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Effect Of Hammer Edge Incline And Grinder Velocity On Some Hammer Mill Performance Indicators

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Abstract The study aims to save hammer manufacturing materials and reduce energy consumption without harmfully impacting the performance of the hammer mill. It involves two factors—the slope of the hammer edge and the angular velocity and their effect on the mill capacity (MC), Modulus of fineness (FM) and specific energy consumption (Spc). A hammer mill was manufactured locally for this purpose, with an electric motor capacity of 1 hp. The hammer edge incline was done by making a deliberate cut in the edge of the hammer in an angle. Therefore, the study was carried out with four levels of incline angles—0^0, 30^0 , 45^0 and 60^0—with three angular speeds for the mill—1100, 1247 and 1467 r p m. The results showed that there was a significant effect of hammer edge and angular velocity in MC, FM and Spc. The 30^0 angle caused a decrease in mill capacity and an increase in the mill's energy consumption more than the rest of the edge angles, as it recorded a mill capacity of 16.96 kg. h -1 vs. 25.12 , 21.2 and 19.46 kg.h-1 for hammer 0^0 angle , 60^0 and 45^0, respectively. The 60^0 angle showed the lowest FM for grinding. The mill capacity increases and the energy consumption decreases as the angular velocity increases.

Key words: blades, crusher , tip speed , fineness degree , hammer type , hammer style and milling efficiency**.**

Introduction

Mills, like the hammer mill, are used to minimize the size of raw materials granules for a variety of uses, including the production of human and animal foods and medicines. The most critical component of a grinding machine is the hammer. Many different hammer types are now available from manufacturers all over the world. Choosing hammers before starting to manufacture the mill, as well as identifying the method of operation and the wearable parts of the operation is necessary to maintain low maintenance costs from the beginning. Additionally, it is necessary to maintain the quantity and quality of the product in an acceptable condition. Hammers without processing the edges in order to strengthen them, according to what is followed by European countries. Hammers with a hardened finish are preferred by feed mills in North and South America (Mark, 2019). Every market has a hammer style that best fits their needs. Various shapes of hammers are available other than the traditional rectangular shape.

Khudher, et.al.,(2021) studied the effect of the surface area of the blade exposed to the force of collision with the corn kernels to be crushed, and they found that the blade with a letter T-shape face provided the same amount of productivity compared to the traditional blade, but it was better when feeding the grinder at high rates. Ali et al., (2019) conducted a paper in which traditional, rectangular hammers were replaced by a hammer made of steel rings connected as a chain. They discovered reduced energy consumption while using the new hammer, but they offered the same quality in performance. Mircea et al., (2013) found an increase in mill efficiency and a decrease in real energy use when a new hammer shape—a triangle with an inclination of 45 degrees from the horizontal plane perpendicular to the mill's rotation axis—was used instead of inclined hammers at angles of 0, 35, and 55 degrees. Satoshi et al., (2004) studied the impact of hammer types by cutting the edge of the hammer at various angles varying from 15 to 30 degrees and found that milling efficiency increased .The angle of travel of the particle towards the sieve and the angular velocity of the hammer are two important factors in the grinder's performance. The angle of travel of the particle can be changed in several ways—including by changing the angle between the longitudinal axis of the hammer and the axis of rotation on which it is mounted, or by changing the angle between the longitudinal axis of the hammer and the axis of rotation on which it is installed (Satoshi et al. 2003). Suliman et al., (2012) compare a serrated hammer against a smooth edge of the tip with the use of stronger impact-resistant metal for the serrated hammer. The toothed hammer had a tip of 25 rad, while the soft hammer had a tip of 10 rad. The soft-edged hammer proved to be highly efficient compared to the serrated, but the serration had the longest life. Four types of hammers were examined by pavaschiv et al., (2021). Three of them have multiple end edges—an angle similar to a staircase—with one step, the length of the side of which is a quarter of the width of the hammer, with two steps, with three steps in a row. As for the fourth hammer, the cut was oblique and smooth. The researchers concluded that the use of multi-edge hammers is not necessary. Satisfactory results can be obtained by using a one-step hammer.

Ismail et al., (2017) recommended replacing the hammer after 220 hours of operation for maize milling and 600 hours after milling wheat. To ensure product quantity and quality in acceptable condition, while Mark (2014) recommends replacing hammers whenever tip wear extends approximately 25% across the width of the hammer or when the suspension bolt hole expands to more than 0.08 inch. Failure to replace leads to a decrease in the mill capacity and efficiency and production capacity. A review of the above scientific sources indicates a discrepancy in judgment on the edge of the hammer. Most of the previous studies focused on the percentage of cut in the edge of the hammer as a proportion of the width of the hammer. Therefore, the current research deals with the cutting edge ratios in a different way. The top edge of the hammer (100% cut in width) was scrapped and pointed. Then I made a seed angle on the face subjected to the force of the impact with the particles of the ground materials . Different angles are made in order to reach an economic hammer in manufacturing materials while maintaining the quantity and quality of grinding.

Materials and methods

Machine description and operation

The hammer mill was manufactured locally in the department of agricultural machinery and equipment described in Table 1, consisting of a feed hopper which is connected to the milling chamber through the seed inlet throat. The milling chamber—that houses four hammer and the sieve—6 mm for the holes—is connected to the discharge port. The components were mounted on the mainframe.

Table 1: Description of hammer mill machine

Parameters	Value, unit	Parameters	Value, unit
Number of hammers	4 in each test	Ground grain exit height off the floor	700 mm
Hammer weight	Different (90-100 gm)	Power engine (Electrical Motor-single phase)	1HP(0.67 KW) , 240 V , 2.8 A
Hammer thickness	6 mm	Hammer disk-diameter	80 mm
Hammer length	100 mm	Engine pulley-diameter	75 mm
Screen Opening	6 mm	Engine velocity	1100 rpm
Total screen area	12800 mm^2 (160x80)	Grinder pulley-diameter	Different (7.5 , 8.5 and 10 cm)
Grinder - effective diameter	300 mm	Grinder velocity	Different(1100, 1247 and 1467 rpm)

Treatments and test

The edge inclination was made at an angle of 0^0, 30^0, 45^0 and 60^0 (Figure 2). Therefore, the experiment was conducted to study two main factors—angles and angular velocity—which included four levels of angles—0^0, 30^0, 45^0 and 60^0 with three angular velocities of the mill—1100, 1247, and 1467 rpm—and the tests were repeated 3 times for each treatment.

Yellow corn was purchased from the local market and then washed with water to remove unwanted substances using a sieve, and then its moisture content was measured according to Oluwole et al., (2019) and Hadi et al., (2017) . The moisture content was 10.3% on a wet basis. Then the clean sample was divided into smaller samples. One sample was 500 grams, poured into the hopper and the machine was run at the required angular speed at each test of the parameters, and after the grinding of each sample was completed, the time spent in milling was recorded and the crushed mass was weighed.

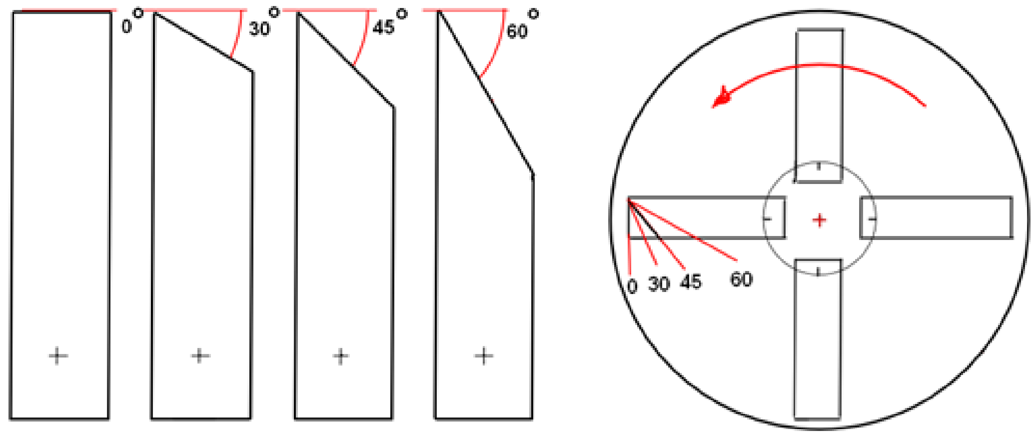


Figure 2 Describe the angle and direction of cutting in relation to the direction of rotation of the milling axis

Parameters

Mill Capacity and Specific energy consumption

Equation 1 was used to calculate the production capacity of the mill. Equation 2 was used to calculate the specific electrical energy consumption (Basiouny and El-Yamani, 2016).

$$MC = \frac{WG}{T} \qquad ...(1)$$

Where,

MC , Mill Production Capacity (kg. h^{-1})

WG , weight of grains after the grinding (kg)

T , the time of grinding(hour)

The core engagement draining declare was designed by spurn the equation 2 (Ibrahim, et.al 2019).

$$Spc. = \frac{CP}{MPC} \qquad ...(2)$$

Where ,

Spec. , Specific energy consumption(kw. h\kg)

Cp , Consumed power (kw) , it Calculated from equation 3

$$Cp = \frac{I.V\ \eta \cos\theta}{1000} \qquad ...(3)$$

Where,

I= line current strength (Amperes).
V = Potential strength (voltage)
Cos θ = power factor
η = Mechanical efficiency assumed (90%).

Fineness modulus (FM)

Fineness modulus is one of the criteria for evaluating the performance of the mill, which expresses the degree or amount of crushing. The lower the value of the calculated fineness modulus, the smaller the diameter of the broken particles, and vice versa. A milled sample—100 grams—was taken from each treatment and sifted with a series of sieves, arranged from the coarsest to the finest (4 , 3.17 , 2.80 , 2.36 , 2.00 and 1.18) mm^2 according to the method described by Senthil kumar et.al., 2015.

Results and Discussion

Effect of the hammer edge angle on the mill capacity

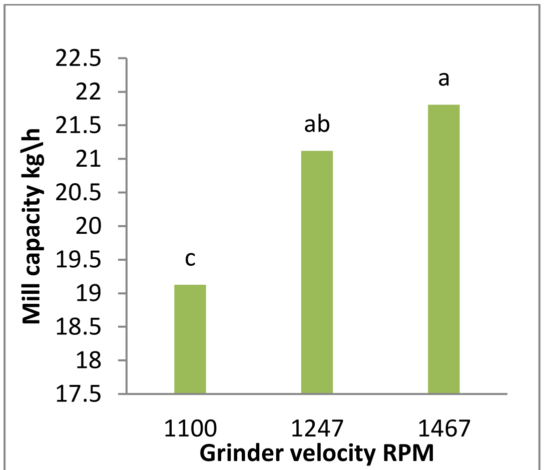
From Figure 3 there is a significant effect of the angle of the hammer on the production capacity of the mill below the level of 0.05 significant. Angle 0 recorded the highest milling capacity of 12.25 kg. h^{-1}, while Angle 30 ° recorded the lowest capacity of 16.96 kg. h^{-1}. It can be seen from Fig. 3 that the production capacity of the mill exponentially increases by increasing the cutting edge of the hammer at an angle from 30^0–60^0. The hammer edge incline has a significant effect on mill production capacity, fineness modulus, and specific energy consumption. The explanation for the decrease in the capacity of the mill (Fig. 3) and fineness modulus (Table. 2) while using the hammer with a cutting angle of 30^0 may be due to several reasons. First, the cutting in the edge of the hammer at a small angle leads to a prolongation of the time of rotation of the materials inside the grinding chamber and thus, delays the arrival of the particle size to the appropriate size to allow exit through the sieve holes. Second, this small cut is similar to the amount of damage to the hammer edge, which occurs as a result of its advanced service life. This is consistent with the interpretation of Marck (2019) that the performance deterioration of the hammer, which occurs as the damage to the edge, is greater than a quarter of the width of the hammer edge. Third ,the cutting at an angle of 30^0 makes the largest area of the hammer facing the particles and This increases the compressive force on the particles, thus the grinding process becomes more difficult, requires longer time and energy consumption per one unit weight of the grinded material (Fig. 4).

Effect of the grinding velocity on the mill capacity

The statistical analysis demonstrates that there was a significant effect of ($P \le 0.05$) the velocity of the miller on the capacity of the mill(Fig.4), as the capacity increased with the increase in the velocity of the grinder. The high and medium speed recorded the highest value of mill capacity with 21. 81 $kg.^{-1}$ and 21.12 $kg.^{-1}$ respectively, compared to the slow speed registering 19.13 $kg.^{-1}$. This result is logical, as the acceleration of the particles increases with the increase in speed, and consequently the impact energy increases, which leads to an acceleration in the cracking of the particles and their exit from the holes of the sieve. A selection of academics such as Oluwole,(2019) and Marck ,(2014) concurs that the results show an increase in productivity with increased velocity. The grinding velocity has a significant effect on the mill production capacity, fineness modulus and specific energy consumption. As the angular velocity increases, the mill capacity increases and the energy consumption decreases. This is due to the acceleration of the grinding of the particles and the decrease in the time of rotation of the particles for the purpose of breaking compared to the lowest degree angle. The 60^0 angle formed the least impact area facing the particles and thus the pressure force is greater on the particles. There is a significant effect of the interference between hammer edge incline and velocity on fineness modulus, while there is no effect of interference on mill production capacity and specific energy consumption. There is a direct relationship between the angles 30^0, 45^0 and 60^0 respectively and the production capacity of the mill. an inverse relationship between 30^0, 45^0 and 60^0 respectively and the fineness modulus and energy consumption. There is a direct relationship between the grinding velocity and the production capacity of the grinder and an inverse relationship between the grinding velocity and fineness modulus, and energy consumption.

LSD $_{angle}$=1.112, the difference letters indicate a significant difference between the average of the treatment

Figure 3 Comparison of the influence of different angles on mill capacity



LSD $_{speed}$=0.895, the difference letters indicate a significant difference between the average of the treatment

Figure 4 Comparison of the effect of grinder velocity on mill capacity

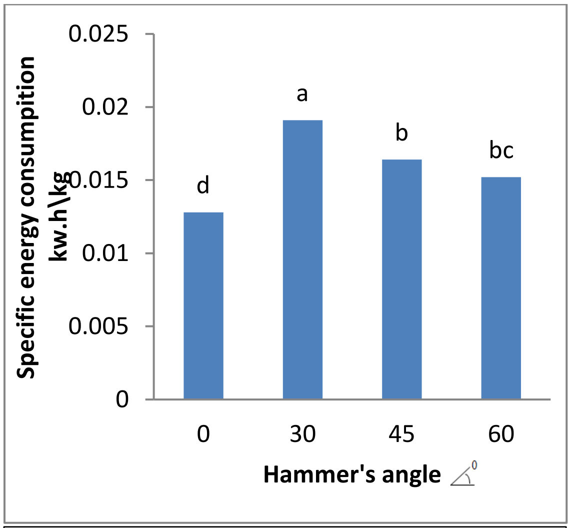
Effect of the hammer edge angle on specific energy consumption

Figure 5 displays a significant superiority of angle 0^0 over the rest of the experimental coefficients, where the lowest specific energy consumption was recorded at 0.013 kw. h. kg^{-1} compared with 0.015 , 0. 016 and 0. 0 19 kw. h. kg^{-1} for angles $60^{0,}$ 45^0 and 30^0, respectively. The angle that recorded the highest productivity with the least amount of energy consumption is the angle 0^0.

As for the rest of the angles—30^{0}, 45^{0}, and 60^{0}—it showed an inverse relationship with the specific energy consumption, as the energy consumption decreased with the increase in the angle. The new hammer (angle 0^{0}) achieved the best grinding capacity with the lowest value for the specific energy consumed, followed by the angle 60^{0}. Compared to the two angles, angle 30^{0} achieved the lowest productivity, highest energy consumption and highest fineness modulus. Therefore, we recommend the use of conventional hammers with strong edges that do not sharpen or wear quickly.

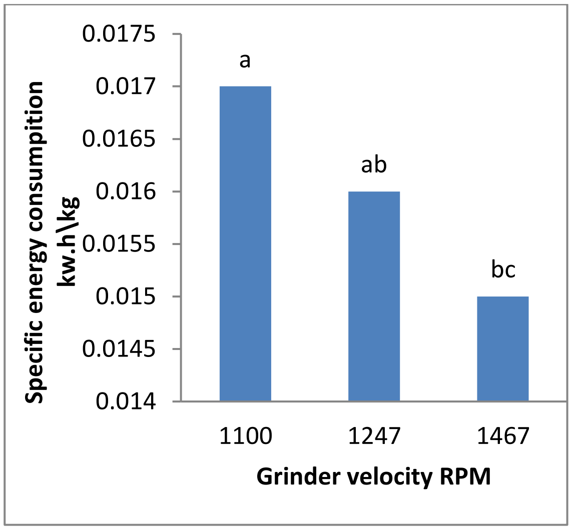
Effect of grinder velocity on specific energy consumption

Figure 6 shows that there is a significant effect of grinder velocity on specific energy consumption was found. There was found decrease in the specific energy consumption by increasing the velocity of the grinder. The recorded speed was 1100 rpm The highest specific energy consumption was 0.017 kw. h. kg^{-1}, While the speed of 1467 rpm recorded the lowest power consumption of 0.015 kW. NS. kg -1.



LSD $_{angle}$=0.001, the difference letters indicate a significant difference between the average of the treatment

Figure 5 Comparison of the effect of different angles on specific energy



LSD $_{speed}$=0.001, the difference letters indicate a significant difference between the average of the treatment

Figure 6 Comparison of the effect of grinder velocity on specific energy

Effect of the edge angle and grinder velocity on the finesse modulus

Table 2 illustrates the effect of hammer's edge angle, grinder velocity and co-interference on finesse modulus. A 30^{0} angle recorded the highest value for the FM while the 60^{0} angle recorded the lowest value. This means that the crushing efficiency improved with the increase in the angle. The angles 0^{0}, 45^{0} and 60^{0} recorded finesse modulus values of 2.82, 2.75, and 2.44, respectively. Table 2 shows the existence of an inverse relationship between the grinder velocity and the FM, where the higher the speed, the lower the FM. Increasing the speed of the crunches from 1100 to 1467 rpm led to a decrease in the FM from 2.85 to 2.68. Effect of the overlap between the main factors presented in the table, the angle 60^0 can be determined with all the grinder velocity understudy as the best angle that had a significant effect on the FM. The angle 60^0 recorded FM 2.85 , 2.70 and 2.68 with a velocity 1100 , 1247 and 1467 rpm, respectively, compared to angle 30^0, the coarsest particles were recorded, followed by angle 0^0 and angle 45^0. The 600 angle hammer has a fineness modulus advantage over the conventional hammer and other angles. Therefore, we recommend using this hammer for its high performance as well as its lighter weight and economy in manufacturing materials compared to new ones.

Table 2 Effect of the hammer edge angle, grinder velocity, and interference on the finesse modulus

Hammer's Edge angle ∠° / Grinder Velocity (rpm)	0^0	30^0	45^0	60^0	Mean of grinder velocity
1100	3.03 a	3.01 ab	2.89 d	2.45 m	2.85 a
1247	2.69 fgh	2.97 abc	2.70 fg	2.45 mo	2.70 b
1467	2.73 f	2.88 de	2.67 fghl	2.44 mop	2.68 bc
Mean of Hammer's angle	2.82 b	2.95 a	2.75 c	2.44 d	

L.S.D, angle = 0.04 ,LSD velocity =0.04 ,and LSD envelope= 0.08 , The difference indicates a significant difference between the averages of the treatments on a level of ($p<0.05$). NS is not significant differences between the averages of the treatments by ANOVA table on a level of ($p<0.05$).

Conclusions and Recommendations

- The hammer edge incline has a significant effect on mill production capacity, fineness modulus, and specific energy consumption.
- The grinding velocity has a significant effect on the mill production capacity, fineness modulus, and specific energy consumption. The mill capacity increases and the energy consumption decreases as the angular velocity increases.

- There is a significant effect of the interference between hammer edge incline and velocity on fineness modulus, while there is no effect of interference on mill production capacity and specific energy consumption. There is a direct relationship between the angles 30, 45 and 60° respectively and the production capacity of the mill. an inverse relationship between 30, 45 and 60° respectively and the fineness modulus and energy consumption.
- There is a direct relationship between the grinding velocity and the production capacity of the grinder, an inverse relationship between the grinding velocity and fineness modulus ,and energy consumption.
- The new hammer (angle 0°) achieved the best grinding capacity with the lowest value for the specific energy consumed, followed by the angle 60° compared to the angle 30°, which achieved the lowest productivity, highest energy consumption ,and highest fineness modulus. Therefore we recommend the use of conventional hammers with strong edges that do not sharpen or wear quickly.
- The 60° angle hammer has a fineness modulus advantage over the conventional hammer and other angles. Therefore, we recommend using this hammer for its high performance as well as its lighter weight and economy in manufacturing materials compared to new ones.

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