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Development of Porcelain Pot Mill for Processing Ceramics Raw Materials

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A ceramic milling machine is a machine for grinding rocks and minerals consisting of a horizontal cylinder made from, or lined with an abrasion resistant material with mechanical force to make it revolve. with porcelain balls or pebbles meant to grind ceramic raw materials while revolving on a roller. It is used in diverse fields, industries, field of engineering and for grinding mineral, cement, clinkers, among other things cetera. It is used instead of a pestle and mortar for mixing and grinding ceramic materials (clay, oxides and glazes) in dry or damp state. The importance of a milling machine as a critical equipment needed in the ceramic studio for the production of glazes for local raw materials has already been established. The aim of this project is to develop porcelain pots alongside with a mini milling machine locally sourced materials, with a view to enhancing the materials processing capability in the ceramics studio. Data collection that was used for the study was sourced from both primary and secondary sources. The Feldspar was sourced from Ikere Ekiti, Kaolin, Ball clay was sourced from Ikere Ekiti and Quartz was sourced from Igbekoda. Experimental research design was adopted for the study. The experiments carried out were analysed. The research outcome shows that 30% of Ball clay, 30% of Kaolin, 20% of Feldspar and 20% of flint are good for a porcelain body. Hence this study was carried out to discover the feasibility of using a locally available, easily assessable materials in developing a ceramics ball milling machine.

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1. INTRODUCTION

The effect of technological development on ceramic industry used to be tremendous (Fowowe 2004) and mankind had come a long way along this path [1]. In the history of every industry however, design and development have become essential ingredients that are necessary as separate activities in machine production (Kayode 2018). Developing design concepts therefore shows no trace of losing momentum in the whole gamut of industrial production (Kayode 2015). Besides, it is established in Patel, [2] and Kingery & Bowen [3] that the necessity of equipment in ceramics production cannot be over emphasized. It is among the important variables in the economic growth of any ceramic industry.

In spite of this, most ceramists in Nigeria are unable to procure and utilize what they need freely and timely. The reason for this is that materials are usually imported and the equipment to process them is too expensive and most times delayed. This dependence on imported technology has hampered the growth and development of ceramics in the country. Researchers such as Ebeigbe and Omem (2010) and Bada [4] suggested that “rather than depend on imported equipment, local adaptations of the required tools could be produced to meet the needs of ceramists in the country. Dearth of equipment in ceramic studios and the need for improvisation by indigenous ceramists and potters is apparently of the essence and may not be peculiar to Nigeria alone” [5-9]. Digitalfire.com [10], affirms “this when it stated that no industrial plant that mixes its own raw materials would be without a ceramics milling machine. Yet potters lack them for a couple of reasons which range from availability to handling cost and then to other extraneous factors [11-15]. This implies that it was not just the cost of most ceramic equipment that prevented their use but also the lack of awareness that some of this equipment could be adapted and fabricated by the studio ceramist”. According to Thorsgaard (2004) “went on to describe in details how to make a functional ceramic milling machine stand that can serve an average ceramics studio. It was quite easy and inexpensive to construct”. Other researchers like Ojie and Esosuakpo [16] and Davis (2014) have documented “their own efforts at producing various functional and less expensive models of ceramic milling machine from materials available within their local environments”.

A ceramic milling machine is described by Fournier (1977) as “a machine for grinding rocks and minerals consisting of a horizontal cylinder made from, or lined with an abrasion resistant material with mechanical force to make it revolve.” Similarly, Otimeyin (2015) described it “as a device which consists of a cylindrical porcelain container with porcelain balls or pebbles meant to grind ceramic raw materials while revolving on a roller. It is used in diverse fields and industries”. According to Scott (1991), it is used in the field of engineering, “for grinding mineral, cement, clinkers, among other things” etc. In ceramics, Chavarria (1994) notes that “it is used instead of a pestle and mortar for mixing and grinding ceramic materials (clay, oxides and glazes) in dry or damp state. The importance of a milling machine as a critical equipment needed in the ceramic studio for the production of glazes for local raw materials has already been established”. There are reasons as Parmelee (1973) explains that “No step in the preparation of glazes is more important than the operations designed to give a homogeneous mixture ready for application to the ware. Therefore, it is absolutely necessary to utilize a ceramic milling machine a device which guarantees this process” [17,18]. One of the major components of the milling machine is the porcelain pot which is the main focus of this research.

Ceramic pot mill can be defined as a kind of mill pot which has wear resistance, pot mill is an ideal equipment for achieving analytically pure and contamination free micro milling of ceramic as well as metallic powders [19-23]. King (2002) described it “as, cylinders with a capacity of about 0.5 litres to 2.0 litres which may be larger depending on the specific need of the studio. The pot comes with an opening for loading and off loading, and a clamp for holding the stopper in place [24,25]. The opening of the cylinder maybe coaxial with the cylinder or it could be located at the circumference, the stopper is conventionally made of the same materials, somehow thick than the wall of the pot [26-30]. If necessary a plastic lid pot can be used. As well as opening the lid after the milling session for discharging becomes much easier, where as porcelain stopper sometimes cause trouble by getting stuck tight”.

This study therefore, intends to utilize indigenous ceramic raw materials for the development of porcelain pot mill in Nigeria. This will help in conversing the economy by improving and developing intermediate technology.

2. METHODOLOGY

The researcher make use of some ceramics raw-materials which are:

I. Feldspar
II. Ballclay
III. Kaolin
IV. Flint

2.1 Experimental Procedure

Step 1: Sourcing of materials

This included Flint, kaolin, Feldspar and Ball clay

Step 2: Chemical analysis of the materials

This was achieved using X-Rays Fluorescence spectrometer (XRF) equipment in order to reveal the material chemical compositions and their suitability for the production of porcelain pot-mill.

The result of X-ray Fluoresence Spectrometer analyzed of the locally sourced raw materials carried out at Afe Babalola University Ado-Ekiti in the Department of Chemical and Petroleum Engineering. (Researcher's Field Work, 2021).

2.1.1 Observation

Table 1 shows the chemical compositions of Ikere Ekiti kaolin, Ikere Ekiti ball clay and Kaolin. As can be observed from this table, silica was the main dominant oxide in Ikere Ball clay sample (32.42%) followed by iron oxide (21.21%). The percentage of alumina (13.39%) potassium oxide (K_2O) 3.74%, magnesium oxide (MgO) and calcium oxide (CaO) are 0.62% and 0.82% respectively. The loss on ignition (L.O.I) is 25.42.

The amount of silica and alumina in Igbekoda Quartz sample are 22.95% and 6.02% respectively. The percentage of potassium oxide (K_2O) and sodium oxide (Na_2O) are 0.38% and 1.13% respectively. Magnesium oxide (MgO) and calcium oxide (CaO) are 2.73% and 35.64% respectively. The coloured oxides are expectedly higher than that of the kaolin sample. Manganese oxide (MnO), titanium oxide (Tio_2) and iron III oxide (fe_2O_3) are 0.14%,0.64% and 5.98% respectively. The loss on ignition (L.O.I) is 23.16%. The amount of silica in kaolin sample is 42.08%while alumina (Al_2O_3) is 6.93%. the percentage of potassium oxide (k_2O) and sodium oxide (Na_2O) are 3.32% and 0.38% respectively. The percentage of calcium oxide (CaO) is 5.41% and magnesium oxide (MgO) is 6.26%. the amount of Iron III oxide (Fe_2O_3) is 1.99%. The Loss on ignition (L.O.I) is 23.14%.

Step 3: Materials processing

This involved crushing of the materials inside a mortar, or hand crushed with hammer, and ball mill to smaller particles sizes, soak all the materials inside water and remove impurities from the surface of the water, dry sieving to a very smooth particles size of mesh 80, pulverization and particle size distribution of the materials.

Produce a porcelain pot mill using a designed casting method for its production

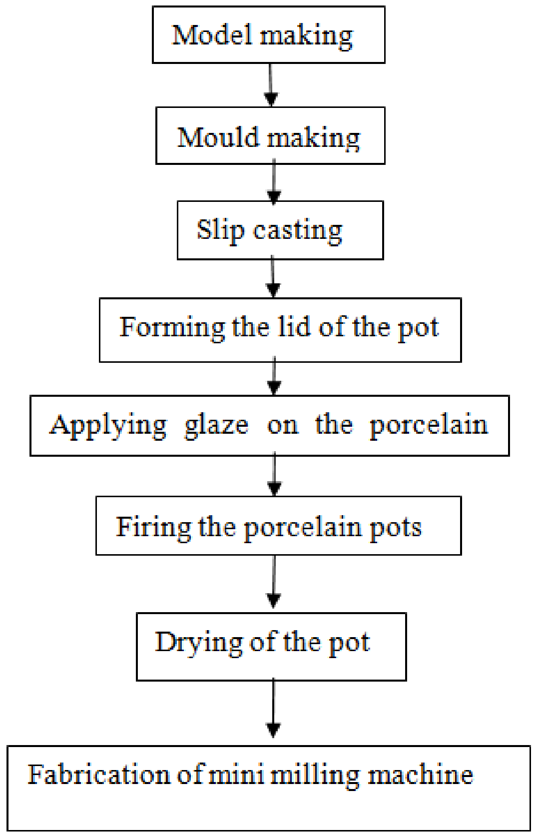

Fig. 1. A flow chart showing the procedure of porcelain pots production

Step 4: Formulation of the porcelain body

These involved mixing of materials in the right proportions, weighing, milling and drying composed. Rapt attention to any observations during these processes was the key in achieving the desired result of this study in due time.

quadaxail blend is method that was adopted, then the best three selection of their test was built on the formulation of the porcelain body.

2.2 Body Formulation

Scott as cited by Carol (2008) explained that tri-axial blend can be used to blend four materials or recipes together. He gave out the layout of the 36 test recipes, given as percentages by weight of each of the four materials named as A-D as shown in Table 2.

This quadaxial blend was adopted for formulating the composition for this study as follows: A Ball clay; B Kaolin; C Flint; D Quartz

Table 1. Chemical composition of ikere ball clay, igbekoda flint and ikere kaolin

Chemical	Ikere Ball clay	Igbekoda Kaolin	Flint
SiO_2	32.42	22.95	42.08
Al_2O_3	13.39	6.02	6.93
Fe_2O_3	21.21	5.98	1.99
MgO	0.62	2.73	6.26
CaO	0.82	35.64	5.41
Na_2O	1.43	1.13	0.38
K_2O	3.74	0.38	3.32
MnO	0.06	0.14	0.08
TiO_2	0.71	0.64	0.32
L.O.I	25.42	23.16	23.14

Source: Source: Researcher's field work (2021)

Table 2. Quadaxail blend of 36 test recipes

1 50A 50B	2 50A 40B 10D	3 50A 30B 20D	4 50A 20B 30D	5 50A 10B 40D	6 50A 50D
7 40A 50B 10C	8 40A 40B 10C 10D	9 40A 30B 10C 20D	10 40A 20B 10C 30D	11 40A 10B 10C 40D	12 40A 10C 50D
13 30A 50B 20C	14 30A 40B 20C 10D	15 30A 30B 20C 20D	16 30A 20B 20C 30D	17 30A 10B 20C 50D	18 30A 20C 50D
19 20A 50B 30C	20 20A 40B 30C 10D	21 20A 30B 30C 20D	22 20A 20B 30C 30D	23 20A 10B 30C 40D	24 20A 30C 50D
25 10A 50B 40C	26 10A 40B 40C 10D	27 10A 30B 40C 20D	28 10A 20B 40C 30D	29 10A 10B 40C 40D	30 10A 40C 50D
31 50A 50B	32 40B 50C 10D	33 30A 50C 20D	34 20B 50C 30D	35 10B 50C 40D	36 50C 50D

Source: Carol (2008)

Table 3. Formulated porcelain body

Raw materials	Sample A	Sample B	Sample C	Sample D
Ball clay	10	20	30	10
Kaolin	50	40	30	40
Calcined Kaolin	30	30	30	40
Quartz	10	10	10	10

Source: Researchers Field Work, 2021

Fig. 2. Some sample of the test tiles

Olasupo and Borode (2009) in a research development of refractory ramming mass observed that ceramics body compositions with 10% silica and above showed no crack. It rather showed low volumetric shrinkage after firing. 10% silica in the composition of the body enhance low volumetric shrinkage after firing. Higher silica content will lower the cold composition strength of the mix and present a rough surface to the fired body.

Henrik (1987) stated that the addition of silica makes a clay mixture more refractory. This owing to the fact that some silica contract and expand and contract suddenly at certain temperature. Hence blends with 20% Quartz and above are not considered suitable for this study.

2.2.1 Observation

Some sample of the test tiles got fused, why some got scatter during the firing, because the cant withstand high temperature, so sample 8 was picked, which is use for the formulation of composition of the body, which is the best. The model was made with ball clay using throwing wheel.

Step 5: Slip casting techniques will be use in forming the porcelain pot

A drop of sodium silicate which is a deflocculating agent was added to the mixed liquid ceramic body. The slurry liquid body was poured into the hollow POP mould, appended with rubber so as to prevent sudden removal or detached on pouring of the slip within about 30 minutes after pouring, a filter of firm clay appeared on the inner surface of the mould. When the desired thickness was developed. The excess slip at the center portion of the mould poured out. The remaining clay body continued to harden until it shrank away from the mould and the porcelain pot was taken out. The process was repeated until all the prepared slip bodies were used up.

Step 6: Fabrication of the milling machine

An understudy of an existing models of ball mills was conducted, with a view to producing a suitable type, through adaptive design. The intended capacity of the ball mill metal frame was an important design consideration in arriving at its suitable size. Also of importance was the desired simplicity in operation ensuring the use of a simple motion transfer mechanism of pulley. Appropriate sizes of components were determined through calculations where applicable using standard formulae. Detailed working drawings and specifications were prepared and adequately utilized. Fabrication was carried out using the processes of cutting, machining (turning) and welding to arrive at the intended design. Finishing of the metal frame was done by smoothing joints and rounding edges where needed. Surface treatment of metal parts was done using a coat of non-absorbent paint to improve aesthetics.

Step 7: Evaluation test

This include closely observing the physical properties.

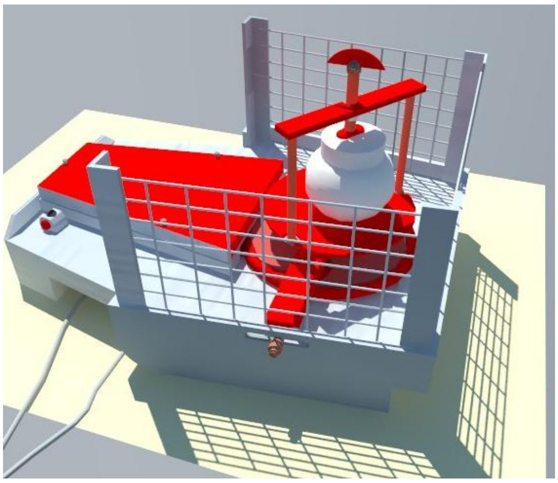

Fig. 3. The Front view of the finish product of the machine

Source: Researcher's Field Work (2021)

3. CONCLUSION

This project was intended to address the problems that are always associated with the particle sizes of raw materials before they are used for research works and production. Compositions and firing tests were carried out on the materials required for the pot mill that will serve the purpose and last long. As stated earlier, there were challenges which requires further research to be carried out in the project areas. Thus, research students and lecturers are implored to take this challenge further in order to achieve the desired aim of this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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