Design and Fabrication of a Hydraulic Press for the Production of Kiln Shelves

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ABSTRACT

Prototype manual hydraulic press was designed and fabricated for the production of ceramic kiln furniture. The design and fabrication of the machine was done according to laid down engineering and industrial design procedures ethics and codes. Standard design calculations were used to develop the drawings and specification. The design drawings were then used in the fabrication of the machine. The design functional machine components were either fabricated as designed or purchased as scrap from the market. The machine has a length of 250 mm, width of 700 mm and height of 1700 mm. The machine is able to produce four to five and seven to eight shelves using semi and the fully motorized mechanism respectively per hour. Eight props could also be produced per hour using the semi motorize approach mechanism. Both the semi and the fully motorized mechanisms all have higher production capacities over that of the manually rammed approach that could possibly produced two to three shelves per hour.
Keywords: Beneficiation, ceramics, design, fabrication, machine and process.

INTRODUCTION

Industrial design (ID) is the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems from the mutual benefits of both user and manufacturer (http://www.idsa.org). Right from the time of industrial revolution, there has been increase in the design and fabrication of machineries needed to meet with the demand of primary, secondary and tertiary industries. Technological breakthrough thus further leads to industrialization; and re-cycling factories, and therefore, wastes, with metal scraps for reuse, no longer constitutes much problem for the developed countries (Jerome, 1979). This is not the case with developing countries where metal scraps, as off cuts from the factories, construction companies and ruins from fatal motor accident, litter everywhere or gathered in junk-yards, thereby constituting health

ISSN: 2141 - 6745

hazards. Contemporary ceramic industries should find solace in the use of metal scraps for the design and fabrication of their required tools and equipment. In that such scraps are indeed ways of producing usable products even at lower cost, providing job opportunities and minimizing waste.

The study therefore intends to design and fabricate a hydraulic press using scrap metals found in some junk-yards in some cities in Nigeria, to produce semi-motorize hydraulic press for ceramic kiln shelves/props. Earlier research efforts in Nigeria and for example at the Department of Industrial Design, Ahmadu Bello University Zaria, were geared towards sourcing for alternative local raw materials. This is an effort to help in the growth of the industry through research of such related raw materials needed for day- to- day running of the department and any other similar departments especially in a developing economy across the globe, for better teaching and learning.

This is because several imported equipment years back are now obsolete with little or no technical know-how to repair them (Ayodele, 2008). In the long run, most efforts to keep the standard of education running till date are on related researches based on locally sourced materials ranging from glazes (Ebeigbe, 1990), kiln constructions (Ewule, 1988), burners (Datiri, 1998), and shelves production (Molokwu, 1991). Need to mention on the other hand are the female students who are made to face the same rigor in producing shelves. They are usually at the receiving end, because of the energy required in manual ramming of grog while making shelves; hence improper and inaccurate compaction of shelves. This informs the need for students' groupings whereby their male counterparts are left mostly to do the production of shelves required for their firing. This of course does last for a few sessions of firing before they are bad. Ironically, the manual ramming approach in the production of ceramic kiln shelves/props is still operational till date in Nigeria, and even at the Department of Industrial Design, Ahmadu Bello University, Zaria, Nigeria; which suppose to be a pioneering department in this field of study. This factor gave an impetus for this research.

The use of polished stones as tools by man in Africa's Paleolithic period implies an innovation and evolution in man's urge toward solving industrial related problems. The application of power-driven machinery to manufacturing is known as Industrial Revolution *(http://www.idsa.org).* It emanates as a need to satisfy the consumer's urge in terms of taste (variations and quality in designs). It was that which deviated from the monotony in the usage of hand made products to that of machine. According to Anonymous 1984, in Gonah (2003), is any device capable of making the performance of mechanical work easier, usually by overcoming a force of resistance that is the load, at one point and by the application of more convenient force that is the effort, at some other point. That challenge provided a new approach to the industries to further look inward to the importance of designs, using machines in solving industrial problems and consumers' related needs (George,

ISSN: 2141 - 6745

1991). Design in this contest and the consideration used here is a mental scheme of how to fabricate a hydraulic press machine that would be able to produce some kiln furniture such as kiln shelves and props. Design would enable one to fulfill five primary responsibilities such as functional, dimensional, safety materialistic, and psychological responsibilities (Jackson et al 1993). Functional responsibility concerns ensuring an invention or new idea is visible in practice and satisfies a need that justifies putting into practice. Ensuring also that each practical construction resulting from the application of an invention is made into size that will best and most economically fulfill the particular service of which is intended. This is known as dimensional part will. While safety responsibility is the art of not endangering lives or properties either in a normal mode of operation or by the likelihood of failure of a machine or order wise.

Materialistic responsibility concerns selection of materials for each individual part that each part will serve its function at low a cost as possible and for sufficient length of time to make it fit in with the normal economic wear and tear of the construction as a whole. That of psychological responsibility is the effect of prejudice on the opinion of an individual about the usefulness of an object or construction (Gonah, 2001). The benefit of the technology design and fabrication of the machine is to produce kiln shelves and props as alternative to the manual ramming methods (see fig. 1 and 2). According to Thomson 1998, in Gonah (2003), fabrication is the art of construction, especially from components. He further states that all machines are built up of parts made of different materials and by various manufacturing processes. While some are cast from metals others are forged and some are produced by machining of different kinds of machine tools. Casting and forging have to be machined before they acquire their proper shape, exact dimensions and surface finishing. Any machine parts whether they are to be machined or not are called forging.

According to Kamesshehikar (1979), forging processes are extremely important in the machine building industry. He acknowledges that no machine, whether simple or complicated, can be built without the use of forging. Beneficiation is the process of refining raw materials in order to optimize their performance or make them useful in the manufacturing process. In this context, is a treatment using metal brushes, sandpaper, thinner and or a piece of rag to remove dust and other dirt trappings on metal surfaces before use. Accumulation of such dirt on metals surfaces results from long period of time such metals are hipped together. This treatment is done in order to make the metals neat and workable.

The word ceramics means porcelain and pottery, while the engineers usually think of the new industrial ceramics, such as sintered oxides, carbides and nitrides (John, 1993). Ceramic being non -metallic materials do not conduct heat and electricity as metals do. They are non organic hydrocarbon materials either, plastics are the organic hydrocarbons. According to Wert (1978), Ceramic materials are usually oxides, clays, feldspar and other minerals which requires high temperature in processing (Gonah, 2003). Product design refers to the Proto-type model through which the right choice of design is reproduced. Kiln is a ceramic oven where ceramic wares are being fired. Kiln furniture has to do with refractory shelves and posts with which ceramic wares are fired in the kiln. Ramming is the Exertion of force on a material for the purpose of compressing it. Any ceramic material that can withstand high temperature over a long period of use without melting or any inorganic material withstanding temperature of 1000^0C and beyond without sagging. This is known as Refractory. Pre-fired clay materials that are crushed into several particle sizes to be are known as the Grog. Props are refractory posts used in the kiln as part of kiln furniture upon which kiln shelves are placed. Based on this backdrop, the objectives of this study are:

1. Explore the possibility of using metal scraps obtained from various junk-yards in Nigeria for hydraulic press fabrication for use in cottage ceramic industries.
2. Design and fabricate a hydraulic press for kiln shelf production as alternative to the manual ramming method.
3. Produce shelves that would possibly overcome problems of irregular pressure application usually characterized with manual ramming method in shelves production; such as uneven thickness, uneven surface, and irregular compaction which results into easy breakage sometimes even after a single firing as well as some particles chipping off into glazed wares during firing, thereby defacing such glazed products.

METHOD

This research utilized experimental methodology through population of the study, material beneficiation, pilot study, welding of metal parts, formulation of dried and fired refractory materials. Other areas of investigations include clay preparation; grog making, characterization tests for modulus of rupture, compressive strength, inclusion of reading mechanism of pressure gauge, were either conducted, or carried out. Standard design calculations were used to develop the design drawing and specification. The design drawing (fig 3) was then used in the fabrication of the machine. The design functional machine components were either fabricated as designed or purchased as scrap from the market. Most fabrications were carried out in the engineering work shops at Ahmadu Bello University Zaria using heavy duty equipment where required.

RESULTS AND DISCUSSION

Product Design: Design can be defined as the presentation of a good conceptualized idea on any surface for effective onward utility. It is an inspirational phenomenon that pleases the mind (Ayodele, 1999). Ekeada (1988) sees design as that which needs to do with forms and perfecting to finish. Design is the exercise of imagination in the specification of form (Smith, 2003). The aim of the design is to give some form, pattern, structure, or arrangement to an intended technological product so that it is an integrated and balanced whole, which will do what it is intended (Wormald, 2003). For example, a hydraulic system built in London in the late 1800s is still in use. It is used to lift bridges, hoists and cranes (Harms and Swernofsky 1999). This corroborates the belief of Stuart (1996) that products do not have to be highly innovative, as long as they do the job properly. He states that too often, we go for high technology products that do not perform. Designing is sometimes represented as a linear or a looped set of processes starting with identification of a problem or requirement, followed by generation of ideas for solutions. It often begins with an idea in a person's mind and the designer has to be able to envisage situations (Microsoft Corporation, ibid). On this note, the design was articulately put down on paper for an onward transformation into a reality. Designs are often backed up with mechanical precisions and calculations. The initial design on paper was made as a working guide and later developed using Computer Aided Design (CAD) (See fig.3).

Frame Mould for the Shelf: The angle bar size used for shelf frame in the manual ramming method is 39 mm in height, and 12.70 mm in thickness. This was constructed to have in to in dimensions of 280 mm x 425 mm. It is imperative to note here that angle bars are of various sizes. In this study however, angle bar size of 78 mm in height, with 15.24 mm in thickness was purchased, cut to sizes and welded to have the same sizes of 280 mm x 425 mm; in to in measurement. Also welded to it are the 3 mm bolts at the points where they would be detachable by loosening the nuts. This frame size was experimented upon in order to properly house the material fed to it at once rather than the refilling method used in the manual ramming approach (See fig. 3 and fig. 4); for the comparison of the two angle bar sizes used for the frame construction. There working principles are of two ways: (a) the semi-motorized and (b) the fully-motorized.

Working Principles of Press Using Semi-Motorized Device: The press is principally driven by the hydraulic jack. When the hydraulic lever is jacked ups and downs, it automatically jacks up the piston. The more the jack, the more the piston moves up until it reaches its maximum limit. As the piston moves, it presses down its source of weight to compact the grog in the angular frame placed under it. Here the reading gauge would have started reading in pressure per square inch (Psi). When the piston could no longer move it is taken that enough pressure has been applied to the shelf grog for proper compaction. At this point, the reading on the gauge will be noted and the nub in the hydraulic jack is loosened to release the piston gradually back to position. As the piston decreases in height, so do the springs stretch back to their former positions pulling along the metal plate where the jack is bolted on and keep it in suspension. Thereafter, the plywood will be gradually pushed forward using the two hands for easy removal from the metal base placement. This process was repeated to produce as many shelves as possible. Producing props using the cylindrical iron, took the same procedure by pressing the galvanized iron rod to exert force applied by the hydraulic jack.

Working Principles of Press Using Fully-Motorized Device: The fully motorized device is a new mechanism principally driven using a gear motor of two horse power. This was connected to a 20 tons hydraulic jack firmly griped by angle frames constructed as stand for effective holds and possible vibrations when electrically powered. The shaft known as eccentric rod was designed and fabricated to press on and off the jack lever piston as it rolls. This was achieved with the use of two cross joints. One was connected to the two horse power motor and a gear box shaft at one end and at the other end of the gear box was the second cross joint connecting the eccentric rod that entered the bearing constructed beside the jack.

When electrically powered, the 20 tons hydraulic jack, placed below jacks up to meet with the roof of the upper frame and pushes it up together with the grog already housed in the angular iron frame place on it. The jacking continues until it keys into the waiting top metal plate for proper compression of the grog. When fully compressed, as indicative from the pressure gauge reading mechanism to about 3500 psi or more, the engine is put off. At this time, the tight nub of the jack is loosed in order to release the piston back to position. Along this line, the compressed grog in the frame also comes down with the jack in readiness for disengagement from its frame mould. To aid this movement however, four (4) grooved metal rollers were fabricated and welded at each angle of the frame for balancing during operation. The performance of the machine was tested using various shelf compositions as well as testing for modulus of rupture (MOR) and the compressive strength test to ascertain their strengths (see tables 5and 6 for MOR and 7 and 8 for compressive strength).

CONCLUSION AND RECOMMENDATIONS

It is also evident from the outcome of this research that the design and fabrication of the semi and the fully-motorized hydraulic jack is quite effective in the production of ceramic kiln shelves for the cottage ceramic industries. Further modification is carried out on the prop mechanism design for better performance since it was so difficult to remove props under high compaction (pressure application) despite the use of lubricants until the pressure was brought to 350 pressures per square inch (Psi).

Table 1: Shelf Batch Compositions I

Compositions	IA	IB	IC	ID
Coarse Kaolin Grog using 9.5mm Sieve	55%	60%	65%	70%
Kaolin using 0.6mm Sieve	25%	20%	15%	10%
Fine Kaolin Grog using 2mm Sieve	15%	10%	10%	10%
Ball Clay using 0.6mm Sieve	5%	10%	10%	10%
Total	100%	100%	100%	100%

Source: Researcher's Studio Experiment, 2011

Table 2: Shelf and Prop Batch Compositions II

Compositions	IIA	IIB	IIC	IID
Fine Kaolin Grog using 4.75mm Sieve	55%	60%	65%	70%
Calcined Kaolin using 0.6mm Sieve	25%	20%	15%	10%
Finer Kaolin Grog using 2mm Sieve	15%	10%	10%	10%
Ball Clay using 0.6mm Sieve	5%	10%	10%	10%
Total	100%	100%	100%	100%

Source: Researcher's Studio Experiment, 2011

Table 5: Modulus of Rupture Test for Composition I

	M.O.R (N/mm^2)			
	Test IA	Test IB	Test IC	Test ID
Test (manually rammed)	5.1395	6.2777	5.0258	5.9462
Test (semi motorize machine)	6.1242	6.3171	5.8831	5.4009
Test fully motorize (electrically powered machine)	6.5100	6.6547	6.5100	5.4973

Source: Researcher's Studio Test, 2011

Table 6: Modulus of Rupture Test for Composition II

	M.O.R (N/mm^2)			
	Test IIA	Test IIB	Test IIC	Test IID
Test (manually rammed)	5.02050	5.8161	5.0469	4.7511
Test (semi motorize machine)	5.8831	7.2816	7,7156	7.7638
Test fully motorize (electrically powered machine)	8.1496	8.2942	9.4998	7.9567

Source: Researcher's Studio Test, 2011

Table 7: Compressive Strength Test for Composition I

	Compressive Strength(N/mm^2)			
	Test IA	Test IB	Test IC	Test ID
Test (manually rammed)	3.63	5.02	4.02	2.95
Test (semi motorize machine)	5.49	7.19	5.38	5.96
Test fully motorize (electrically Powered machine)	9.04	10.35	6.16	7.04

Source: Researcher's Studio Test, 2011

Table 8: Compressive Strength Test for Composition II

	Compressive Strength(N/mm^2)			
	Test IIA	Test IIB	Test IIC	Test IID
Test (manually rammed)	6.79	6.24	6.13	4.10
Test (semi motorize machine)	6.79	6.60	5.57	4.31
Test fully motorize (electrically powered machine)	8.42	7.94	6.45	5.20

Source: Researcher's Studio Test, 2011

Figure 1: Manual ramming method used in Shelf Production
Source: Studio Practice

Figure 2: Manual ramming method used in Props Production
Source: Studio Practice

ISSN: 2141 - 6745

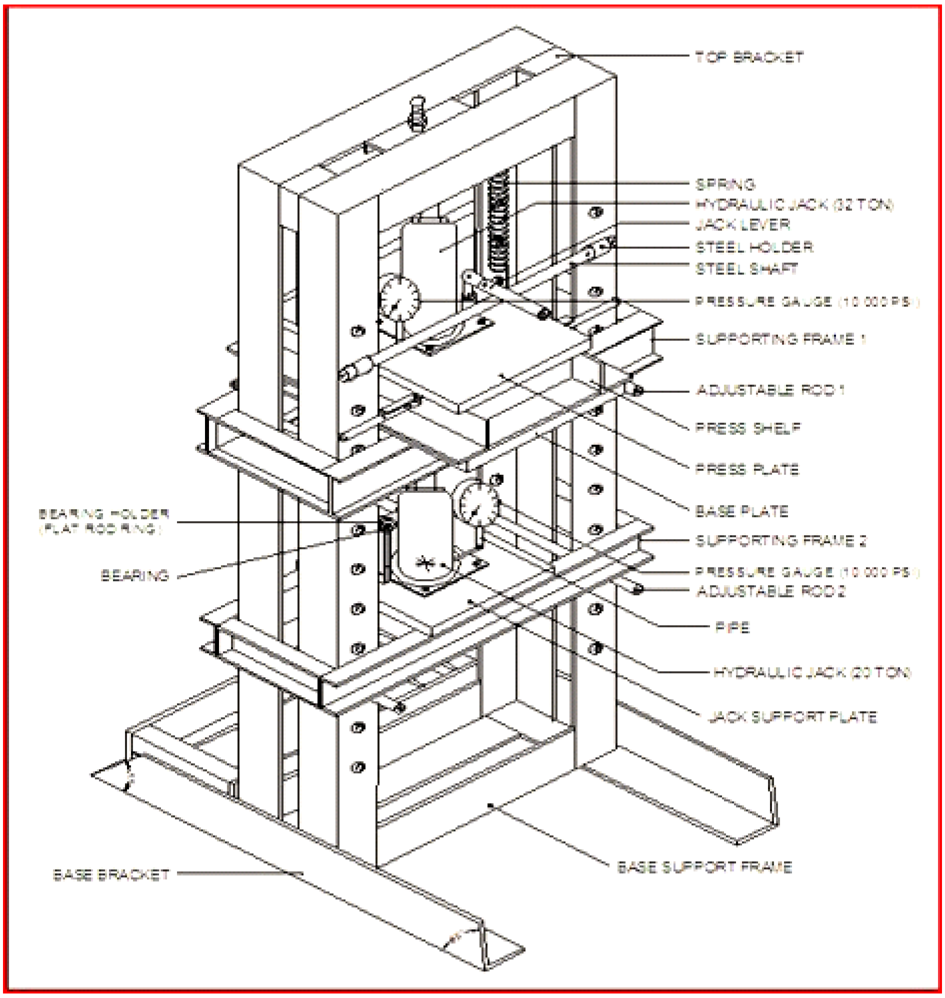

Fig. 3: The Hydraulic Press Machine

Source: CAD and Engineering Workshop Construction by the Researcher.

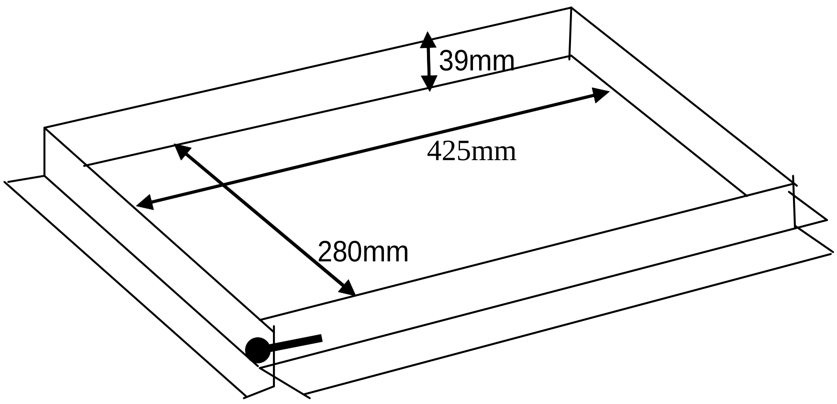

Fig. 4: The Angle bar Frame Size commonly used is 39 mm

ISSN: 2141 - 6745

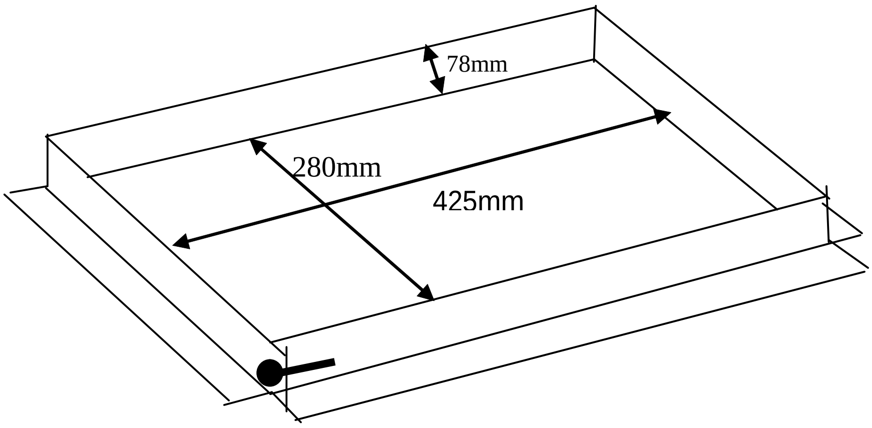

Fig. 5: Angle bar Frame Size Experimented upon having 78mm in height

Fig. 6: Guiding for the proper fitting of the top metal plate into the angular frame containing shelf materials using semi-motorize mechanism

Fig. 7: The assembled machine/Pressing of Prop in Progress

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Fig. 8: Shelves Produced using Manual Ramming/Semi-Motorized Method

Fig. 9: Front View of the Design Machine

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ISSN: 2141 - 6745