect, the researcher recognized the basic and structural forms relevant in the constructions. Also, these drawings guided the artist on how best the construction should follow so that readers can understand and analyze the construction accordingly.

Fig 1: Presents Sketch of the Proposed Model . Source: the researcher (2023)

Fig 2: Presents Sketch of the Proposed Model Oil Tank. Source: the researcher (2023)

Under this design process, the conceptual design was illustrated with a thorough understanding of the furnace functions and how these functions are to be undertaken. The initial stage taken was the concept development of the design. Planning the object from some selected materials available and exploring them to produce the major components. The idea to have the furnace form in cylindrical orientation was chosen based on functionality. This selection, stems from the fact that fluidity movement and kinetic nature of flame in the annular gap best move in centrifugal with the thin space in the combustion chamber.

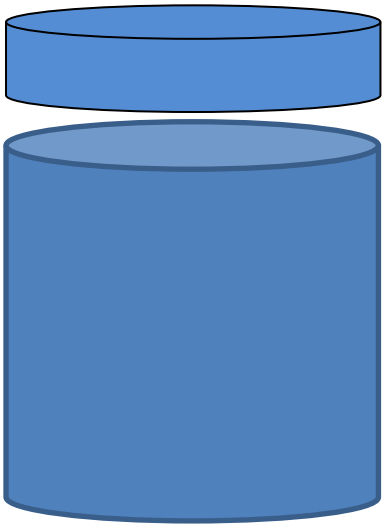

Fig 3: Cylindrical form of the shell.
Source: the researcher (2023)

Design Composition

The furnace was fabricated as a system with three different components:- a cylindrical structure of 70 inches high by 24 inches diameter for the shell, a 5-foot high oil tank stand with a 10-litre oil tank and a custom-made electric blower. Each component was craftily produced in stages. The arrangement of the completed furnace is such that the fuel tank stands apart, separated from the combustion chamber and the electric motor (blower) bears the power regulator/control panel, all to be portable.

Stage Two: Metal Fabrication - Fabrication of the Shell and the Burner

The shell was cut and formed from 18 gauge sheet metal, measured 70 inches in width x 25.5 inches in length and was bent using a table and hammered to the shape of a cylinder 24 inches in diameter. The bottom plate was cut with an angle grinder machine after the plate was welded into drum form. Subsequently, at the base of the drum 5 inches above, a space for a burner where oil meets with a blast to produce heat was cut open.

Plate 3: Showing the Researcher Hammering the Rolled Sheet Metal
Source: Phot by Gaius.

Plate 4: Researcher Welding on the wheels on the base of the Cylinder
Source: Photograph taken by Gaius.

Next was the burner,2 inches thick round pipe was cut out 12 1nches long,a thin hole bore at the middle to insert a thin pipe or oil sourced from discarded automobile part. The thin oil pipe was bent, inside the draught pipe facing towards the hearth and the exterior it was fixed with bolt and nut. Later, the former oil/air duct was passed the refractory walls, tangentially located the hearth at 45^{o}c and was welded on the shell. The duct connects the blower and oil channel,to facilitate combustion.

Plate 5: The Picture of the Formed Duct Channel Welded to the Shell.
Source: Photograph taken by the Researcher, (2023)

Stage Three: Forming Cover of the Furnace

The shell top was marked 5 inches and cut round to realize the rim that formed the cover. The rim was coved with plates formed in octagon shape. Ssubsequently, both ends were seemly rimmed 1 inche allowance with 5mm metal bar to reinforce the edges of the refractories against collapsing and to prevent heat loss. Later, vents were attached to the top of the lid, and the two sides. Then a pivot for lifting lid was welded with 20mm pipe from inside wall of the heat chamber. Also, on wall of the lid where both sides connected to each other, a 1.5 inches pipe was inserted through the connecting hole to enable the lid move tangential on horizontal axis, for opening the furnace. Finally, a socket was fixed for the handle to carry and slide open the furnace cover open when need to feed in charcoal or bale in and out the crucible.

Plate 6; Shows How Top of the Cover was Welded on Shell Before Cutting.
Source: Photograph taken by Gaius.

Plate 7: The Researcher is Shown Cutting Open Spaces for the Vents
Source: Photo by Gaius

Stage Four: Fabrication of Oil tank with a Stand

Fabrication of the oil tank and stand started with selection and composition of the available materials suitable for the design. Discarded car exhaust drum was cut open to remove the inner fittings, carbon remains were also cleared and washed. Later, the cut part was replaced and welded with oxyacetylene. The terminal pipe on the drum was created to serve as filling opening to create as filling opening, at the bottom side outlet pipe was fixed and hose was joined to it. Finally, it was painted with gray enamel paint.

The oil tank stand was fabricated with the available 14mm metal rods and 2 inch channels selected from scrap. The 14mm rod was cut 5feet, bent curve at one end welded to support the two sides of the framed channels. It was also reinforced in-between with 2 pieces of 14mm metal rods. A 14mm rod cut into 2 pieces of 18 inches bent curve and welded perpendicular projection to serve as the hanger for the oil tank. This was also connected across with metal rod. Then, on the top of the stand is a locket which was formed and welded using angle bar and curved flat metal bar. Two Holes were bore on two sides for the nuts and bolts to guard the locket.

Plate 8: The Researcher Shown Cutting and Removing the Exhaust compartments
Source: Photo by Gaius

Plate 9: The Researcher Mountting and Examing the Oil Tank Stand
Photograph taken by Gaius.

Stage Five: Construction of the Blower and installation

Considering capacity of this crucible furnace under investigation, a suitable air-drafting blower was comstructed to support the fuels. The researcher selected a fan with moderate speed of 1240 RPM. From 20 gaugesheet metal 2 round plates of 8.5inches' radius measured cut o size the blades rotation. Then, one was centrally cut 6 inche open to draft-in air. Then, a rectanglar sheet metal was cutand bent for the cylinder pattern measuring 5 inches wide and 30 inches long. It was welded to form the air blower, and a space created for air outlet with pipe connected to the furnace for air inlet. Then, the cover was rimmed and holes for the spindle shaft, bolt and nut drilled to mount the electric motor. At last, the welded spots was grinded, filled with body-filler and smoothened. It was Painted using pressure spraying gun. Later, the electrical components installed with assistance of technician. The electric motor spindle was passed through the hole and mounted with capacitor on the blower with nut and bolt. Finally, the electrical connection was tested to observe how it works.

Plate 10: The Sculptor Cutting Open a Void for Air Draft-in the Box.
Source: Photograph taken by Gaius Ikenna.

Plate 11: The researcher fixing the Blower on the Casing. Source: Pix taken by Gaius Ikenna.

Stage Six: Preparation of the Refractories and Heat Chamber Installation

Bentonite clay and kaolin were sourced locally from Amaokpala and Ukpo communities, all in Anambara state.They were sun dried, crushed, sieved and mixed in water with terracotta grog at ratio of 1: 3: .5 to prepare for the mortar coating and brick. Purpose of this clay combination is to enhance the insulation capacity instead of using other materials like glasswool or asbestors as basic insulator.

Plate 12: Showing the Researcher Pounding the Clay Used for the Refractory. Source: Photogragh taken by Gaius Ikenna.

Plate 13: Sample of the Brick used in the Combustion Chamber.
Source: Photo by the Researcher.

A portion of the prepared clay was used to mold bricks, size 9 x 5 x 2 inches. The molded bricks were later seasoned for 1 month under controlled temperature of during dry season. The installation sequence was cut of fibermat blanket layed first on bottom and wall before the clay slab. The clay slab was rammed 4 inches slab to fill in the lid and around the chamber wall after bricks lay on. It was exposed for dehydration to shrink to size for two months. Subsequently, fire bricks were layed round the rammed clay wall with kaolin mortar. The bricklaying has only two coaches of stack bond soldier.

Plate 14: The Researcher filling and Ramming Refractory Clay on the Furnace Lid with Sheet of fiberglass Under.
Source: Photograph taken by Gaius.

Plate 15: The Researcher Filling and Ramming Clay upon Fiberglass Lining in the Combustion Chamber.
Source: Photograph taken by Gaius.

Plate 16: The Completed Furnace
with the Components. Photograph taken by Gaius.

Operation of the Furnace

The project is a crucible furnace fired with waste engine oil and charcoal. The combustion chamber works alongside the oil tank when the blower is connected through the fire exchanger and electrical source is switched on. From the tank, oil flows through distribution channel down into the air blast duct where the atomised oil mixed up to fire. From the energy source charcoals aglow as the flame is ignited. Then combustion continues in the chamber. Quality of waste engine oil considered suitable is a low viscous type, on the contrary, high viscosity causes poor supply and combustion. Therefore, distillation of the oil will cause it to pump and ensure easy atomization. As this continues, charcoal burns freely and the flame emits satisfactory heat in the combustion chamber to heats up, heat is transferred by radiation in centrifugal motion and cross-section wise round the crucible necessary for melting metal scrap. Through the flue chimney (vents), the furnace releases the monoxides and gases. It also maintains pressure in and outside combustion chamber. However, consideration was made to reduce the gas passage to moderate allowing at least only 10% – 20%. This is one aspect that hold out both undeniable danger of explosion and extraordinarily save energy from loss. In addition, the furnace is constantly covered to reduce loss of heat.

Results and Discussion

This section deals with the presentation of data and analysis of the empirical survey, description and interpretation of the findings of this study. As was pointed out earlier, the data collection included interviews, questionnaires, observation and review of literature on the subject. The theoretical studies focused on the philosophy of constructivism. This section also analysed the data collected from 86 (eighty-six respondents) from the sampled institutions that offer Sculpture and Ceramics. The results are shown in tabular forms for easy comprehension and the data is tabulated with respect to the items in the questionnaire. The result therein determines whether an item is accepted or rejected and was decided by finding the 50-percentage cut-off point of the responses as shown.

Data Presentation and Analysis

Section B: Research Questions

Research questions 1: What is the possibility of using locally sourced materials and energy sourced, such as used engine oil and charcoal for operation of a portable furnace?

Table5 Respondents view onlocally sourced materials for fabrication and energy source for the operation of portable furnace.

Items	SA	A	U	D	SD	Total Agreed	Total Disagreed	Total Respondent	Total Percent
Metal scrap (sheet metal, angle bars, flat bars, rods, pipes, nuts and bolts)	40 46.51%	29 32.72%	-- --	11 12.79 %	6 7.0%	69	17	86	100%
Automobile metal junk (pulley, brake- pad back iron, washers)	30 34.9%	24 27.9%	6 7%	16 18.6%	10 11.6%	54	32	86	100%
Locally sourced refractory clay	50 58.14 %	28 32.56 %	-- --	8 9.30 %	-- --	78	8	86	100%
Used engie oil	48 55.81%	18 20.9%	3 3.49%	13 15.11%	4 4.65%	66	17	86	100%
Charcoal	52 60.47%	27 31.4%	0 --	5 5.81%	2 2.33%	79	7	86	100%
TOTAL						**346**	**81**	**430**	

Source : Researcher's Field Survey (2024)

In the above Table all the items received positive returns as most of the respondents agreed that all the items are essential and either used for construction or used for firing of the furnace. The respondents agreed that scrap (metal sheets) isessential for fabrication as 80% attest to this while only 19% disagreed. Furthermore, automobile scraps are also considered essential for fabrication of the furnace parts as up to 63% of the respondents agreed to this, whereas 30% disagreed. Locally sourced clay is vital materials in fabrication of heating device especially the lining, based on this, majority of the respondents agree 91% while just 9% of the respondents hold contrary view.

On the source of energy, respondents agreed that used engine oil and charcoal can make good combination with following results obtained 77% and 92% respectively. Also they are perceived essential energy source for the operation of portable furnace. However, 20% disagree on the use of used oil and only 8% of the respondents disagree on use of charcoal for the operation. Finally, 91% of the respondents accept that charcoal is an essential energy source for the operation of portable furnace wheras 8% disagree.

4.1.3.2 Research questions 2: What are the potentials inherent in used engine oil and charcoal as energy source with low cost for operation and maintenance?

Table 6: Respondents view on potentials of used engine oil and charcoal as energy source with low cost for operation and maintenance.

S/N	Items	SA	A	U	D	SD	Total Agreed	Total Disagreed	Total Responden	Percentage %
1.	Adaptive	32 37.2%	48 55.8%	**--**	1 1.1%	5 5.8%	80	6	86	99,9
2.	Sustainable	34 39.5%	27 31.4%	0	18 20.9%	7 8.1%	61	25	86	99.9
3.	Effective	67 78%	18 21%	--	1 1.1%	**--**	85	1	86	100
4.	Economic	58 67.4%	21 24.4%	--	**7** 8.1%	**--**	79	7	86	99.9
5.	Combustible	40 46.5%	21 24.4%		15 17.4%	10 11.6 %	61	25	86	99.9
6	Environmental friendly	36 41.9%	42 49%	2 2.3 %	4 4.7%	2 2.3%	78	8	86	100
7	Inflammable	39 45.3%	38 44.2%	--	9 10.5%	**--**	77	9	86	100
	Total						**521**	**81**	**602**	

Source : Researcher's Field Survey 2024

In Table 6 above, it was discovered that all the items, from 1 to 7 of the instrument received positive responses. This confirm the potentials of used engine oil and charcoal as energy source with low cost for operation and maintenance.This outcome was expected because of the quality of these fuels. Individually, agreed responses have the following percentage scores: - 93%, 71%, 99%, 92%, 71%, 91%, and 90% respectively. All the results are above 50% (cut-off point). These results implied that they agree with the identified potentials of used engine oil and charcoal as energy source with low cost for operation and maintenance.

Research questions 3: What are the strategies for improving locally produced furnace to meet with the challenges of teaching and learning metal sculpture in Nigerian Art schools?

Table 7: Respondents view on research question 3 **-** Strategies for improving locally produced furnace for teaching and learning metal sculpture.

S/N	**Items on Questionnaire**	**SA**	**A**	**U**	**D**	**SD**	**Number of**	**Percent age**
1.	Practical tasks should involve melting and casting.	64 74%	14 16%	--	8 9%	--	86	100%
2.	Regular lecturers' knowledge update on foundry technology.	30 35%	21 24%	1 1.1%	12 14%	8 9%	86	100%
3.	Ensure that there is conducive teaching and learning environment for local manufacture	52 60.5%	14 16%	0	16 18.6	4 4.7%	86	100%
4.	Ensure that there is efficient exploitation of waste materials with well equipped studio	74 86%	10 11.6	2 2%	--	--	86	100%
5.	Ensuring that there is interdisciplinary cooperation and schools synergy on the technology in schools	57 66%	25 29%	--	4 5%	--	86	100%
6.	Provision of adequate construction infrastructural facilities.	69 80%	13 15%	--	4 5%		86	100%
7	High taxation on imported furnaces.	34 40%	7 8.1%	5 6%	23 27%	17 20%	86	100%
8.	Indigenous technology innovation promotion by establishment of technological hub.	77 90%	9 10%	--	--	--	86	100%
9.	Organizing seminer workshops for students on benefits and potentials of foundry practice.	64 74%	20 23%	--	2 2%	0	86	100%

10	Government to set up motivational policy for invention.	71 83%	13 15%	--	2 2%	-- --	86	100%

Source : Researcher's Field Survey (2024)

From Table 7, in the analysis above, 9 out of the 10 items obtained positive responses with percentage value more than the 50% cut-off point, only item 7 got 48.1% score for agree which is below 50%. On the contrary, 47% of the respondents disagreed on the strategy, while6% response was undecided. These indicated disapprovals for the strategy, the view of High taxation on imported furnaces is not an acceptable strategy. In short the researcher alleged that respondents view might be that it will affect other types of furnace importation. So, it is not approved. Accordingly, answers to research question three, shows that every other strategy highlighted could be adopted to improve locally produced furnace for teaching and learning metal sculpture. Consequently,acceptance of these strategies will significantly improve and contribute to development of foundry in our art schools as well as advance the technological stand in Nigeria.

Discussion of Results

Research question One: What is the possibility of using locally sourced materials for the fabrication and energy source such as used engine oil and charcoal for operation of a portable crucible furnace? It was however, investigated and findings revealed that every item in the instrument received high number of responses. In item 1, metal scrap - (locally sourced material) receive positive returns of 79% while those that disagree is 19%. In addition, in item number 2 - automobile metal junk was identified as another possible material for fabrication of furnace and agree responses was rated 70% and 30 % of the respondents disagree. From list of works reviewed all the researches discovered possibilities of substituting material in their studies. For instance, Ogundu, et al (2015), improvised their Pit furnace with scrap sourced from automobile, a heavy truck wheel was used and refrigerator compressor for the crucible oil pot. Therefore, result findings of this study revealed that waste and locally sourced materials such as the metal scrap and discarded vehicle parts are considered the among list of materials useful for making of components of furnace. Local clay was found to have propriety suitable for lining of the furnace. It has favourable result from majority of the respondents with 91% agreed that local sourced clay was suitable and vital material for insulation of the chamber. Olusegun (2012) study presented estimation of his project: use of local sourced clay reduced the production cost of construction a bale-out crucible furnace with one-tenth cost of an imported furnace.

Items number 4 and 5 deal with used engine oil and charcoal as energy for operation of portable furnace. Indeed these items appears to be the most important things required for operating the furnace. In this regard, heat - chemical and, mechanical energies are forms of energy required for the transformation or material processing.

Opinion of the respondents on charcoal and waste engine oil is that suitable fuels used for operation of furnace are suitable. Used engine oil obtained 77% in favour from the respondent while only 23% of respondents disagree. In the same vein, 92% of the respondents agree with use of charcoal while 8% of the respondents answered negative. The results indicated that they are essential energy source for the operation of portable furnace. In addition, Ugwu and Ogbonnaya (2013), buttressed the result as they stated in their research that; "the choice of using charcoal instead of coke for their design was necessitated by the fact that charcoal is more available and abundant. Charcoal provided the heat needed for the

reactions in the furnace whilst at the same time acting as accelerator". Greatly, it has high calorific energy value than other solid fuels. In relation to the result obtained, studies like that of Olalere, et al (2015) Adeolu, et al (2017), Golorunnishola, et al (2019), and Adewuyi, et al (2020) whose researched on fabrication of furnaces fired with spent engine oil and it revealed that use of spent engine oil proved to be economical. Also, it is comparatively cheaper than gases (LPG, LNG, and CNG) and electricity as a source of energy for operation and maintenance of furnace. 'Necessity they say is the mother of invention', this phenomenon vividly manifested in current prevailing economic situation of our country where institutions of learning can longer fund students learning practices. Thus, invention of this equipment orchestrated exploration of waste to muffle economic condition of the country. On the other hand, Yusuf, Bahri, Awati (2022) state that the crucible furnace was designed hopeful to attain a maximum temperature of 700^{oc}.within shortest period. The research used Liquified Petroleum Gas (LPG) to fire their furnace and 6kg of aluminum machining chips melted at 700^{o}c temperature for 52 minutes. For sure, gas is faster for melting metal however, it is not the best option for our art school as supply can not be constantly maintained.

Research Question Two, focused on Potentials of used engine oil and charcoal as energy source with low cost for operation and maintenance. The analysis shown that seven of the identified potentials were all acknowledged as qualities characterized with the fuels. The results were expected with majority of the respondents agreed with positive view towards the perceived potentials. The total number of respondents that agreed on these potentials stood at 521 representing 87 % , while disagreed responses stood at 81 representing 13 %. With the result, it revealed that potentials of used engine oil and charcoal as energy source with low cost for operation and maintenance were acceptable.

Item number 1: Adaptablility - Respondents view on adaptability shown that it is a distinctive quality of the sculpture furnace. The basic function is melting of non-ferrous metals. It is designed to operate with dual fuels which can easily be changed to the alternative fuel without being malfunctioned. The findings of this study showed these fuels are capable of alternating each other in case of unavailability. In such situation the device works with single fuel and independently produce quality heat for melting. The findings of this study is also supported by Mastrukov (1986) who states that advantages of oil-fired and charcoal furnace are low investment cost, easy operation and maintenance ability and capable of melting of small batches of various alloy.

Item number 2: Sustainability - presents views of the respondents on Sustainability as potential of used engine oil and charcoal. The item scored 71%in favour which is very much above cut-off point. Only 29% was gotten from respondents that disagreed. This result indicated that the materials used for firing are sustainable. Obviously, operation of thefurnace is predicated on availability, abundance and efficient source of energy among other things, blower, refractory materials and tools being part of it. Nevertheless, energy is central to sustaintce of the operation.on this circumstances, sustainability is potential determinant of material application of energy.The furnace under-study fires with unconventional fuels considered to be readily available at all time. Certainly, a material must be readily available in large enough qualtity for the intended application. In terms of materials scarcity, this

constraint becomes significant, (Khanna 2015). Therefore, abundance and availability of used engine oil and charcoal as energy source in this study are found out to be essential base on what it cost and how much effective they could be.The study revealed that there are means of providing fuels and it is cheaper compared to diesel, gas or electric energy for furnace use.

Item number 3: Effectiveness – the responses from respondents shown that agreed got 99%. A possible explanation of this great result is that these fuels usually produce exponential resultswhen used in firing. Also, they are capable of producing thermal energy that melts metals. Consequently, the fuel consumption is something important for measure of quality construction. Thus, record of 2 litrers of the used engine oil and 2 Kg charcoal in 1-hour presented the device fuel consumption as economic and effective. Really, these fuels are cheap, cost less but in turn produce enormous effectin combustion. Furthermore, the application in this study immensely helped with optimal supply of heat. In similar study Sani (2015), supported the research when presented performance evaluation of his work by melting 10kg aluminum scrap with charcoal as the main fuel. He observed in his study that: " the required to melt 10kg of alminum to melting temperature QT= 35,859.13Kg in a duration of 1 hour 33 minutes, the total heat absorbed by the furnace components was QFC= 25,425.44Kj and the heat transferred to the crucible was QC= 14,118.72 xxii Kj".Comparatively, both furnaces share same capability of quick melting of metal and moderate consumption of fuel.

Item 4: Economic – Fuel economy plays significant role in selection of fuel type and the application to suitthe model. This is one of the important potentials, aimed at enabling usage with regard to cost-effective of the fuels. This factor apparently gave rise to the approach used for the construction which contributed to what should be value of material employed at the long run. It was discovered that respondents accepted potency of used engine oil and charcoal as being economical. Consequently, the cost reduction of materials in this construction and its management is a fundermental design principle justified at the planning for proper production, teaching and learning of sculpture. In line with this view, Mastrukov, (1986), highlighted that some of the advantages of oil-fired and charcoal crucible furnace are low investment costs, easy operation and maintenance ability. They are capable of melting small batches of various alloys, the melt can be treated directly in the crucible and the alloy can be quickly and easily replaced as necessary". Ogudu, et al (2015), did a study on reduction of energy cost and modification of foundry practice in institution of learning through fabrication of furnace. Finding of their study revealed that improvisation of furnace reduces cost of forging metals in college. In this regard, both studies are similar, they adopted charcoal as their source of energy for operation because of its cheap and available. In contrary, there is unstable power supply of electricity for industrial use. Gas on the other hands are expensive even the supply cannot be compared to cheap source of charcoal and used engine oil.

Item 5: Combusibility of furnace fuel material - is crucial to the performance, hence selection of used engine oil and charcoal were considered on ability of combustion. This research objectively considered the selection based on the previous observation of the materials in foundry operation. According to answers to the item 1, it was found that the nuture of the fuels resulted to what were obtained on it. As such application of these fuel materials were apt in view of the usage.

Item 6: Environmental friendliness – according to answers to the item it was found that potential of engine oil and charcoal as energy source are identified as environmental

friendly. The finding showed a surprising positive result from the respondents with little above 50% percentage cut-off point. Relating the result to a practical experience during firing,usually the combustion exbhits emission of monoxide at start and disappear at constant fuels combustion. However, study of Joakim (2004) revealed results inconsistent with present respondents view of research understudy. His study focused on thermal energy utilization expansion against adverse effect of the Nuclear energy at use in the countrywhich was successful substituted with biomass waste for energy. The study found out that biomass and fuels of the present research are not conventional energy source and have no harmful effect to the environment.

Item number 7 based on the capacity of these fuel to catch fire without delay. Both the solid and liquid petroleum fuel played complementing role in producing heat if ignited. The result buttressed fact that they are inflammable. Item 1, 2, 3, 4, 5, 6, and 7 were accepted by the respondents as the potentials. With these results, it could be deduced that the Potentials of used engine oil and charcoal as energy sourcewith low cost for operation and maintenance were recognized as essential. In addition, the researcher concluded that the potential attributes are good indices of the fuel for effective operation.

Research Question Three, was designed to find out views on strategies for improving locally produced furnace for teaching and learning metal sculpture. It was discovered that respondents accepted nine of the strategies with positive results, exceptt item number 7- (high taxation on imported furnaces) that was rejected. The agreed scored lesser than 50%, while 52.8% was obtained from discordents respondents who perceived the strategy unacceptable. According to answers of the research questions for improving locally produced furnace -Practical tasks should involve melting and casting; Regular lecturers' knowledge update on foundry technology**;** There is conducive teaching and learning environment for local manufacture**;** There is interdisciplinary cooperation and schools synergy on the technology in schools**;** Provision of adequate construction infrastructural facilities**,** Indigenous technology innovation promotion by establishment of technological hub**,** Organizing seminar/ workshops for students on benefits and potentials of foundry practice and that Government should to set up motivational policy for invention were all accepted as germane strategies. Findings of the positive responses revealed that those strategies for improving locally produced furnace for teaching and learning metal sculpture are satisfactory. While high taxation on imported furnaces was rejected as suitable strategy. The number of disagreed obtained greater percentage above 50% cut off point. Research suggests that respondents perceived the strategy as inadequate, it could affect every other class of imported furnace which will contrawise affect growth of the large scale foundry industries. Use of high taxation implies that they should be selective on some type of furnace. The result is disagreeing with NEEDS (2005) which states that: selective import restrictions are used as safeguards against unfair trade practices also to provide temporary protection to firms and industries that need to restructure and upgrade their technologies.

Furnace operational Analysis

At completion of the construction the furnace was put test to acertain performance and to determine the time taken to melt 4kg scrap metal loaded in the crucible. The design is crucible furnace which the mode of heat transfer to burden (material) is through radiation and partial conductivity. So, inside the hearth heat does not come in direct contact with the melting material. It directly receives the electromagnetic wave imparted by a medium heated.

That is to say that metal scraps in the crucible receive heat from wall of the crucible. Thus, heat comes as a wave and does not need any physical medium as crucible being covered. Although sometimes the material in the crucible may have a partial contact with that of particles from the charcoal or gas.

Analyzing the product design, functional analysis was carried-out to see whether the system works as designed through observation of the operation. The furnace operates with combined fuels - used engine oil and charcoal. The reasons for use of these fuels are for economics, handling and availability or procuring over other fuels. The idea is that a liter used engine oil plus some grammes of charcoal take the place of kilogrammes of the exorbitant fuel like CNG, LNG, LPG and even electric elements. During operation the oil and carbonized fuel combined to facilitate fire and generate heat effectively. The amount of heat generation is also responsible to the refractory application and capacity of electric blower used. So, while in operation the electrical energy runs the motor by rotating shaft continuously, then fan turns with high velocity. This mechanical work caused by the electrical energy produces draft from blade rotation which intensifies the thermal energy, i.e. heat temperature. The combustion and temperature are controlled by switching on or off the blower to gain or lose velocity from switch on the control panel. Secondly, the oil in-let pipe to the furnace also turned down or up to control the combustion. The energy source and transfer of the charcoal combusts in air (oxygen) mixed with the used engine oil as it receives blast from the electric blower then heat produced is directly used as the thermal energy source for melting charge in the crucible.

Conclusion

The study is a studio exploration on the use of waste and locally sourced material to produce a portable furnace fired with used engine oil and charcoal. The exploration was successfully achieved for casting metal sculptures in art schools in South-eastern Nigeria. Materials employed for construction of the furnace were sourced locally, selected based on their availability and suitability for the purposes intended; in fabrication, as energy source, and as refractory material to withstand temperature of the system. Consequently the design was achieved through construction with the materials and consideration of relevant theories that support the practical application was based on small scale usage. The use of local materials reduced to minimal level, the cost of manufacturing the furnace and its subsequent maintenance cost. It was used and aluminum scrap-melted in a shortest period of time of 45 minutes and brass scrap in 67 minutes with low consumption of the fuels. It was observed that the furnace attains $1250^{oc.\ By}$ this it was observed to be fuel economic and effectively managed those potentials of used engine oil and charcoal manifested.

Based on the findings, it was concluded that many art schools that offer Sculpture and Ceramics do not have furnace of any class for casting, teaching and learning metal sculpture. In view of this problem this project attempted at reducing the cost of operating foundry and satisfies the need of metals casting for both Fine and Applied Arts, Engineering students and other related areas. It will also encourage entrepreneurs to engage in small scale metal-casting as an entrepreneurial venture and promotion of foundry practice in Nigeria.

Recommendations for Further Studies

To address the problem of lack of furnace in the art schools in South-eastern Nigeria, the research is of the opinion that there should be collaborative synergy between school

departments of Materials and Metallurgical engineering, Mechanical engineering with Fine and Applied Arts for advancement of furnace designs. A closer professional synergy should be established between sculptors, ceramist, and mechanical engineers in south eastern Nigerian in order to encourage more development of furnaces fired with cheap fuels.

Further studies should be carried out on reuse of discarded materials like the metals and used oil for construction of other heating devices use for foundry and other related devices such as kiln. Studies should be made on areas that promote the appreciation on reuse of local resources to improve Nigeria's economy. Opportunities to reduce cost of materials and energy must be pursued to increase patronage.

Studies should also be made on topics which create room for artistic creativity, which examines both production of cast metal sculpture and the functional application of the indigenously fabricated furnace for a better insight into the background of metal sculpture practice.

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