DEVELOPMENT OF BLENDER-HAMMER MILL FOR MULTIPURPOSE USE

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Abstract

Few problems that have been identified with most of the existing developed blending and hammering machines/mills was strengthening on to achieved better performance. The aim of this project is to develop a blender-hammer crushing machine suitable for domestic and laboratory use for production of fine paste and coarse aggregates. The design was based on elimination of metal to metal contact, contamination of grinded material and excessive vibration. The blender-hammer mill consists of the following components; inlet hopper, grinding chamber, a combined crushing hammer blades vertically set and blending blade that are horizontally fixed. The mill was constructed from locally sourced martensitic stainless steel 420 series. A sieve was introduced beneath the hammer chamber to sieve the ground mass. The main shaft was mounted on two sealed ball bearings, and it rotates at speed of 2880 rpm transmitted by two ‘B’V belt driven from a 3.75-kilowatt electric motor. The results showed that better efficiency for both dry corn and cassava. We conclude that a blender hammer machine developed is capable of grinding grains legumes, dry cassava, and yams into fine and coarse aggregates.

Keywords: Blender, Harmer, Mill, Multipurpose, Machine

1.0 INTRODUCTION

Hammer mills, as the name implies, are mills for grinding grains into powder by impact [1]. The materials are poured into a loading hopper at top of the hammer mill, and inflow is controlled by a small gate designed to allow the grains enter into the grinding chamber [2-4]. The grains are fed into the path of the hammers either through the front plate or through the top side of the cover plate. The grains are impacted by the hammers and shattered before they pass through the screen beneath the hammers [5-6]. The produced flour falls either by gravity into the chamber or outlet hopper below, or is forced by air flow velocity generated by revolving hammers and blade into a collecting bowl [7]. The hammers and the blender blades mounted on the main shaft generate airflow fan effect within the grinding chamber [8]. Generally, hammer mills parts include a large cylindrical chamber, the main shaft on which several rows of free-swinging hammers blades are installed at one end and at the other a pulley drives powered by a prime mover (electric motor /generator) [9]. The hammers revolve in the grinding chamber underlain with perforated metal screen through which the flour is collected. According to Brian and Alexandra (2006) hammers blades on the shaft are driven by two or more sets of V- belts that link the prime mover and the mill. The hammers revolve at high speed, ranging between 2000 and 4000rpm resulting to hammers tip speed of about 65 m/second [9-10]. They affirmed the speed of the mill must commensurate with the size of the mill, as small mills revolve at higher speed than larger ones. Cylindrical screens are incorporated in some hammer mills but most modern designs have their screens that cover lower periphery such as half of grinding chamber or less, this allows easy replacement of screens [12-14]. Beater bars are
incorporated on short shafts located in-between pitch circles of two plates against which the grains are impacted. Hammer works very well for grains with moisture content of about 11 to 13%. [15]. Plate mill is one of the earliest mechanical mills developed and very popular in West Africa most especially in Nigeria. Its operating system is more of shear component than compression. This type of mill’s major parts are two circular cast iron plates, one fixed and the other rotational with adjustable narrow gap in-between mounted to face each other [16].

The plates are splined on one face in order to grind by shear mechanism through friction when in contact. The grains pour into the center of the mill are sheared by the grooves of the two rotating plates by frictional force. When the grains move toward the edges of the plates, the grooves become narrower [17]. Consequently, the grains sizes are reduced by the grooves of the plates designed like the old type fabricated for stone mills. Plate’s diameters range between 200–350 mm and are usually aligned in a vertical direction, but more convenient when horizontally aligned in mills run by a diesel engine. The normal speed of plate mills is between 2500 to 3500 rpm, but the friction between the plates and overheating reduces the speed of the mill accordingly [18]. The refinement of the flour ground is achieved by increase in pressure asserted on the grain by narrowing the gap between the plates. The mill should not be run idle i.e. without grains which act as lubricant between the plates, because wear. Excessive wear occurs when the plates are in contact.

To obtain fine flour or meal from a plate mill, product must be reloaded into the mill two or three times with increase pressure each time. The advantage of this mill over the hammer mill is that it can grind both dry and wet grains, vegetables and fruits.

2.0 Materials and Method
2.1 Material Adopted for the Grinding Machine

The material adopted for the major grinding parts were martensitic stainless steels with designations of 400 series and 500 series in AISI/ASTM, 1.4006 to 1.4423 series in EN number. The carbon content of martensitic stainless group was relatively high from (0.1 - 1.2%). They are plain chromium steels like ferritic stainless steel, they both contain between 12 and 18% chromium.

2.2 Bearing selection.

Two FAG standard 307 sealed ball bearings with one side purposely opened for constant lubrication because of high speed of the shaft were selected. The selection was based on the load and speed the shaft exerted at rest and in operation. It was also based on the diameter of the shaft and the bearing housing designed for support and rigidity. The bearing designation of 307 signifies medium series bearing with bore diameter of 32mm and 60mm external diameter.

2.3 PRINCIPLE OF OPERATION OF THE MACHINE
2.3.1 Size reduction Principle.

Blender hammer shown in Figure 1 and 2 used shear and impact principle in sizes reduction of grains and other dried products fed into it. The energy required to effect change (dx) in the size of the grain or any item for grinding was calculated by this equation (22) – (Onwualu et al., 2006)

\[
\frac{dE}{dx} = \frac{k}{x^n}
\]

Where k= is a constant,

n= is an exponent.
For grinding, Rittinger’s law was used and by substituting variables and integrating between $x_1$ and $x_2$, the energy equation developed as shown in equation 2

$$E = k \left( \frac{1}{x_2} - \frac{1}{x_1} \right)$$

Where $x_1$ = Regular original size of the material
$x_2$ = Product normal size
$E$ = Energy per unit mass
$K$ = Rittinger’s constant

2.3.2 Testing of the machine
There are two types of testing that are of necessity needed to be carried out on any new designed and manufactured machine to ascertain the following;

a. Safety in operation of the machine  
b. The performance evaluation  
c. To detect defects for possible improvement  
d. To evaluate the achievement level of the research.

2.3.3 Idle testing or running
This is operating the machine without load at low speed first, then at increased speed for about 30 minutes to 1 hour to detect unusual noise and also the level of vibration.

2.3.4 Load test and procedures
This is operating the machine with the designed loads or specimen to evaluate the performance, which is the work ability and efficiency of the machine.

3.0 RESULTS.
The blender-hammer has been produced from locally sourced material. The machine was loaded as indicated in the table below tested using 1 kg of dry corn, millet, guinea corn. 1 kg of dry corn was fed into the inlet hopper with the inlet regulated gate closed before the
engine was switched on to allow accurate timing procedure. The engine was switched on and the inlet gate was opened at the regulated flow rate to avoid ground product clogging on the screen. The time taken for full grinding and also the weight of the recovered corn was recorded. This was repeated twice for each sample of picked washed and dried corn, rice, guinea corn, cassava and beans.

3.1 Output Capacity and Tonnage
The output capacity could be calculated by simple multiplication of output per second and estimated period in view.

Table 1: Output capacity

| S/ N | Items          | Output/sec. Kg | Output per/hr. Kg | Annual tonnage T |
|------|----------------|----------------|-------------------|-----------------|
| 1    | Wheat          | $1.53 \times 10^{-3}$ | 5.51              | 13.5            |
| 2    | Corn           | $1.11 \times 10^{-3}$ | 4.00              | 9.8             |
| 3    | Rice           | $1.57 \times 10^{-3}$ | 5.65              | 13.8            |
| 4    | Guinea corn    | $1.5 \times 10^{-3}$  | 5.4               | 13.2            |
| 5    | Beans          | $1.63 \times 10^{-3}$ | 5.87              | 14.4            |
| 6    | Cassava        | $2.08 \times 10^{-3}$ | 7.5               | 18.3            |
| 7    | Slice dry yam  | $1.65 \times 10^{-3}$ | 5.95              | 14.6            |

Output capacity as shown in Table 1 above was based on 8 hours work day for 6 days per week and 51 weeks per year taking into considerations holidays and stoppage time for maintenance for daily one shift operation.

3.2 DISCUSSION
The newly developed blender hammer mill runs at 2880 rpm by electric motor of 3.75kw a milling efficiency of 89% to 99% as indicated in table 1 above was achieved. It was observed during the test that the machine required smooth regulated feeding of the product into the machine to avoid overstuffing the sieve thereby causing clog at the outlet. The machine runs smoothly, with less noise, vibrations and dust [19]. The beaters didn’t show any sign of wears because they were well space to avoid metal to metal contact. Refinement test carried out on the cassava flour produced by the blender hammer machine showed that the fineness obtained was about 0.30 and the uniformity index was ratio 0.5:0.9:5 which ratio of (coarse: medium: fine) 2.10 and below modulus signifies fine flour grade. However, the fineness ratio reduced slightly in yam flour, beans rice and corn respectively [20].

The crushing capacity of the machine is very good that is better in comparison with the contemporaries. The sticking of the powdery particles to the wall of the crushing chamber, blender and hammer blades and sieve caused initial loss experienced. The design and built up of the machine enhanced stability and smooth running thereby vibration and noise level was suppressed to the barest minimum. The total length of the step shaft is 400mm it is supported by two seals on diameter 35mm and two ball bearings 100mm apart from each other at the middle of the shaft (see auto card drawing and analysis above) [21].

There is no metal to metal contact that can result in unnecessary friction and metal particles in the ground flour [22]. Vibration and noise, consequently metal particles in the ground mass is
completely eliminated. The one load principle of the machine is achieved by the massive blender hammering system and predetermined end result by section of appropriated sieve. As a result of this loading and reloading and regrinding of mass is avoided. This also enhanced productivity and efficiency of the machine. The durability and cost effectiveness of the machine is ascertained by choice of the material used [23]. The machine was developed for easy disassembly and assembly for easy transportation from one location to another. Fuel and diesel combustion engine of the same capacity can substitute for the electric motor used in this project to achieve same result.

4.0 CONCLUSION

The purposes and intentions for which this research was set to achieve have been achieved. The blender hammer machine with easily detachable incorporated sieve was designed and fabricated from martensitic stainless steel. Idle and load tests were carried out and found to be capable of pulverizing to milling efficiency of 89% to 99% which shows that the performance of the machine compares favorably with the performances of the other mills developed. The machine can be powered either by electric motor or fuel powered engines of the same capacity to achieve the same efficiency and effectiveness. Observation deduced from the tested results showed that the performance of the newly developed machine is better than the exciting versions. The machine is capable of grinding grains legumes, dry cassava, and yams into fine and coarse aggregate. The selling price of the single sample machine produced stood at about one hundred and seventy-three thousand Naira only. Mass production cost of the machine will be much less by at least 10=15%, consequent to the quality of material used and the durability of the machine, it could be rightly concluded that the newly developed machine would compare favorably with the existing ones. It is also commercially viable.

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