*Journal of Social and Environmental Sciences* (JOSES) 4(1) February, 2022: 17-22.
ISSN 2714 2493 Online
2714 2280 Print

# Fabricating a DC 24V Pugmill for the Department of Visual Arts, University of Cross River State, Calabar.

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**ABSTRACT**
The Department of Visual Arts, University of Cross River State does not have a pugmill to process clay for work in its ceramics studios. Whereas the pugmill is inalienable to the visual arts studio equipment, it has been difficult to find funds to procure one. Minus freight and customs duty costs, an imported pugmill from the shop costs more than ten thousand dollars ($10,000.00), or more than 5 million naira at the present exchange rates. This study sought to employ standard industrial materials available locally to fabricate a pugmil for the Department of Visual Arts, University of Cross River State, Calabar. Using stainless steel and various other industrial components, this study designed and fabricated a pugmill at less than half the cost of an imported version. The pugmil performed well in studio conditions and was able to pug various clays to the right consistency. The assurance that there is no risk of electric shocks because the machine works with 24V DC (Direct Current) made students very comfortable with the use of the pugmill.

**KEYWORDS**: Fabrication, Direct Current, pugmill, Nigeria content.

## Introduction

Established in 2002, the University of Cross River State, Calabar, is a relatively new institution. One major disadvantage of operating a university in the present socioeconomic milieu in Nigeria is the lack of adequate funding for the purpose of acquisition and maintenance of vital teaching facilities and equipment. The evident result of this is that, in most academic departments in Nigerian universities, lectures, practicals and tutorials are carried-out without students actually seeing or using the required specialized equipment. In effect, students are graduating from programmes often with only a glimpse of necessary equipment in the pages of textbooks and the Internet. This scenario is far more profound in departments where practicals, raw materials processing and demonstrations are primary, such as visual arts departments.

At the Department of Visual Arts, University of Cross River State (Unicross), Calabar, clay is the most vital raw material for sculpture, ceramics production and three-dimensional works. Clay is used by undergraduates (years 1-4) and graduate students too. While the clay we use in the department is sourced from the local environment, there is a great deal of processing required to prepare it for use in the ceramics and sculpture studios. The most vital equipment required for the processing of clay, in readiness for ceramic and sculpture production, is a pugmill, which is a heavy-duty machine that mixes, kneads and pugs the clay in a right consistency for the production of art objects. Sadly, the lack of adequate funding has meant that the department has not had a pugmill and teaching and learning at both undergraduate and graduate levels has been grossly inadequate. In 2017, we made a low budget pugmill that helped in the pugging of clay and teaching. Sadly, it was vandalised and the detachable stainless steel auger inside the machine was stolen, leaving the department totally without means to pug clay. Thus, beyond pictures in textbooks, our students graduate without having seen or used a pugmill. This is clearly a negative development that should be addressed by providing vital equipment for students to use in training. Without the pugmill, hundreds of man hours are wasted in the department during the manual preparation of clay. This manual method neither provides enough clay for studies nor generates the right

This research was funded with the generous support of the Tetfund *Institution Based Research* (IBR) Grant.

quality of clay for use. The unavailability of a pugmill has therefore hindered the ability of the Department of Visual Arts to execute its curriculum, approved by the National Universities Commission (NUC). Therefore, the pugmill is an urgent need in the department.

**Statement of the Problem**

There is no pugmill in the Department of Visual Arts (Unicross) for the processing of clay, as required in the curriculum. Owing to this, lecturers and students have not been able to process clay and clay-related raw materials adequately and efficiently, which severely hinders teaching and learning. The justification for this study lies in the fact that, as against the inability to process clay efficiently and adequately in the department, this research will produce a functional pugmill for use in lectures, practicals and tutorials in the studios.

Furthermore, while pugmils are inextricable equipment for teaching and learning in the visual arts, they are very expensive facilities. For example, the Vpm-60Te pugmill shown in Plate 1 costs close to ten thousand dollars ($10,000,00) to import. At the current exchange rates, that means this imported pugmill costs more than five million naira, minus accessories and costs of importation. If, as Pitelka (2007) notes, improvisation, self-sufficiency and fabrication of a pugmill can be done for about half the cost. Using his own creative skills and some parts acquired from hardware markets, Pitelka built his pugmill, which processes 2000 Ibs of clay per hour, and has been working perfectly with no modifications and minimal maintenance for twenty five years (2007). That we can have such a vital but expensive equipment for half of its market cost is in itself a sufficient orther justification for undertaking this study.

**Objectives of the Study**

This research sought to employ both custom and industrial materials available locally to design and fabricate a pugmill for the Department of Visual Arts, University of Cross River State. The specific objectives are:

1. To design a pugmill powered by 24V Direct Current (DC), to eliminate the risks of electric shocks.
2. To use stainless steel in the design and fabrication for durability, since the machine shall be used in the manipulation of clay pastes that are corrosive to ferrous metals.
3. To create a design that will prevent stealing by making the auger non-removable, and enable the cables to be stowed away after use.

**Literature Review**

A pugmill (or pug mill) is a machine in which clay or other materials are mixed into a plastic state. According to Porters Without Boarders (2017), the machine integrates the work of two machines, a mixer and a standard pug mill. Pugmills are applied industrially to the preparation of clay and clay-materials for pottery, bricks, cement and some parts of the concrete and asphalt mixing processes. Owing to its design and action, the pugmill can achieve a thoroughly mixed, homogeneous mixture in a few seconds, and the right machines can be matched to the right application by taking into account the factors of agitation, drive assembly, inlet, discharge, cost and maintenance (Philips 2017). A typical pugmill consists of a horizontal boxlike chamber with a top inlet and a bottom discharge at the other end, shafts with paddles, and a drive assembly. Furthermore, the author states that ceramics pug mills, or commonly just "pugs", are not used to grind. Rather they mix and extrude clay bodies prior to shaping processes. Some pugmills are fitted with a vacuum system that ensures the extruded clay bodies have no entrapped air. Pugmills fitted with the vacuum pump are called "de-airing" while those without are referred to as "non-de-airing" (Graham 2003). Typically, a clay pugmill consists of a shaft armed with projecting knives, which is caused to revolve in a hollow cylinder, tub, or vat, in which the clay body is placed (see Plate 3). Graham (2003:1) says that a pugmill contains some kind of "auger", rotating slowly inside a barrel. The auger has blades arranged in a spiral pattern along a stiff, strong shaft, so that it chops and pushes the clay along inside the barrel. As Graham indicates, the input end of the pugmill's barrel is some kind of hopper where lumps of clay are fed to be squashed and kneaded. The other end of the barrel tapers suddenly so the exit hole is smaller, about half the area of the main barrel. Clay emerges from the barrel's end in a long cylinder, squashed smoothly, ready to use. Some of the factors affecting mixing and residence time are the number and the size of the paddles, paddle swing arc, overlap of left and right swing arc, size of mixing chamber, length of pugmill floor, and the material being mixed (Pugmill 2017).

According to Philips (2017), several key factors impact the pugmill's performance. The primary factor is the

Fig. 1: The Vpm-60Te Tile Extruding Peter Rugger Pugmill
Source: http://www.sheffield-pottery.com/Peter-Pugger-Pugrnills-s/45.htm

Fig. 2: A ceramist using the pugmill to pug clay for production. Notice the consistency of the pugged clay (out of the pugmill) and the pottery that have been made from the clay. Source: http://www.sheffield-pottery.com/Peter-Pugger-Pugmills-s/45.htm

method of agitation. This often comes in the form of paddles, and their size, number and swing arc, which all play integral roles. In pugmill design, a proper drive assembly is essential to reduce processing time, ensure consistent quality and mitigate complications. A drive assembly that is too powerful may be a waste of money, in that it is overpowered and using too much energy for the process. On the other hand, having a drive assembly that is too weak will end up costing extra cash in the long run, by increasing processing time, running up man hours and budget, possibly ruining batches and eventually leading to complications with more frequent repairs and maintenance from sizes and types of batches. Other considerations include the design, dimensions and quality of components. According to Finck and Heumannskaemper (2013) of Morgan Advanced Materials, choosing materials that will provide maximum performance for one's operation is an individualized and complex task. The authors insist that any material selected must be able to withstand the maximum pressures that may be applied to the equipment. Also, in terms of equipment fabrication, Ighodalo (2011) recommends the incorporation of control systems in equipment design and the determination of best practices in professional operations. Thus, this study shall include simple to use control systems to make it safe and user friendly. According to Graham (2003), in order to fabricate pugmills, one can use mild steel, cast aluminum and stainless steel. While mild steel has serious rust problems, cast aluminum pugmills begin to corrode internally within a year of use. Thus, stainless steel is the recommended material for fabricating pugmills (Graham 2003). Therefore, for this research, stainless steel will be used. In the context of the assertions of Philips (2017), Finck and Heumannskaemper (2013), Ighodalo (2011) and Graham (2003), this study shall employ materials that will ensure a strong drive assembly, adequate shaft and paddles, including effective and safe control systems. The aim is to use materials that will provide maximum performance, while ensuring work safety for the staff and students of the Department, of Visual Arts who will be using the fabricated pugmill.

There are no doubts at all that fabricating and using equipment such as a pugmill in the studio or classroom setting is of utmost importance, particularly in technical courses such as the visual arts generally. Scholars have established the importance of using the

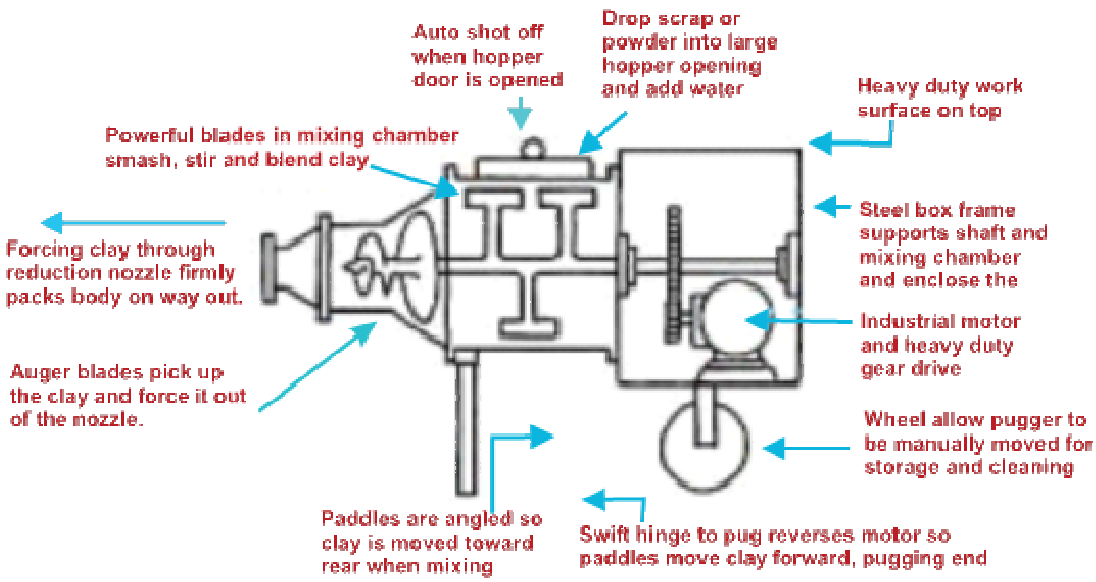


Fig. 3: A simple, diagrammatic illustration of the internal workings of a pugmill
Source: http://www.sheffield-pottery.com/Peter-Pugger-Pugmills-s/45.htm

right equipment in the teaching of technical courses in tertiary education (Ogundu 2011, Ugwua and Ogbonnaya 2013, and Ogundu and Wordu 2014). Ogundu (2011), for instance, sought to determine the effect of teacher constructed equipment on students' performance in metal work technology in technical colleges in Rivers state. The study adopted a quasi-experimental design that involved the use of a control group, pretest - post-test design, using a population of 194 students from four technical colleges in Rivers state. The results indicate that the use of the constructed equipment had positive effects on students' performance in the course. The study established a difference in performance between those taught using the constructed equipment and those taught without the equipment.

Also, working with experimental and control grouping of 194 final year students of four Technical Colleges offering Metal Work in Rivers State, Nigeria, Ogundu and Wordu (2014) studied the effect of using fabricated equipment on students' performance in foundry operations. Data indicates that those taught foundry operations using the fabricated equipment performed better than those taught without it. The vital point that the authors make is that school workshops, laboratories and the environment where technical education such as visual arts is given needs be adequately equipped. According to the authors, working with the actual equipment (rather than theorizing it) will expose the students to the use of professional materials, which will lead to the acquisition of relevant knowledge and skills. In the light of their empirical findings, Ogundu (2011) and Ogundu and Wordu (2014) recommend that governments, institutions and relevant agencies should provide funds to procure materials and components for designing and constructing equipment for teaching. This present study is in line with these authors' recommendation by seeking to fabricate a pugmill for the study of visual arts in the University of Cross River State (Unicross), so that students can acquire the relevant knowledge and skills in ceramics.

**Methodology**

The methodology for this study was experimental, using industrial-grade components and custom-built materials, including locally purchased parts to design and produce a stainless steel pugmill. After conceptualizing the design, the authors made sketches of the machine and a schedule of various materials to be acquired for the project (see Table 1). 3D drawings of the pugmill was also made, to properly guide the production (Fig 4). All metals were measured, cut, welded and filed according to the design. While the body of the pugmill itself was made of stainless steel, the mainframe of the structure on which it is mounted was constructed with heavy 3-inch angle iron, to ensure firmness and durability.

**Table 1: Some Materials Acquired for the Research**

| | |
|---|---|
| 1/4" sheets of stainless steel | Large Stainless-steel bearing |
| 1/8" sheets of stainless steel | Shaft seals |
| 1/2" stainless steel sheet | Large distributor bearings |
| 2" stainless steel rod | Various electric cables |
| 10" stainless steel pipe | Indicator lights |
| stainless steel electrodes | Industrial transformer 24V 120A |
| 4" stainless steel pipe | Motor controller 24V |
| Heavy duty planetary gear box | 2-way power switch |
| PX130-D130-1000 DC 24 Motor | Heavy duty 15 Ampère plug |
| 2 pieces Stainless flanges 10 inches | Armoured cable |

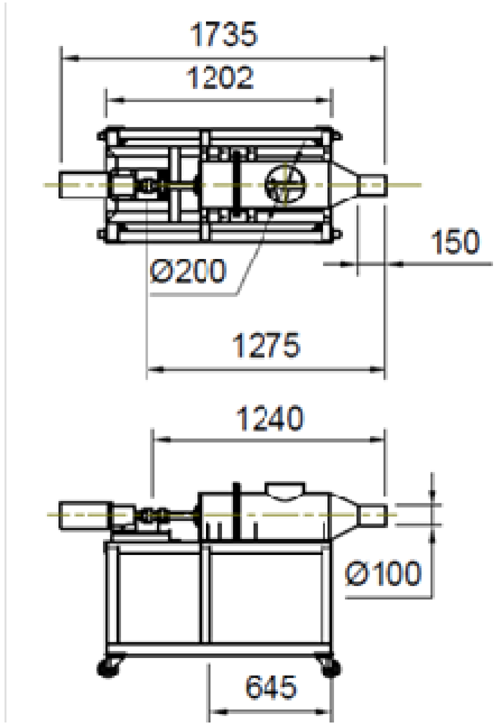

Fig 4: 3D drawings of the pugmill, with dimensions.

The authors used simple controls, including a two-way switch for driving the motor forward and reverse. For, in operation, a pugmill needs to be able to pug (rotate clockwise) and mix (rotate anti-clockwise). The main drive shaft was crafted from a 50mm solid stainless-steel rod. The auger blade, paddle and shaft assembly was intricately designed (see Figs. 5 & 6). The auger was then crafted from thick 5mm plates of stainless steel, just as the paddles too. After crafting the auger blades and paddles, they were welded to the drive shaft according to the design dimensions. Thick 5mm stainless steel pipes were used to form the mixing chamber, the inlet and the outlet too. The size of pipe used for the main chamber was 10 inches, that for the inlet was 10 inches and the one for the outlet nozzle was 4 inches. Teflon blocks were milled to fit and used as lid for both the inlet and outlet.

Since the pugmill was designed for 24V DC, a high torque D130 Series DC Motor Plus, of 1000W, and a

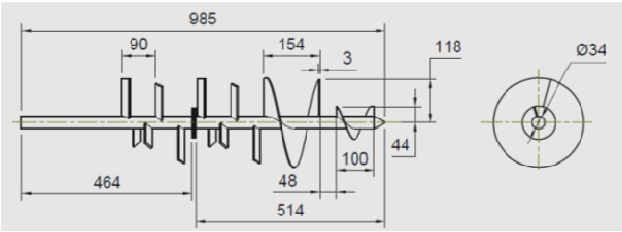


Fig. 5: The dimensional diagram of the auger assembly.

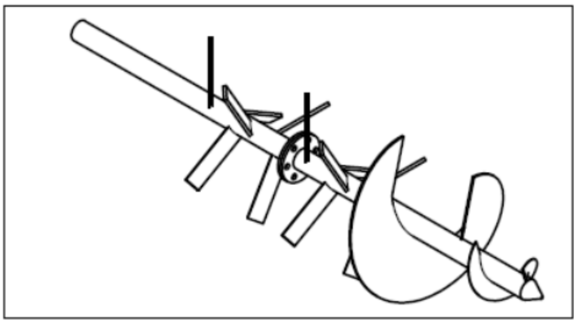

Fig. 6: Detailed drawing of the auger assembly.

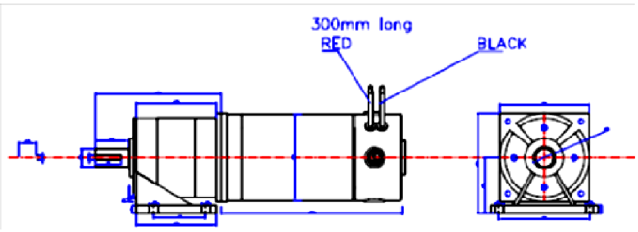


Fig. 7: The D130 Series DC Motor Plus and PX130 planetary gearbox alignment.

Fig. 8: The rugged PX130 planetary gearbox in detail.

Figs. 9 & 10: The thick stainless-steel halves of the chamber being fabricated. Note the auger assembly.

Fig. 9: The finished pugmill, unsprayed.

matching PX130 planetary gearbox with output 30rpm were used to drive the shaft and auger. An industrial grade step-down transformer was used as the superstructure for the 24V DC system. A heavy-duty motor controller was used for the motor, which was connected to the 2-way switch and indicators. 2 mm sheets of steel were used to make the encasement, and then body work and undercoats were applied, before spray painting was done with auto base paint.

**Results**

The stainless steel 24V DC pugmill designed and produced in this study was tested and was able to mix and pug clay to a professional consistency (Fig. 9). The electronic and electrical system also proved adequate, because it was able to achieve the forward and reverse motions required of a pugmill, using the two-way switch. Also, the lids made by machining blocks of Teflon were able to cover the entry and entry points of the pugmill, to keep the chamber air-tight, and preserve the moisture content of materials in the pugmill. Since the framework was made with heavy duty steel, the machine operated without vibrations in the structure. Overall, the pugmill controls were user friendly, simple and conveniently located on the instrument panel within the easy reach of the user. The function indicator light included in the design helps to notify users that the equipment is in operation.

**Conclusion**

Whereas the stainless-steel DC 24V pugmill, designed and produced in this study was less than half the cost of an imported one, the functionality is very much at par with professional pug mills. The clay pugged in the machine come out in very professional consistency, and both staff and students were able to produce ceramic works with the output. There is no doubt at all that the machine will last in use because it is made of stainless steel and will not corrode. And, unlike the earlier pugmill made in the department, this one has a continuous shaft system and there is a lockable compartment where the vital cables are stowed away after use. This will keep the equipment safe and prevent misuse and vandalization. Also, while the fabricated pugmill works with a Direct Current (DC) 24V power and eliminates the risks of electric shocks during use, all respondents feel particularly comfortable about this feature of the machine. From the apparent success of this study, the authors expect it to engender further researches in studio equipment fabrication as a sustainable approach to filling facilities gaps in other departments and universities. In particular, the pugmill is a very useful tool in agriculture, for mixing, milling and extruding animal feed. All that is needed is to install the right form to the nozzle of the pugmill, and it becomes a feed extruder.

**Acknowledgement**

The researchers wish to acknowledge John Qu for his help with the configuration of the complex electrical systems; Kubiat Akpan who helped in the 3D drawings and in the laborious process of forming the stainless-steel components; and Bassey Ofem also for helping with the electrical connections.

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