

Improvisation of mini Crusher by Engineering design and fabrication Principles: Imperative for Demonstration of Mechanical method of Powder Manufacturing Processes in Higher Vocational Schools

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ABSTRACT

The provision of equipment for the purpose of teaching and learning of technological courses in higher vocational schools is limited because of the high cost of importation. Hence, the purpose of this study is "repositioning indigenous technology via design and fabrication of mini crusher for teaching powder manufacturing principles in higher vocational schools". To achieve this, the study carried out design analyses that determined the following parameters: torque on the Shaft = 39 Nm; power required to crush material = 3.5 hp; driving and driven pulley = 600 rpm; length of belt = 1.32 m; speed of driving and driven pulley = 7.86 m/s; weight of pulley = 492 N; weight of crusher on the shaft = 1.45 kg; shaft diameter \approx 22 mm; and tension on V – belt = $T_2 = 1.213$ N, $T_1 = 13.21$ N. The selected materials are sheet and square pipes of mild steel. Other selected accessories are; V- belt, shafts, two ball bearings, bevel gear, an electrical motor of 0.5 hp, switch, plug, four meter 1.5 electrical cable, and pulley of 0.05m and 0.41m diameter. The components are joined together by both permanent welds; and temporal (bolt and nut) methods. The fabricated equipment operates electrically. The equipment was tested by feeding some bulk quantity of hardened clay materials into the machine and allowed to operate for ten minutes. The resultant product was fine powder particles. The following recommendations were proffered: government at all level should encourage mass production of this equipment locally to save importation cost; and also to make it available for school workshop; technologists and instructors of higher vocational schools, should embrace this equipment as a means of improvisation for teaching and learning process of manufacturing technology; and the fabricated equipment should be used for entrepreneurial purposes.

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INTRODUCTION

Indigenous technology is the product of applied science and engineering developed within a specified locality. The application of local scientific knowledge for practical purposes of design and fabrication of devices and machineries; will assist government, indigenous industries and higher vocational schools in saving cost of importation of instructional equipment like the crusher for demonstration of practical in powder manufacturing processes. The application of scientific and engineering principles into physical manufacture of machines starts with design processes.

According to Khurmi and Gupta (2010) design is a physical process that involves planning that translates into creation of physical product that satisfies specific need. So, design is a decision-making process in the field of manufacturing

engineering. Shajad (2010) explained that in design, there are factors to be considered such as: production specifications (capacity, size and weight, and service life), design specification, available material, cost and others. Also, design also involves analysis, optimization and evaluation. The study adapted similar design method of Nzukbee, Fsetus, and Kpabep (2013) where the crusher is design in a way that it holds material between two parallel or tangent solid surfaces and applies sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate or change alignment in relation to each other. After the design analysis was achieved, fabrication processes were initiated; where materials to be use will be sourced locally.

Fabrication is a manufacturing process in which an item is made (fabricated) from raw or

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semi-finished materials instead of being assembled from ready-made components or parts. The fabrication processes of the crusher were done in line with the design analyses already established (Yeshwant and Sahu, 2014). Each component parts were fabricated; while some like the AC motor, ball bearing, and others were bought and assembled. The motor is mounted at the bottom which is a driving member which drives the pulley by means of a V-belt. The pulley drives the shaft mounted with cutters which performs the crushing action. The product of design and fabrication efforts leads to the final production of the crusher.

In the context of this study, a crusher is equipment used for reduction of bulk materials into smaller particles for further application in manufacturing processes. Husang and Sheik (2015) described mechanical crushers as having the ability to reduce the size or change the form of waste materials so they can be more easily disposed of or recycled. Also, the crusher can reduce the size of a solid raw material like the ore in order to achieve different particle size composition. For instructional purposes, mini crushers are necessary in higher technological schools laboratory; most especially in the foundry workshop for demonstration of practical in powder metallurgy technology studies where metal scraps will be crushed into different particle sizes for further usage in production of powder metallurgy or cast products. For foundry purposes, the sand used for the mould can also be crushed into fine grain sizes using a crusher. According to Vishal and Ninawe (2014) crushers are important for metal recycling as well as plastic recycling. The design and fabrication of a crusher for laboratory and workshop use in schools will ease some problems of equipment availability.

The teaching and learning of powder production techniques for foundry, powder metallurgy processes, and other manufacturing practices in tertiary vocational schools; is limited as a result of non-availability of instructional aid like the crusher. In school foundry technology workshop, conversion of bulk and coarse materials into different grain sizes for student's practical are done manually by pounding and grinding with stone.

Hence, the construction of this equipment will apparently reduce the difficulties in manual grinding operation; and will lead to enhanced method of delivery powder manufacturing processes with the use of the equipment. With this, the teaching and learning of powder

metallurgy technology in higher vocational schools will be improved. In view of the problems highlighted above, the study objective tends to address using engineering principles.

Objective of the Study

The objective of the study is "repositioning indigenous technology via design and fabrication of mini crusher for teaching powder manufacturing principles in higher vocational schools". Specifically the study sought to:

1. Carry out design analyses for the component parts.
2. Select relevant engineering materials.
3. Fabricate mini crusher using appropriate techniques
4. Test the fabricated equipment.
5. Demonstrate engineering principles of mechanical power transmission.

METHODOLOGY

In design process of the crusher, there are some major factors that were taken into consideration. These factors include the size, availability of material, ease of operation, cost of manufacture, maintenance, and as well as operating cost.

Design Analysis

1. Determination of Torque on the Shaft

Torque on the shaft = weight of the grain x radial distance to the conveyor shaft:

$$T = Wg \times R_d \text{ Equation (1)}$$

Weight of sample material (hardened clay) (Wg) = mass of material X acceleration due to gravity, $Wg = m \times g$. Using the highest mass of clay for the calculation (say 22 kg); taking $g = 9.81 \text{ m/s}^2$

$$Wg = 22 \times 9.81, W = 216 \text{ N, Radial distance } (R_d) = 183 \text{ mm} = 0.183 \text{ m}$$

$$\therefore \text{Torque developed on the shaft } (T) = 216 \times 0.18, T = 39 \text{ NM.}$$

2. Determination of Power required for crushing material

$$P = \frac{2 \times N \times T}{60} \text{ Equation (2)}$$

Where:

P = power transmitted on the shaft

N = Speed of revolution per minute = 600 rpm

T = Torque developed on the shaft = 39 NM

P = 175.44 W = 1.8 HP (since 1 HP = 766 W)

Using the factor of safety 2

$$\text{Design power required} = 175.44 \times 2 = 350.88 \text{ W} = 2.6 \text{ kw (3.5 HP).}$$

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3. Determination of Driving and Driven Pulley

The diameter of driving pulley and driven pulley selected are $D_1 = 100$ mm, $D_2 = 250$ mm respectively. According to India standard as stated by Khurmi and Gupta (2005)
 $N_1 = 1500$ rpm as for 2639 W (2.6 kw) 3.5 Hp electric motor and it has a gear ratio of 1:2.5.

$$\therefore N_2 = \frac{N_1}{R} = \frac{1500}{2.5} = 600 \text{ rpm.}$$

4. Determination of Length of Belt

D_1 = Diameter of the motor pulley = 100 mm
 D_2 = Diameter of the crusher pulley = 250 mm
To determine the center distance (c)

$$C = \frac{D_2 + D_1 + D_2}{2} \dots\dots\dots \text{Equation (3)}$$

$$C = 425 \text{ mm}$$

The pitch length of the belt is given by (John and Stephen, 1984)

$$L = 2c + \frac{\pi}{2} (D_2 + D_1) + \frac{(D_2 - D_1)^2}{4c}$$

$$L = 1323.09 \text{ mm} = 1.32 \text{ m}$$

5. Determination of the Speed of Driving and Driven Pulley

$$V_1 = \frac{\pi D_1 N_1}{60} \dots\dots\dots \text{Equation (4)}$$

Where $D_1 = 100 \text{ mm} = 0.1 \text{ m}$; $D_2 = 250 \text{ mm} = 0.25 \text{ m}$

$N_1 = 1500 \text{ rpm}$, $N_2 = 600 \text{ rpm}$ and, $V_1 = 7.86 \text{ m/s}$.

$$V_2 = \frac{\pi D_2 N_2}{60}$$

$$V_2 = 7.86 \text{ m/s.}$$

6. Determination of the Weight of Pulley

Tangential load per arm of pulley on the shaft W_p
 $W_p = \frac{T}{R \times n/2} = \frac{2T}{R.n} \dots\dots\dots \text{Equation (5)}$

Where, T = Torque of the shaft = 16.8 Nm, R = Radius of the pulley = 125 mm = 0.125 m
 N = number of arms = 4
 $W_p = 67 \text{ N}$, Total Weight at the Pulley Point on the Shaft = $T_1 + T_2 + W_p = 492 \text{ N}$

7. Determination of weight of Crusher on the shaft

$$W_g = M_g \cdot g \dots\dots\dots \text{Equation (6)}$$

Where

W_g = weight of the grinder; m = mass of the crusher; g = acceleration due to gravity.

$m_g = \rho V = \rho A.t$, Where ρ = density of the cast iron grinder = 7250 kg/m³, V = volume of the grinder, A = cross sectional area of the grinder, t = thickness of the grinder = 0.08 m = 8 mm
 $A = \pi r^2$, r = radius of the cast iron crusher = 0.09 m,
 $A = 3.142 \times (0.09)^2 = 0.025 \text{ m}^2$
 $M_g = 7250 \times 0.025 \times 0.008 = 1.45 \text{ kg}$
 $W_g = m_g \cdot g$ (making $g = 9.81 \text{ m/s}^2$) = 1.45 × 9.81,
 $W_g = 14 \text{ N}$.

8. Determination of shaft diameter

$$d^3 = \frac{16}{\pi S_s} [(K_b M_b)^2 + (K_t M_t)^2] \dots\dots(7)$$

S_s = maximum shear stress = 42 mpa = 42 N/mm², $K_b = 1$, $K_t = 1$, $M_b = 12.72 \times 10^3 \text{ Nmm}$
 $M_t = 41.88 \times 10^3 \text{ Nmm}$
 $d = 21.5 \text{ mm}$, $d \approx 22 \text{ mm}$.

9. Calculation for Tension in V - Belt

Given that $(T_1 - mv^2) = e^{(ua/\sin \theta / 2)} \dots\dots\dots \text{Equation (8)}$

$$T_2 - mv^2$$

$$M = 0.106, V = 0.47 \text{ m/s}$$

$$\text{If } \sim = 0.9$$

$$= 40^\circ$$

$$\theta = 2.78 \text{ radian}$$

$$\text{But } P = (T_1 - T_2) V$$

$$5.66 = (T_1 - T_2) 0.47$$

$$T_2 = 1.213 \text{ N}, T_1 = 13.21 \text{ N.}$$

Material Selection

The selected engineering materials were based on availability, cost and durability while in use. The selected materials are sheet and square pipes of mild steel for the fabrication of the frame and crusher housing; it was used because it is readily available and cost-effective. For the power transmission unit, V- belt was selected for driving the pulleys that turn the crushing device; the reason is because V – belt has more power output compared to flat belt due to its less surface contact with the pulley groove. Other selected accessories are; two ball bearings, bevel gear, an electrical motor of 0.5 hp, switch, plug, four meter 1.5 electrical cable, and pulley of 0.05 m diameter.

Fabrication Techniques

The sheet and square pipe mild steel was cut into the required dimensions joined together by method of welding to form the frame and the crusher housing. An electrical motor of 0.5 Hp was fitted with a smaller pulley of 0.05 m diameter. This is connected to a larger pulley of 0.41 m diameter by means of a v- belt drive. The main shaft is supported on the machine frame by means of two ball bearings housed inside the Plummer blocks to prevent vibrations. The pulley is

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connected to the crushing device by means of a shaft.

Principle of Operation

The fabricated equipment operates electrically. The electrical energy generated from the electricity is converted into mechanical energy by means of the incorporated electric motor through shaft and belt. The crusher is composed of two jaw plates; one is permanently fixed, while the other is moveable by action of rotation. The fixed jaw is vertically mounted on the front wall of the machine body, the movable jaw is inclined and a crushing cavity is formed which is big at the top and small at the bottom. The movable jaw plate swings back and forth, up and down with an eccentric shaft, driven by the motor through the pulley, so that the movable jaw plate conducts a cyclical circulatory motion. The feed material to be crush enters the crushing cavity at the time of separation of the jaws; and is squeezed to break when the two jaw plates meet together; the broken aggregates are discharged from the outlet provided.

Test and Results

After the fabrication process, the equipment was tested by feeding some quantities of hardened clay materials into the machine; and the power source was switch on; and allowed to run for ten minutes. The feed material was crushed into fine grain powder particles; and was discharged from the outlet. The crusher performed significantly efficient. It meets the design function for which it was targeted. This proves that the equipment is suited for use in higher vocational tertiary school foundry workshops and laboratories to demonstrate practical on powder manufacturing and utilization.

Maintenance Requirements

1. The power cable should be inspected at regular intervals to avoid power leakage.
2. The equipment should be loaded with suited materials and quantity according to the capacity of the machine.
3. Routine preventive maintenance should be carried out on the equipment.
4. Loosed nuts and bolts should be tightened regularly.
5. Sliding parts should be lubricated at regular intervals.

CONCLUSION

The design and fabrication processes of the crusher were successfully achieved according

to specifications. The crusher was constructed to ease powder manufacturing operation in small scale quantity for student's practical in school laboratories. It is efficient and cost-effective in production. It was tested by converting bulk clay sand into powder particles. This means that the equipment was suitable for use in foundry workshops for students practical on both casting and powder metallurgy practices.

RECOMMENDATIONS

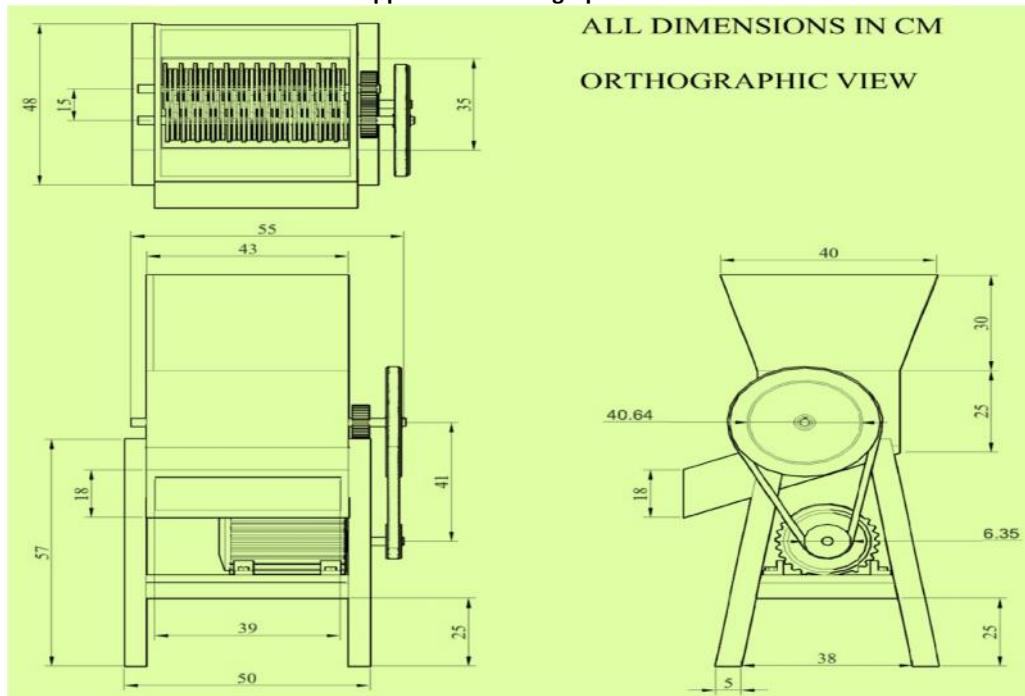
Based on the usefulness of the fabricated equipment, the study recommends that:

1. Government at all level should encourage mass production of this equipment locally to save importation cost on teaching equipment for school workshop.
2. The technologists and instructors from higher vocational schools should embrace this equipment as a means of improvisation for teaching and learning process of manufacturing technology.
3. Apart from school use, the fabricated equipment should be used for entrepreneurial Purposes of business ventures like; food processing, beverages, and other domestic products.

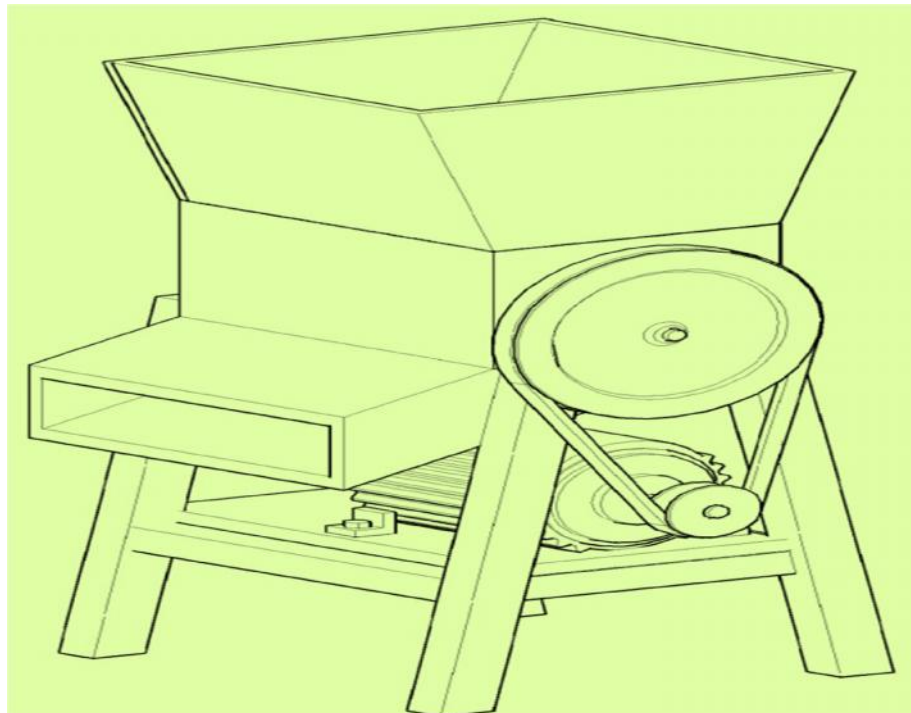
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Appendix A: Orthographic view



Appendix B: Isometric View



Appendices C: Assembly Drawing

