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Department: Mechanical Engineering

Level: 500LVL

Course: MEE510 (Product Design)

 ASSIGNMENT

**Product/Project Designed**

Development of a Hammer mill.

The aim of the project is to develop a hammer mill machine that can crush the dried bone used in production of livestock feed. In achieving this aim, the following tangential objectives were pursued;

1. Design the hammer mill with the use of AutoCAD
2. Source for materials locally
3. Fabrication of the hammer mill based on design specification
4. Carry out the performance evaluation of the hammer mill

**Material Selection**

 The materials that were used in the production of the hammer mill machine are mild steel, shaft, bearing, plate sheet, angle bar, bolt and nut, belt, pulley, electric motor, socket, cutting stone and filling stone.

 Since the machine is expected to be a means by which agricultural workers in the rural area of the country can convert bone waste or maize to feed, the machine has been designed to keep cost low by using materials that are readily available and cheap.

**Factors Considered in Choosing the Materials**

Mild steel was chosen as the material to fabricate the milling machine due to its strength and low medium carbon content which makes it easy to weld and gives it a low weight thus enhancing ease of conveyance. Since the machine is expected to be a means by which agricultural workers in the rural area of the country can convert bone waste or maize to feed, the machine has been designed to keep cost low by using materials that are readily available and cheap.

So therefore, the factors considered in choosing the materials for the development of the hammer mill are the;

1. Strength of the material
2. Availability of the material
3. Cost of the material
4. Weight of the material

**Design Specifications**

The hammer mill machine designed would be used to reduce the size of dried bone in particular into smaller particles for the production of livestock feed and the machine was designed for a maximum capacity of 20kg.

**Details Drawing**

The parameters obtained from the system design consideration gave rise to the diagrams below. Figure 1.1 shows the side view of the top casing which is semicircular and designed with the hopper. The hopper or feeder is fabricated to ease intake of feeds. Figures 1.2, 1.3a and 1.3b show the frame, hammer shaft and main shaft respectively; it is the main support for all the components. Figure 1.4 is the hammer. There are 16 all together and each is bolted to Figure 1.5. The rotor disc is welded to the shaft that transfers force for crushing. Figure 1.6 is the screen or sieve that determines the milled product size. The bottom casing which houses the rotor disc with hammers and screen is shown in Figure 1.7. Figure 1.8 is the exploded view of the proposed hammer mill machine which illustrates the various components for assembling. Isometric view of the developed hammer mill is presented in Figure 1.9



Figure 1.1: The Side view of the top casing and hopper



Figure 1.2: The Frame



Figure 1.3a: The Hammer shaft



Figure 1.3b: The Main shaft



Figure 1.4: The Orthographic and isometric view of hammer.



Figure 1.5: The Top and side view of the rotor disc.



Figure 1.6: Diagram of screen with perforated holes.



Figure 1.7: The Orthographic and isometric view of the bottom casing.



Figure 1.8: The Exploded view of the hammer mill machine.



 Figure 1.9: The Isometric and orthographic view of the developed machine



Figure 1.10: The front view of the hammer mill machine



Figure 1.11: The side view of the hammer mill machine



Figure 1.12: The Hammer on the auxiliary shaft of the hammer mill machine

**BEME (Bill of Engineering Materials and Evaluation)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S/N** | **Specification** | **Quantity** | **Unit Price** | **Price(N)** |
| 1 | Mild steel | 1 | 18000 | 18000 |
| 2 | Pulley | 2 | 2500 | 5000 |
| 3 | Bearing | 2 | 2500 | 5000 |
| 4 | Electric motor (5.5hp) | 1 | 30000 | 30000 |
| 5 | Screen | 1 | 5000 | 5000 |
| 6 | Rotor Disc | 1 | 5000 | 5000 |
| 7 | Belt | 1 | 3500 | 3500 |
| 9 | Bolt and Nut | 1 | 2500 | 2500 |
| 10 | Damper | 1 | 4000 | 4000 |
| 11 | Driving Shaft | 1 | 6000 | 6000 |
| 12 | Main Shaft | 1 | 6000 | 6000 |
| Total = 90,000 |

**Design Calculation**

The values used in the design calculations are actual measured dimensions of the fabricated prototype. A shaft of 25 mm was machined and used.

**1.1 Determination of shaft speed**

To calculate the shaft speed, the following parameters were measured from the constructed work and consequently used in Equation 1.1 (Spolt 1988):

D1 = 0.09m, D2 = 0.07m, N1 = 1725 rpm

$\frac{D\_{1}}{D\_{2}}=\frac{N\_{1}}{N\_{2}}$ (1.1)

where, N1, revolution of the motor pulley, rpm; N2, revolution of the shaft pulley, rpm.; D1, diameter of motor pulley, m; D2, diameter of shaft pulley, m

Therefore,

$$N\_{2}=\frac{N\_{1}D\_{2}}{D\_{1}}$$

=$N\_{2}=\frac{1725\*0.07}{0.09}=1341.7rpm$

**1.2 Calculation of length of belt**

The length of the belt was calculated from the measured driver and driven pulley diameters and also the centre distance between the driver and driven pulley. The centre distance is 490 mm. The Equation 1.2 below was used (Patton,1980)

L= 2C + $\frac{π}{2}\left(D\_{1}+D\_{2}\right)+\left(\frac{D\_{1-}D\_{2}}{4C}\right)^{2}$ (1.2)

where, L, Length of the belt, mm; C, Centre distance between shaft pulley and the motor pulley = 490 mm (measured on the fabricated machine)

L= 2(490) + $\frac{π}{2}\left(90+70\right)+\left(\frac{90-70}{4x490}\right)^{2}$

L = 980 + 251.36 + 0.0001 = 1231.33mm

**1.3 Belt contact angle (actual values of construction materials used)**

The belt contact angle is the angle the belt makes with the pulley. It is given in Equation 1.3 by (Hall, Holowenko, and Laughlin 1980)

$β=sin^{-1}\left(\frac{R-r}{C}\right)$ (1.3)

where, R, radius of the motor pulley, mm; r, radius of the shaft pulley, mm

$β=sin^{-1}\left(\frac{45-35}{490}\right)$= 1.17o

The angles of wrap around each pulley are given by Equation 1.4 and 1.5:

$α\_{1}$ = 180 + 2$ β$ for motor pulley (1.4)

$α\_{2}$ = 180 − 2$ β$ for shaft pulley (1.5)

where, $α\_{1}$, angle of wrap for the motor pulley, deg; $α\_{2}$, angle of wrap for the shaft pulley,

 Therefore,

$α\_{1}$ = 180 + (2 × 1.17) = 182. 34°

$α\_{2}$ = 180– (2 × 1.17) = 177.66o

**1.4 Determination of weight of hammer**

The mass of the hammer was weighed to be 0.2 kg (Patton 1980)

Wh = Mh g,

where, Wh, Weight of hammer, Mh, Mass of hammer, g, acceleration due to gravity (9.81 m/s2).

Therefore,

Wh= 0.2 × 9.81 = 1.962 kg/m2

**1.5 Centrifugal force exerted by the hammer**

Centrifugal force exerted by the hammer can be calculated from the Equation 1.6 below (Hannah and Stephens 1984)

Fc = $\frac{MV^{2}}{r}$ (1.6)

where, M is Mass of the hammer, kg; V is Velocity of the shaft, m/s; r is the radius of the shaft, m (25 mm diameter shaft); D1, diameter of motor pulley, m; N1, speed of motor, rpm. The shaft velocity is calculated by equation 1.7, given below as

V= $\frac{πD\_{1N\_{1}}}{60}$ (1.7)

V= $\frac{3.142X 0.09 X 1725}{60}$= 8.13m/s

Therefore, the centrifugal force is obtained below using Equation (1.6).

Fc = $\frac{0.2 X8.13^{2}}{0.0124}$= 1066.07 =1.07kN

**1.6 Determination of tensions on the belt**

The belt drive primarily operates on the friction principle. The driver pulley on the electric motor gives motion to the belt that is then transmitted to the driven pulley. Due to the presence of friction between the pulley and the belt surfaces, tensions on both sides of the belt are not equal. So, it is important to identify the higher tension side (tight) and the lower tension side (slack). The density of belt (rubber) is given as 1140 kg/m3 (Hall, Holowenko, and Laughlin 1980; Khumi and Gupta 2010) in Equation 1.8.

$\frac{T\_{1}}{T\_{2}}= e^{μθ}$ (1.8)

Or

$\frac{T\_{1-}T\_{c}}{T\_{2}-T\_{c}}= e^{μθ} $ (1.9)

TC = MV2 (1.10)

Also,

TC = $\frac{T\_{1}}{3}$ (1.11)

where, T1, Tension on the tight side, N; T2, Tension on the slack side, N; TC, centrifugal tension, N; μ, coefficient of friction between the belt and the pulley = 0.3 (assumption); θ, angle of wrap of the motor pulley, deg.; M, mass of belt per unit length (width × thickness × belt density), kg/m; V, velocity of the belt, m/s2

Note: The belt used is a V belt with 13 mm width and 8 mm thickness. Therefore, mass of belt per unit length is calculated below

M = 0.013 × 0.008 × 1140 = 0.1186 kg/m

From equation 3.10, centrifugal tension is

TC = 0.1186 × 8.132 = 7.84N

Hence using equation 1.11,

3TC = T1; T1 = 3 × 7.84 = 23.52N

from equation 3.9,

$$\frac{23.52-7.84}{T\_{2}-7.84}= e^{0.3X5.48}=5.176$$

15.68 = 5.176(T2 − 7.84)

Hence, T2 = 10.87 N

**1.7 Determination of power transmitted by the belt**

The power transmitted by the belts is obtained from the tensions in the tight and slack side of the belt and the velocity of the electric motor in Equation 1.12.

Power = (T1 + T2) V (1.12)

P = (23.52 + 10.87) × 8.13 = 279.59W

**Design Process/Manufacture**

The mild steel plate was cut to specification to fabricate the hopper, and some other parts were considered to specification so as to fit the design. Flat metal plate was welded to the tip ends of the hopper front: This serves as a channel through which the base will be joined to the hopper using bolts and nuts. Solid shaft of adequate size was selected. The hammer chamber plate was also cut to specification and welded together, six auxiliary shafts were welded to the gaps between the disc and two hammers where inserted on each of the shafts, making twelve hammers all together and the entire component was welded to the stand. The angle iron bars were welded together to form the support on which the hammer chamber stands.