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Modern Design, Construction and Evaluation of A Magnetic Sieve Grinding Machine

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Abstract
The modern use of milling and grinding machine is one of the best methods of processing raw materials alternative to the traditional methods of processing using grinding stones, soaking and squeezing, mortar and pestle. Modern machines constructed using metal or steel plates which results in tearing and wearing away of the materials of construction. The negative effect of this machines result to the contamination of the processed foodstuff through leakage of lubrication oils, emission of toxic gases and other factors. The resultant factors may develop into negative health implications to those who consumed the finished materials from the machine. This work evaluate the designs, construction and performance of magnetic sieve grinding machine as used to remove the toxic metal filing contaminants that cause the health hazard in food when consumed. The machine consists of a 0.05 m^3 capacity hopper, a machine housing, a blower with 14.36 m/s air speed, a cyclone, set of hammers that effect the size reduction of the materials been fed, 13 cm width rotor pulley, a shaft of 60 cm in length and a magnetic sieve that separate metal filings from the grounded food stuff. The machine is powered by a 6.97 kW diesel engine. Performance evaluation showed that 11.6 g of the machine parts were worn out after 11 hours of grinding. The throughput capacity and the efficiency of the machine are 700 kg/hr and 88.6% respectively. Thus, from the results of the investigation, the objectives of the study were achieved. The use of the magnetic sieve grinding machine by local food processors will help reduce the rate of food contaminations during post harvest processing of biomaterials and also safeguard people's health through food security.

Keywords: Grinding Machine, Magnet, Sieve, Design and Construction

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I. INTRODUCTION

Grinding process reduces the size of solid materials by mechanical action, and it achieves this by dividing them into smaller particles (Akusu, 2018). Grinding of agricultural products is one of the oldest cultural techniques of humanity. As a result of size reduction, processing, and storage, farmers were forced to develop technology for grinding their produce. The most extensive application of grinding in the food industry is in the milling of the grains/tubers pellets to make flour, but it is equally used in many other processes, such as in the grinding of corn, for the manufacture of corn starch, grinding of millet, grinding of millet. Raw materials often are present in sizes that are too large to be used and they must be reduced in size. It is frequently necessary to reduce for different purposes the size of solid materials in many food processes such as expression and extraction depending on whether the material is a solid or a liquid. The operation of a size reduction can be divided into two major categories. In the case of solids, the operations are called grinding and cutting. While in the case of liquid materials, the process is defined as emulsification or atomization (Ngabea, 2018).

Grinding and cutting reduce the size of solid materials by mechanical action, dividing them into smaller particles. Grinding of agricultural materials is one of the oldest cultural techniques of humanity. All civilizations that feed more or less exclusively from cereals were forced to develop technology for grinding grain crops. Perhaps the most extensive application of grinding in the food industry is in the milling of the grains to make flour, but it is used in many other processes, such as in the grinding of corn, for the manufacture of corn starch, grinding of millet, grinding of cassava. In all traditional civilizations, grinding is the domain of women. There are two different techniques used in effecting size reduction of grains (Ngabea, 2018).

Iron filings produced as part of the grounded food as a result of the grinding plates rubbing each other have some long term health effects on the human body. All metals are soluble to some extent in water. While excessive amount of any metal may present health hazard, only those metals that are harmful in relatively small amounts are commonly labelled toxic. "Dose makes the poison" other metals fall into the non-toxic group (Adetunde *et al*, 2010). The accumulation of metal filings in the human body system for a long time results to many of the lung and abdominal problems of the alimentary canal. Recently, it was discovered that, the frictional plates of the local Burr mills wear out too frequently.

The Objectives of the Study include, the design a magnetic sieve grinding machine, construct a magnetic sieve grinding machine, undertake the test performance evaluation of the magnetic sieve grinding machine to determine the throughput capacity using cassava as a test sample and determine the efficiency of magnetic sieve grinding machine.

II. MATERIALS AND METHODS

The selection of materials and methods of construction of the magnetic sieve grinding machine are based on the preliminary investigation, design and the drawing of the machine components carried out.

Description of the Machine

The magnetic sieve grinding machine is of hammer mill type. In this case, there is hammer-like projection mounted on a shaft. The hammer revolves at high speed and grinds the materials fed into pieces by beating. Moreover, the machine can grind only the dry materials.

The machine is incorporated with a magnetic sieving mechanism to ensure fineness of the grounded material and separation of metal filings from the flour. The magnetic sieve is made up of wire cloth with aperture sizes ranging from 870µm to 2mm and circular magnets arranged beneath the sieve, spaced 4cm with each other. The machine is powered by the use of eight Horsepower (6.97 kW) diesel engine with a speed of 850 rpm.

The entire construction is brought about by locally sourced material thereby making the cost not prohibitive. The machine elements are easily accessible and detachable to facilitate assembling and maintenance process. Although the machine is sufficiently rugged to function properly for a reasonable long period, it is cheap enough to be economically feasible.

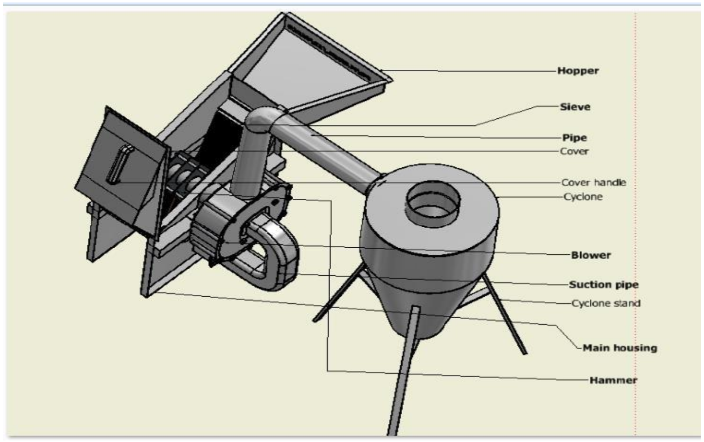

Fig.1 Isometric view of the Magnetic Sieve Grinding Machine

Construction Materials

The magnetic sieve grinding machine is a size reduction machine that grinds corn, cassava, millet guinea corn and so on to flour and simultaneously separating the flour from the metallic contaminants that result from tearing and wearing of the machine parts. This machine is constructed manually with the available materials thereby making the cost less expensive. It is sufficiently strong and rugged to function properly for a very long time.

Table 1.1 Construction materials

S/NO	ITEMS	QUANTITY
1.	Gauge 14 mild steel sheet	2½ sheets
2.	Gauge 16 mild steel sheet	3 sheets
3.	50cm stainless steel shaft	1
4.	1mm aperture sieve	1
5.	Bar magnets	4
6.	Bearings	2
7.	3mm Angle Bar	1
8.	Flat Bar (5mm)	1
9.	Paint	1 tin
10.	Bolts, and nuts	36
11.	Pulley (12cm Diameter)	1
12.	Grease	1 tin

The materials for the construction of the magnetic sieve grinding machine were selected on the basis of low cost, availability, resistance to corrosion, ease of operation and machining, suitability and convenience.

Methods of Construction

This is the process by which various components of the machine are fabricated in stages before being assembled into a complete functional unit.

The Hopper

The hopper was fabricated according to Indian standard institution specifications which ensure safety and comfort for the operator as well as an efficient feeding operation (Is: 9020, 1979). The material of construction was gauge 14 mild steel sheet. The bottom length of the hopper is 500mm while the length of the top from the inlet of grinding zone is 400mm which ensures that the operator does not get injured regardless of his position while feeding in the grinding material. The depth of the hopper is 200mm. The front depth is 100mm and 500mm wide. The hopper is bolted to the main Housing casing. The hopper is inclined at an angle of 35^0 to the horizontal towards the main Housing to ensure efficient feeding of the material to be grind. The height of the hopper above the ground is 850mm. Fig. 3.1 shows sketch of the hopper.

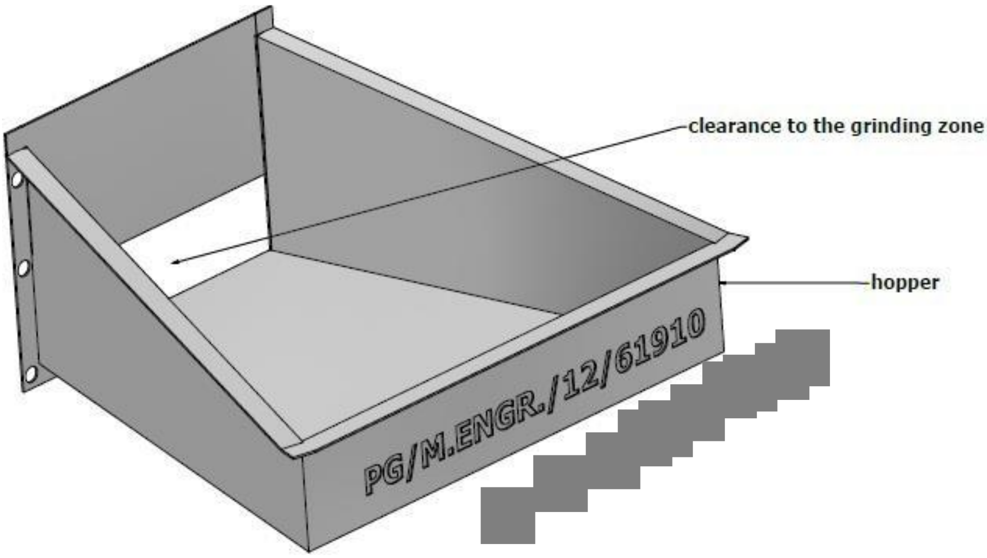

Fig. 2: Diagram of the hopper

The main Housing

The main Housing is constructed with a gauge 14 mild steel frame up with 50 mm x 50 mm angle iron bars. The front height of the housing is 800mm. The shape is truncated rectangular base prism.

The top width is 650 mm while the bottom width is 700 mm and the back height is 520 mm. The two housing casings was coupled together with 20 mm bolts and nuts. The side and bottom of the housing was covered with gauge 14 mild steel in a convex form beneath the magnetic sieve which formed the collection chamber. All other components of the machine are housed on the main housing.

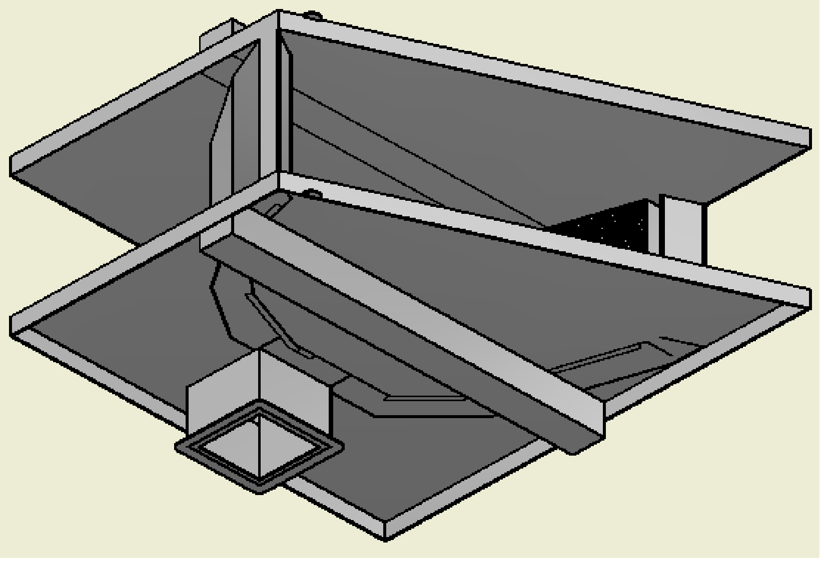

Fig.3 Sketch of the main housing

The power Train

Power transmission in this machine is achieved by the use of V- belt drive. A sketch illustrating the drive train is shown in fig.4. The pulley is identified and described in sketch. The machine obtains its power from a 7.98 kw diesel engine through a pulley of 600 mm in diameter while the driven pulley is 120 mm to achieve grinding speed of 4250 rpm. The corresponding shaft operates the hammer assembly and the blower at the opposite side of the driven pulley. Fig. 4 shows the detailed of the power train.

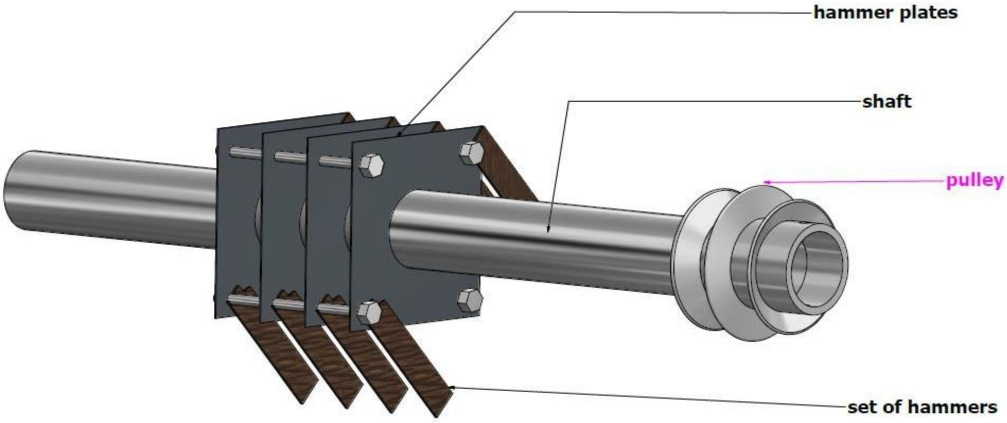

Fig 3.4 Diagram showing the power train

Centrifugal blower

The centrifugal blower was constructed with gauge 16 mild steel sheet, 450 mm in diameter plates with a round sheet separating the two plates. The plates are bolted with 12 bolts and nuts to form the blower casing. The straight blade centrifugal blower fan was constructed with gauge 14 mild steel sheet. As the fan rotates, it blows the product in a very high displacement of suspended flour particles from the settling chamber to the cyclone. The centrifugal blower is mounted or coupled at the left side of the machine with a cyclone pipe of 100 mm in diameter where the product passes to the cyclone.

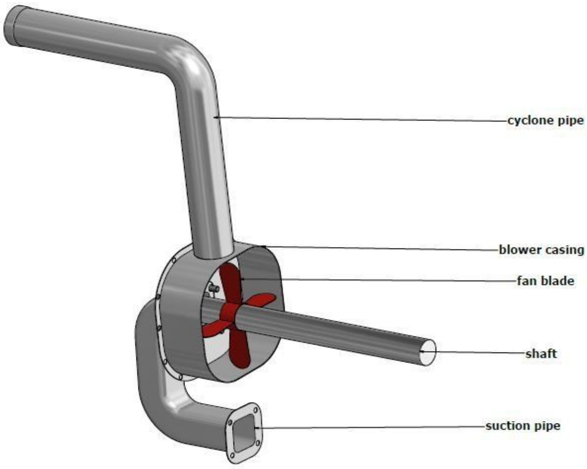

Fig. 5 Diagram of a Centrifugal Blower

Main Shaft

A 40 mm diameter stainless steel rod was cut to a 500 mm in length using power hacksaw. The shaft was drilled at the extreme ends for the pulley and fan keyways. The key ways was cut on it using milling machine. Fig. 3.6 below shows the sketch of the main shaft.

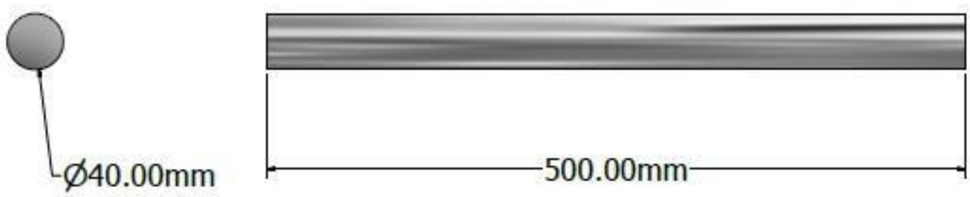

Fig. 6: Showing the length and thickness of shaft

Hammer

A 3 mm thick bar of 150 mm was cut into 10 pieces. A hole of 10 mm was drilled at the one side of each hammer using twist drill, to enable it to be put into position on the set of hammer plates.

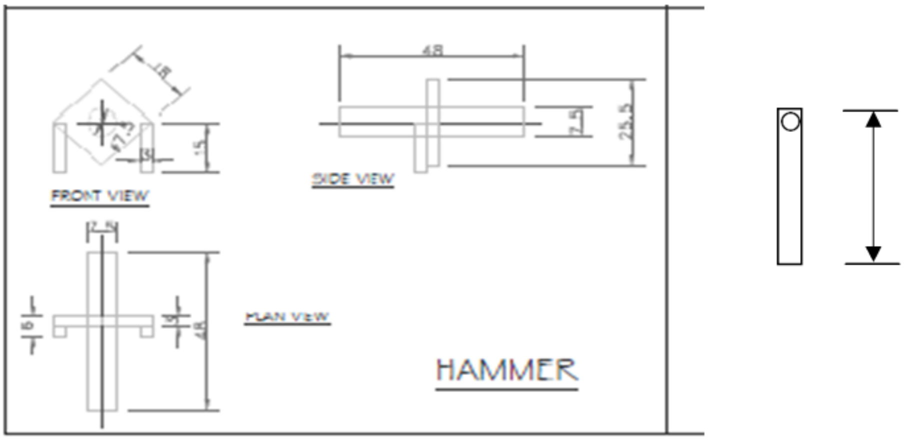

Fig.7: A sketch of the hammer

Cyclone

The cyclone was constructed by coning a gauge 16 mild steel sheet in a cylindrical shape with an internal diameter of 500mm. The inner surface was formed by a helical round duct of 200mm. At the bottom of the cylinder ends a cone shape which has an opening for discharging the flour. At the upper portion, an inner tube of 200mm in diameter was formed and welded to the cylinder through which air is discharged to the surrounding.

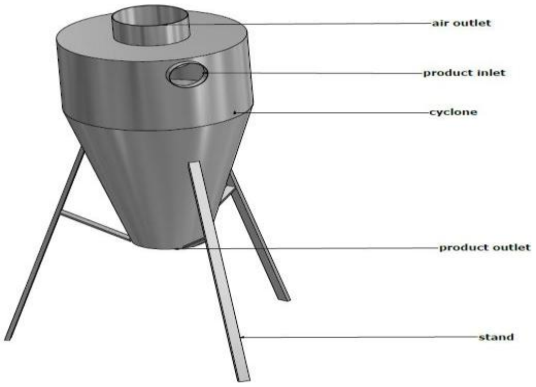

Fig. 8: Diagram of the Cyclone

Magnetic Sieve

Four round magnets with internal diameter 30mm, external diameter 50 mm and thickness of 10mm were arranged spaced 5cm to each other under a hyperbolic galvanized gauge 18 mild steel sheet perforated sieve with the following dimensions; length of sieve is 750mm, width of 20mm and apertures of 1.5mm. Fig. 3.9 below shows. The cross-sectional diagram of the magnetic sieve coupled to the machine.

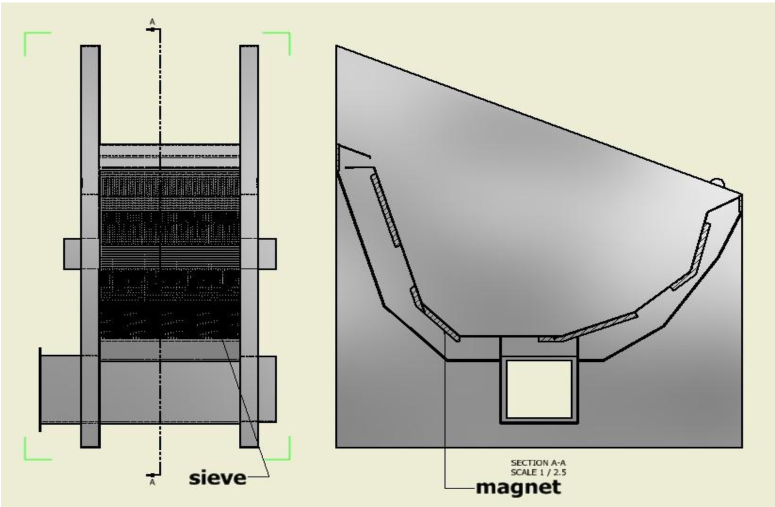

Fig. 9: Cross section of the magnetic sieve

Cost Estimate of the Magnetic Sieve Grinding Machine

The costing of the materials used for construction of the machine was based on the 2021 prices. Prices of standard materials such as bearings, V–belts, pulleys, bolts and Nuts which were not constructed by the author were also included. A summary of the production cost of the machine is presented in Table 2 and shows a total material cost of one hundred and thirty thousand, eight hundred naira only (N131, 800) excluding the cost of power unit.

Table 2: Cost Estimate for the Construction of Magnetic Sieve Grinding Machine

s/no	Items	Quantity	Rate (₦)	Amount (₦)
1.	Gauge 14 sheet	2½ sheets	13,000	19,500.00
2.	Gauge	3 sheets	9,000	27,000.00
3.	Shaft (50cm x 4cm)	1	4,000	4,000.00
4.	Sieve (200mm x 750mm)	1	4,400	4,400.00
5.	Bearings	2	1000	2,000.00

6.	Round magnets	4	1000	4, 000.00
7.	Flat Bar (5mm)	1	2,000	2,000.00
8.	Paint	1 tin	4,000	4,000.00
9.	Bolts and Nuts	36	1000	36,000.00
10.	Pulley (12cm in Diameter)	1	1,200	1,200.00
11.	Grease	1 tin	700	700.00
12.	Welding workmanship	-	12000	12,000.00
13.	Miscellaneous	-	-	15000.00
		-	**Total**	**₦131, 800.00**

Machine Assembly

The grinding action results from the impact of free swinging hammers that rotates in an anticlockwise direction on a shaft. The hammers strike the material as it enters the machine by beating the material fed into fine particles. The separation of the flour from the metal contaminants is achieved by the use of magnetic sieving component.

Analysis of the Machine Operation System

Grinding Machines

Raw materials often occur in sizes that are too large to be used and therefore, they must be reduced in sizes. The size reduction operations are called grinding.

A grinding mill is a unit operation designed to break a solid material into smaller pieces. There are many different types of grinding mills and many types of materials processed in them. Historically mills were powered by hand (mortar and pestle), working animal (horse mill), wind (windmill) or water (watermill). Today they are also powered by electricity (Paris, 2018).

The grinding of solid matters occurs under exposure of mechanical forces that trench the structure by overcoming the interior bonding forces. After the grinding the state of the solid is changed: the grain size, the grain size disposition and the grain shape. Grinding may serve the following purposes in engineering:

i. Increase of the surface area of a solid.
ii. Manufacturing of a solid with a desired grain size.
iii. Pulping of resources (Ngabea, 2018).

Grinding and Cutting

Grinding and cutting reduce the size of solid materials by mechanical action, dividing them into smaller particles. Perhaps the most extensive application of grinding in the food industry is in the milling of grains to make flour, but it is used in many other processes, such as in the grinding of corn for manufacture of corn starch, the grinding of sugar and the milling of dried foods, such as vegetables.

Cutting is used to break down large pieces of food into smaller pieces suitable for further processing, such as in the preparation of meat for retail sales and in the preparation of processed meats and processed vegetables.

In the grinding process, materials are reduced in size by fracturing them. The mechanism of fracture is not fully understood, but in the process, the material is stressed by the action of mechanical moving parts in the grinding machine and initially the stress is absorbed internally by the material as strain energy. When the local strain energy exceeds a critical level, which is a function of the material, fracture occurs along lines of weakness and the stored energy is released. Some of the energy is taken up in the creation of new surface, but the greater part of it is dissipated as heat (Baron, 2005). Time also plays a part in the fracturing process and it appears that material will fracture at lower stress concentrations if these can be maintained for longer periods. Grinding is, therefore, achieved by mechanical stress followed by rupture and the energy required depends upon the hardness of the material and also upon the tendency of the material to crack - its friability.

Milling with the mills

Besides these traditional technologies that are still widespread in the African rural areas, small mills have emerged in towns and villages. Two major types of mills, functioning on different principles, the wheel mills and hammer mills (Keddie, 2009).

The wheel mills

The principles of operation of these mills are the grinding of the grain by crushing it between two abrasive surfaces. They consist of a fixed wheel and a mobile wheel turning upon the first in a horizontal or vertical plain. The two wheels of the machine are identical regardless of the material and dimensions (Donald, 2005).

The important factors to be studied in the grinding process are the amount of energy used and the amount of metal filings produced during grinding.

Grinding Equipment

Grinding equipment can be divided into two classes - crushers and grinders. In the first class the major action is compressive, whereas grinders combine shear and impact with compressive forces.

Crushers Jaw and gyratory crushers are heavy equipment and are not used extensively in the food industry. In a jaw crusher, the material is fed in between two heavy jaws, one fixed and the other reciprocating, so as to work the material down into a narrower and narrower space, crushing it as it goes. The gyrator crusher consists of a truncated conical casing, inside which a crushing head rotates eccentrically.

The crushing head is shaped as an inverted cone and the material being crushed is trapped between the outer fixed, and the inner gyrating, cones, and it is again forced into a narrower and narrower space during which time it is crushed. Jaw and gyratory crusher actions are illustrated in Fig. 10 (a) and (b).

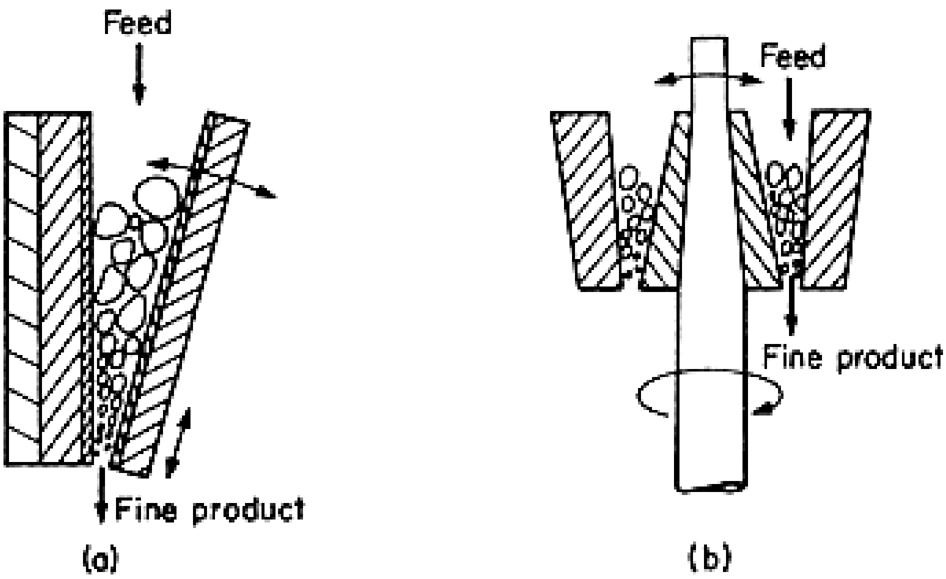

Fig.10 Crushers: (a) jaw, (b) gyratory

Crushing rolls consist of two horizontal heavy cylinders, mounted parallel to each other and close together. They rotate in opposite directions and the material to be crushed is trapped and nipped between them being crushed as it passes through. In some case, the rolls are both driven at the same speed. In other cases, they may be driven at differential speeds, or only one roll is driven. A major application is in the cane sugar industry, where several stages of rolls are used to crush the cane.

Hammer mills

In a hammer mill, swinging hammerheads are attached to a rotor that rotates at high speed inside a hardened casing. The principle is illustrated in Fig. 11 (a).

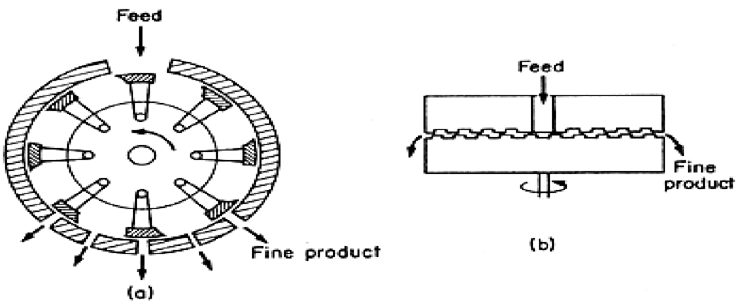

Fig. 11 Grinders: (a) hammer mill, (b) plate mill

The material is crushed and pulverized between the hammers and the casing and remains in the mill until it is fine enough to pass through a screen which forms the bottom of the casing. Both brittle and fibrous materials can be handled in hammer mills, though with fibrous material, projecting sections on the casing may be used to give a cutting action.

Plate mills

In plate mills the material is fed between two circular plates, one of them fixed and the other rotating. The feed comes in near the axis of rotation and is sheared and crushed as it makes its way to the edge of the plates, see Fig. 11 (b). The plates can be mounted horizontally as in the traditional burr stone used for grinding corn, which has a fluted surface on the plates. The plates can be mounted vertically also.

Developments of the plate mill have led to the colloid mill, which uses very fine clearances and very high speeds to produce particles of colloidal dimensions (Earle, 1983).

Sieving

Sieving is a simple and convenient technique of separating particles of different sizes. A small sieve such as that used for sieving flour has very small holes which allow only very fine flour particles to pass through the coarse particles are retained in the sieve or are broken up by grinding against the screen windows. Depending upon the types of particles to be separated, sieves with different types of holes are used.

Uses of Sieves

Wherever solid materials are handled or processed, test sieves find application. In laboratory or plant these simple precision instruments are invaluable. Test sieves are used, for example, by chemists and pharmacists, physicists and geologists, chemical and civil engineers, mining and metallurgical engineers.

The uses to which test sieves are put are as many and varied as the types of people who use them. Most solid raw materials and finished product specifications contain a clause which stipulates the range of the size spread or the maximum or minimum size in terms of some standard sieve series (Mullin, 2017).

Magnets

Magnets are object that has a magnetic field. It is usually made of iron or steel, but it can also be made of any ferromagnetic substance or a ferromagnetic composite. Magnets have uses based on their magnetic attraction. This attraction draws other ferromagnetic materials to the magnet or the magnet towards them. It can be used to pick up small ferromagnetic items such as screws and metal shavings (metal filings) as a “Magnetic Stirring rod” on a laboratory hot plate and to hold papers and other items to the sides of refrigerators among many others (Tipler, 2014).

A magnet both produces its own magnetic field and responds to magnetic field it produces is at any given point proportional to the magnitude of its magnetic moment. In addition, when the magnet is put into an external magnetic field, produced by a different source, it is subject to a torque tending to orient the magnetic moment parallel to the field. The amount of this torque is proportional both to the magnetic moment and the external field. A magnet may also be subject to a force driving it in one direction or another, according to the positions and orientation of the magnet is subject to no net force, although it is subject to a torque (Serway *et al.*, 2006).

dried cassava chips. The machine was found to be dust free and the beaters do not wear when running freely.

From these results obtained, the machine is effective. It has a throughput capacity of 600kg/hr and machine efficiency of 87.5%. The efficiency proves that the machine has served its purpose.

Care and Maintenance

i. The machine should be cleaned or washed before and after used.
ii. The machine should be housed, not to be exposed to the atmosphere.
iii. The movable joints of the machine should be lubricated at least after using it for about 8 times.
iv. The magnetic sieve should be removed and cleaned after 50 hours of operation.

III. RESULTS AND DISCUSSION

The results obtained from preliminary investigations carried out was used for the computation of the machine's parameters.

Results of the calculated parameter

The results obtained from design calculations are shown in table 3 below

Table 3: The physical and technical specifications of the machine

s/no	Specifications	Values obtained	Unit
1.	Shaft speed	4,250	rpm
2.	Length of belt	233.34	cm
3.	Rotor's pulley diameter	12	Cm
4.	Driving pulley diameter	60	cm
5.	Shaft twisting moment	19.79	Nm
6.	Diameter of Hammer shaft	40	Mm
7.	Weight of Hammers	2.01	N
8.	Size of Bearing	4.0	cm
9.	Belt maximum tension	56.0	N
10.	Belt contact Angle	56.0	Degree
11.	Belt cross-sectional Area	2.87	mm^2
12.	Power transmitted by the belt	5.96	kW
13.	Air velocity	13.35	m/s
14.	Fan blade diameter	15.0	cm

Performance Evaluation

The performance evaluation of the magnetic sieve grinding machine was based on the criteria of through put capacity (kg/hr) and efficiency of extraction of metal filings.

Table 4: Summary of Performance of the Machine

s/no	Parameters	Values Obtained	Unit	Time taken
1	Quantity of dried cassava chips handled by the machine	10	Kg	One minute
2	Throughput capacity	600	Kg	One hour
3	Initial mass of hammers	2.0	Kg	-
4	Final mass of hammers (after grinding)	1.988	Kg	10 hours
5	Percentage value of the material worn out	0.012 (12g)	Kg	-
6	Percentage value of iron filings obtained on the magnets	0.0105 (10.5g)	Kg	-
7	Machine efficiency	87.5	%	-

IV. CONCLUSIONS AND RECOMMENDATION

The results obtained from preliminary investigation, design and performance evaluation showed that, the magnetic sieve grinding machine was designed, fabricated, tested at the experimental research laboratory and found to have a throughput capacity 600 kg/hr and efficiency of 87.5% also a speed of 4,250 rpm with air velocity of 13.35m/s. From the results the following conclusions were made:

Conclusions

The machine efficiency was influenced by the strength of the magnets as stated in table 4. There was no damage by the hammers (beaters) to the magnetic sieving component at a speed of 4,250rpm.

The magnetic sieve was able to extract 10.5 g of metal filings from the grounded cassava flour after 10 hours of operation. Thus, with the extensive job done on the basis of the design, construction and performance evaluation as stated above. The aims and objectives of undertaken this project have been achieved. The use of the magnetic sieve grinding machine by local food processors will help reduce the rate of food contaminations during postharvest processing of biomaterials to the minimum level and also safeguard people's health through food security.

V. RECOMMENDATIONS

The following recommendations are considered pertinent for the maintenance of the magnetic sieve grinding machine:

i. For mass production of the machine, stainless steel materials should be used in construction.
ii. An electric motor of rated speed up to 4,250rpm, 6 -8 Hp may be used as a power source.
iii. Field trial of the machine performance may be undertaken and the experience gained should be used to optimize the design of the machine if necessary.
iv. Given the level of performance achieved. It is recommended that, this magnetic sieve grinding machine should be manufactured and popularized for adoption to avoid assimilation of contaminated food into human body system in Nigeria.

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