FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL AND PROCESS ENGINEERING

FINAL YEAR PROJECT REPORT

PRODUCTION OF AN IMPROVED POWER FACTOR LOW NOISE MAIZE MILL FOR SMALL SCALE MILLERS IN UGANDA

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DECLARATION

This report is as a result of our own research work and efforts of the entire team. We therefore affirm that no one in any institution has used it in the attainment of any academic award.

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DEDICATION

We dedicate this report to our beloved project supervisor Mr. Sserumaga Paul and to the head of department of our program Prof. Kant Kanyarusoke as well as the staff under chemical and process engineering department.

ACKNOWLEDGEMENT

Firstly, we thank the Almighty God for the gift of life, wisdom and perfect health.

We also thank our head of department of chemical and process engineering as well as our project supervisor for the opportunity and guidance granted us to undertake this study.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AC – Alternating current

DC – Direct Current

FAO – Food and Agriculture Organization

GMP – Good Manufacturing Practices

ISO – International Standards Organization

KVA – Kilo Volt Ampere

KVAR – Kilovolt Ampere Reactive

KW – Kilo Watt

OGTR – Office of the Gene Technology Regulation

SPRING – Strengthening Partnerships, Innovation and Results in Nutrition Globally

UNBS – Uganda National Bureau of Standards

ABSTRACT

This report describes the design and construction of a high power factor low noise maize mill utilizing materials that were sourced locally aimed at meeting the demands of the food industry. The developed machine was aimed at assisting in the grinding of maize into whole meal flour that has the capability of serving the desired demand and quality. The maize hammer mill has the ability to accommodate various grain particle sizes as required through the holes of the sieve positioned beneath the hammer assembly. The grinding process is achieved by actions of the hammers in beating the material (maize grains) fed into it. The fineness to be achieved depends on the perforated hole size of the detachable screen (sieve). This maize mill operates at a power factor of 0.90 and runs with appreciably less noise (89 dB) having a milling efficiency of 91.2%. The design and construction was done by Solidworks software designs which were then used as a basis for fabrication processes such as measurement, cutting, machining among others. This machine cost an initial investment of Ugx 5,000,000 including the power system having a probability index of 16.4. It was also noted that for better results, stainless steel material should be adopted as well as a vibration damping material for machine installation to damp as much vibrations as possible.

CHAPTER ONE: INTRODUCTION

1.1BACKGROUND

Hammer mills in Uganda have been in use for several decades, primarily for processing maize, cassava, and millet. According to a study by SPRING Uganda 2017, hammer mills were introduced in Uganda in the 1940s as a way of modernizing the small-scale agricultural sector. These mills were initially powered by diesel engines, but as electricity became more widely available due to the rural electrification programme, electric-powered mills became more popular. The hammer mills are typically operated by small and medium holder farmers who use them for processing their own crops and for selling processed grains to other farmers and traders (SPRING Uganda, 2017).

The type of hammer mill introduced to Uganda 60 years ago is still prevalent in the milling of maize and sorghum (Independent Consulting Group, 2003). These hammer mills are highly inefficient (USAID, 2010). Hammer mills are very important in Uganda and neighboring countries as a time- and costeffective means of milling grains. Most are manufactured by in-country artisanal fabricators. However, there are a number of concerns with locally fabricated hammer mills including: longer time required to reduce the material to the required particle size, contamination of flour due to poor quality of the steel alloy (usually scrap mild steel), especially the hammers resulting in presence of iron filings in the final flour as result of excessive wear and tear, and low power efficiency (i.e., high energy consumption per mass of ground material) (Ebunilo et al., 2010).

Particle size reduction of food solids is widely used in various food industry operations when creating smaller particles from larger particles of the same material (Brennan, 2005; Reid et al., 2008). Hammer mill performance is usually measured by the energy consumption and the final particle size distribution of the ground product (Ghorbani et al., 2013). Performance can be affected by machine variables such as screen design (size of openings, position of screen, and effective screen area), hammer tip speed, hammer pattern, number of hammers, hammer position (swinging or stationary), uniformity of input materials, and concave clearance (Wasswa, 2016). In addition, input material variables such as initial moisture content, initial particle size, and feed rate also affect hammer mill performance (Dey et al., 2013). The particle size distribution and the degree of fineness are very important from the technological point of view when evaluating performance of a hammer mill.

According to findings of a research study by Wasswa Deo, 2016, 60% of milling businesses in Eastern Uganda closed due to high energy requirement of hammer mills coupled with escalating tariffs as these were operated at low installed capacity of 30 – 50%, frequent failures of electrical components due to overloading during peak periods. Also, most of the hammer mills were locally fabricated, with various design considerations omitted.

Studies by Arthur et al. (2002) show that energy consumption increases with larger rotor size, smallest screen hole diameter, largest hammer thickness, smallest tip speed, highest power losses, largest concave clearance and highest feed rate. It was also noted that the smallest screen hole diameter (1.5 mm), largest hammer thickness (6 mm) and smallest tip speed (68.12 m/s) were responsible for higher energy consumptions.

In addition to the above, most hammer mills in Uganda operate at low power factors (usually ranging from 0.72 – 0.87) hence consume high amounts of electric power yet low efficiency (about 30-50%) thereby increasing the cost of production. The hammer mills have low power factors due to the use of large induction motors that draw large amounts of reactive power. This reactive power causes a voltage drop and reduces the overall power factor of the system (Wasswa, 2016).

Also, according to the study by Erasto Elias et al, 2014, maize mills present a significant source of excessive noise pollution both on site and in the surrounding locality which can possess a significant occupational health hazard. Studies conducted in a number of milling small and medium enterprises in Dar-es-Salaam by Pesambili (2014) and Kizima (2017) revealed that maize millers are subjected to high levels of noise ranging from 88 to 104 dBA, which were above the recommended safe limit of 85 dBA exposure in 8 working hours (Berrekette, 1973). Such high noise, if allowed to be generated, would cause stresses, irritation, headaches and sleeplessness to machine operators and neighbors. Some of the causes of this excessive noise are; use of thin materials for the milling chamber, vibrations due to hammer misalignments, loose fittings, high hammer densities and improperly designed foundations for machine and motor installation.

1.2 PROBLEM STATEMENT

Hammer mills are widely used in various industries for grinding and crushing different materials. However, traditional hammer mills have low energy efficiencies (about 45-60%) and consume a significant amount of energy, resulting in high costs of milling. The current hammer mills have low power factors (usually ranging from 0.72-0.82) due to the use of large induction motors that draw large amounts of reactive power and experience high electrical losses such as resistance in equipment and phase losses. This reactive power causes a voltage drop and reduces the overall power factor of the system. The low power factor results in increased energy consumption lower efficiency, and higher electricity bills as well as frequent failures of electrical components due to overloading during peak periods. In addition to this, hammer mills produce excessive noise whilst running, and this poses a significant health hazard to operators and the surrounding locality.

This study sought to design and construct a machine using a high power factor motor (0.98), with a wellbalanced rotor size including optimized hammer size and number, appropriate size of disc plates and blower for balancing the load on the motor as well as improving the milling efficiency; appropriate concave clearance and tip speed that is capable of maximizing the crushing rate; well aligned milling components and a vibration damping installation base to help minimize excessive noise and vibrations.

1.3 OBJECTIVES

1.3.1 Main objective

To design and construct a maize mill that uses less power, capable of producing a higher output compared to the existing machines and running with less noise.

1.3.2 Specific objectives

1. To conduct research on power consumption and improvement of power usage by hammer mills.
2. To produce the maize hammer mill with a high power factor and minimized noise.
3. To test the maize hammer mill for performance evaluation.

1.4 JUSTIFICATION

There is emphasis for governments to support and develop industries for economic growth to higherincome status (UIA, 2015). Therefore the improved power factor of the hammer maize mill increases energy efficiency, reduces power consumption, and lowers energy costs, and this has economic benefits for farmers and small-scale millers because they are capable of producing more maize flour at a lower cost, which can be sold at a competitive price in the local market. Also, Minimized costs of maintenance and inventory due to reduced electrical component failures as energy efficiency is achieved. In addition, reduction of noise helps safeguard the machine operators and the surrounding locality from effects of long hours of exposure to excessive noise such as hearing impairment, irritation, headaches among others.

1.5 SIGNIFICANCE

With the increasing population throughout Uganda, the demand for maize flour is growing especially in institutions, hotels, prisons among others, due to change in consumption patterns.

The project sought to develop and construct a high power factor maize milling machine that is more energy-efficient than existing machines. This helps to reduce energy consumption, improve milling efficiency, and reduce overall costs for millers. By reducing energy consumption and improving the efficiency of the milling process, more people are encouraged to undertake the milling business since the biggest challenge in this field is the energy cost. This also certainly increases the production levels of maize flour, improve the per capita income for farmers as well as create employment opportunities in the community. This project will also contribute to the sustainable development of the food industry and help to ensure food security for the populations that depend on maize as a staple food.

1.6 SCOPE OF STUDY

This study was limited to the design and construction of an high power factor, less noise motorized hammer mill for small scale millers in Uganda and testing its performance within a period of four months from May – August 2023.

CHAPTER TWO: LITERATURE REVIEW

2.1 MAIZE PRODUCTION AND PROCESSING IN UGANDA

2.1.1 Maize cultivation in Uganda

The study is focused on maize because it is an important crop in Uganda. Maize is the most highly cultivated crop with about 86% of Uganda's agricultural households, (UBOS, 2014). Maize is the numberone staple food for both rural and urban population, in institutions such as schools, hospitals and the military. Also, the crop is the number-one source of income for almost 70 districts in Uganda. The main production agro-ecological zones are in the west, east, north and southeast parts of the, (Ferris et al., 2006).

The crop is cultivated by over 3.6 million households on about 1.5 million hectares of land (UBOS, 2006). In terms of area planted, maize is the third most cultivated crop after banana and beans. In some regions of the country, the crop has now become a staple food, replacing crops like sorghum, millet, cassava and banana. It is a growing source of household income and foreign exchange through exports. For example, maize is presently considered a major source of income in the districts of Kapchorwa, Mbale, Iganga, Masindi and Kasese, with about 75–95 percent of the household harvest being sold to earn money. In 2008 alone, maize is estimated to have generated over US$ 18.5 million in export earnings from an estimated 66,700 tonnes. The regional destinations for maize exports include Kenya, South Sudan, Rwanda, Burundi, Zambia and DR Congo.

2.2 MAIZE MILLING AND PRODUCT CONSUMPTION IN UGANDA

The Government of Uganda has made considerable progress in advancing the food value addition agenda and developing food quality control systems. These efforts are to improve the quality of foods and reduce micronutrient deficiencies. Uganda has made significant progress in fortifying edible oils/fats, wheat flour, and salt; however, fortification of maize flour remains a challenge. The maize-milling sector is dominated by millers whose production capacity is less than 20 metric tons per day, the capacity specified in the mandatory fortification policy(Usaid and Spring 2017).

SPRING/Uganda conducted the survey in the four major regions of Uganda: central, eastern, western, and northern(Usaid and Spring 2017). According to the survey, maize flour in Uganda is produced in all four regions of the country; the central region is the leading producer, followed by the eastern, northern, and western regions, respectively. Of the four regions, the central region has the largest number of maize flour producers (38 percent of millers), followed by the eastern and northern regions (22 percent in each), and lastly, the western region (18 percent). The majority of these use small and medium scale hammer mills with a few using roller mills. One practice commonly observed in all the regions was the use of poor quality machinery, such as fabrication of the milling machines with local, non-food grade materials. These metal parts put the consumer at a high risk of consuming maize flour contaminated with metal chippings, especially if the facility does not use magnets to remove the metal (a GMP).

2.3 MAIZE HAMMER MILLS IN UGANDA

The maize hammer mill, which can otherwise be referred to as Cereal Miller, is designed for grinding, and sieving all kinds of cereal grains, such as maize, wheat, millet, corn, sorghum, wheat. It can also process non-cereal materials such as dry cassava tuber(Ibrahim, Omran, and Abd EL-Rhman 2019). 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. This equipment comprises essentially of a power unit, belts, pulleys, a transmission shaft, hammer shafts, an inlet hopper, milling chamber, fan, bearings, hammer assembly, suction pipe, flour cyclone and a stand frame.

2.3.1 Principle of grinding/milling

Grinding is achieved through impact and attrition between particles of the material being ground, the housing (milling chamber) and the grinding elements (hammers). As the material being ground is fed into the grinding chamber, it is initially struck by the rotating hammers and then thrown against perforated plate. Therefore, the material is ground by the repeated impacts of the hammering elements, collisions with the screen and walls of grinding chamber as well as particle on particle impacts(Princewill 2017). As soon as the particle size of material is reduced to the size smaller than that of the holes of the screen, it will pass through the screen and blown by a fan through the pipe to the flour cyclone. The fineness of the particles is regulated by the use of sieves of different mesh sizes.

2.3.2 Factors affecting the milling efficiency

Several factors including design considerations as well as physiological parameters of the material being ground have a significant effect on the milling efficiency of hammer mills. These include rotor speed, concave clearance, total input power, screen hole diameter, hammer size, number of hammers and the configuration of the hammer assembly. Other factors include the moisture content of the material being ground and the feeding rate. It is noted that low rotor speed, large concave clearance, low input power, small screen hole diameter, smaller hammer width, few hammers and high moisture content cause a low milling efficiency of the hammer mill.

2.3.3 Power requirement of hammer mills

Parameters that affect the performance and efficiency of a maize hammer mill include: thickness of the hammers, the mill clearance, sieve-hole diameter, drum rotational speed and capacity of the mill (Vigneault et al, 2008). Poor design of such parameters leads to high power consumption during the milling process. This has made about 60% of the maize mills in Uganda close up due to high electricity bills (Ali Twaha observers, 2015). This high power consumption is also attributed to the use of large induction motors with low power factors which draw much reactive power from the supply yet producing less output. However, this can be improved by installation of a power factor correction unit consisting of capacitors to reduce the amount of reactive power required by the system. In addition

2.3.4 Power factor correction system

Power factor is the ratio between the useful (true) power (kW) to the total (apparent) power (kVA) consumed by an item of a.c electrical equipment or a complete electrical installation. It is a measure of how efficiently electrical power is converted into useful work output. When the power factor is less than one the ‘missing’ power is known as reactive power which unfortunately is necessary to provide a magnetizing field required by motors and other inductive loads to perform their desired functions. Reactive power can also be interpreted as wattless, magnetizing or wasted power and it represents an extra burden on the electricity supply system and on the consumer’s bill. A poor power factor is usually the result of a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or a distorted current waveform.

Power factor correction is the term given to a technology that has been used since the turn of the 20th century to restore the power factor to as close to unity as is economically viable. This is normally achieved by the addition of capacitors to the electrical network which compensate for the reactive power demand of the inductive load and thus reduce the burden on the supply. There should be no effect on the operation of the equipment. To reduce losses in the distribution system, and to reduce the electricity bill, power factor correction, usually in the form of capacitors, is added to neutralize as much of the magnetizing current as possible. Capacitors contained in most power factor correction equipment draw current that leads the voltage, thus producing a leading power factor. If capacitors are connected to a circuit that operates at a nominally lagging power factor, the extent that the circuit lags is reduced proportionately. Typically the corrected power factor will be 0.92 to 0.95

2.3.5 Methods of power factor correction

There are several methods of power factor correction in small and large scale industries which include;

1. Use of synchronous condenser

When a synchronous motor operates at no-load and is over-excited, it is called a synchronous condenser. When a synchronous motor is over-excited, it provides leading current and works like a capacitor. In a synchronous motor, a separate DC source is used to excite the field winding. Therefore, the input supply only provides current to energize the stator, i.e., the current provided is in-phase with the supply voltage. So the power factor remains unity. The power factor can be adjusted by varying the DC excitation. By increasing the DC excitation, the power factor varies from lagging to unity and leading power factor.

When the DC excitation increases, the field windings are over-magnetized. The input supply provides a current component to the stator to compensate for this over-magnetization. This current leads to the supply voltage, causing a leading power factor or generating reactive power.

2. Use of static capacitors

Most industries and power system loads are inductive, which causes a decrease in the system power factor due to lagging current. To improve the power factor, static capacitors are connected in parallel with these devices operated on low power factor. These static capacitors supply leading current, which balances out the lagging inductive component of the load current. This effectively eliminates or neutralizes the lagging component of the load current and corrects the power factor of the load circuit to enhance the overall efficiency.

2.3.5. 1 Advantages of using capacitors for power factor correction.

i) Improved power factor:

One of the most significant advantages of capacitors in power factor correction is that they help to improve the power factor of the system. Capacitors are capable of absorbing reactive power, which is responsible for a low power factor, and converting it into active power. This results to an improved power factor, which leads to reduced energy losses and improved system efficiency.

ii) Reduced energy costs:

Capacitors can also help to reduce energy costs by reducing the amount of reactive power required by the system. This is because reactive power does not contribute to useful work and is therefore wasted. By reducing the amount of reactive power required, capacitors can reduce energy costs and improve overall system efficiency.

iii) Increased system capacity:

Capacitors can also increase the capacity of the system by reducing the amount of reactive power flowing through the system. This means that more active power can be transmitted through the system, increasing its capacity and reducing the risk of overloading.

iv) Improved voltage regulation:

Capacitors can help to improve voltage regulation by reducing voltage drops and fluctuations caused by reactive power. This results in a more stable voltage supply, which can improve the reliability of the system.

3. Use of phase advancers

The Phase Advancer is a simple AC exciter that connects to the main shaft of a motor and operates with the motor's rotor circuit to improve power factor. It is commonly used in industries to improve the power factor of induction motors. Since the stator windings of an induction motor take lagging current 90° out of phase with voltage, the power factor of the motor is low. By supplying exciting ampere-turns from an external AC source, the current does not affect the stator windings, and the power factor of the induction motor improves.

2.3.6 Challenges of Power Factor Correction in Uganda

Despite the potential benefits of power factor correction in hammer maize mills in Uganda, there are several challenges that need to be addressed. One of the main challenges is the cost of capacitors and installation, which can be a barrier for small-scale millers and farmers who operate on low budgets. Additionally, the variability of load in hammer maize mills can make it difficult to determine the optimal capacitor size and configuration.

2.3.7 Innovations in Power Factor Correction

In recent years, there have been several innovations in power factor correction technology, including the use of intelligent capacitors that can adjust their capacity according to the load. These innovations have the potential to overcome some of the challenges associated with power factor correction in Uganda and make the technology more accessible and affordable.

However, synchronous motors with usually high power factors would help mitigate the issue of high energy requirement of induction motors but they are associated with several costs including high purchasing costs and limited availability in the market.

Conclusion:

In conclusion, power factor correction has been shown to be an effective way to improve efficiency and reduce energy consumption in various industrial applications. While there is limited research on its application to hammer maize mills in Uganda, the existing studies suggest that power factor correction can significantly improve the efficiency of these mills. However, there are several challenges that need to be addressed, including the cost of capacitors and installation and the variability of load. Innovative technologies, such as intelligent capacitors, have the potential to overcome these challenges and make power factor correction more accessible and affordable for small-scale millers and farmers in Uganda.

2.3.8 NOISE PRODUCTION IN HAMMER MILLS

Industrial machines and processes produce noise, which can possess a significant occupational health hazard if it is excessive. Maize flour mills present a significant source of excessive noise pollution both on site and in surrounding locality (Evans et al, 2004). This noise is largely caused by the hammering process of the speeding hammers during milling. Other causes may include machine vibrations, misalignments, poor clearances and loose fittings.

Noise is measured in a unit called "decibel" (dB) which is a measure of how much pressure or sound intensity is created by the sound wave producing the sound as a function of power ratio. The range of decibels is from 0 to about 140, or from the smallest sound human ears can hear to the sound level that will do immediate and permanent damage to the ear. The other end of the scale is known as the threshold of pain (140 dB), or the point at which the average person experiences pain. Both the amount of noise and the length of time one is exposed to noise determine its ability to damage one's hearing.

2.3.8.1 Effects of long exposure time to noise

The health effects of hazardous noise exposure are now considered to be a public health problem. Many research investigations on the effects of noise on human health indicate a variety of health effects. The World Health Organization (WHO) suggests that noise can affect human health and well-being in a number of ways.

In practice, the effects of noise can be categorized into three major areas:

(a) Physiological effects: noise-induced hearing loss or aural pain, nausea and reduced muscular control, threat to cardiovascular system, systolic blood pressure, and digestive system disorders; (b) Psychological effects: noise can startle, annoy and disrupt concentration of sleep; and (c) Interference with communications.

2.3.8.2 Control of noise in machines and equipment

Some of the significant technical solutions to eliminate excessive noise in maize mills include;

(a) Proper installation of milling machines: sufficient fixation and application of vibration damping materials.
(b) Properly designed foundation for machine and motor installation to minimize machine vibration and therefore noise level.
(c) Carrying out a study to improve design and material specification of milling hammers, followed by standardization by UNBS so that manufacturers can use standard hammers.

(d) Establishing proper balancing procedure of milling hammers as well as proper alignment of all moving parts.

(e) Use of proper thickness (>3mm) of materials for milling chamber of the maize mill so as to contain the noise of materials being hammered.

(f) Use of sound proofing materials such as acoustic foam and fabric panels, sound blankets, fibre glass, acoustic membrane among others.

2.3.9 NOISE LEVELS OF FLOUR MILLS

Daily noise exposure points, exposure points per task and exposure points per hour were computed by using noise exposure calculator developed by Health and Safety Executive (HSE) UK. The sound level meter was used to measure sound level at 50 cm and 3 meters from grinding machines at receiver's position during operation. Noise monitoring was also recorded when one, two and three machines were operating individually and simultaneously (Nimgade and Kamble, 2018).

Table 1.2 Comparison of noise level range and average noise level

Flour mill operating condition	Noise sampling distance from source	Noise level range dB(A)	Average noise level range dB(A)
Single machine	50cm 3m	80 -97 70 – 77	89.75 74.0
Two machines	50cm 3m	95 – 118 75 – 95	106.0 85
Three machines	50cm 3m	123 – 130 110 – 117	126.5 113.5

CHAPTER THREE: METHODOLOGY

The main aim of this proposal is to design and construct a high power factor and minimized noise maize mill, with efficient power usage and high-quality output. The chapter provides the step-by-step procedure of how the proposed study was implemented following the specific objectives stated above.

Specific objective (i): To conduct research on power consumption and improvement of power usage by hammer mills

3.1 DATA COLLECTION AND REVIEW

Information relating to the energy consumption of existing maize hammer mills, energy requirement and hence energy cost of operating the machines was thoroughly studied by reviewing various literature from different sources. Also, noise production and noise/decibel levels of existing mills were also studied as well as technologies available to mitigate high sound levels.

This was achieved through field surveys, one-on-one questionnaires with millers and technicians, field tests such as decibel level tests, as well as secondary data from internet, journals, design textbooks and handbooks, results from previous researchers and experimenters.

Specific objective (ii): To produce the maize hammer mill with a high power factor and minimized noise.

3.2 DESIGN OF THE MAIZE MILL

3.2.1 Machine description

The proposed maize milling machine was made up of five major units; that is the feed chute, crushing chamber, stand frame, the power unit and the power factor correction system.

i) Feed chute

It was pyramidal in shape and made from 3mm thick mild steel plate. The plate was marked, cut to measured sizes and then welded together.

ii) Milling chamber

This unit comprised of the main shaft (transmission shaft) of 38mm diameter and 720mm length which was cut using power hacksaw with a key way cut on both ends using a milling machine for fixing the driven pulley and the fan, top and bottom casing within which the hammer assembly with 24 hammers, 4 stopper shafts and 4 hammer shafts each of 21mm diameter was and 3 spacer plates was installed, and a fan was fixed at one side of the milling chamber. It was a mechanical fan comprising of four straight impellers attached to the shaft. The hammer assembly was made of mild steel hammers arranged on 4 hammer shafts and spaced by washers onto 3 spacer plates. The stopper shafts passed through the spacer plates. The main shaft rested on pillow block bearings at each end. Attached to one of the ends of the shaft was the driven pulley.

iii) Stand frame

This acted as the base of the machine onto which all other members sit including the milling chamber and the motor. It was made of 5mm mild steel angle bar welded to form a suitable shape for mounting both the milling chamber and the motor.

iv) Power unit

This unit consisted of a 10hp electric motor fitted by bolts and nuts onto the motor mounting and a startdelta motor starter. A V-belt was used to connect the motor pulley (driver) to the one attached onto the main shaft (driven) pulley.

v) Power factor correction unit

This unit consisted of the capacitor bank and contactors to help improve the power factor of the motor. The capacitors are connected in series with each other and then parallel with the motor terminals. The contactors and circuit breaker helped to protect the capacitors in case of any overload or short circuit. Power factor correction static capacitors operating with three phase supply were chosen for this purpose.

3.2.2 Machine operation

To accomplish milling, the high speed of the electric motor was transmitted to the shaft via the pulleys, belts and bearings. The hammers at their different positions then stood upright during the high-speed rotation in between the spacing plates. The walls of the casings housing the hammer assembly and the hammers themselves was made so close that no incoming materials would escape being hammered before dropping on the sieve. The high angular speed of the hammers was imparted on the incoming materials (maize grains) from the feed chute, thereby splitting the materials into several small particles continuously which then passed through the tiny holes on the sieve (mounted in the milling chamber under the hammer assembly) and flour was sacked by the fan through the suction pipe to the flour cyclone. The little vibration un-damped helped to push the materials from the feed chute to the hammers and then the particles from the sieve to the outlet channels were sucked by a fan, thereby making the machine selfacting. The milled materials were collected from the flour cyclone into a receiver.

3.3 DESIGN OF THE COMPONENTS OF THE MACHINE

3.3.1 Design considerations.

The following considerations were made in the design of the improved power factor maize mill and they include; the availability of design and construction materials, the loading capacity per unit milling operation, cost of the materials, ergonomics, environment, shape and size of the machine among others.

3.3.2 Design of the hopper (feed chute)

It was trapezoidal in shape and was made from 3mm thick mild steel plate. The plate was marked, cut to sizes and then welded together.

3.3.3 Design of the main shaft

A 38mm diameter cast iron rod was cut to a 720mm length using power hacksaw. Keyways were cut on its both ends using milling machine for the fixing of the driven pulley and the fan. The shaft of the hammer mill which is rotating the hammers and fan was to 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 equation given as;

$$d^3 = \frac{16}{\pi \sigma_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \ldots\ldots\ldots\ldots \quad (1)(J.K. GUPTA 2005)$$

Where □□ is diameter of the shaft, □□□□ is maximum yield stress (N/m^2) = 42 MPa, □□□□ is bending constant, □□□□ is bending moment, □□□□ is torsional constant and □□□□ is torsional moment.

Also, an equation for determination of Turning/Twisting moment (T) on the pulley is as shown;

$T = (T_1 - T_2) R$, where; T_1 = Tight side tension (N), T_2 = Slack side tension (N) and R = Radius of pulley (m).

To calculate the shaft speed, this equation was used;

— = — ……………………………………………………………………(2) (J.K. GUPTA, 2005)

Where;

D_1 and N_1 =Diameter (m) and revolution of the smaller pulley (rpm) respectively.

D_2 and N_2 = Diameter (m) and revolution of the larger pulley (rpm) respectively.

To obtain the speed of the driving and driven pulleys, the following equations were used;

□□= ____ and □□= ____ ………………………..…(3)(R.S. KHURMI J.K. GUPTA 2005)

Where □□ and □□ are the speeds (m/s) of the driving and driven pulleys respectively.

This shaft speed is only obtained when there is no slip condition of the belt over the pulley. When slip and creep condition is present, the value would be reduced by 4%.

The power required by the machine shall was obtained from the equation below;

$P_h = T\omega$ ………………………………………………….(4)(R.S. KHURMI J.K. GUPTA 2005)

Where P_h= power, T = torque and ω= angular velocity.

3.3.4 Design for the belts

The selection of the belt was based on the power transmitted and according to the Indian standards as per (IS: 2494-1974). The number of belts required to transmit the power from electric motor was calculated using the given equation:

□□ = ________ ……………………………….(5)(Natarajan, 2000)

Calculation of belt length L was obtained from the equation below;

□□ = _ (□□ + □□) + 2□□ + ( ) ______ ………………….(6)(J.K. GUPTA, 2005)

Where, L = Length of belt (mm), D_1= Smaller pulley diameter (mm), D_2= Larger pulley diameter (mm), C = Centre distance of pulleys (mm).

The power transmitted by the belt, P, is given by;

$P = (T_1 - T_2) V$……………………………………….(7)(J.K. GUPTA, 2005)

Where, P = power transmitted, T_1 = tension on tight side of belt, T_2 = tension on slack side of belt, V = linear velocity of the belt.

3.3.5 Design of the hammers

A 6mm thick mild steel flat bar of 125mm length and 40 mm width was cut into 24 pieces using a hack saw. A hole of 21.5mm was drilled at the ends of each hammer, using twist drill, to enable it to be put into position on the hammer shaft.

The centrifugal force on the hammers, F_h, was be obtained from;

$F_h = N_h m_h r_h \omega_h$. ………………………………………(8)(Princewill 2017)

Where, F_h = centrifugal force, N_h = number of hammers, m_h = mass of each hammer, r_h = radius of hammer, ω_h= angular velocity of hammer.

3.3.5.1 Calculation of the hammer wear-life:

Hammer wear life (hours) = (Hammer weight/Wear rate) x (Production rate/3600)

Where Hammer weight is the weight of the hammer (in kg), Wear rate is the wear rate (in mm^3/Nm), and Production rate is the hourly production rate (in kg/h).

3.3.6 Selection of bearings

Ball rolling contact bearing of standard designation 307 is proposed was selected for the machine. This selection was based on the type of load the bearing would support when at rest and during operation and also based on the diameter of the shaft. The designation 307 signifies medium series bearing with bore (inside diameter) of 38mm.

3.3.7 Design of the stand frame (structural base).

The base structure of the maize hammer mill was constructed with a 5mm thick mild steel angle bar. This was measured, cut and welded together to obtain the desired frame

3.3.8 Sizing of a capacitor for power factor correction

The capacitance of a capacitor to be used in a power factor correction unit was calculated using the following formula:

C= ________

Where: C is the capacitance of the capacitor in farads (F), kVA is the apparent power in kilovolt-amperes (kVA), V is the voltage in volts (V), f is the frequency in hertz (Hz) and PF is the desired power factor.

3.4 FABRICATION AND ASSEMBLY OF THE MACHINE COMPONENTS

The construction of the prototype involved the selection of suitable materials and fabrication processes that were used to come up with the prototype.

3.4.1 Material selection

The properties associated with ability of the material to resist the different forces and loads applied on the material were considered. The mechanical properties that were considered include toughness, strength and hardness. Other factors like Surface finish, density, interaction with environment, fabrication cost, maintenance cost and availability of materials; ease of fabrication and safety of materials was also considered. The materials that are readily available on the market were preferred so as to speed up the fabrication process.

3.4.2 Fabrication methods

The methods that were used in the fabrication of the machine included; measuring of linear parameters, mass/weights, cutting, machining such as bending, forging, drilling, and grinding, welding among others.

3.4.3 Tools and equipment

The different methods that were employed in the construction of the machine were accomplished by using various tools and equipment as shown below;

i) Lathe machine to machine different parts ii) Bending machines for bending the parts iii) Angle grinders for cutting the different parts iv) Welding machine for welding the different parts to give the full assembly.

v) Protective wears (overall, dust coats, eye goggle, nose and mouth mask, gloves).

3.4.4 Fabrication of the main components

Before the construction started, the machine components were designed and drawn using Solid works software. There-after, the following processes were followed to come with the required design of the maize mill.

a) Stand frame.

By the use of the measuring and cutting tools, the frame was dimensioned to a desired length and spot welded to give the general look of the machine frame.

i) Main shaft.

A long cast iron was cut into the desired length using a power hack saw and keyways machined on both ends for fitting the driven pulley and the fan. A standard bearing pair was then selected for the desired shaft diameter. Spacer plates were welded onto the shaft onto which the hammer shaft holding the hammers and the stopper shafts were fitted.

ii) Milling chamber/housing

A flat mild steel sheet was cut and folded to an appropriate length and diameter and welded on both sides to form a top and bottom casing. A small feed hole with the dimensions of one side of the feed chute was cut at the side of the casing for fitting the feed chute.

iii) Hammers

A long flat mild steel rod was cut using a hacksaw into minimum of 24 pieces of a measured dimension. A hole of 21.5mm was drilled at the ends of each hammer, using twist drill, to enable it to be fitted on the hammer shaft.

iv) Spacer plate.

Circular plates were cut from a flat mild steel sheet using an angle grinder into 3 pieces. 16 holes of 21mm diameter will be drilled on each plate to allow for fixing the stopper and hammer shafts. Washers of about 22mm diameter were cut from a hollow rod for spacing the hammers on the hammer shaft. v) Fan

Blades of the desired dimensions will be cut from a flat mild steel plate and welded on a circular plate and fitted on one side of the main shaft. A casing for the fan with a suction inlet and outlet pipe will be fitted on to the casing.

3.4.5 Assembly of the prototype

All the components enumerated above were systematically assembled and carried by the structural base (stand frame) of the machine. The pulley on the electric motor was connected to the pulley on the main shaft by a V-belt. The shaft was suspended on bearings mounted on their seats on the two sides of the bottom casing of the milling chamber. The bottom casing was bolted strongly on the structural base. The hammers, discs and their hangers (hammer shafts) and separators (spacers) were situated at the middle of the shaft inside the bottom casing. The bottom casing was connected to the top casing using robust hinges, so that the top casing can open in one direction only. When closed, they were held together by a locking bolt. The parabolic top casing was open to some extent at the top. On this opening the inclined feed chute with its regulatory device was connected. The feed chute and the top casing formed one component. The semi-circular particle sieve was mounted inside the bottom casing. The fan sucked the fine flour through the inlet suction and through the suction pipe to the flour cyclone. Bolts and nuts, locking devices, split pins, lock nuts were used for securing components in their correct positions.

3.5 TESTING THE PROTOTYPE

The machine prototype was tested after fabrication and assembly so as to determine the milling parameters such as milling efficiency, energy requirement, degree of vibration, and the level of noise. This was done by introducing dried maize of a measured quantity into the machine and taking the observations of the required parameters after a given time period. The weight of the maize was measured using a weighing scale and milling was timed using a stop clock. Current level as well as voltage was measured using a current multimeter. The level of sound from the machine was analyzed using a digital sound meter by placing it firstly on the body of the milling chamber and then at distances of 30cm, 50cm and 3m away from the machine.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

Specific objective ii) ‘To produce the maize hammer mill with a high power factor and minimized noise’

4.1 DESIGN PARAMETERS

The machine was an assembly of various component parts such as the milling unit comprising of hammers and hammer assembly, bearings, main shaft, blower fan, cyclone and the power unit.

4.1.1 Milling unit

4.1.1.1 Determining the weight of hammers

Using the density of mild steel for the hammer, ρ = 7850kg/m^3, length of each hammer = 150mm, width = 40mm and thickness = 6mm

□□$_h$ = 24□□7850□□0.15□□0.04□□0.006

□□$_h$ = 6.78□□□□

Mass of each hammer = 6.78/24 = 0.2825kg

4.1.1.2 Determining the shaft speed

Diameter of the larger pulley, □□2 = 204mm and that of the smaller pulley (mill pulley), □□1= 123mm, speed of the motor □□2 = 1440rpm

—— = ——, N_1 = 2388rpm

4.1.1.3 Determining the velocity of the hammers

Taking the milling chamber of radius 296mm;

V_h = ______________ = 74m/s

4.1.1.4 Determining the centrifugal force exerted by hammers

The hammers are attached to the hammer shafts, onto the disc plates and onto the shaft, all contained in the milling chamber of radius 0.296m. The rotation of these components generates the centripetal force (F_c) that facilitates the hammers to grind the maize grits into flour.

□□= ______ = 125.4kN

4.1.2 Design of shaft

The length of the shaft was pre-determined as 720mm as well as a diameter of 38mm. The following assumptions were made during the determination of the design stress and torque on the shaft; Weight of the shaft is negligible, the shaft is straight, effect of stress concentration is negligible, the Shaft material is perfectly elastic.

$\frac{}{16}$ □□ = = 28.98Nm

$\frac{16x28.98x4.2}{}$ Design stress = = 11.296Mpa

4.1.3 Required power for the mill

The power requirement of the machine was calculated as follows;

From; □□ = ______ ______________, = = 7.247kW

Therefore, a prime mover (motor) with a power rating of about 7.5Kw was required for the machine to provide the above required power.

4.1.4 Power factor correction system

The required capacitance for increasing the power factor of the motor to 0.98 was calculated from;

Using the motor with specifications P =10hp, I = 15.4A, V= 415V, PF = 0.90 and efficiency = 0.91

Total input power = (10x746)/0.91 = 8.24kW Total

apparent power = 8.24/0.90 = 9.15kVA

Total reactive power = $\sqrt{9.15 \quad - 8.24}$ = 3.98kVAR

Provided that we intended to increase the power factor to 0.98, the new apparent power would then be; Pa = 8.24/0.98 = 8.4kW

New reactive power = $\sqrt{8.40 \quad - 8.24}$ = 1.63kVAR

The required reactive power to be supplied by capacitors = 3.98 – 1.63 = 2.35kVAR

The required reactance = $2350/415^2$ = 0.014Ω

Hence the required capacitance C =1/(2x3.142x50x0.014) = 0.227F

Therefore, a three phase capacitor with rated voltage of 380 – 420V, Current of 6A, reactance of 0.014Ω capable of supplying 2.35Kvar reactive power was judged suitable for the power factor correction unit of the system. Also a capacitor bank that can supply 2.35Kvar could be used to accomplish this design. However, this unit could not be installed as it was difficult to source the required capacitor locally in the country. The capacitor banks available were too large to be used for a 10hp motor as these would lead to over correction with associated effects such as self-excitation of the motor.

4.1.5 Air pressure

The air velocity was obtained from the equation below as follows;

□□ = ____________ = 300m/s

Therefore the air pressure exerted by the fan was obtained from;

□□ = _____, Where □□□□ is the air pressure, □□ is the pipe line friction factor, □□ is the length of the pie, □□ is the air density, □□ is the air velocity and □□ is the diameter of the pipe.

The flour pipe was 2m above from the ground and the calculated diameter of the pipe was 0.1m.Therefore the air pressure that lifts the flour and delivers it to the cyclone is determined as below

□□= ________________ = 20.07kPa

4.1.6 Prototype assembly

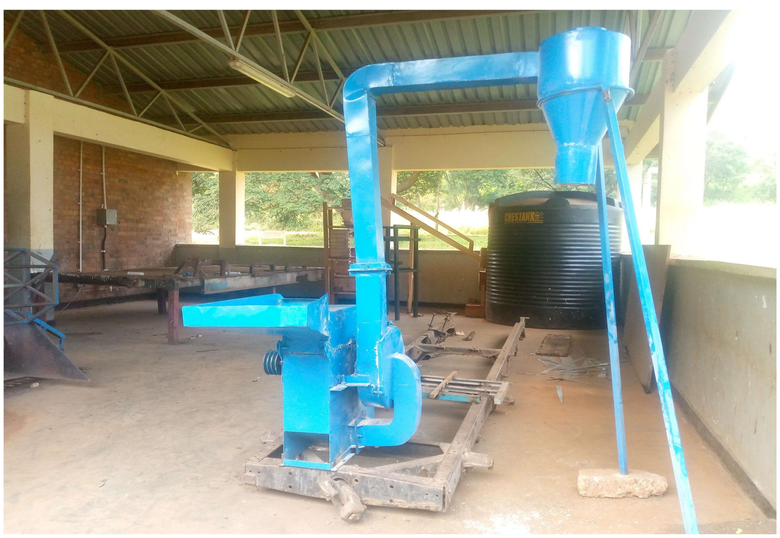

Figure 1.4 Prototype before final assembly

Figure 2.4 Prototype after final assembly

4.2 TESTING RESULTS

4.2.1 Energy usage and costing estimation.

A three phase asynchronous motor with the following nameplate specifications was chosen basing on the required power for the machine;

Rated output power = 7.5kW, Rated current = 15.4A, Rated voltage = 415V, Efficiency = 91% and power factor = 0.90.

Power consumed = □□ = $\frac{\sqrt{\ } \ . \ \ . \ \ .}{\rule{4cm}{0.4pt}}$ = 9.056kW

Energy consumption per hour = 9.056kWh

Given that a unit of energy is Ugx 611.8 for commercial users (ERA, 2023)

Energy cost per hour = 611.8 x 9.056 = Ugx 5,540

If the machine is run 6 hours daily, daily cost of milling = 5540 x 6 = Ugx 33,240

4.2.2 Milling results

Dry maize of 3.4kg was used for testing the prototype, and the following results were obtained;

Amount of input = 3.4kg, Amount of flour = 3.1kg, Time taken = 60s

Milling efficiency = (3.1/3.4) x 100% = 91.2%

Through put capacity = (3.1/1) x 60 = 186kg/hr.

Daily earning in 6hrs estimating milling to be Ugx 200 per kg, = 200 x186 x 6 = Ugx 223,200

Daily profits (after excluding energy costs) = 223,200 – 33,240 = Ugx 189,960.

The above figures are suitable for investment for a small scale miller. Since some other costs such as overheads are not high for instance cost of maintenance and operator's wage, the above profit level is deemed worthy to be undertaken

4.2.3 Noise level measurement

When the machine was turned on for milling, a digitalized sound meter was used to measure the noise level after 30 seconds of recording and the average noise level was found out to be 89dB which is within the range of 80-97dB recommended for safe milling operation as per table 1. At this noise level, the health of the operator is exposed to minimum risks that accrue due to long exposures to high noise levels.

4.3 ECONOMIC EVALUATION OF THE MACHINE

The Initial investment of the maize hammer mill is Ugx 5,000,000/=. This value includes the cost of the motor used to run the mill.

The assumption made is that the salvage value of the machine is Ugx 500,000 after 5 years, annual cash inflow is Ugx 36,000,000 and the interest rate is 15%.

Table 1.4 Results of the economic analysis of the constructed machine

Narratives	Year	Cash flows	15% rate	Present value of cash flows
			Discounting factor	
Initial investment	0	5,000,000	1.0000	5,000,000
Annual cash flows	1 – 5	36,000,000	3.3522	120,679,200
Total costs	1 -5	10,000,000	3.3522	33,522,000
Salvage value	5	500,000	0.4972	248,000
			NPV	81,909,200

Since the Net Present Value (NPV) is positive, the project is viable.

Therefore the profitability index of the machine was obtained as the ratio of the Net present value to initial cost of investment.

Profitability index; PI = 81,909,200/5,000,000 = 16.4.

Therefore, the return on every amount invested in the maize hammer mill is 16.4.

4.4 MAINTENANCE OF THE MACHINE

To keep the machine in a good working condition and eliminate frequent failures, the following measures should be undertaken.

i) Frequent inspection of the machine for leakages and spills during operation

ii) Frequent inspection of the belt alignment, belt tensioning, heating of bearings, bolted parts and excessive vibrations and fix any abnormalities.

iii) Daily inspection of the electrical connections and fitting of loose connections iv) Daily blowing of the motor to prevent clogging of the fins with dust flour and overheating

v) Lubricating of the bearings after a minimum of 7 days

vi) Quarterly replacement of the hammers by flipping to avoid excessive wear and tear vii) Replacement of bearings in-case of overheating

viii) Daily clean-up of the working area to prevent contamination of the product and operator safety

CHAPTER FIVE: RECOMMENDATIONS, CHALLENGES AND CONCLUSIONS

5.1 RECOMMENDATIONS

The following recommendations are considered pertinent for improvement of the maize hammer mill.

i) Use of stainless steel for hammers and hammer assembly for high quality and safe product ii) Use of a larger driver to driven pulley ratio for instance 4 : 1 for maximum speed of rotor iii) Use of material thickness of above 5mm for the milling camber top cover to damp as much noise due to beatings as possible.

iv) Smaller conclave clearance for instance 3-4mm

v) Use of vibration dampers such as mattress onto which the machine can be mounted during installation

vi) Given the level of performance achieved, it is recommended that, this maize hammer mill should be manufactured and popularized for adoption for small scale millers in Uganda.

5.2 CHALLENGES

Whilst implementing the project, the following challenges came along our way;

i) Limited time devoted for adequate research and literature review as this study was done alongside other academic schedules.

ii) Insufficient financial resources for purchasing high quality materials such as capacitor bank, stainless steel and energy efficient motor which could produce better results.

iii) Limited access to existing machines with similar parameters and design specifications which could be used for carrying out comparisons in terms of energy usage, noise levels and milling efficiencies. This necessitated us to have produced two prototypes for better comparisons but it was impossible as resources were only limited to one machine. iv) Some relevant components could not be sourced locally for instance power factor correction static capacitors and energy efficient synchronous motors.

5.3 CONCLUSION

The results obtained from the design and performance evaluation showed that, the maize hammer mill was designed, fabricated, tested and found to have a flour throughput capacity of 186□□□□/h□□, a milling efficiency of 91.2% and operating at a speed of 2388rpm. From the results, the following conclusions were made:

i) The milling efficiency was influenced by the rotational speed of the hammers, the mill clearance and the moisture content of the maize grits.

ii) There was no damage by the hammers (beaters) to the sieving component at a speed of 2388rpm.

Since the efficiency of the mill was increased from 60% for local maize hammer mills (Ali Twaha observers 19 October 2015), there is reduction in power consumption due to reduction in down time and an increase in maize flour production

Thus, with the design, construction and performance evaluation as seen above, the aims and objectives undertaken in this project were achieved. The use of the maize hammer mill will help reduce power consumption leading to increase in profits to the maize millers.

CHAPTER SIX: INDIVIDUAL CONTRIBUTIONS TO THE PROJECT

This section describes the individual contributions of all the seven members towards the successful completion of the project.

6.1 NUWAMANYA ANTONY BU/UG/2019/0126

Successfully served as the group leader and was able to accomplish the following towards the success of the project.

1) Design of the prototype using Solidworks software. This included establishment of desired design dimensions and specifications, material selection, software drawing and dimensioning, simulation of forces and failure analysis, printouts of the 2D and 3D designs for fabrication purposes.
2) Correction of identified errors and making necessary improvements during prototype iteration and optimization using Solidworks software.
3) Material property analysis and simulation at every stage of prototype development and construction.
4) Coordination of the group members with the group supervisor and making significant reports to the group supervisor as far as project progress was concerned.
5) Participated in machine testing and performance evaluation such as calculation testing of machine vibration and identification of leakages.
6) Participated in optimization of the design and fabrication process as well as final assembly of the prototype.

6.2 KARUNGI PENINAH BU/UG/2019/2310

Worked in the group as the prototype functionality analyst and performed the following roles;

1. Analysis of prototype consistency with the software design specifications, identification of any design inconsistencies and making the relevant adjustments during the fabrication stage.
2. Marking out the constructed drawings of the component parts especially milling chamber, feed chute and the cyclone.
3. Performed hammer assembly as well as rotor balance. This included; determination of appropriate hammer dimensions and arrangement, alignment of disc plates, spacers and hammers and calculation of the required hammer mass, disc plate diameter as well as fan size.
4. Also participated in the design of the safety parts of the machine such as motor starter box and the belt guard.
5. Participated in machine testing and performance evaluation such as calculation of milling efficiency and through put capacity.
6. Participated in optimization of the rotor balance process as well as final assembly of the prototype.

6.3 ALLELUIA DERRICK BU/UP/2019/1026

Actively worked as the main fabricator of the machine and accomplished the following tasks

1. Cutting of the marked component parts using an angle grinder as well as surface finishing of the sharp edges to eliminate possible injuries.
2. Welding of the individual parts using TIG welder, including all the parts that were fabricated locally other than purchased from the market.
3. Machining of some component parts such as key ways, disc plates and fan blades to achieve better surface finishing and accuracy.
4. Performed belt to pulley alignment as well as motor to mill alignment on the structural base. This was to ensure better power transference and efficiency.
5. Participated in machine testing and performance evaluation as the miller, introduced the maize grits into the machine while regulating feed rate and timing the milling process.
6. Participated in optimization of the design and fabrication process as well as final assembly of the prototype such as in fitting and fastening of component parts.

6.4 OFEZU SILIVERI BU/UG/2019/0032

Worked as the group secretary and performed the following duties towards the success of the project.

1. Review of literature about energy consumption and energy requirement of the existing hammer mills as well as noise level analysis of flour mills. Also carried out noise level and energy consumption tests of the nearby machines
2. Electrical component analysis and sizing for the particular machine. This included calculation of required power of the prototype, total energy consumption, power factor correction calculation, motor selection and motor starter wiring and starter component sizing.
3. Individual mechanical component analysis and calculation such as torque on shaft, centrifugal forces by hammers, air velocity and pressure exerted by fan, length of belt, pulley ratio and rotor speed calculation.
4. Report compilation and editing. This included gathering of literature on selected sections, data analysis and evaluation as well as typing and editing all the sections of the report.
5. Participated in machine testing and performance evaluation such as calculation of milling efficiency, energy consumption, and daily milling cost estimation as well as through put capacity calculation. Also recorded the sound level of the machine using a digitalized decibel analyzer called ‘decibelX’.
6. Participated in optimization of the design and fabrication process as well as final assembly of the prototype such as in alignment of component parts and fittings.

6.5 NABUKEERA ZAKIA BU/UG/2019/0123

Worked as the project marketing and publicity head, and performed the following duties which include;

1. Project feasibility testing as well as market condition analysis. Reviewed data concerning the viability of the milling business, maize flour consumption and potential market centres as described under chapter two of this report.
2. Reviewed literature on the cost of milling and the profitability of milling business. Studied data concerning the causes of high energy requirement of hammer mills, ways of minimizing energy costs of maize mills, as well as the existing technologies that have been developed to curb energy consumption by hammer mills so far in the country.
3. Determination of potential source of materials required for the construction of the prototype. Visited several marked centres and made various contacts with those who have access to such materials which helped the group purchase materials at fair prices.
4. Participated in component parts assembly after all the parts were fabricated and made ready for assembly of the prototype. This included spanner work such as bolting, fitting, alignment and balancing.
5. Worked in taking relevant records of every stage of project implementation such as design, measurements, fabrication, assembly and testing. This was in form of videos and photos.
6. Participated in painting of the prototype after final assembly.

6.6 RYABONYE RAMONA BU/UP/2019/1024

Worked as the group treasurer and performed the following roles that helped the group achieve its objectives.

1. Financial mobilization amongst the group members and safe storage of the groups' finances that were committed to the completion of the project.
2. Transparently allocated the agreed-upon amounts of money for the required purposes as far as project implementation was concerned such as purchase of materials, transportation of purchased items, communication, printing work as well as group welfare.
3. Participated in measurement, marking and spot welding of component parts for further welding and assembly especially the hammers, structural base and main shaft.
4. Participated in the motor starter wiring and motor terminal connection including fastening of wire connections using connectors as well as motor testing and mounting.
5. Participated in machine testing and performance evaluation such as calculation of milling efficiency and through put capacity.

6. Participated in optimization of the design and fabrication process as well as final assembly of the prototype by making adjustments in part sizes and dimensions.

6.7 KABAALE PATRICK JACKSON BU/UP/2017/163

Worked as the group accountant and was able to perform the following contributions towards the successful completion of the project.

1. Establishment of material prices and making comparisons between the different market prices from different market centres so as for identify potential fair suppliers.
2. Issuing of purchase orders and making follow-up on all materials paid for until deliveries were made.
3. Welding and cutting of component parts such as the suction pipe, fan and cyclone as well as assembly of the same parts at the assembly stage of the project prototype.
4. Cost analysis and evaluation of the maize mill. This included calculations of the net present value as well as the profitability index of the constructed machine.
5. Participated in the assembly and testing of the design prototype and advised on relevant adjustments that could be made to improve the performance of the prototype such as regulating of feed rate and belt tensioning.
6. Participated in optimization of the fabrication process by making significant part size adjustments and shape improvements as well as final assembly of the prototype.

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