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Research Article

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Design of an Improve Hammer Mill

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Abstract This research work focus on the design of a hammer mill machine for milling of agricultural products into final products mainly for consumption and storage. The machine consists of hopper, a crushing chamber, a screw feeder, belts and pulleys, crusher and electric motor for power transmission. Solid work modeling was used to physically model the design machine. The machine was designed such that a minimum crushing force of 8.7N and power of 3hp-5hp can uniformly crush agricultural products for storage. The results of the physical model showed that when the machine is fabricated, it can be used domestically and for low scale industrial use.

Keywords Hammer Mill, Design, Physical modelling, SolidWork

1. Introduction

For proper processing of agricultural products such as cereal, millet, maize, etc., particle size reduction is required. Reduction of agricultural products can be achieved through hammer mill. Hammer mills are mainly used for crushing of materials. It operates by revolving beater that either swing or rigidly connected and it construction are relatively simple. They are available in various sizes and most importantly it is design in such a way that the mill wears do not affect their efficiency [1-2]. There are several hammer mill that are in existence but many has major limitation such as the inability to produce uniform grinding due to high revolution per minute (rpm) [3]. Also, their cost of construction is too high for local farmers and their power requirements may be too high than what is demanded by a local farmer.

Besides the limitations, hammer mills over the years has recorded success in both food and feed industries as a milling machine [4]. Its advantages of high productivity and flexibility of grinding a large variety of products make hammer mill the best choice for agro-materials [5]. The advantages of hammer mill over its disadvantage are more when compared to other milling machines. Size reduction processes need a lot of energy to overcome frictions and energy in form of heat that is dissipated to the product thereby wasting energy from the mill to the product in milling [3]. Considering the huge agricultural products that is produce in Nigeria, there is need to design an improve hammer mill that is cost effective, efficient and most importantly suitable for Nigeria market and local farmer usage. This research work is focus on the design of an improve hammer mill.

2. Materials and Methods

The machine consists of feed hopper, a crushing chamber, rotating crushing blade, crushed product outlet tray, belts and pulleys and electric motor for power transmission. Solid work modeling will be used to physically model the design machine. The machine is design to provide resistances against;

- Friction/ impact on rubbing surface
- Strain of the machine element and
- Heating up cause by operation on the material

In this improve design, the efficiency of the hammer mill can be increased by the following way;

- Increasing their resistance against wear and this can be achieved by reducing the strain in the material of its working tool.
- Also, by decreasing the number of deformation cycles of the materials to ground and
- Finally, by decreasing the breaking stress of the working tool of the materials.

Design consideration

- The hammer mill machine will consist of a crushing chamber
- The length of the horizontal axis must not exceed 400mm and 200mm respectively
- It will operate within a rotating speed of 1440 and 4000rpm
- The machine must not deliver force that can exceed 8.7N
- The shearing force must not exceed 5.8N. A safety factor of 1.5 will be used
- Determination of approximate length of the belt (m)
- Determination of load on shaft pulley and belt tensions (N)
- Selection of bearing for shaft
- Determination of minimum shaft diameter (m)

Detail design

Determine of crushing force and crushing power [6]

$$P = FV \qquad (1)$$

Where,

P = power to turn the shaft

V = speed

F= Force= mass x acceleration due to gravity

$$V = \frac{\pi DN}{60} \qquad (2)$$

Where,

V= Speed

D= Diameter

N= Speed in revolution per minute

Force = mass x acceleration due to gravity

That is,

$$F = ma \qquad (3)$$

Where,

m = mass

a = acceleration due to gravity

Power to crush the material is the power required to drive the shaft.

Substituting equation 2.2 and equation 2.3 into equation 2.1

$$P = \frac{ma\pi DN}{60} \qquad (4)$$

2.2.2 Belt design

$$2.3 \log \left({}^{T_1}/_{T_2} \right) = \mu\theta \qquad (5)$$

Where,

θ = angle of wrap of an open belt

μ = coefficient of friction

T_1 = Tension in the tight side of the belt

T_2 = tension in the slack side of the belt

x = distance between the pulleys

For cross belt,
Angle of contact is given by

$$\sin\alpha = \frac{R+r}{x} \quad (6)$$

For open belt,
Angle of contact is given by

$$\sin\alpha = \frac{R-r}{x} \quad (7)$$

Angle of wrap;

$$\theta = 180 \pm 2\sin^{-1}\left(\frac{R-r}{x}\right) \quad (8)$$

Where,
r = radius of small pulley
R = radius of big pulley
X = distance between the two pulleys
For peeling machine with inner (rotation) the angle of contact is,
For open belt, angle of contact is given by

$$Sin\alpha = \frac{R-r}{x} \quad (9)$$

Angle of wrap,

$$\theta = 180 \pm 2\sin^{-1}\left(\frac{R-r}{x}\right) \quad (10)$$

$$P = (T_1 - T_2)v \quad (11)$$

Where,
P = Belt power (watts)
V = Belt speed (m/sec)
T_1 and T_2 are tension on the tight and slack sides respectively (N)
But,
$1hp = 750watts$

$$T_1 - T_2 = \frac{p}{v} \quad (12)$$

From, equation 3.5

$$2.3\log\left({}^{T_1}\!/_{T_2}\right) = \mu\theta$$

Where μ = coefficient of friction between belt at pulley for mild steel pulley and rubber belt, $\mu = 0.30$
But for open belt, angle of contact is given by,

$$\text{Sin}\,\alpha = \frac{R-r}{x}$$

Therefore,

$$\text{Sin}\,\alpha = \frac{75-25}{160}$$

$$\text{Sin}\,\alpha = 0.3125$$

$\propto = sin^{-1}0.3125 = 18.21°$

Also,
$\theta = 180° - 2\propto$

$\theta = 180° - 2 \times 18.21°$

$= 143.58°$

Converting the angle from degree to radian

$143.58° \times \frac{\pi}{180°}$

= 2.51rad

Recall from equation 3.2

$V = \frac{\pi DN}{60}$

= 3.142x 0.15x1440/ 60 = 11.31m/sec

From equation 3.11,

$P = (T_1 - T_2) V$

Therefore,

$T_1 - T_2 = \frac{P}{V}$

$T_1 - T_2 = \frac{1500}{11.31}$

$T_1 - T_2 = 132.62N$ (13)

Calculating the belt ratio for an open belt

$2.3\log[\frac{T1}{T2}] = \mu\theta$

$\mu =$ Coefficient of friction between belt and pulley

But for mild steel pulley and rubber belt,

$\mu = 0.30$

$2.3\log[\frac{T1}{T2}] = 0.3 \times 2.51$

$2.3\log[\frac{T1}{T2}] = 0.753$

$\text{Log}[\frac{T1}{T2}] = \frac{0.753}{2.3}$

$\text{Log}[\frac{T1}{T2}] = 0.3274$

$\frac{T_1}{T_2} = e^{0.3274}$

$\frac{T_1}{T_2} = 1.387$

Therefore,

$T_1 = 1.387T_2$ (14)

From equation 2.13,

$T_1 - T_2 = 132.62N$ (15)

$T_1 = 132.62N + T_2$ (16)

Equating equation 14 and equation 16

$1.387\ T_2 = 132.62N + T_2$

$1.387\ T_2 - T_2 = 132.62N$

Therefore,

$0.387\ T_2 = 132.62N$

Therefore,

$$T2 = \frac{132.63N}{0.387} = 342.71N$$

Also,

$T_1 = 1.387T_2$

$T_1 = 1.387 \times 342.7 = 375.34N$

From equation 2.16,

$T_1 = 132.62N + T_2$

$T_1 = 132.62N + 342.71N = 475.33N$

Design for velocity ratio for belt drive

Velocity ratio for belt drive is the ratio between the velocity of the driver and the follower (driven). It may be expressed mathematically as:

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \quad (17)$$

Where,

d_1 = diameter of the driver

d_2 = diameter of the follower

N_1 = speed of the driver

N_2 = speed of the follower

Length of the belt that passes over the driver in one minute is given by;

$$\pi d_1 N_1 \quad (18)$$

Similarly, length of belt that passes over the follower in one minute is given by,

$$\pi d_2 N_2 \quad (19)$$

Since the belt passes over the driver in one minute is equal to the length of the belt that passes over the follower in one minute

Therefore;

$$\pi d_1 N_1 = \pi d_2 N_2 \quad (20)$$

Therefore,

$$\frac{N_2}{N_1} = {d_1}/{d_2} \quad (21)$$

But,

d_1 = 50mm

d_2 =150mm

N_1 = 1440rpm

$$N_2 = \frac{50mm \times 1440rpm}{150mm} = 480rpm$$

$N_1 : N_2 = 1440 : 480$

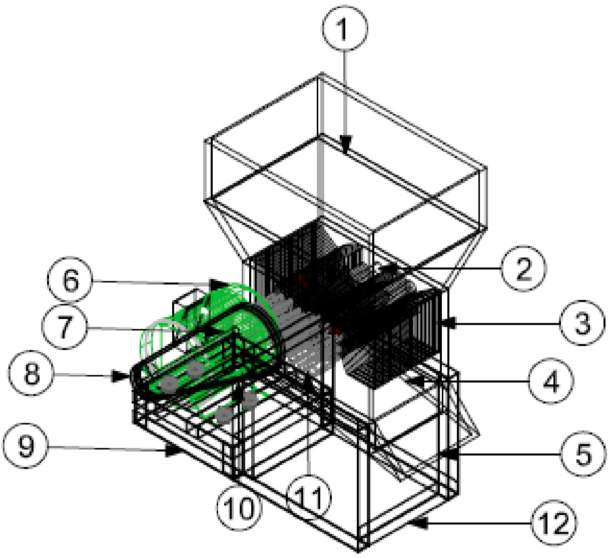
$= 144 : 48$

= 3:1

Therefore,

Velocity ratio of belt drive = 3:1

Figure 1 shows isometric skeletal view of Hammer mill and Figure 2 Model view of Hammer mill



S/NO.	DESCRIPTION
1.	FEED HOPPER
2.	SHAFT
3.	ROTATING CRUSHING BLADE
4.	CRUSHING CHAMBER
5.	CRUSHED PRODUCT OUTLET TRAY
6.	ELECTRIC MOTOR
7.	DRIVEN PULLEY
8.	DRIVE PULLEY
9.	ELECTRIC MOTOR BASE FRAME
10.	DRIVE TRANSMISSION BELT
11.	GEAR
12.	MACHINE FRAME

Figure 1: Isometric skeletal view of Hammer mill

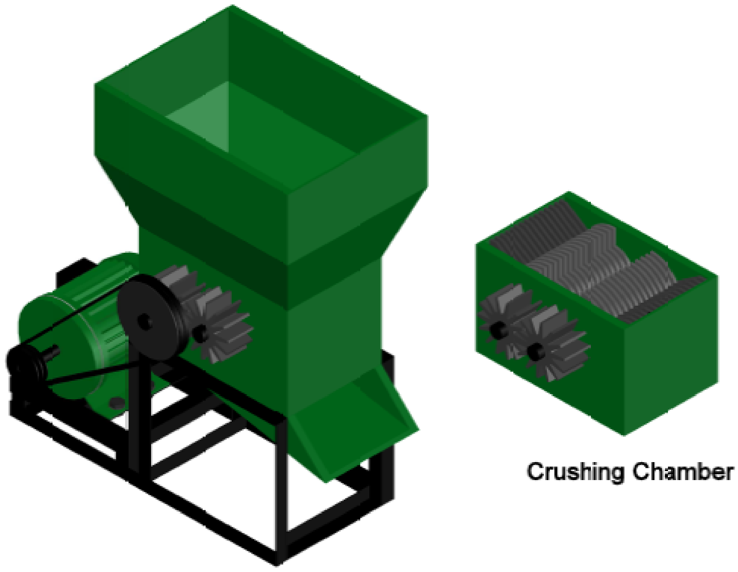


Figure 2: Model view of Hammer mill

Results and Discussion

An improve hammer mill designed for milling agricultural by-products in Nigeria was evaluated for performance. The hammer mill machine was physically model with SolidWorks software. From the detail design of the machine, the machine was design in such a way that the force to be delivered by the machine must not exceed 8.7N. This value was obtained from the applied design factor of 1.5 and the shearing force of 5N require to crush the agricultural by products. Although, from the work of other researchers, 10HP was calculated for but from the analysis and estimation, 3hp-5hp can be used. The analysis of the physical modeling using SolidWorks showed that the machine will be able to crush agricultural products to the required sizes for storage and consumption.

Conclusion

An improve hammer mill for crushing agricultural products was successfully designed. A physical model of the machine was analyze using solid work. Detail design was carried out and the results showed that minimum crushing force and power can be used for crushing agricultural products. The new design required less materials parts, thus cost effective.

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