International Journal of Information, Engineering & Technology

Volume 11, Issue 3, PP 52-58, ISSN: 2360-9194, December, 2020
Double Blind Peer Reviewed International Research Journal
garcjournalssubmit@gmail.com
Journal Series: Global Academic Research Consortium (garc)

Modification Design and Construction of Small Size Hammer Mill

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Abstract: *A small size hammer mill was modified designed and constructed using locally available materials. The modification of the design was done in such a way that the hammer of the machine can be mounted directly onto the shaft of the prime mover (petrol engine) which replaced electric motor that is mostly used. This makes possible that the machine can be used without the need for electric source of power supply and also reduces cost of production and maintenance since use of transmission device such as the belt has been eliminated. Efficiency and fuel economy tests were carried out upon completion of the machine. It was found that the efficiency was 85% and with a liter of petrol the machine can mill about 60kg of maize. However, this largely depends on the ability of the operator.*

Key words: *hammer, milling, economy and efficiency*

Introduction

Cereals are main energy providers and give significant amount of protein, vitamins especially vitamin A and C, and minerals like potassium and calcium. Cereals are made into various forms in order for them to be consumed as food by human and animals, these forms include; paste, noodles cakes breads etc. depending largely on the ethnic group and culture of the people. The residues of the processed cereals are important in feeding animals (Ismail *et al.,* 2010). Cereals provide about 80% of the energy requirements in most parts of Africa. Cereals crops produced in larger quantity in Nigeria include maize, millet, sorghum and sugarcane. However, most of these cereals cannot be eaten without their sizes being reduced; this calls for the use of various methods and means of size reduction. In the ancient time, two stones were used to crush the cereal grains to the required sizes before they were prepared as a food for human consumption. But these were gradually replaced by modern tools such as grinding machines, and Hammer mills that are made from steel material (Donnel, 1983). Most of the modern machines are power-driven and the availability and reliability of power supply presented serious challenge in the use of these modern machines. The unreliability and unavailability nature of the power supply has even hindered other economic activities in the country especially small business. Most businesses now decided to use on-site diesel powered generators as their means of power supply (Etukudor *et al.,* 2015). Nigeria's electricity capacity was lower than that of Slovakia, a country with about 3% Nigeria's population, the (Economist group, 2020).

Efforts have been made in the recent time, in design and construction of cereal size reduction machines. However, most of the machines developed have one problem or the other. Grinding machine that used two plates to crush the cereals grains for instance has the disadvantage that the part of plates goes into the ground product as a result of friction between the two plates. Other machines include hammer mills that used electric motor which need source of power supply (external), hammer mills that have many component parts etc.

This paper therefore, aimed at producing hammer mill of simple design that utilizes petrol engine (Prime Mover) instead of the electric motor that needs external source of power supply. The machine consists of few component parts as such it will be easier to operate and maintain.

Material and methods

Materials: The materials selection for the construction work is based on the availability of the material in the market, Cost, durability, malleability, rigidity and ease of fabrication. Therefore, mild steel sheet and angle- iron were chosen in the construction of the machine.

Methodology

The design method adopted in this work was conceptual design, which is based on analysis. The design analysis of various component parts was carried out and the machine was constructed according to the results obtained from the analysis.

Hub design

As the hammers are mounted directly onto the petrol engine shaft by means of a hub, there is no need to design the hammer shaft.
Hub is designed as a hollow shaft subjected to torsion. Thus

$$T = \frac{\pi}{16}\frac{(d_o^4 - d_i^4)}{d_o} \times \boldsymbol{\tau_h}$$

Where τ_h = permissible shear stress in hub

d_o=outer diameter of hub

d_i=inner diameter 0f hub

Empirically

$d_o = 2d_i$ (i.e. outer diameter is twice the inner diameter or diameter of shaft)

$$t_n = \frac{d_o - d_i}{2}$$

The diameter of the petrol engine (Prime Mover) which is the d_i = 20mm

Therefore, d_h = 2x20mm = 40mm

The thickness of the hub $t_n = \frac{d_o - d_i}{2}$

$$t_n = \frac{40 - 20}{2} = 10mm$$

Hammer weight was determined using the formula

W_h= $m_h$xg

Where:

M_h= mass of the hammer in (g)

The material used was mild steel, density of 7.85g/cm^3

$W_{h=}$ 0.79kg

Determination of Power & Torque

The main engine drives the milling beater through power from the shaft of the engine under definite physical specification.

The amount of power transmitted is given by equation.

P= $\frac{2\pi NT}{60}$

Since power of the prime mover is known and the hub was directly mounted to the shaft of the prime mover, it was assumed that the power transmitted to the hub is the same. Based on this, the power was taken as

5.5×745=4097.5w

Torque acting upon the shaft is given by

$$T = \frac{\pi}{16} \frac{(d_o^4 - d_i^4)}{d_o} \times \tau_h$$

And from this relation

$$\frac{t}{j} = \frac{t}{r}$$

Where J polar moment of inertia of the shaft about the axis of rotation

T= Torsional sheer stress

r =Distance from neutral axis to the outer most fiber, that is $\frac{d}{2}$

Torque transmitted to the hub was found to be 20.363Nm

Determination of centrifuge force (f_c)

$F_c = \frac{mv2}{r}$

But v = ωr

And $\omega = \frac{2\pi N}{60}$

N= 3000 rpm (manufacturer specification)

$\omega = \frac{2\pi 3000}{60}$

= 314.2 rad/sec

r= radius of the prime mover shaft =10mm (manufacturer specification)

$F_c = m\omega^2 r = 2\times0.08\times314.2^2\times0.1 = 1580N$

Damping Characteristics

Damping characteristic of the machine is determined as below:

The mass of the machine = 43.8kg

The coefficient of damping C = 75u/m

The stiffness of the material k = 750N/m

The natural frequency $w_n = \sqrt{\frac{k}{m}}$

$$w_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{750}{43.8}} = 4.13$$

The damping factor of the material

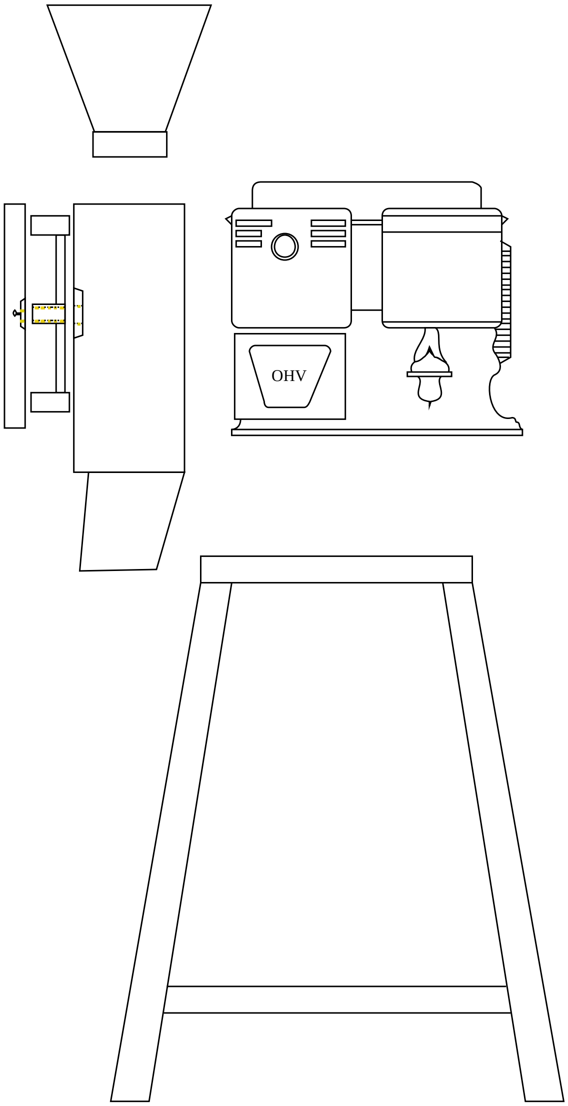
$$\eta = \frac{c}{2mwn}$$

$$\eta = \frac{750}{2\times45.56\times16.46} = 0.50$$

$$w_d = w_n\sqrt{1-\eta^2}$$

$$w_d = 4.13\sqrt{1-0.5^2}$$

$$w_d = 3.6rad/s$$



S/NO	Part
1	Hopper
2	Milling Chamber Cover
3	Hammer
4	Milling Chamber
5	Main Frame
6	Prime Mover

Figure 1 exploded view of the machine

Figure 2 photograph of the milling machine

Results and Discussion

Table (1) Milling results

test	types of organ	input (kg)	Output(kg)	time taken (s)
1.	Maize	2	1.6	3.06
2.	Maize	2	1.8	3.30
3.	Maize	2	1.5	3.34
4.	Maize	2	1.7	3.19
5.	Maize	2	1.9	3.47

Average output (kg) = 1.6+1.8+1.5+1.7+1.9 = 8.5/5 = 1.7kg
Average time taken (min) = 3.06+3.30+3.34+3.19+3.47/6 = 3.27min
Rate of milling = 1.02/3.27 = 0.31kg/min
Efficiency = output/inputx100=1.7/2.0 x 100 = 85%

Table 2 Quantity of petrol consumed using two hammers

Test	Mass (kg)	Initial reading	Final reading	Quantity of fuel (ml)
1	2	6.7	48.2	41.5
2	2	6.4	36.7	30.3
n	2	2.1	36.6	34.5
4	2	1.2	33.8	32.6
5	2	1.3	48.7	47.4

Average quantity of petrol consumed 2kg = 41.5+30.3+34.5+32.6+47.4/5=35.3ml/2kg
Therefore, quantity of petrol consumed per kg = 35.3/2 = 17.7ml

Discussion

The modification of the machine has been achieved by eliminating some component parts of the machine like the belt and pulleys which were used to transmit power from the prime mover. Moreover the hammer shaft has also been eliminated instead the hammers were mounted to the shaft of the prime mover by means of a hub and thus the design was simplified. The machine was the constructed based on the modified design. The tests for determination of efficiency and fuel economy conducted has yielded positive results in that the efficiency was quite impressive and the fuel consumption of the machine revealed that the machine is economical to use.

Conclusion

The hammer mill has been designed and constructed in accordance with the design parameters. And tests were carried out to determine the efficiency and the fuel economy of the machine. It was found that the efficiency was 85% and fuel consumption of the machine was 17.7ml per/kg.

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