Design, Analysis and Development of a Studs Grinding Machine

[1]EJEHSON PHILIP SULE, [2]KENNETH .O.ENEBE, [3]ASHA SATURDAY, [4]UGWU HYGINUS SUNDAY
[1,3,4]Scientific Equipment Development Institute SEDI, BOX 3205, Enugu, Enugu State, Nigeria
[2]Agricultural Machinery and Equipment Development Institute (AMEDI), Mbutu, Aboh Mbaise, Imo State. Nigeria

***Abstract*-Nigerian grains like millet, sorghum, maize, cowpeas, guinea-corn and soya beans grinded into flour by mills which could be time consuming, energy sapping, monotonous and virtually environmental pollution usually associated with the operation of conventional mills A Stud grinding machine has been designed, fabricated and tested. The tests and analysis were carried out by using vertical throw electromagnetic sieve to determine particle size distribution on the grinded roasted soya beans by the stud grinder to show its efficiency of specific size of 50 µm to 80µm .at an optimum speed of 2880RPM powered by a single phase 2hp 1440RPM electric motor . This would diversify storage options for the grains, deepen and widen the available food choices for all Nigerians and enhance food security and rural development.**

***Index Terms:* design and development, Nigerian grains, stud grinder, particle size distribution efficiency.**

1. INTRODUCTION

Grinding and milling may be interchangeable when referring to particle size reduction. Hammer mills for fine pulverizing and disintegration are operated at considerable high speeds. The rotor shaft may be vertical or horizontal, generally horizontal; Perry and Don, [1998]. The shaft carries hammers, sometimes called beaters. The hammers may be T-shaped element, bars, or rings fixed or pivoted to the shaft or to disks fixed to the shaft. The grinding action results from impact and attrition between lumps or particles of the material being ground, the housing and the grinding elements. It also consists of a heavy perforated screen (Henderson and Perry, 1982) which can be changed. Though it is a versatile machine and its hammer wear does not reduce its efficiency, yet the power requirement is high and it does not produce uniform grind. Common types available in the industry include the Imp Pulveriser, the Mikro Pulveriser, the Fitz Mill, etc. Another class of size reduction machines is the Ringroller mills. They are equipped with rollers that operate against grinding rings; Perry and Don, [1998]. Pressure is applied with heavy springs or by centrifugal force of the rollers against the ring. Either the ring or the rollers may be stationary. The grinding ring may be in a vertical or a horizontal position. Ring-roller mills also are referred to as ring roll mills or roller mills or medium-speed mills.

Another category available is the Attrition Mills. The disc attrition which is sometimes called the Burr mill consists of a set of two hard surfaced circular plates pressed together and rotating with relative motion , Onwualu, A.P., C.O. Akubuo and I.E. Ahaneku ,[2006]. Stones are replaced by steel disks mounting interchange metal or abrasive grinding plates rotating at higher speeds, thus permitting a much broader range of application. They are used in the grinding of tough organic materials, such as wood pulp and corn grits (Perry and Don, 1998). Grinding takes place between the plates, which may operate in the vertical or horizontal plane. The material is fed between the plates and is reduced by crushing and shear. Though the power requirement is low, operating empty may cause excessive burr wear and a lot of heat is generated during shearing action.

These are good designs with their respective limitations besides the bulkingness of the machines, environmental pollution with the dust of the products. Stud grinder is portable, manufactured with light locally sourced materials while considering the fact that it is made for grinding consumables.

2. PROBLEM STATEMENT

Bulkingness of a machine will rise the cost of its production and will in turn affect the selling price, this is a source of discouragement on the side of the user or the producer besides its performance or efficiency. Production and quick output turn out have to be considered with the time saving and energy conservation ability of a mechanical product; hence the design and fabrication of a stud grinder for grinding of bone dried or roasted grains.

3 SCOPE OF STUDY

This study show case the design and analysis of a stud grinder with all equations involving the design synthesized and detailed to be use for the fabrication in SEDI Enugu.

4. AIMS AND OBJECTIVES

Design and development of a stud grinder is aim at :

1. Saving time and conserving energy for grinding bone dried grains in mills.
2. Minimizing spills that would result to pollution.
3. Developing a portable machine where weight reduction is considered.
4. Establishing a choice for using stud grinder when grinding bone dried or roasted grains than mills.
5. Creating a source of revenue for local fabricators since the materials were locally sourced and enhancing the use and consumption of local products.

5. MACHINE DESCRIPTION

The stud grinding machine is comprise of three main units- power transmission unit, grinding unit, and delivery unit besides the frame . Power transmission unit includes v-belt ,v-pulley with power shaft and machine shaft. Grinding unit is the rotating disc with studs mounted, and the cylindrical grinding chamber. Deliverying unit is the hopper ,perforated sieve,and chute. The frame is to give rigidity and support to all other components parts of the machine like the skeleton to the human body. The grinding operation is by continous impact of the solid particle of materials to be grinded with the studs and wall of the grinding chamber.

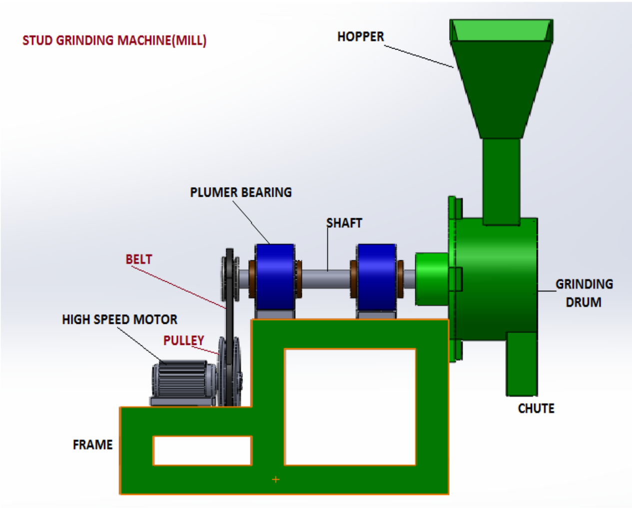

Fig1 VIEW OF THE STUD GRINDING MACHINE SHOWING COMPONENTS

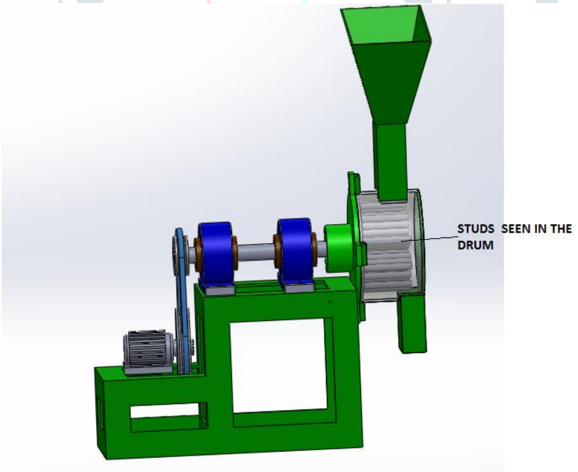

Fig 2.VIEW OF THE MACHINE SHOWING STUDS IN THE DRUM

6. DESIGN

6.1 DESIGN CONSIDERATION

Design is the transformation of concepts and ideas into useful machinery (Bernard *et al*., 1999).

The following factors were considered in the design and development of a stud grinding machine.

i. Material selection.
ii. Corrosion.
iii. Size of electric motor or power requirement.
iv. Size of machine shaft.
v. Hygiene.

a. MATERIAL SELECTION

All materials are locally sourced on the basis of the local content initiative in Nigeria. The pulley is aluminum made ,the machine shaft is stainless steel together with the disc, the studs ,cylindrical grinding chamber, hopper chute and the perforated sieve. The frame is mild steel with the bushon for the aluminum pulleys. Since different materials are involved, hence different metal joining processes and alloy electrodes will be used with stainless steel and mild steel.

b. CORROSSION AND HYGIENE

Corrosion is prevalent in engineering materials especially the mild steels. The machine is designed for processing consumables hence in making choice of materials corrosion must be considered to avoid food poisoning and contamination. Thus ,the choice for stainless steel material which are also very available in local markets.

6.2 GRINDING PROCESS ANALYSIS

The stud grinding machine grinds by impact method. The disc and the stud have impellers ability to hit and deform or break the particles continually among the member studs or with the hard wall of the grinding chamber. Each stud is in a particular radius R_A from the axis of rotation (0).Thus, the have different impacts since their radii R_A are different and under the different angular speed as their individual radius R_A is a function of their relative position to the axis of rotation ,this follows the principles of placing two masses at different position relative to the axis of rotation. Assuming the impelling studs to posses equal masses m but different radii R_A.

Tangential linear velocity of the particle, V_t

$V_t = \omega R_A$ (1)

The acceleration of the Particle, a_T

$a_T = \frac{V_t^2}{R_A}$ (2)

the centripetal force Cf is determined as

$Cf = ma_T$ (3)

Where m =mass of particle

Therefore,

$Cf = m\omega^2 R_A$ (4)

Collision between the particles and particles and the studs is perfectly elastic.

7. ELECTRIC MOTOR SELECTION

Considering the load to be carried by the motor on full load condition at starting torque of the motor

Weight of the studs and shaft assembly W_S

Weight of machine pulley W_P

Weight of materials to be grinded W_M

The Torque Load F

$F = (W_S + W_P + W_M)g$ (5)

Where ,

g=acceleration due to gravity =9.81m/s^2

Considering a safty factor(sf) of 1.5

Maximum load =sf x applied load

Thus ,Ultimate load F_{ult}

$F_{ult} = 1.5F$ (6)

Torque developed by the electric motor T_M

$T_M = F_{ult} R_M$ (7)

Where

R_M =radius of motor pulley

Power of the motor P_M

$P_M(KW) = \frac{T_M N_M}{9550}$ (8)

8. DESIGN FOR PULLEY

The machine pulley diameter was selected using the equation for speed ratio determines the sizes of the pulleys. A speed ratio of machine to electric motor is chosen to be

$\frac{N_C}{N_m} = \frac{2}{1}$ (9)

$\frac{D_m}{D_C} = \frac{N_C}{N_m}$ (10)

where,

Nm = Rotational speed of electric motor = 1440 rpm

Dm = Measure diameter of motor’s pulley = 0.15

D_C = Measure diameter of machine’s pulley

Nc = Rotational speed of machine (rpm)

9. DESIGN FOR BELT

Selection of belt type is based on the power transmitted (3.7 kw) and according to the Indian standards (IS: 2494-1974), belt type A was selected from Khurmi and Gupta (2004) developed equation for calculation of length, L:

$$L = \frac{\pi(D_1+D_2)}{2} + 2X + \frac{(D_1+D_2)^2}{4X} \quad (11)$$

where,
L = Length of belt (in)
D1 = Smaller sheave diameter = Dm
D2 = Larger sheave diameter = Dr
x = Centre distance of pulleys

10. DESIGN FOR SHAFT:

A shaft is the rotating machine element which transmits power from one place to another (Khurmi and Gupta, 2004). The shaft of the cassava flour machine which is rotating the beaters and fan will be subjected to twisting moment only. For a shaft subjected to twisting moment only, the diameter of the shaft was obtained by using the torsion only

$$T = \frac{\pi\tau d^3}{16} \quad (12)$$

where,
T = Twisting moment (Nm)
τ= Torsional shear stress (N/m2) = 42 MPa (Khurmi and Gupta, 2008).
d = Diameter of shaft (m)
from the equation T can also be calculated as

$$T = (T_1 - T_2)\mathrm{R} \quad (13)$$

where;
T1 = Tight side tension (N)
T2 = Slack side tension (N)
R = Radius of machine pulley (m)
The tight side tension was gotten as:

$$T_1 = T_m - T_C \quad (14)$$

Tm = Maximum tension in belt (N)
Tc = Centrifugal tension (applicable for belt running at high speed).
Tm = Maximum stress x cross-sectional area of belt

$$T_m = \sigma A \quad (15)$$

11. DETERMINATION OF BELTS CROSS-SECTIONAL AREA, a:

The cross-sectional area of the belt was calculated by considering area of a trapezium with top width, a= 13 mm; thickness, h = 8 mm and by calculation, the bottom width ,b ,was got as 8 mm. Source (Khurmi and Gupta, 2008)

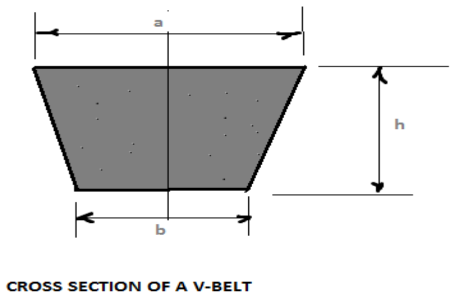

Fig 3. Cross section of the belt showing its trapezoidal orientation

$$A = \frac{(a+b)h}{2} \quad (16)$$

or on analytical approximate basis

$$A = bh \quad (17)$$

Maximum allowable stress of belt, σ = 2.8 MPa (2.8N/mm^2)The centrifugal tension, Tc was determined using

$$T_C = mV^2 \quad (18)$$

where m = mass of belt per unit length. It was calculated using:

$$m = \rho a \quad (19)$$

Where, ρ = density of belt material (Rubber) (m3/s) = 1140kg/m^3(Khurmi and Gupta, 2004)
V = linear speed of belt given as:

$V = \frac{\pi DN}{60}$(20)

V-belt drive, the tension ratio is given by

$\frac{T_1 - T_C}{T_2 - T_C} = e^{\mu\theta cosec \alpha/2}$(21)

where, :

μ= Coefficient of friction between belt and pulley

θ= Angle of wrap (radian)

α= Groove angle = 34° (Khurmi and Gupta, 2004))

$\theta = \left[180 - 2sin^{-1}\left(\frac{D_1 - D_2}{2X}\right)\right]\frac{\pi}{180} radian$ (22)

12.KEY AND KEY WAY DESIGN

The assembly between alluminium pulley and the mild steel shaft involves two engineering materials.Wear should be avoided as it is imminent if they are used together,hence, flanged bushons are force fitted and bolted to the pulleys.The thickness of the bushons are sush that the key way can be created.A square sunk key is considered.

W=t=d/4=7.5mm (23)

Where;

w=width of the key

t=thickness of the key

d=diameter of the shaft=30mm

As standard,a shaft of 30mm diameter has 8mm thickness and 10mm width,

[R.S Khurmi &J.K Gupta,table 13.1,pp.472]

The depth of the key way =h=t/2=4mm (24)

The force acting [F]on the key is given as a function of the torque [T] and diameter [d]of the shaft.

F = 2T/d =633.3N (25)

12.1 EFFECT OF KEY WAYS ON SHAFT

The experiment conducted by H.F.Moore, showed that key way on shaft reduces the load carrying capacity as regards the tensional strength of the shaft.

13.BEARING SELECTION

Design consideration:

(1) Rating life of bearing

(2) Inner diameter of bearing

Bearing selection is important for reduction of friction or grinding .noise pollution and efficiency or performance of the machine. The relations stated below are guide to determine the life of a bearing and the choice of selection for the inner diameter. It is determined by the size of shaft. A rolling bearing is selected for the under listed reasons:

i. They give warning sign on event of failure
ii. They can be preloaded when desirable to reduce deflections in the bearing
iii. They can be pre packed with grease to provide maintenance free installation
iv. They have an advantage of having starting torque to be high because of loads for short periods

14.DETERMINATION OF LIFE OF A BEARING

The approximate life of a bearing is given by:

$L_b = \left(\frac{C_*}{P_e}\right)^3$ million revolution (26)

L_b = life of a bearing

c_* = specific dynamic capacity of a bearing

P_e = equivalent load

$P_e = XV_* Fr + \gamma Fa$ (27)

This is the equivalent load for radial and angular contact bearing of conventional types except filling slot bearing under combined constant radial and thrust load.

X = radial factor

Fa = thrust load N

Fr = radial

V_* = rotational factor

The X and γ are obtained in the table 11.3 on ref no 10 for dynamic loaded bearing.

For single load bearing,

When wt/wr ≥ θ

Xo = 1, Yo = 0

The maximum reaction load on the bearing at A

Assuming a factor of 2 for V – belt taking into account of both dynamics as it affects the belt vibration and additional force to maintain proper tension in the belt.

$Fr = RA.2$ (28)

Mg = Impeller weight = 25N

Fa = 25N
V = 1
Fa/VFr = 25/1857.64 = 0.013
Wt/WR = fa/FR 0.013
Hence deep groove ball bearing is selected because this value is found in table 27.4 pp1008[Gupta/Khurmi)The diameter of shaft is 30mm. The bearing bore will be less than However 30mm for clearance. Assume a clearance of 5mm for a bore of 25mm, the bearing number 205 having 25mm bore,5mmclearance,52mm outside diameter,width 15mm is chosen using thetable 27.1 pp1000 [Gupta/Khurmi).The dynamic load capacity C,is selected from table 27.6 pp1013[Gupta/Khurmi)

15. POWER TRANSMITTED BY BELT, Pb

The power transmitted per belt was calculated using

$P_b = (T_1 - T_2)V$ (29)

16. NUMBER OF BELTS REQUIRED, n

The number of belts required to transmit power from electric motor was calculated using

$$n = \frac{electric\ motor\ power}{power\ per\ belt} \quad (30)$$

17. CONCLUSION

The stud grinding machine was designed and developed to investigates the performance and efficiency of the machine on bone dried grains or roasted grains. Focusing on the design are basic factors that can lead to dynamic imbalance, hence it was ensured that the shaft was turned with good running centers on the lathe and same was maintained using a four jaw chuck for the pulleys. This is made possible with good marking ,the assembly become necessary for alignment of the components. The shaft and the bearing must be aligned to have a common axis of rotation this helps to solve problem of dynamic imbalance that will cause vibration. Tension on the belt and pulleys alignment should be monitored as this could lead to a great deal of heat generation that will burn the belt at some certain speed. It is therefor necessary to build an alternative machine that will be energy ,power and time saving in grinding dried or roasted grains than the stone grinder

REFERENCES

[1] Onwualu, A.P., C.O. Akubuo and I.E. Ahaneku, 2006. Processing of Agricultural Products: Fundamentals of Engineering for Agriculture. Immaculate Publications Limited, Enugu, pp: 260.
[2] Perry, H.R. and G.W. Don, 1998. Size Reduction and Enlargement: Perry's Chemical Engineering Handbook. 7th Edn., McGraw-Hill International Publishers, New York, pp: 20-22.
[3] Khurmi, R.S. and J.K. Gupta, 2004. A Textbook of Machine Design. 13th Edn., S. Chand and Co. Ltd., New Delhi, pp: 456- 498, 657-659
[4] Agboola, S. (1992), "Technologies for Small-scale Storage of Grains in Nigeria". Proceedings of 3rd CODRI seminar on Food Storage, Processing and Utilization. CODRI 1(1):22-27.
[5] Hall, A; Holowenko, A. and Laughlin, H. (2004),"Theory and Problems of Machine Design". Tata McGraw-Hill Publishing Company Ltd, New Delhi. 4th Edition, pp6-89
[6] Hannah, J. and Stephens , R. (2004), "Advanced Theory and Examples in Mechanics of Machines". Edward Arnold (Publishers) Ltd, London; 5th Edition, pp.1-128.
[7] Khurmi, R. and Gupta, J. (2007), "Theory of Machines". Eurasia Publishing House (PVT) Ltd, New Delhi, 8th Edition, pp72-381
[8] Khurmi, R and Gupta, J. (2008), "A Textbook of Machine Design". Eurasia Publishing House (PVT) Ltd, New Delhi, 1st Edition, Pp677-819
[9] Norton, R. (2006), "Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines". WCB/McGraw-Hill Publishers Inc, 2nd Edition, pp8-16