DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF ELECTRIC MOTOR OPERATED ANIMAL FEED GRINDER

Desalegn Semani Mogessie

A Thesis Submitted to the Department of Mechanical System and Vehicle Engineering
School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

December, 2021

Adama, Ethiopia

DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF ELECTRIC MOTOR OPERATED ANIMAL FEED GRINDER

Desalegn Semani Mogessie

Advisor: Dr. Ing. Simie Tolla (Associate Prof.)

A Thesis Submitted to the Department of Mechanical Systems and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science in Agricultural machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

December, 2021

Adama, Ethiopia

DECLARATION

I hereby declare that this Master's Thesis entitled **" Design, Fabrication and Performance Evaluation of Electric Motor Operated Animal Feed Grinder"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Desalegni Semani Mogessie	______________________	_______________
Name of the Student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the thesis entitled **" Design, Fabrication and Performance Evaluation of Electric Motor Operated Animal Feed Grinder”** prepared under my guidance by **Desalegn Semani Mogessie** submitted in partial fulfillment of the requirements for the degree of Masters of Science in Agricultural Machinery engineering. Therefore, I recommend the submission of the thesis to the department following the applicable procedures.

Dr. Ing. Simie Tola	______________________	_______________
Advisor	Signature	Date

APPROVAL PAGE

I, the advisor of the thesis entitled **" Design, Fabrication and Performance Evaluation of Electric Motor Operated Animal Feed Grinder"** and developed by **Desalegn Semani Mogessie,** hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Ing. Simie Tola	____________________	______________
Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Desalegni Semani Mogessie have read and evaluated the thesis entitled "**Design, Fabrication and Performance Evaluation of Electric Motor Operated Animal Feed Grinder"** and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

____________________	____________________	____________________
Chairperson	Signature	Date
____________________	____________________	____________________
Internal Examiner	Signature	Date
____________________	____________________	____________________
Eternal Examiner	Signature	Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

____________________	____________________	____________________
Department Head	Signature	Date
____________________	____________________	____________________
School Dean	Signature	Date
____________________	____________________	____________________
Office of Postgraduate Studies, Dean	Signature	Date

ACKNOWLEDMENT

First and foremost, I want to express my heartfelt gratitude to the almighty God for his constant and costly assistance and for allowing me to complete my graduate studies successfully. I would like to convey my heartfelt thanks to my adviser, Dr. Ing. Simie Tolla, for his priceless counsel, consistent motivation, and direction during this study. I am grateful to all the Melkasa Agricultural Research Center (AIRIC) staffs for their positive co-operation and supports during fabrication. Special thanks shall also go to Mr. Dereje Alemu (Agricultural Engineering Research Process Representative) allow to me to work there and giving me valuable supports for the input of the research. My gratitude goes to my friends who helped me in one way or another during the study. I owe a great debt of gratitude to my parents, who worked tirelessly to ensure that I had access to school.

TABLE OF CONTENTS

CONTENTS **PAGE**

LIST OF TABLE

Table **Page**

LIST OF FIGURES

ACRONYMS AND ABBREVIATION

MARC	Melikasa Agricultural Research Center
AIRIC	Agricultural Implements Research and Improvement Center
RCBD	Randomized Complete Block Design
ASTM	American Society for Testing and Materials
CSA	Central Statistical Agency
GDP	Gross Domestic Product
TMR	Total Mixed Rations
DM	Dry Matter
Wb	Wet basis
Db	Dry basis
Qty	Quantity
MS	Mild Steel
RMC	Repair and Maintenance Cost
ETB	Ethiopian Birr
MC	Moisture content

ABSTRACT

In Ethiopia, different stakeholders emerge in the field of animal farming. Farmers and stakeholders who engaged in the field of animal fattening are facing feed shortages during the dry season because of an increment of agricultural production which increases cultivated area and decreases the grazing land. On the other hand, feed preparation is mainly performed through traditional systems like direct delivery of feed materials leads to mass feed loss. The objective of this study is to design, fabricate and evaluate the performance of an electric motor-operated feed grinder machine to solve the above problems. The machine has designed by considering design parameters, and also the machine was fabricated at the Mellkasa Agricultural Research Center workshop. The electrical motor, cutting blade, cylindrical hopper, housing and frame are the main components of the feed grinder machine. The overall dimensions of the prototype are 1060 mm in length, 700 mm in width and 1200 mm in height. CATIA V5 R20 design software and Microsoft Excel was used for modeling the machine components and for data analysis respectively. For the performance evaluation the feed rate, moisture contents, sieve diameter, blade type, length of the cut, grinding capacity and uniformity were considered as the test parameters. The experiment was performed in RCBD, with the sieve diameter and blade types as main blocks, the moisture content and feeding as sub-block with three replications. The treatments were 10 mm and 12 mm sieve diameter by considering different levels of feed (2.5kg, 5kg and 7.5kg) and moisture content (13.22% and 24.63 % wet basis). The experiment result indicates that the minimum and maximum capacity of the grinder machine was 76kg/hr. and 289.6kg/hr. at 10mm sieve diameter, 25% MC with a local blade, 7.5kg feed and at 12mm sieve diameter, 13.22% MC with a standard blade, 2.5kg feed respectively. The 12 mm sieve diameter has a better performance on output capacity for standard blade and locally fabricated blade, and also, in both types of blades, when the moisture content increases the output capacity and the length of cut decrease. Furthermore, it was observed that as the feed increases the output capacity decreases, this happens due to the maximum hopper filling level and this leads to the limited blowing air in the grinding housing. Finally, the machine has a capacity that suits its purpose; however, by adding sieve hole diameter, inclination angle of the outlet and rpm of the motor to the machine, it is possible to increase its performance.

Key words: Design, Fabrication, Grinding, Capacity, Animal feed, Performance

CHAPTER ONE

1. INTRODUCTION

1.1. Background and Justification

Ethiopia is endowed with abundant livestock resources. Clearly, the country has a large livestock population in Africa, ranking fifth in the globe. Despite receiving scarce public spending over the years, the livestock sector remains one of the country's huge amounts of foreign export revenues and accounts for nearly 40% of agricultural Gross domestic product (GDP) (Tegegne and Feye, 2020).

According to the CSA and the World Bank, (2011-12), the livestock population survey showed that Ethiopia has about 52.13 million heads of cattle, 24.2 million sheep, and 22.61 million goats, 1.96 million horses, 6.4 million donkeys, 0.37 million mules, 0.99 million camels and 44.89 million poultry in all the regions of the country excluding the none sedentary population of three zones of Afar and six zones of Somali regions. The animals feed requirement per annum is 95.83 million tons dry matter but the available feed is 65.64 million tones dry matter per annum. The difference between the supply and demand shows 30.2 million tones dry matter shortage per annum. However, wise use of those resources and advanced animal feed preparation technology can minimize the gap.

Boldyreva, (2014), states that people all over the world, are attracted to increase the production of beef, meat, and milk products. Now a day in Ethiopia also, different stakeholders are emerged on the field of poultry production, animal fattening and dairy farming. However, Feed shortage has remained to be the most limiting factor in livestock production in Ethiopia (Gizaw et al. 1017). The demand for animal feeds is derived from the demand of animal products as human food. Though, feeding animals with natural grazing is a great problem because of the decrease of graze land. To meet the above demand farmers and stakeholders are using agricultural by products and commercially available processed animal feeds.

According to Jenny Gustavsson, (2013), agricultural by-products, like straws are available wherever cereal or legume grain production occurs. Cereal straw production is slightly higher than the corresponding grain production, it can be estimated that 2 to 3 billion tons of straw were produced in the world in 2007. In Ethiopia, the most widely used animal feed is crop residues such as teff straw, wheat straw barley straw, sorghum, legumes and conserved forage. Crop residues, particularly cereal residues are the major livestock feed mainly in the dry seasons of the year, providing 40-50% of the total annual livestock feed consumption (Malede and Mastewal, 2012).

According to Chander, (2010), straws can be treated by grinding, soaking, boiling and fermenting. Grinding (also called chaffing or chopping) is the preferable method. Also, he stated that, in India, chopping straws and stovers reduced fodder wastage by 30% as animals could not select between leafy parts and dry stems. Grinding animal feeds are also used to provide the feeds for other treatment, to reduce sort in mixed ration and to improve storability of the feeds.

In Ethiopia, the grinding operation is done by human, animal and mechanical machines. The manual practice is done by holding a bunch of straws in one hand and cutting it by sickle. Grinding straws by animals is done in the same way as that of threshing teff, wheat, and barley cereals. The traditional method (human and animal) of grinding the animal feeds requires high energy and they are wasteful, time-consuming and risky operations.

The animal feed grinding machines are mechanical devices that are used to cut the straws into small pieces, so as to mix them together with other forage grass and feed them to animals. This improves the animal's digestion and prevents animals from rejecting any part of their food. Furthermore, developing an animal feed grinding machine, which increases the palatability of the product which leads to a decrease in animal feed losses.

The science community conducts researches in the designing and developing of agricultural by-product grinding machines. However, particularly machines that grind straws are not promoted well, and also according to cost, easiness, efficiency and safety, most of them are not preferred by Ethiopian farmers and stakeholders. Therefore, it is important to improve and introduce animal feed grinding machines for the purpose of reducing human effort, feed wastes and increasing animal feed quality by blending the cut straws with locally available ingredients. Therefore, a motor-operated animal feed grinding machine was designed and fabricated to bridge the existing technology gaps in the area of animal feed preparation.

1.2. Statement of the Problem

Nowadays, animal feed preparation becomes a great problem because of an increment of agricultural production which increases cultivated area and decreases the grazing land. In Ethiopia, widely available animal feed is crop residues in the dry season but these feed resources are directly delivered for animals without physical treatment. The most common physical treatment of postharvest animal feed grinding practice is manual chopping which is most local farmers are using. Unfortunately, the traditional method of grinding the animal feeds leads to uncountable feed loss and also, they are tedious, laborious, time-consuming, dangerous to operator, and lack uniformity.

In recent years, different stakeholders are strongly participating in livestock production because of its high profitability. However, farmers and stakeholders who are engaged in the field of livestock production are facing feed shortages during the dry season. Due to this reason developing a compound animal feed in Ethiopia becomes a promising opportunity. Therefore, to provide the raw material for feed processing at the required length and size, the feed grinding machine is required. Therefore, this study has initiated to design and fabricate a motor-operated animal feed grinding machine to reduce the challenges are listed above, since it requires less time and labor.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study is to design, fabricate and evaluate the performance of electric motor operated animal feed grinder.

1.3.2. Specific objectives

- To design the feed grinder machine and its components.
- To fabricate the feed grinder machine and its components
- To evaluate the cost of the feed grinder machine
- To assemble the fabricated feed grinder machine components
- To evaluate the performance of feed grinder machine.

1.4. Significance of the Study

Feeding animals with natural grazing is great problem because of the decrease of graze land. Animals cover large areas for finding and searching for foods in dry season and have not accessed to get enough food. While in wet season the area is limited for animals for searching of food. Due to this reason farmers and stakeholders are using manual grinding and chopping of the feeds. The importance of fabricating feed grinding machine is to increase the quality of animal production through promoting mixing ration. It is economically beneficial for small land holders and for those stakeholder's participating in animal feed producer as well as animal fatteners. This study is contributed important role for feed management by reducing feed waste.

1.5. Scope of the Study

Based on the intended design objectives, the coverage of this study is to study the physical property of the feed materials, design simulations of machine, fabrication and performance evaluation of the animal feed grinder machine. This study is limited to design a machine for the purpose of grind dry hay family such as cereal straws like wheat, barely rice straw grinder. The parameters such as moisture content and bulky density are under consideration. And also includes all the processes needs to develop and fabricate the grinder machine at local work shop. This study also limited to considers animals only dairy cow, calf, sheep and goat as a boundary of studies.

1.6. Organization of the Study

The study structured in five chapters. The first chapter holds introduction to background and justification of the study, objectives of the study, problem statement and the boundary in which the study limited. Chapter two include the literature review which is related to feed grinding practice and developed machineries and their parameters including the gap found was reviewed. Chapter three presents materials and methods and the procedure adapted to allocate all the steps including the analysis of the data. Chapter four shows the result and discussion of the study. The last chapter comprises conclusion and recommendations of the study.

CHAPTER TWO

2. LITREATURE REVIEW

2.1. History of Grinding

The practice of grinding of animal food stuffs can be traced back in a long story. Grinding promotes an increase in intake and weight gain on all-roughage diets. The researcher also studied the effect of the roughage digestibility. Grinding reduces digestibility but it is the best supplementary food if it is properly managed while increasing the net energy value of the straw by allowing the animal to better utilize the nutrients that are digested. With poor quality roughages, this increase in net energy value may be more pronounced.

2.2. Particle Size Reduction

Particle size reduction increases the total surface area, pore size of the material and the number of contact points for inter-particle bonding in the compaction process (Moharrery, 2010). Appropriate range of straw size for animal feed is 2-5 cm (Heuzé, 2021). For determining particle size distribution of threshed wheat straws, two sieves with opening sizes of 2.5 and 4 cm were used. A successful chopping reduces the length of straw, avoiding long pieces of material fouling on cultivation and swing implement. He designed a local straw chopper and operated it at rotor speed of 2300 rpm under three different clearances of 12.5, 25 and 31 mm.

Crushing of crop residues is on the increase with the global quest for sourcing of renewable energy through pre-processing of bio-masses. Physical and mechanical properties of biomasses species and varieties are very important when considering the energy requirements for particle size reduction of agricultural residues. Of the various types of grinding equipment available, hammer mills are the best known equipment used for the shredding/grinding, in which the material fragment are subjected to complex forces and then the resulted particles are used in the following operations from the pellet obtaining technology. (Moiceanu et al. 2012).

2.3. Feed rate and Power Requirement

El-Khateeb et al. (2010) evaluated rice straw chopper, they found that, the increase of cutter head knives speed from 23.0 to 33.0 m/s tends to decrease the chopping length from 14.0 to 10.5 mm and increase energy required from 2.593 to 3.198 kW.h/Mg, chopping efficiency from 79.0 to 88.0% and increase the degree of destruction from 52.0 to 62.0%, respectively.

Acording to AL-Gezawea et al. (2016) by increasing drum speed from 560 to 1040 rpm, chopping efficiency values of wheat straw increased from 92.4 to 95.2, from 90.4 to 93.8 and from 94.7 to 96.8% at using knives, hammers and knives with hammers, respectively.

Mady et al. (2015) evaluated the performance of chopping machine during cutting some farm residues (rice straw and faba bean stalks) to minimize their size and volume. The results indicated that the highest machine productivity for rice straw and faba bean stalks of 0.144 and 0.120 Mg/h and the highest machine efficiency of 99.5 and 98.0% and the lowest energy requirements of 12.50 and 15.0 kW.h/Mg and the lowest operating cost of 21.22 and 25.46 LE./Mg for rice straw and faba bean stalks respectively,

Moiceanu et al. (2012) reported that, of the various types of grinding equipment available, hammer mills are the best known equipment used for the shredding/grinding, in which the material fragment are subjected to complex forces and then the resulted that increasing the speed of cutter head from 0.75 to 1.88 m/s tends to increase the chopping length by 24.1 % and 60.5 % for serrated and straight-edge shapes.

2.4. Crop Residues Collection and Storage Practices

According to the study in case of the experience of East Shoa Zone, Ethiopia done by Tesfaye, (2007) and all over Ethiopia assessment done by Gizaw et al. (2017) crop residues collection and storage practices were observed to depend on the mechanism of harvesting grain from the crops. With tef, wheat, barley and haricot bean, collection of grains from the crops necessarily demands the harvesting and transporting of the crops to homesteads where they are threshed and their grain and straws are separated. Finally the straws are stacked near homesteads and, in some cases, fenced with locally available wood as shown in Figure 2.1. It is supported by recent studies by Kassahun, (2016) in Horro and Gudru district Western Ethiopia, states that, Small seeded crops such as: teff, wheat and barley are transported to a threshing ground located in the homestead area where they are threshed to separate the grain from the straws. The straw is then stored in the form of a heap around the homestead Figure 2.1. The heap is commonly fenced with locally available materials especially with thorny branches of trees and shrubs for protection from free roaming animals. The storage of the straws could be under tree shed or in an open field.

In most tropical regions, the majority of bovine feeds available are the poor quality crop residues and agro-industrial products. Improper management of feed resources, especially those of the bulky and fibrous crop residue is a contributing factor to low productivity of ruminant livestock in the tropical regions. Crop residue management should include the use of processing technologies for the manufacture of balanced complete straw-based feed for ruminants (Walli et al. 2012).

Figure 2.1. Dry forage storage practices in Ethiopia

Source: Farmers' Feed Storage and Losses in Ethiopia (Bachewe et al. 2020).

2.5. Crop Residues Treatment and Preparation Practices

Crop residues and hays is usually prepared using a variety of traditional tools, such as scissors, knives, and axe or it may be by cutting by hands. Various earlier works mentioned in the preceding sections have depicted that some sort of processing or treatment of crop residues have positive effects on improving, to a variable degree, the intake and/or digestibility of crop residues and farmers process their stoves by means of chopping manually or threshing by animals (Gizaw et al. 2017**).** This idea is directly supported by the other authors Kassahun, (2016), processing and treatments of crop residues have positive effects on improving the intake and/or digestibility and availability of crop residues. Chopping, soaking and urea treatments were the known processing methods in the study areas. Soaking dry crop residues either with water and/or with dissolved salts and/or chemicals Figure 2.2 seems more popular and practiced by 70% of the respondents from the highland and 61.3% from the mid altitude areas (Kassahun, 2016).

Figure 2.2. Chemical treatment of chaffed crop residue

Source: African Farm Resource Centre, (2020)

2.6. Physical Properties of Wheat Straws

The physical properties of wheat straws obtained from three countries Egypt (Africa), Canada (North America) and Guyana (South America) were determined. These included moisture content, particle size distribution, bulk density and porosity. The moisture contents of wheat straws were in the range of 5.02-7.79%. The majorities (56.87-93.36%) of the wheat straw particles were less than 0.85 mm and the average particle sizes were in the range of 0.38-0.69 mm. The bulk density of shredded wheat straws was in the range of 97.52-177.23 kg m^{-3} while in a lose state the bulk density was vary from 21.2 – 40.7 kg m^{-3}. A negative linear relationship between the bulk density and the average particle size was observed. The porosity of the wheat straws was in the range of 46.39-84.24% (Yaning, 2012). Zhang et al. (2012) studied physical properties of agricultural crop residues. The moisture content determined was 7.79% and 6.58%, respectively. The average particle sizes for the wheat straw and rice straw were 0.42 and 0.40 mm respectively. The average bulk density was 160.7 166.29, kg/m^3 for the wheat straw and rice straw respectively. Chevanan et al. (2010), the angle of repose of wheat straw which is varies between 40.6º to 41.6º.

2.7. Mechanical Properties of Wheat Straws

Tensile strength was in the range 21.2 to 31.2MPa and shear strength in the range 4.91 to 7.26MPa. Young's modulus was between 4.76 and 6.58 GPa and the rigidity modulus in the range 267 to 547 MPa. Plant maturity had some significant effects on shear strength, which was highest for the first stage of maturity and for Young's modulus which increased with maturity, but had no effect on rigidity modulus (Wang, 2016). This study is supported by with the recent study done by Zhang, (2016), states that the tensile strength and impact strength decreased linearly with the increasing MWS load. The maximum values recorded for the tensile strength and the impact strength were 25.16 MPa and 3.47 kJ/m^2, respectively.

2.8. Previous Studies on Grinding Machine

Gudadhe, (2015), stated that Chaff Cutter Machine is hay or straw cutting machine which is used for uniform chopping of fodder for livestock to agro industries and also, Zakiuddin et al. (2010) stated that a chaff cutter is a mechanical device used to cut the straw or hay into small pieces so as to mix it together with other forage chaff and fed to horses and cattle. This improves the animal's digestion and prevents animals from rejecting any part of their food. According to AL-Gezawea et al. (2016), it can transform bales of fodder to easy image to feed the animal and reduce losses of bales strewn by using the developed bales chopper.

Astanakulov, (2020) study on preparation and distribution of forage by chopping. According to authors, researches were performed and size-mass indicators of the pressed coarse fodder were determined also technological scheme of the device which mixes coarse fodder with ground and concentrated forages was developed (Figure 2.3)

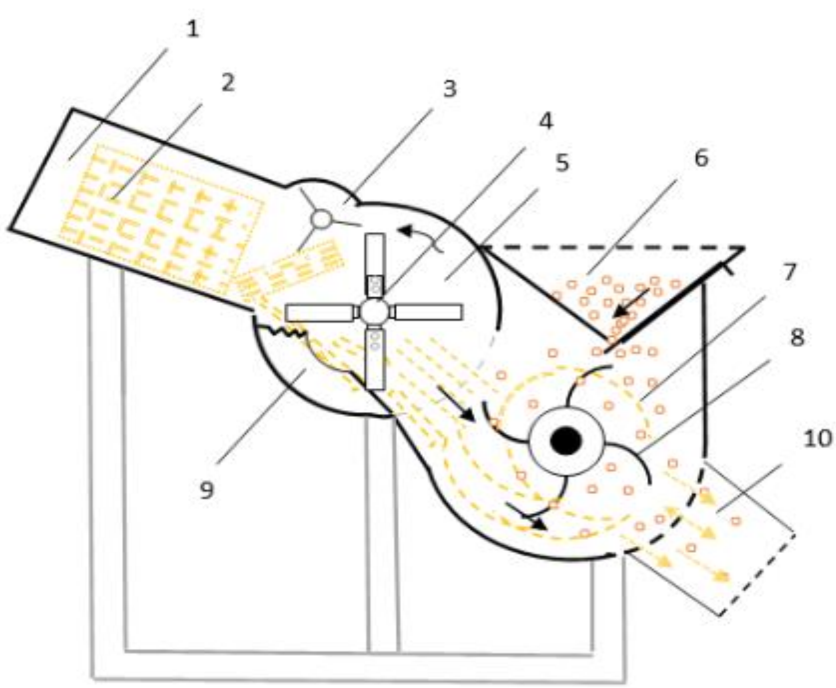


Figure 2.3. Technological scheme of bale grinder cum mixing machine

1. Hopper
2. Pressed straw
3. Transmitter
4. Chopping rotor
5. Chopping chamber
6. Feed bunker
7. Mixing chamber
8. Drum mixer
9. Opposite cutter
10. Exit rod

El-Haddad, (2010) developed the local stationary thresher for chopping and grinding of rice straw Figure 2.4 and maize stalks for pelleting process. The main idea was to check the effect of drum revolving speed, concave hole diameters on machine productivity, energy consumption and particle size distribution. The results revealed that mere slight modifications on the threshing drum and concave can certify the stationary threshing machine to be used in chopping and grinding operation. The optimum conditions were obtained at drum revolving speed of 1200 rpm and concave hole diameter of 3 mm.

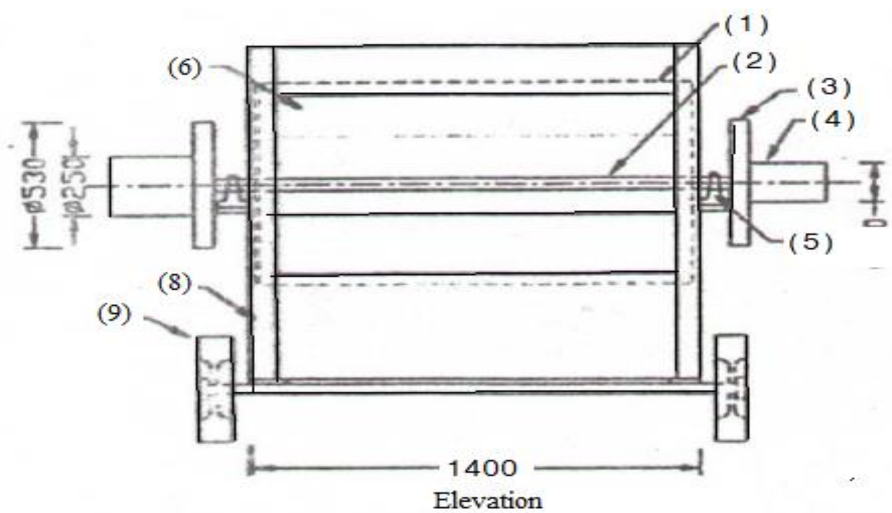


Figure 2.4. Stationary rice straw threshing machine

Source: Subdual of stationary thresher machine for chopping restudies. Arfa, (2007).

1. Feed opening
2. Shaft
3. Flywheel
4. Driving pulley
5. Bearing
6. Milling
7. Frame
8. G round wheel
9. Flange
10. Hammer

Jibrin et al. (2013) designed and developed crop residue crushing machine. They reported that crop residues majorly used for livestock feed during dry season and 58% of farm residue used for livestock feed during rainy season. During the drought time, leftover graze provides more than 90% of the feed for cattle feed. The supply of crop residues grinding machine was invented for animal feed and operated by diesel engine.

Basher et al. (2010) designed, developed and assessed a stalk chopper by using locally accessible materials and the chopper was developed for supply of fodder for animal farming business. It has a chopping capacity of 45. 69 kg/ h and chopping efficiency of 91 %.

Arshdeep et al. (2011) evaluated a straw chopper and cum spreader placed on a tractor to overcome the problem out left out straw after combine harvesting in the paddy field for paddy wheat rotation as shown in the Figure 2.5. They first chopped the paddy straw by using this machine and then incorporated in soil with minimum tillage efforts. They selected two levels of moisture content of paddy straw viz. 30 % & 40 % (wb). Three levels of chopping speed viz. 1300, 1450 & 1600 rpm and three levels of forward speed viz. 20, 25 & 30 km/h respectively. Effect of moisture content on chopping was found to be non-significant. Size of cut (up to 4 cm) of paddy straw increased with increase in chopper feed and decreased with increase in forward speed. Fuel consumption at lower moisture content was low. Fuel consumption (L/ h) increased with increase in chopping spend as well as with increase forward speed. Finally optimized the combination of chopping speed and a forward peed were 1450 rpm and 2.0 km/h.

Figure 2.5. Tractor operated straw leftover chopper and spreader machine

Zakiuddin et al. (2010) investigated the use of a pedal-operated flywheel motor as a fodder chopper's power source as shown in Figure 2.6. The authors came to the conclusion that pedal-operated flywheel motors are critical in developing nations experiencing energy crises. This machine is eco-friendly and helps to conserve energy. The authors get to the conclusion that non-conventional power should be used as a source for the fodder chopper machine. This machine employs both males and females who are unskilled. Human power is used to drive the flywheel. The fly wheel accelerates to 600 revolutions per minute. The authors presented a pedal-operated flywheel motor that included a flywheel, hay cutter, shaft, clutch, and gear. Its effectiveness is determined on manpower.

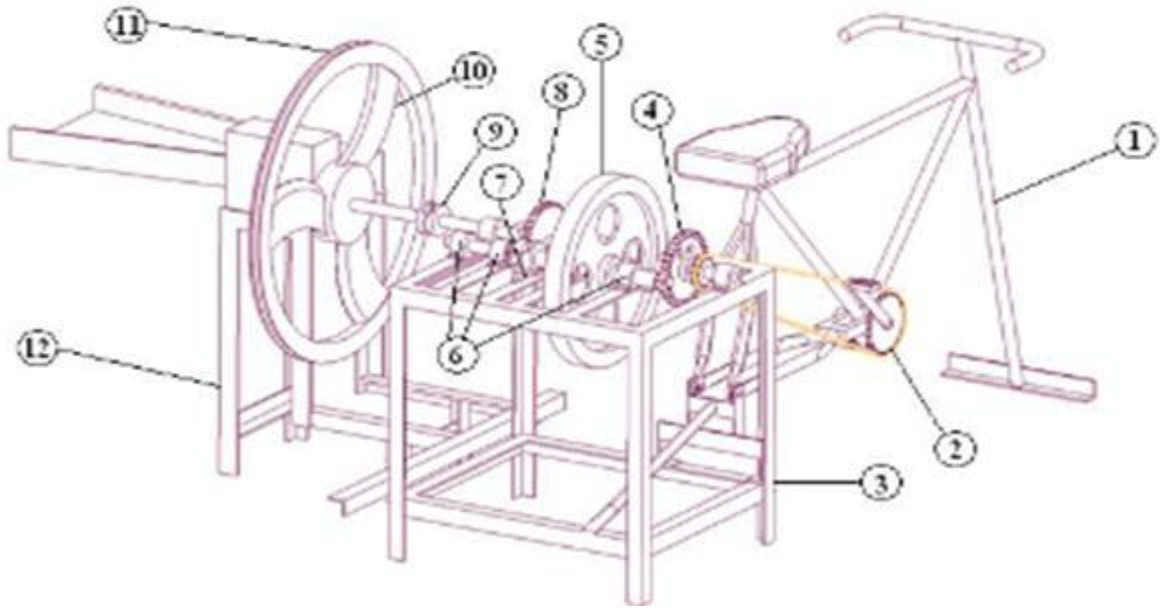


Figure 2.6. Pedal-operated fodder chopping machine

1. Cycle Stand
2. Sprocket
3. Frame
4. Speed Rising
5. Flywheel
6. Bearing
7. Clutch
8. Torque amplification gear pair,
9. Coupling
10. Cutter shaft
11. Cutter blade
12. Cutter Frame.

Bandiwadekar et al. (2016) reviewed on the design and development of chaff cutting machine and the safe design characteristics of chaff cutter machines. In the communities, fodder chopper machines are a major source of serious accidents both to adults and children's hands. There are two types of machine accidents. Adults sustain injuries from the feeding side, loose clothing, and hand contact with the blade while sharpening the blade. They also did a study on the evaluation of danger variables in the elimination of hay cutters. According to the researchers, traumatic grain grinder removals are severe and unusual damage. Patients of all socioeconomic groups are affected, and children are also affected by feed chopper removals. The majority of the time, this occurs when youngsters are left alone in their houses while their guardians are at work in the farmyard. A total of 73 patients were affected by the power operated machine in this study. There were 32 men and 41 women among them. It may be done with the adequate training of the cutter machine's working outline.

Bandiwadekar et al. (2016) investigated the design and development of a debris cutting machine. The authors propose a new cutting machine that is safer, requires less effort, and uses less electricity. The new machine is a kind of small scale equipment aimed for small scale agriculturists who need to feed their cows on a daily basis in a little to medium-sized space. The wear and tear on the sides is negligible as a result of the new cutting innovation, whereas a conventional machine requires frequent edge sharpening.

Thakur, (2019), is conducting a research on design of portable waste shredder machine for domestic compost Figure 2.7. Agriculture waste is fed vertically into the system via hopper directly to the cutters in this shredding machine. Cutters are mounted on a shaft that is supported by bearings that can be installed at the system frame. One shaft was pushed through the motor, while the other was pushed through the spur wheel, and each shaft was rotated in any way. The motor is rotated at a constant speed of 1440 rpm, and a gearbox is used to reduce the rate and enhance the torque.

The shearing movement takes place when crop waste comes into contact with revolving cutters or blades. The enormous length of trash is reduced to a small micro length as a result of this shearing movement. The micro length will degrade faster than the macro length. The clearance between revolving blades is determined by the size of the natural waste being chopped.

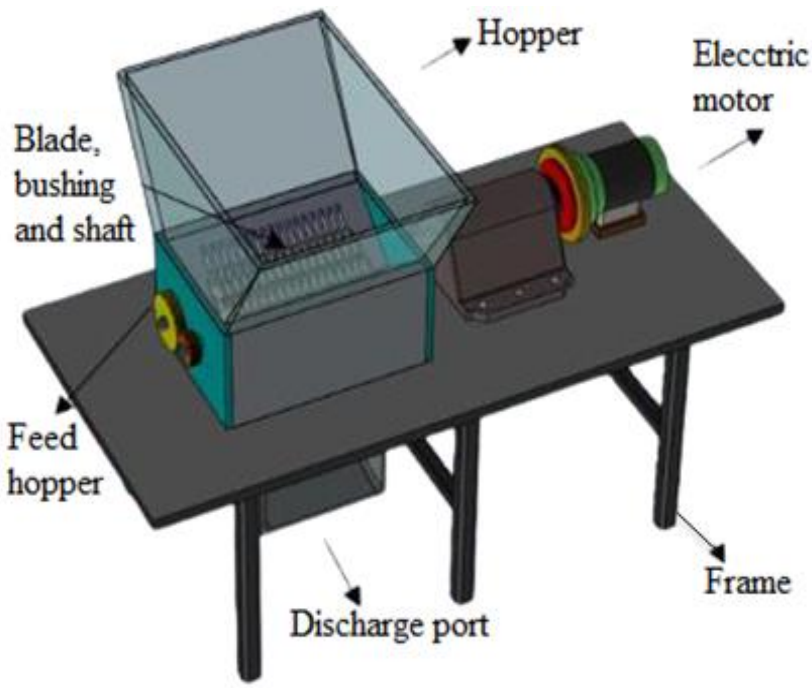


Figure 2.7. Agricultural waste shredder machine

Yousif, (2013), conducted a research on chaff cutter .The authors said that Chaff cutter is hay or straw cutting machine which is used in uniform chopping of the fodder for livestock or raw material to agro industries. The various types of fodder can be processed in this machine are forage grass, green grass, dry corn straw, and wheat stalk. The final products can be used to feed cattle, goats, deer, and horses. It can also process cotton stalk, bark, small branches; they can also be used to generate electricity, and to make paper. Chaff cutters have developed gradually from the basic machines into commercial standard machines that can be driven at various speeds so as to achieve various lengths of cuts of chaff with respect to animal preference type.

Engine driven and flywheel assisted machine was investigated by (Karunya et al., 2015). In order to feed the animals, many farmers grind the hay into fine particles with sharp knives or sickles, which might also increase the consumption and digestion ratio. Conventional feed chopper are not appropriate for quick and large-scale chopping, which is required by increasing animal farms. This were conducted at the College of Agriculture Engineering, Bapatla, to evaluate the performance of a engine power driven chaff cutter for para grass at three speed ranges which is 0.1, 0.12, and 0.14m/s with two straight edge and serrated edge types of blades at various moisture content levels (63.13 %, 56.25 %, and 51.3 %). The evaluation showed that the efficiency of the machine may be increased when the moisture content and cutting speed rise. The highest efficiency was 85.1% at 0.14 m/s with a highest moisture level of 63.13 %, while the lowest efficiency was 48.5 % at 0.1 m/s with a highest moisture content of 51.3 %. In this research serrated blades were more efficient than straight blades, with a 66.4 %. The Maximum and minimum capacity of the machine were 0.471 Mg/ h and 0.309 Mg/ h respectively. It was also discovered that the longest cut length corresponded to the lowest moisture level, and vice versa.

2.9. Literature Summary

Chaff Cutter Machine is hay or straw cutting machine which is used for uniform chopping of fodder for livestock to agro industries. A chaff cutter is a mechanical device used to cut the straw or hay into small pieces so as to mix it together with other forage chaff and fed to horses and cattle. Chaff cutters have advanced from simple devices to commercial standard machines that may be run at different speeds to generate different lengths of chaff cuts according on the animal preference type. These machines can transform bales of fodder into easy images to feed the animal and reduce losses of bales strewn by using the developed bales chopper.

The average length of cut of materials was 25mm but sometimes it varies up to 50mm this length makes it suitable for the preparation of dry season animal feeds with the chopped crop residues as major component and minerals, portents vitamins as a constituent.

Basher et al. (2010) designed, developed and assessed a stalk chopper by using locally accessible materials and the chopper was developed for supply of fodder for the animal farming business. Researches on a chaff cutter machine which is a hay or straw cutting equipment that is utilized in homogeneous shredding of hay for animals or raw materials are agricultural crop residue such as forage grass, green grass, dried wheat straw are among the fodders that may be processed by this equipment. Conventional feed chopper are not appropriate for quick and large-scale chopping, which is required by increasing animal farms.

2.10. Research Gaps on Previous Studies

The above researches have their own strength and limitations. Some of the literature has high capacity and efficiency, but they are costly and not preferred by small-scale farmers. Zakiuddin et al. (2010) machines are more complicated in the concerns of design and also their machines are not properly designed through considering the safety matter. Therefore, a low-cost and the simple motor-operated grinding machine was designed along with its protection and safety provision to minimize the risk of injuries.

CHAPTER THREE

3. MATERIALS AND METHODS

The research provided here outlines for the approach taken in the design and fabrications of electric motor operated animal feed grinder, as well as the test procedures used to evaluate its performance of the machine. This chapter describes the materials utilized and the techniques employed in the development of an electric motor operated animal feed grinder.

3.1. Description of the Study Area

The research was conducted at Melkassa Agricultural Research Center (Figure 3.1). It is found around 117km South East of Addis Ababa along sodere road, and one of the emerging town of Oromia region. It is located at an altitude of 1466m above sea level and lies on the geographical coordinates of 8° 24' 0'' N, 39° 20' 0'' E Latitude and Longitude, respectively.

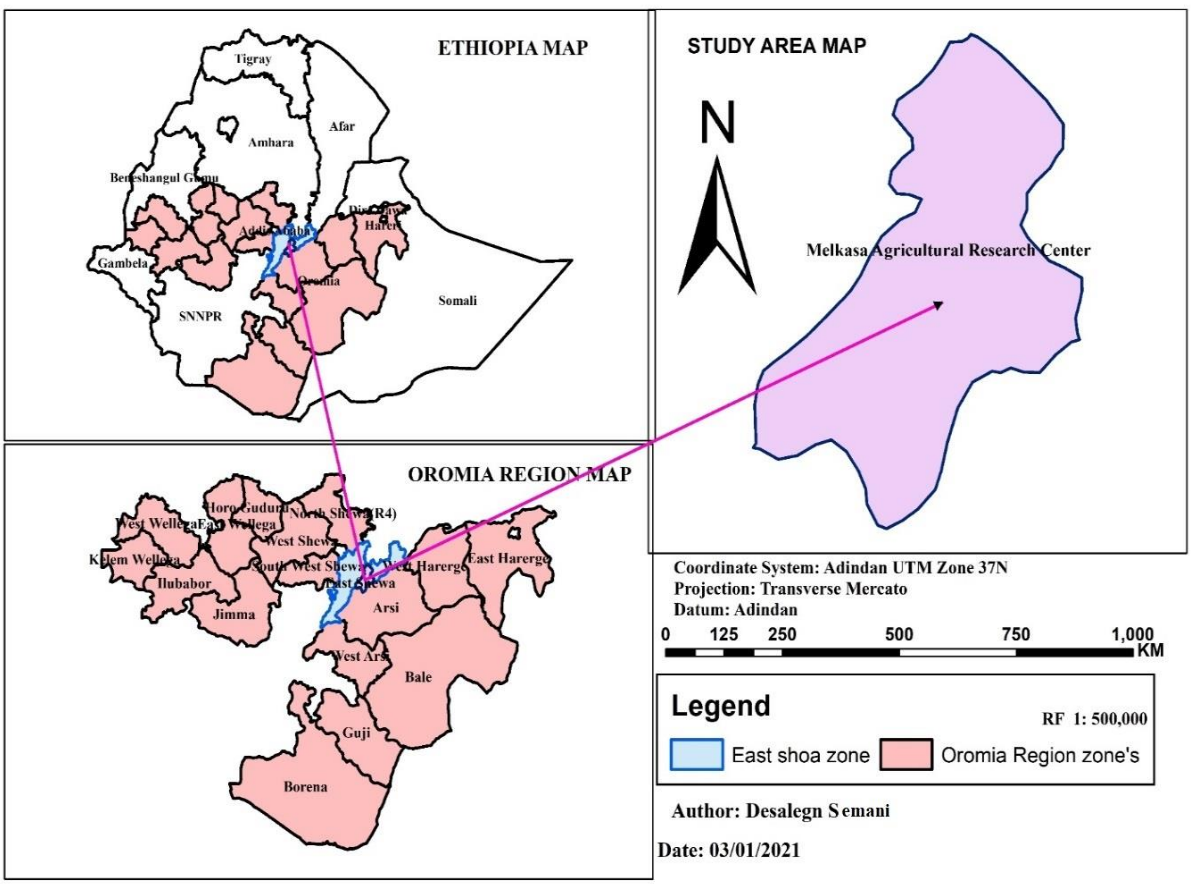


Figure 3.1. Map of the study area

3.2. Materials and Machines Used to the Study

The material selection for designed animal feed grinder machine parts were selected and bought from the market to fulfill the requirements. The materials were based on durability, strength, endurance, availability and cost. The materials used for the fabricating of the machine as shown in the Table 3.1 and Table 3.2.

3.2.1. Materials and work shop machine used to the study

Table 3.1. Material used for fabrications of grinding machine

No.	Materials list	Applications	Unit	Qty
1	Electrical motor	Used for a power source	Pcs	1
2	Sheet metal	Used to cover top part of the housing	Pcs	1
3	Sheet metal	It is used for the base of the housing	Pcs	1
4	Sheet metal	It is used for the side cover for housing	Pcs	1
5	Sheet metal	It is used for the hopper	Pcs	1
6	Angle iron	It is used for the frame	Pcs	1
7	Mild steel round	Used for joining the cutter disc with shaft	Pcs	1
8	Brass bushing	For friction reduction for smooth running	Pcs	1
9	Bolt and nut	M-12 x 50 joining housing with the frame	Pcs	12
10	Bolt and nut	M- 14 x 40 joining motor with the frame	Pcs	4
11	Bolt and nut	M- 6 x 20 joining blades with the cutter disk	Pcs	46
12	Electrodes	3.2mm for welding metals	Pack	2
13	Paint	For painting fabricated machine	liter	2

Table 3.2. Workshop machines used for the fabrication of prototype

No	Type of machine	Application
1	Welding machine	For joining parts
2	Grinder	To face the welding parts
3	Drilling machine	Making hole in different parts
4	Lathe machine	For general purpose
5	Hacksaw	For cutting parts
6	Bending machine	For twisting parts
7	Steel scale	Measurement of linear distance
8	Steel tape	Measurement of linear distance
9	Centre punch	Hole marking
10	Hammer	To form a part
11	Chisel	Cutting
12	Scissors	Cutting sheet metal
13	Wrench	Tightening nut and bolt
14	Screw driver	Tightening screw
15	Hand grinder	Grinding metal sheet
16	Flat file	Smooth rough edges
17	Weight balance	To weigh during test
18	Vernier caliper	To measure dimensions precisely
19	Oven dry	To dry the moisture of the straws
20	Vibrometer	To measure the vibrations behaviour
21	Stop watch	To record time taken during testing
22	Digital balance	To measure the weight of the sample

3.2.2. Working flow of the study

The design procedures for feed grinder machine were performed under the following flow chart in order to make clear and proper flow of the task. There were proper breaking down of a major one into a smaller one for management of the study. The workflows were clearly in the following chart Figure 3.2.

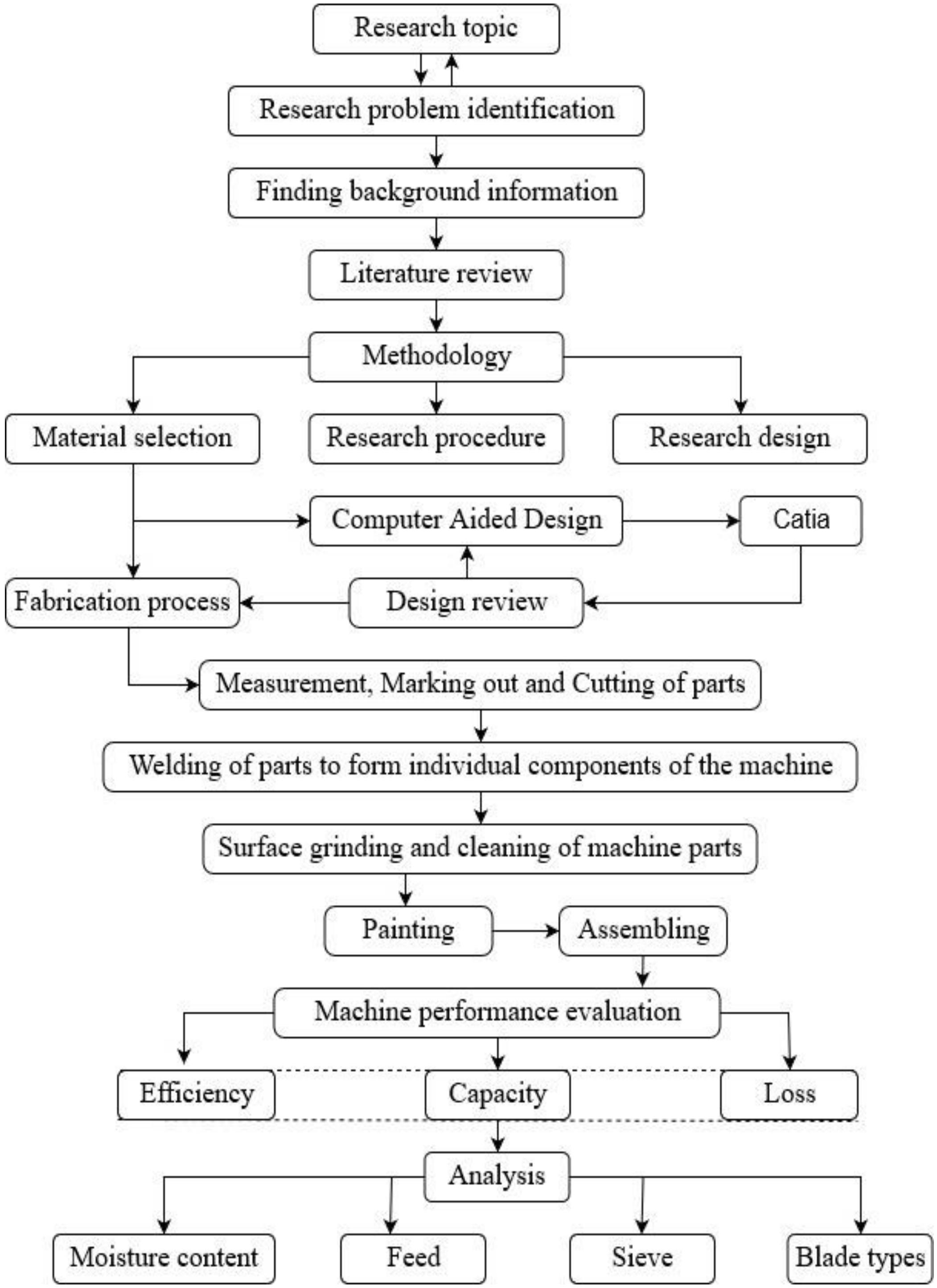


Figure 3.2. The study workflow chart

3.2.3. Instruments used for performance evaluation

Different parameters like weight, time required, moisture content, capacity and dimensions were measured while conducting the laboratory and field tests. The following instruments were used:

a) Stop watch

Stop watch having least count of 0.01 second was used for recording the time parameter during tests.

b) Vernier caliper and steel tape

This measuring instrument was used to measure the dimensions of the machine components and length of the cut.

c) Digital weighing balance

Digital weight balance was used to measure weight of straw to find moisture content and weight of cutter blade.

d) Oven dry

Oven (temperature 105 ^{0}C) was used for measuring the moisture content of the straw for 24 hours had recorded.

e) Vibrometer

Vibrometer was used for direct measure of the vibration behavior of a machine.

3.3. Design Considerations of Feed Grinder Machine

The animal feed grinding machine was designed based on the following design considerations.

- A physical and mechanical property of the straw was considered in the design of machine components.
- The machine size was given great attention for the workability and conformability for the operator under consideration.
- The availability of materials and compatibility to the respective work
- Cost of fabrication.
- Easiness to fabricate, repair and maintenance.
- Easy of assembling the machine components and flexibility for transportation was considered.
- Ergonomics aspects were considered

3.4. Description of the Feed Grinder Machine

The basic design of machine parts includes the functional simplicity and flexibility to use and changing the grinding blade and the sieves inside the housing. Radial shape housing was mounted on the frame and has rotor disk with multiple blades for the purpose of grinding wheat straw to an acceptable length suitable for animal feeding. The hopper was equipped and mounted on the feed grinder housing. For the purpose of size reduction different sieve diameter were used as accessories. Inside the housing there is a rotor equipped with serrated blades arranged for shearing of straws to the required length. The sieve is tightening with the help of bolt and nuts with hosing.

The major components of animal feed grinder machine have; the frame, hopper, housing, sieve, blades and electrical motor as shown in the Figure 3.3.

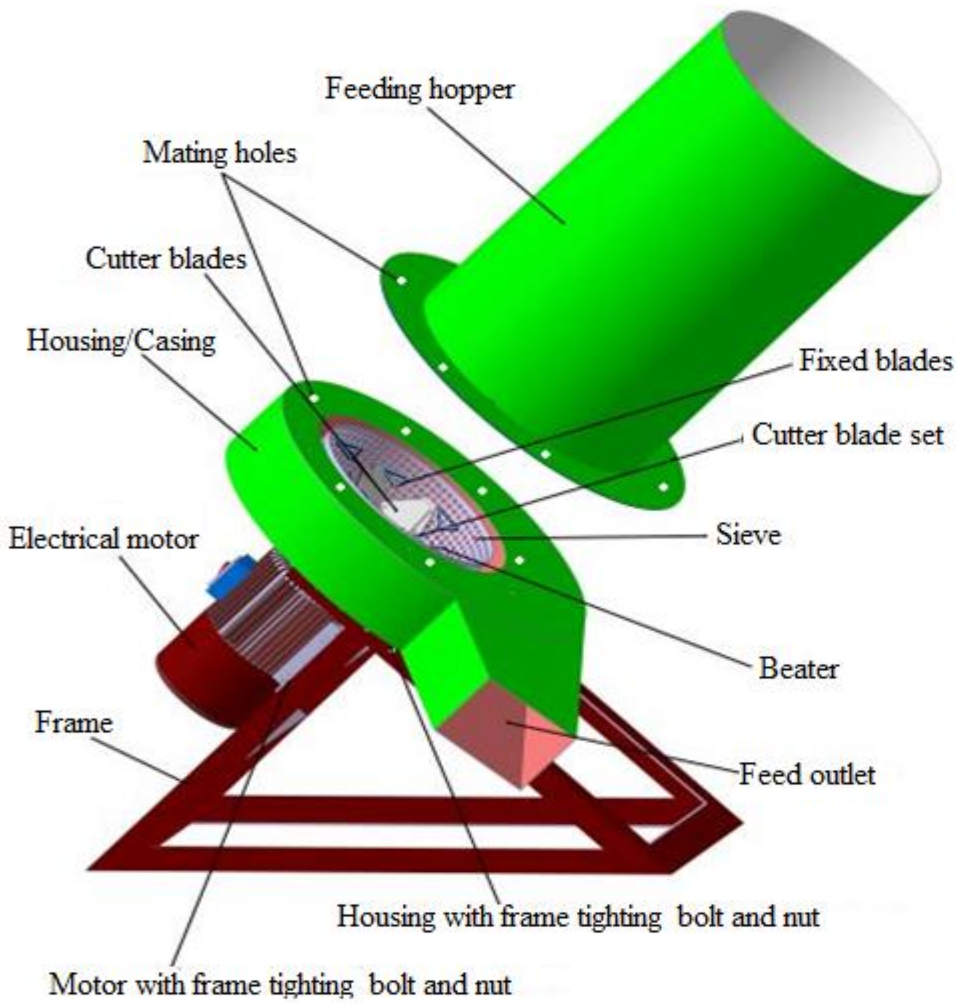


Figure 3.3. 3D view of grinder machine developed by CATIA V5 R20 software

3.5. Determination of the Power Required to Operate the Machine

Determinations of force, power, and torque of the grinder was the most critical part of the study; those are essential parameters which enable the rotational motion of the part of the machine, such as shaft and cutting blades.

3.5.1. Design of rotational blade

Based on Jibrin, (2013) the rotational knife design is calculated as follows:

$F_C = S_C \times A$ -- (3.1)

Where: F_C = Cutting Force.

S_C = Shear strength of the straw = 7.2 MPa (Wang, 2016).

A = Cross-sectional area of straw materials

$\mathrm{A} = \frac{\pi \mathrm{D}^2}{4}$ -- (3.2)

Where: D is the diameter of the straw.

The average diameter of the straw is 4.51 mm so, the cross sectional area is:-

$$\mathrm{A} = \frac{\pi \mathrm{D}^2}{4}$$

$$A = \frac{\pi 4.51^2}{4}$$

$$A = 15.96\ mm^2$$

Therefore force required to cut the straw is calculated by using equation 3.1:-

F_C = 7.2 MPa × 15.98 mm^2

F_C = 115 N

Calculated torque required to cut the straw

The torque was calculated by multiplying the force required to cut the straw and cutting blade radius. But the cutting blade radius is 0.21m.

Torque = 115N × 0.21m

Torque = 24 N-m

Power required is calculated by the following formula:-

Different scholars have recommended that the optimum speed of the motor is 1450 rpm (Basiouny, 2016) and (Arshdeep et al., 2011).

Power = Torque × Angular velocity

$$\text{Power} = 24\ \text{Nm} \times \frac{2 \times 3.14 \times 1450}{60} \text{ --3.3}$$

Power = 3642.4 Watt

Power = 3.64 KW

3.5.2. Design of grinder beater

To determine the capacity of the beater that push straw in mass can be determine by the expressions indicated as under (Ebunilo, 2010):

$$F_b = m \times g \text{ --3.4}$$

Where: m = mass of beater

g = gravitational acceleration

But the force is calculated based on the relation power and torque, which is the rotational power.

$$P = \frac{2\pi NT}{60} \text{ -- (3.5)}$$

$$3.6 = \frac{2\pi \text{ x } 1450T}{60},$$

T = 23.7N

Therefore from this result force is the product of torque and radius.

23.7 = F × 0.21, F = 23.7/0.21[1] = 112.8N

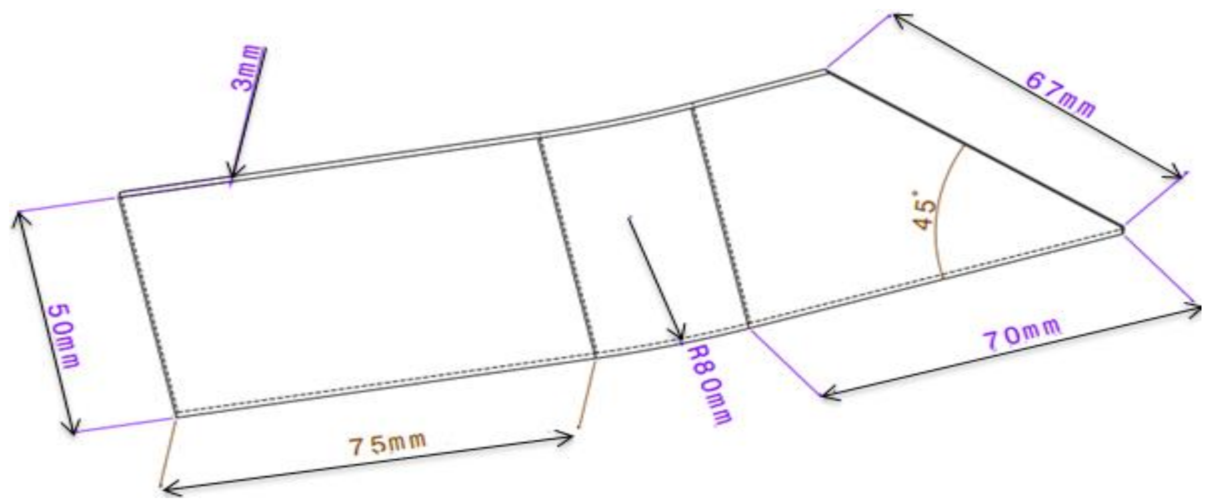


Figure 3.4. A 3D view of beater.

From equations 3.3 force of beater is the product of;

Mass of straw time's acceleration due to gravity

[1] The linear velocity of 1450 rpm is 31.87m/s^2 at 0.21m radius as recommended by Basuiony et al. (2015). Therefore the radius of the cutting unit is selected

Therefore, F_b = mg

Determining mass of beater with the relation, m = $\frac{Fb}{g}$ = 112.9/9.81 = 11.5kg

The mass of the material is 11.5 kg therefore the beater is able to push of the straw at a maximum of 11.5kg.

3.6. Design of the Machine Components

3.6.1. Frame

The frame (Figure 3.5) supports the entire weight of the grinding machine. The overall weights carried by the frame includes: the weight of the motor, the weight of housing, weight of the grinding unit and weight of the hopper. The major supporting structure was the basement with a triangular-shape; its dimensional values are shown in Figure 3.5 and Figure 3.6. This frame is made up of angle iron. This was done to give it more stability and make it more portable. Weight and strength were the two design variables used to determine the material needed for the frame.

On the right side of the mainframe, the grinding and housing unit was installed which contains grinding mechanisms with nut and bolts and on the left side of the main frame three phase electrical motor was installed for the purpose transmitting power to the grinder mechanism with the help of bolt and nuts. The height of the foundation frame maintained in such a way that, it should ergonomically suit to facilitate easy feeding of fodder into the hopper.

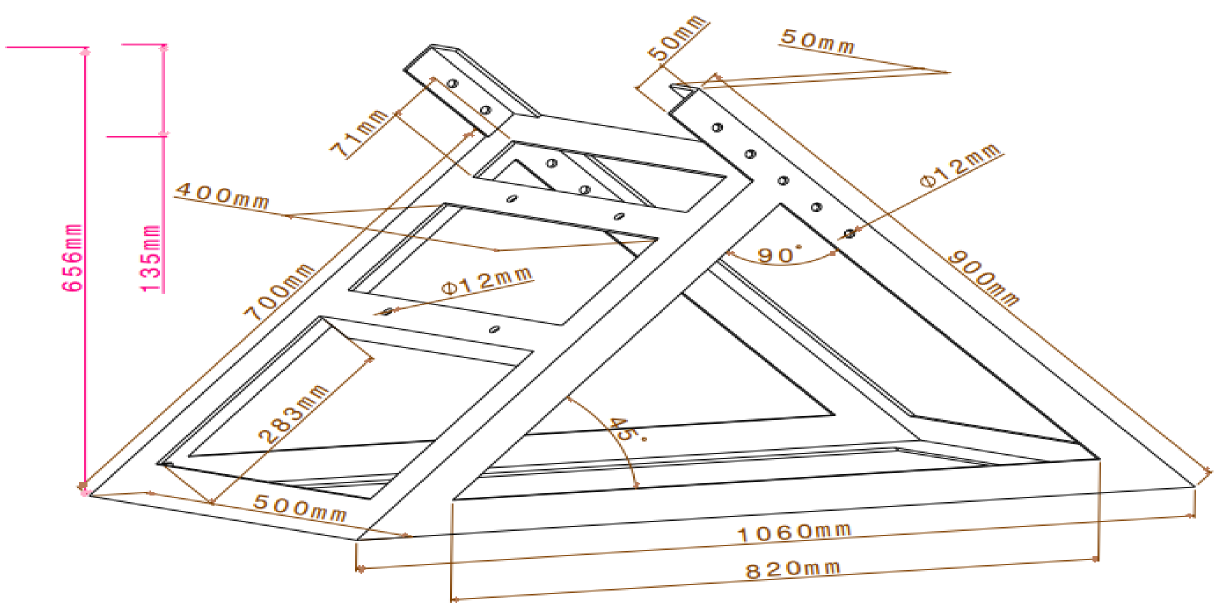


Figure 3.5. The 3D view of the frame

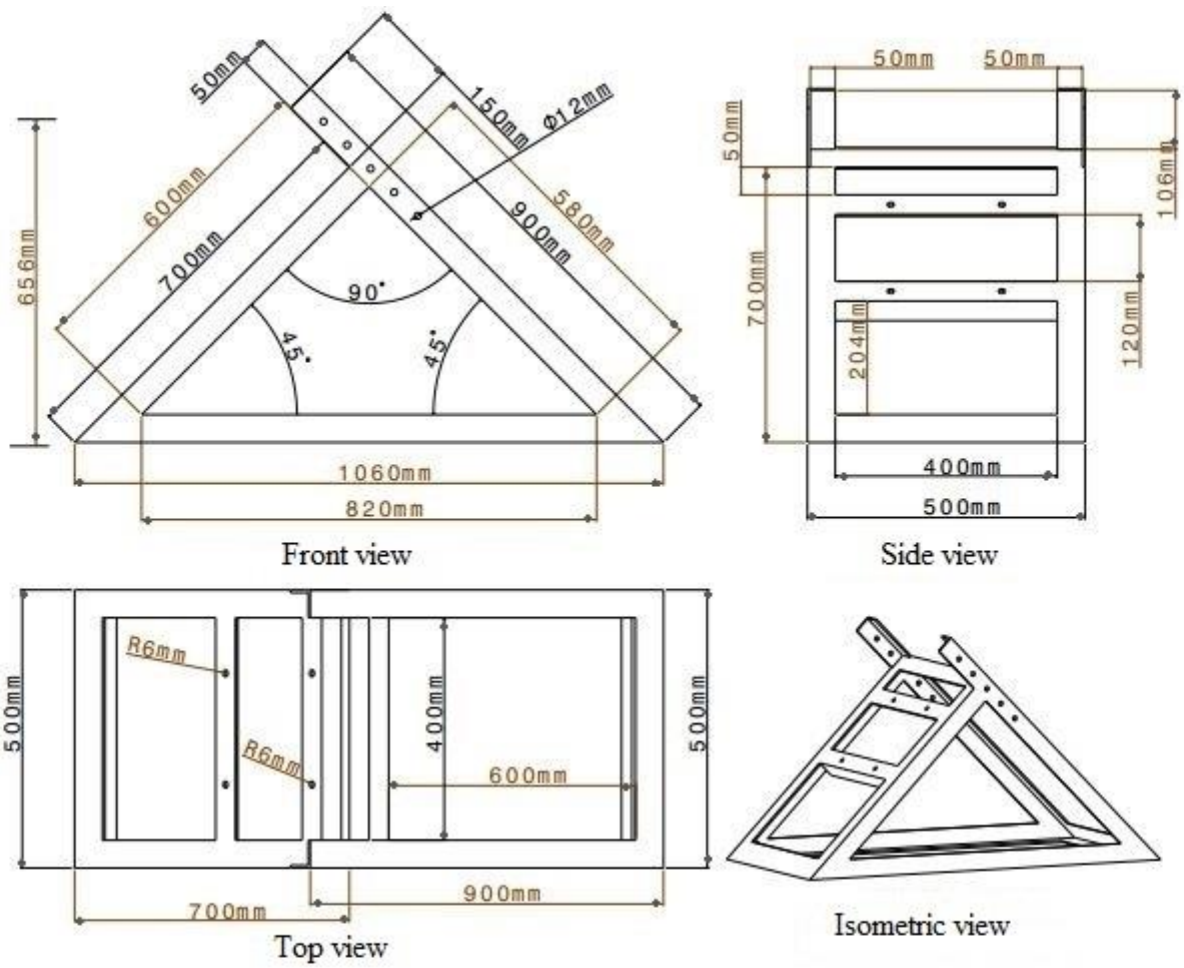


Figure 3.6. Detail view of the frame design

3.6.2. Housing

Housing covers the cutting blade and also used for impacting action for the purpose of grinding the feed which is taking place within the housing and also it is used for safety of the worker during operation. The housing was installed at 45º frame for better fluidity of the straw according to the author Chevanan et al. (2010), angle of repose of chaffed straw was lied between 40.6º to 41.6º.

The housing unit of feed grinder was made up of mild steel sheet metal which is containing four main components. These four main components are base plate, side cover, top cover and outlet that were mounted on main frame.

The height of the housing was decided depends on the maximum possible inclination angle of the blade and the height bushing in which the cutter plate was attached. The length of the blades was 80 mm as shown in the Figure 3.7.

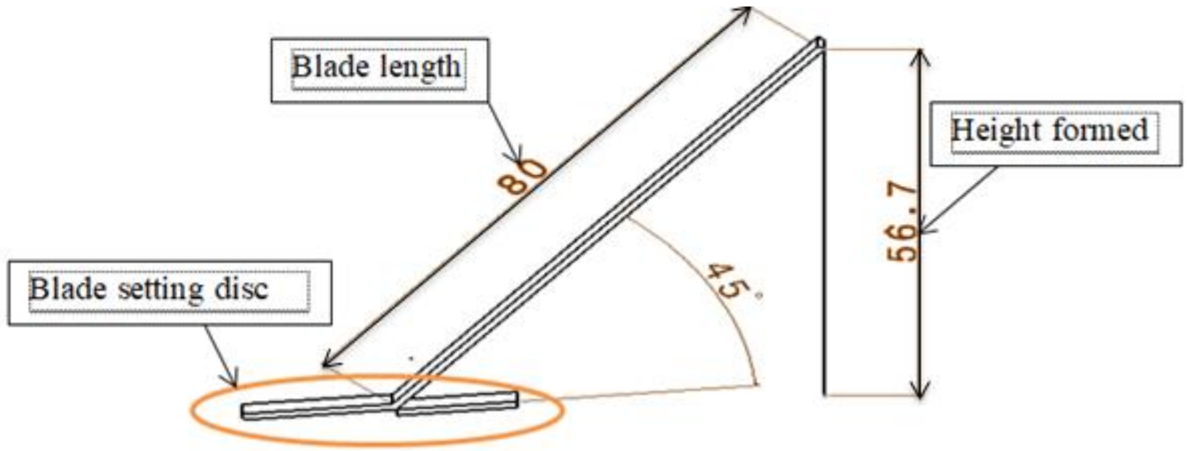


Figure 3.7. Maximum inclination of the blade

The height formed between the base plate and the cutter bladed disc was 60 mm. The height due to the blade from the cutter plate adjustment was 56.7 mm. The overall height with consideration of safety is 150 mm Figure 3.8.

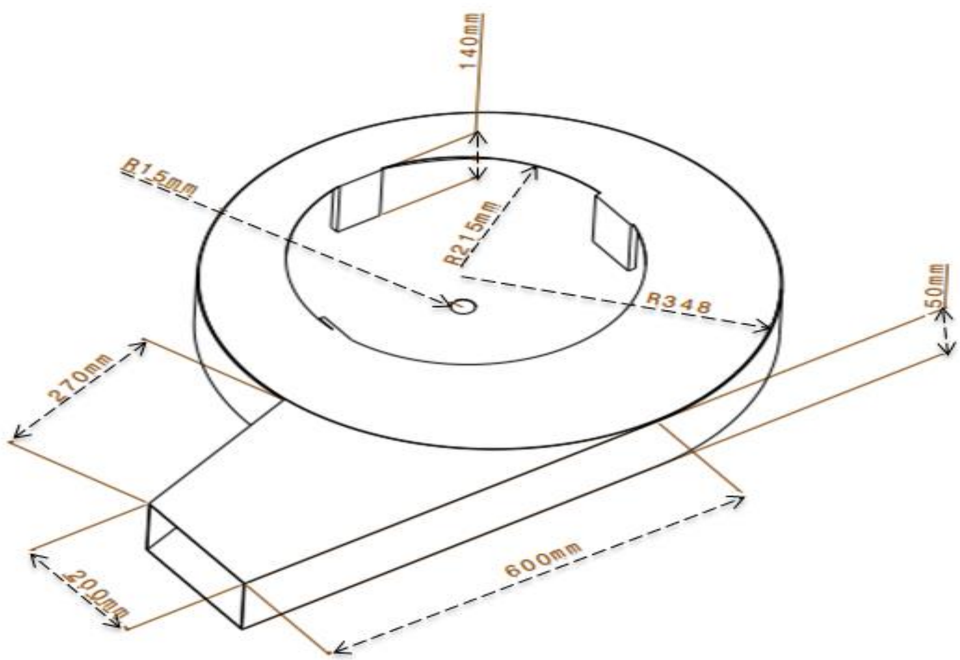


Figure 3.8. Detail view of the housing of the grinder machine

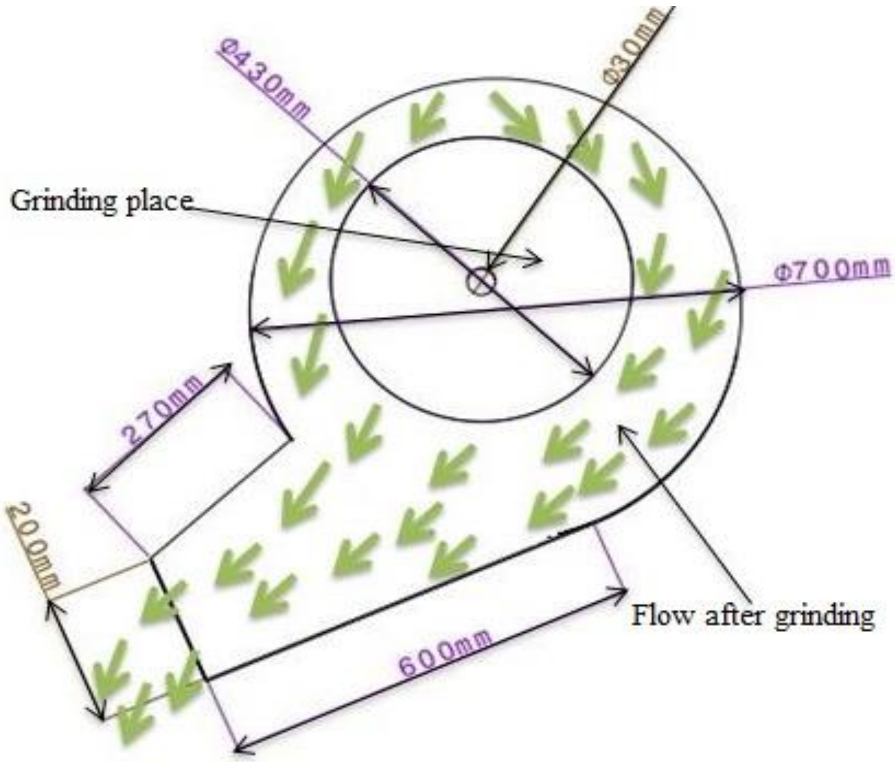


Figure 3.9. Grinding chamber and flow direction after grinding

3.6.3. Feeding hopper

The cylindrical hopper was made up of 1 mm thickness of sheet metal. The hoppers were fixed on the top part of housing unit with the help of bolted joints and it has adequate volume and inclination. The continuous feeding system is applied through manual feeding. The fodder was applied through the hopper to the grinder housing.

In order to determine the volume of the hopper assumptions were made for the maximum capacity of the hopper and the height of the hopper based on the safety and ease of the machine to operate.

Assume the hopper can hold 5 kg of straws at once and the height of the cylinder is 600 mm. therefore the volume of the cylinder calculated by the relation between the mass and the bulk density.

$$V = \frac{M}{\rho} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.6)$$

Where: V = Volume of the hopper, (m^3)

M = Mass of the straw, (kg)

ρ = Bulk density of the straw, (kg/m^3) = 30kg/m^3 at lose state (Yaning, 2012).

$$V = \frac{(5kg)}{(30\ \text{kg}/m^3)}$$

V = 0.167m^3

The casing diameter is calculated by assuming the height of the hopper to be 800mm. Therefore volume is the product of area of the hopper and its height.

$$V = \frac{(A = \pi D^2)}{(4)} \times \text{height}$$

$$D^2 = \frac{(4\ x 0.167 m^3)}{(\pi) \times 0.6\text{m}} = 0.266$$

D = 0.59m ~ 0.6 m of casing diameter.

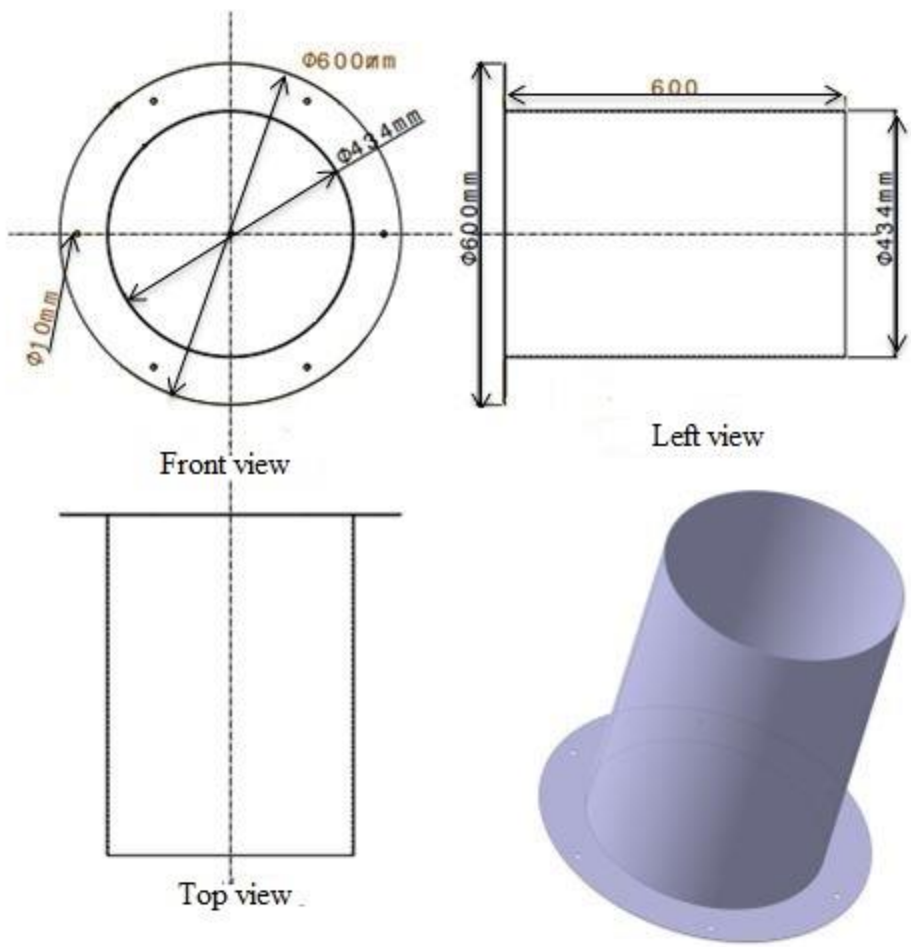


Figure 3.10. Detail view of feeding hopper

3.6.4. Grinding unit of the machine

The feed grinder machine cutting mechanism consists of a cutting and grinding unit with serrated blades. Mild steel flat disc was used in the cutting unit. When the fodder material comes into contact with the fixed and rotating blades, the blades shear and cut the fodder into the required size (until it pass through the sieve) and the fodder then moves through the casing to the discharge unit.

The cutting rotor has an overall diameter of 420 mm and its thickness is 5 mm was used. A cutting rotor disc consists of 14, V-shaped blades and 6 fixed V shaped blades on the periphery of the disc and on the periphery of the sieve respectively. Eight fan blades were welded under the bottom of rotor disk in order to blow the grinded straws. This rotor grinds cereal straws Figure 3.11. and Figure 3.12.

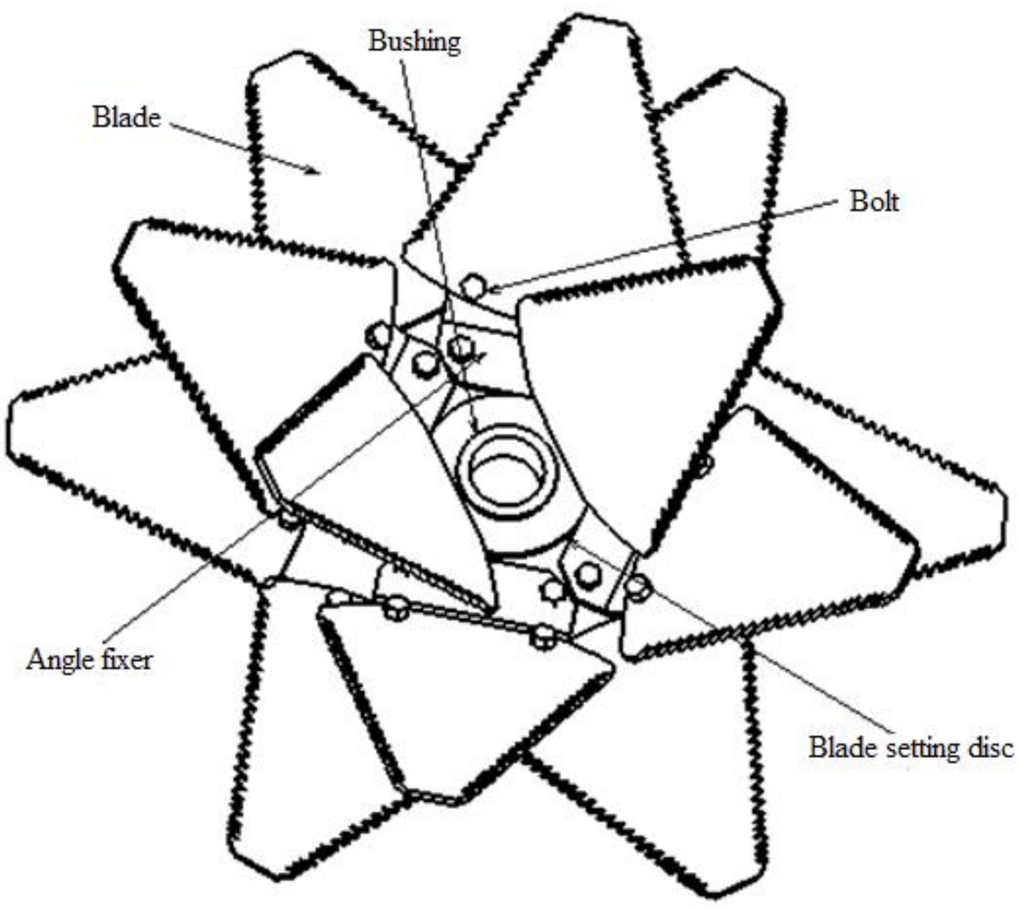


Figure 3.11. 3D view of cutter disk with the blade

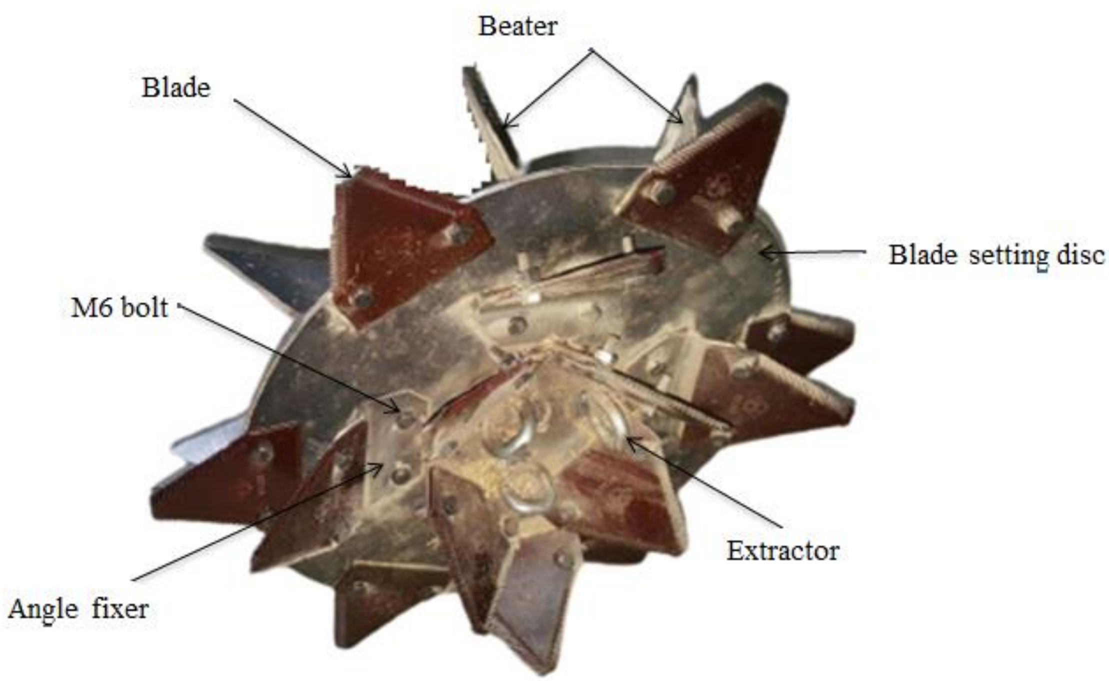


Figure 3.12. Fabricated cutter disc with the blades

An angle fixer is a simple device used to connect the blade with the cutter blade setting disc. Hence the blade has become wear after many operations; therefore in order to replace the old blade with the new one easily Figure 3.13. There is a need of this angle fixer. All the dimension of the angle fixer is in mm.

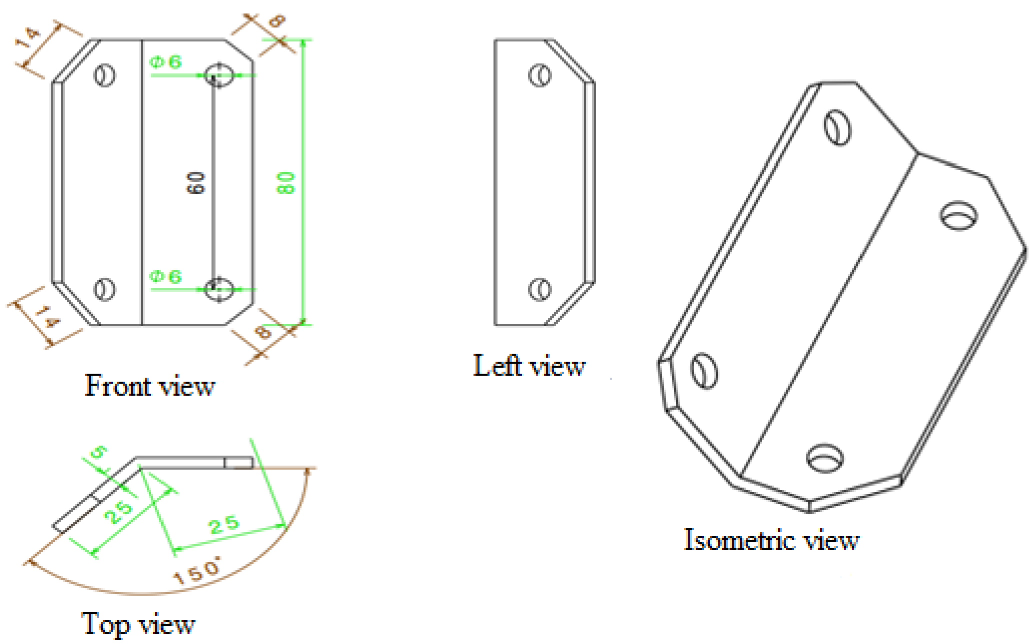


Figure 3.13. Detail view of angle fixer.

3.6.5. Discharge unit

The discharge unit of trapezoidal shape were mounted to the left side of the main housing of side cover and welded to it. The part view of the hopper outlet is shown below. The dimensional values were shown in the Figure 3.8 and Figure 3.9.

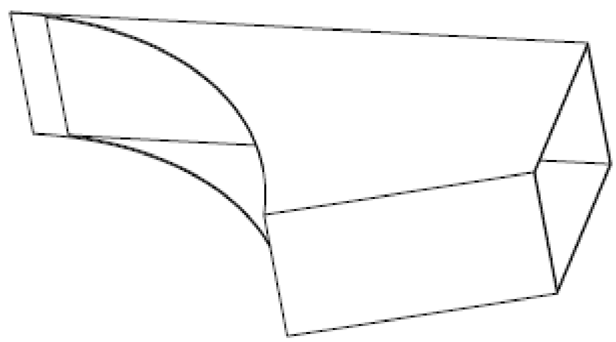


Figure 3.14. The out let view of the grinder

3.6.6. Sieve

Sieve size was selected based on the recommended hole size according to feed size or particle size for different animals. According to the Egyptian standard specification for prepared animal feeds and feedstuffs, compressed feeds are sized into four categories a) sizes < 2mm in diameter ranked: powder or mash, which was used for all types of poultry and birds. b) Sizes 2-6mm in diameter, which was used for rabbits, goats and fishes. c) Sizes 5-10mm in diameter for small animals (<6months). d) Sizes 10-22mm in diameter for large animals (>6months) (Basiouny, 2016). Therefore 10mm and 12 mm sieve diameter were selected.

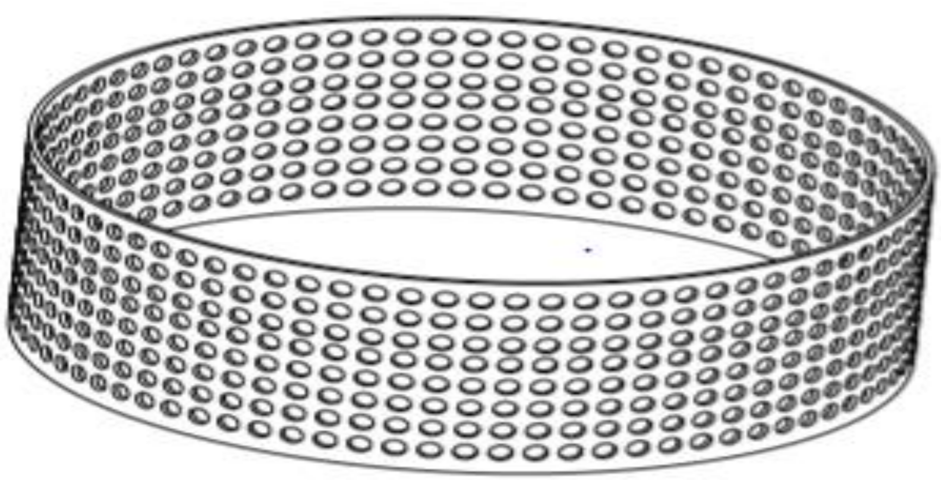


Figure 3.15. Sample sieve for the grinder

3.7. Weight Determination of Machine Components

In order to estimate the loads on each and every parts of the proto type , it used to be necessary to estimate weight of all parts the machine these are the frame, cutter discs, housing, hopper and the blades of the grinder machine were calculated by of using CATIA V5 R20 software. The input of the software was part design equipped with dimensions and material type selection. The software has its own material types with their densities. Once the part design was feed with dimensions and it material type, the CATIA gave the output of the selected component area, volume and mass.

Table 3.3. Weight of machine components

SN	Components	Qty	Area (m2)	Volume (m^3)	Density (kg/m^3)	Unit mass (kg)	Total Mass (kg)
1	Frame	1	1.477 m^2	0.00224 m^3	7870 kg/m^3	17.679kg	17.679 kg
2	Housing	1	2.258 m^2	0.002 m^3	7870 kg/m^3	17.733 kg	17.733 kg
3	Sieve	1	0.275 m^2	0.000311 m^3	7870 kg/m^3	2.448 kg	2.448 kg
4	Hopper for straw	1	2.294 m^2	0.001 m3	7870 kg/m^3	9.016 kg	9.016 kg
5	Beaters	8	0.0075m^2	0.0000225 m^3	7870 kg/m3	0.175 kg	1.413 kg
6	Blade	25	0.02m^2	0.00025 m^3	7870 kg/m^3	0.197 kg	4.6 kg
7	Knife bushing	1	0.015m^2	0.000065 m^3	7860 kg/m^3	0.515 kg	0.515 kg
8	Cutter plate	1	0.121 m^2	2.78e-004 m^3	7860 kg/m^3	2.19 kg	2.19 kg
9	Angle fixer	8	0.009 m^2	1.14e-005 m^3	7860 kg/m^3	0.09 kg	0.72 kg
10	Brass Bearing	1	0.008m^2	0.0000026m^3	8216 kg/m^3	0.215 kg	0.215 kg
Total weight							56.84 kg
11	Weight of electrical motor						21 kg
12	Weight of switch and control casing						2 kg
Over all weight of the machine							79.83 kg

Total mass which lay on the frame was 62.829 kg excluding the weight of the frame.

W = m x g ---3.7

W = 62.829 kg x 9.81 m/s^2

= 616.35 N

Where: W = weight,

m = total mass of the parts,

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

3.8. Force Analysis for Critical Component of the Machine

When the feed grinder machine is operating some components of the machine are subjected to both static and dynamic forces. Particularly, the frame is subjected to static force and the cutter disk, the blade and beaters are subjected to dynamic force. Due to that failures may occur during machine operation if the components are not designed through considering the forces which are acted up on it. On the other hand, if the machine is overdesigned to have far more strength than required, the machine may not be competitive in terms of cost, weight, size and also power requirements. Therefore CATIA V5 R20 software was used to analyze the force analysis of the critical components of the machine by simulation**.**

3.8.1. Static force

The load which is applied on the frame was the summation of weight of the machine components and the feed materials except the frame weight. The weight being applied to the frame surface was calculated in Table 3.3 above and the method determining the weight explained in equation 3.7. Therefore, the static force analysis of the frame was done by applying 697.55N. The simulation result is shown in the Figure 3.16 below and it indicates the frame is safe.

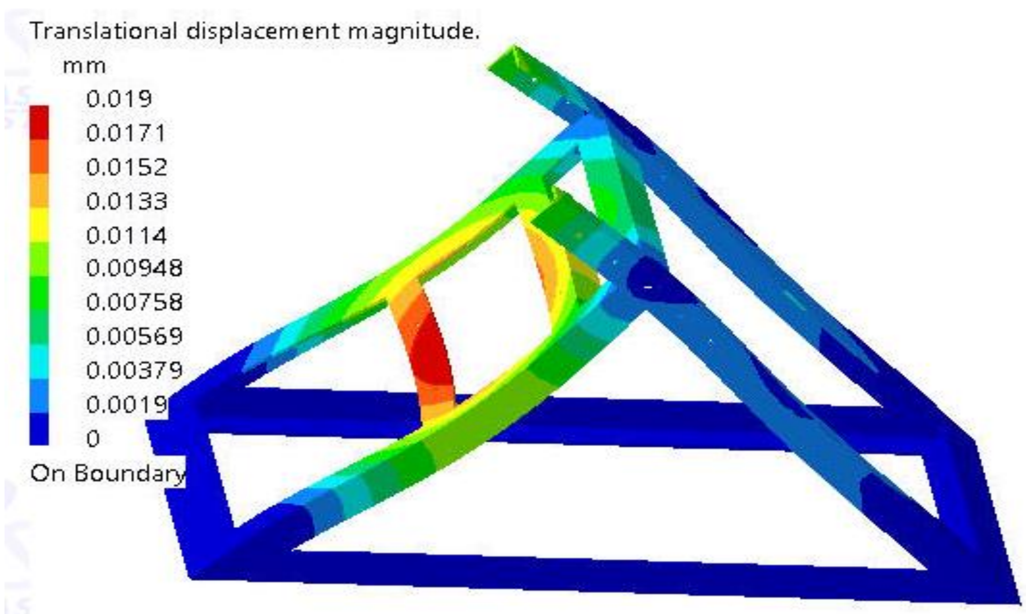


Figure 3.16. Load distribution on the frame.

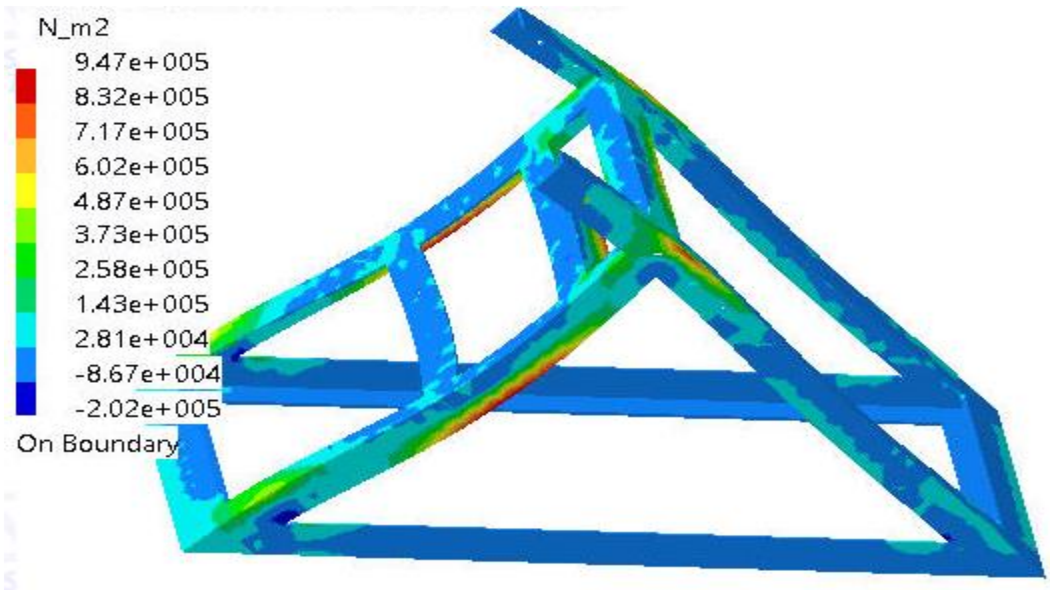


Figure 3.17. Stress distribution on the frame

Load on the frame is 697.55 N caused by the weight of the machine components (616.35N) including feed weight (81.2N) acts as a load on the frame. The output result maximum translational displacement caused by the load on the frame is 0.019 mm and maximum stress distribution caused by the load on the frame is 9.47x 10^5 N/m^2 Figure 3.17 which is below the allowable stress of mild steel that indicates the beater is safe.

3.8.2. Dynamic force

The dynamic force occurs from the rotational motions of electric motor. As a result the cutter disc, beater and the blade are components of the machine; primary subjected to dynamic force. These forces occur on the principles of rotating disks. The dynamic force analysis of those components was analyzed through considering the rotational torque of the motor and fixing joint force. The simulation result is shown in the Figure 3.18 below and it indicates they are safe.

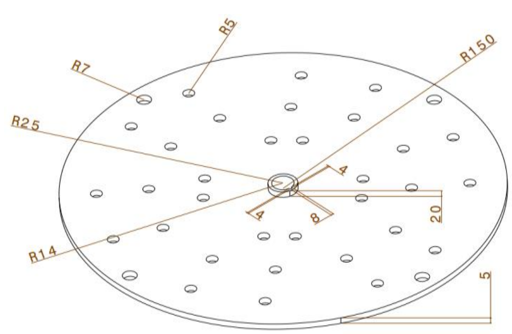


Figure 3.18. Cuter disc with its dimensions (mm)

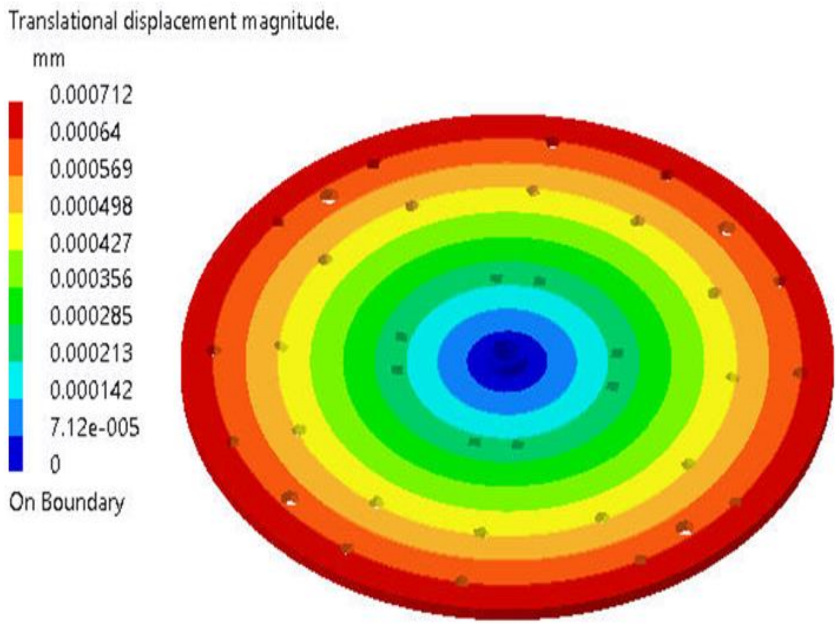


Figure 3.19. Load distribution on the cutter disk

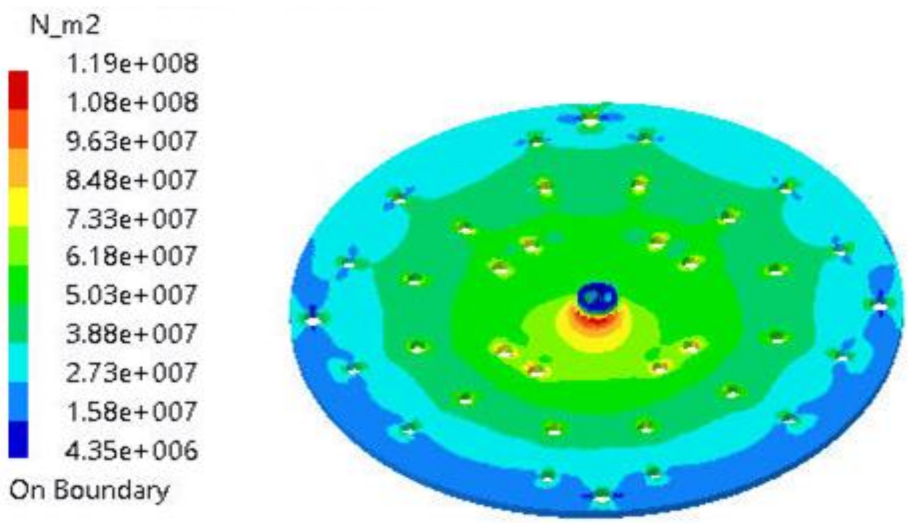


Figure 3.20. Stress distribution due to the cutter disk.

To ensure safety, analytical simulations were run and modifications were performed using CATIA V5 R20 software. The impact of the load and rpm of the motor, the failure rate increased as the thickness of the disc decreased caused by the revolution and the weight of the feed in the grinding chamber. On the basis of these response indicators, optimization of the disc was carried out. The input load on the disk includes the weight of the feed plus the weight of the blades and the rotational force. Angular velocity = 151.76rad/sec derived from rpm of the motor and angular momentum developed was, M = (8.1kg)[2] x 31.87 m/s x 0.21 m, = 54.21 kgm^2/s. The output result maximum translational displacement on the disk is 0.00072mm Figure 3.19 and the maximum stress distribution on the disc is 1.19×10^8 N/ m^2 Figure 3.20 which is below the allowable stress of mild steel that indicates the beater is safe.

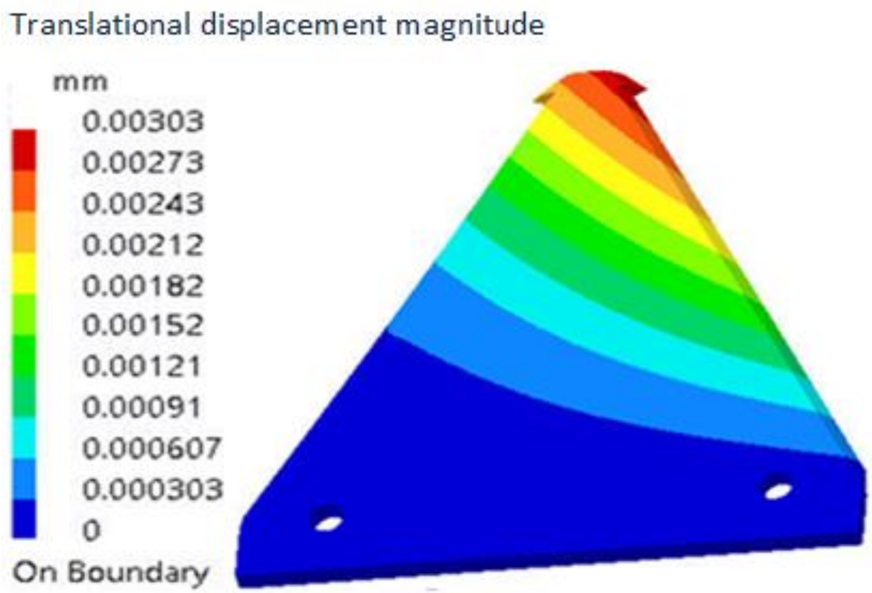


Figure 3.21. Load distributions the blade.

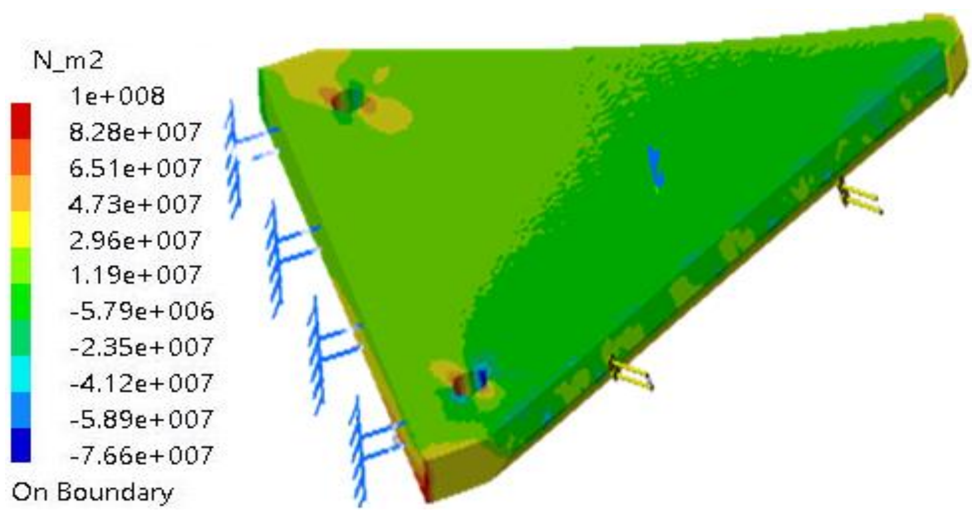


Figure 3.22. Stress distributions on the blade.

Simulations were used to conduct the analysis, and actual geometry was inserted to the software. This simulation allows seeing how much the machine blades are stressed. Load due to rotational force on the blade derived from rpm of the motor (1450). And the load created by

[2] 8.1 kg is the sum of weight of blade, cutter plate and beater (Table 3.3) and 31.87 is linear velocity.

shearing force is 114.96 N. The output result translational displacement on the blade is 0.00303 mm Figure 3.21 and the maximum stress distribution on the blade 1 x 10^8 N/ m^2 Figure 3.22 which is below the allowable stress of mild steel that indicates the beater is safe.

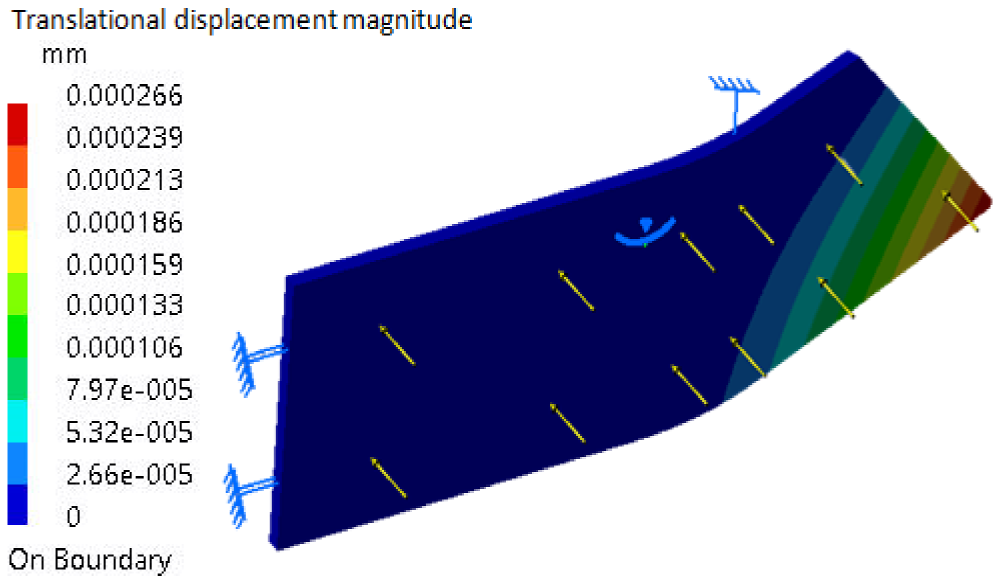
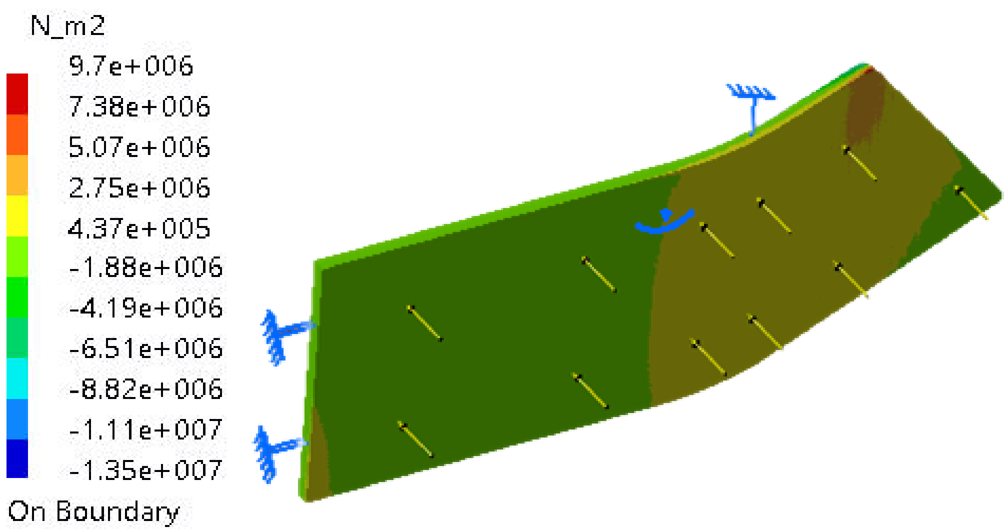


Figure 3.23. Load distributions on the beater.



[3]

Figure 3.24. Stress distributions on the beater.

CATIA software was used to complete a critical portion of the beater. Case simulations were used to conduct the analysis, and actual geometry was inserted to the software. This simulation allows seeing how much the machine beaters are stressed. Load on the beater at the maximum

[3] N-m2 is the software output of newton per meter square. This is stress distribution on the beater caused by force divided by area of the beater.

feed can be = 11.5 x 9.81m/s^2 = 112.8N and due to the rpm of the motor. The output result, translational displacement on the beater is 0.000266 mm Figure 3.23 and the maximum stress distribution on the beater 9.7 x 10^6 N/ m^2 Figure 3.24 which is below the allowable stress of mild steel that indicates the beater is safe.

3.9. Fabrication of the Machine

First, the software drawing was developed by using CATIA V5 R20 software and then the different component of the feed grinder machine parts mentioned in previously described subheadings was fabricated step by step by considering their position, design and assembled in the workshop of MARC (Melikasa Agricultural Research Center).

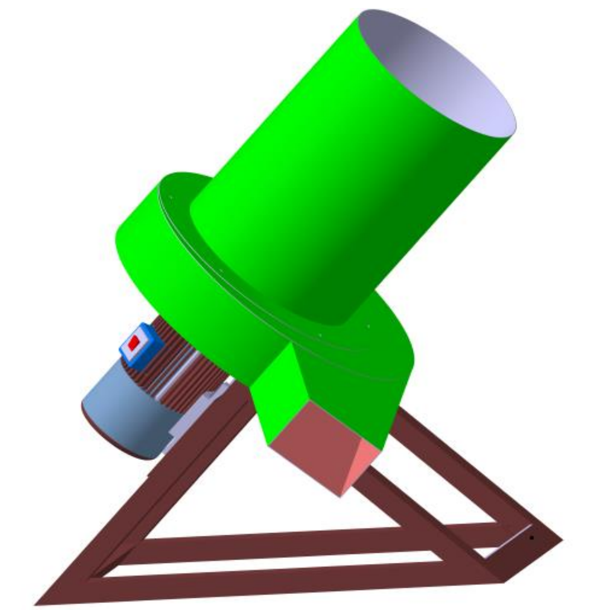


Figure 3.25. Developed machine with CATIA

Figure 3.26. Fabricated machine in the shop

3.10. Performance Evaluation of the Machine

The performance of feed grinder was evaluated under lab conditions. The parameters such as chopping length, machine output capacity, percentage loss and uniformity were recorded during the lab tests. The necessary parameters for determining machine performance were measured. The preliminary performance evaluation of the feed grinder machine was carried out (Figure 3.27) before conducting the actual performance evaluations (Figure 3.28). The evaluations were carried out at Melkassa Agricultural Mechanization Research Center, Melkassa on 27 October 2021. The samples of test materials (wheat straw) were brought from Dodota office of agriculture and natural resource.

Figure 3.27. Performing pretest on the machine.

Figure 3.28. Performing actual test on the machine.

The performance was tested by running the machine and the materials were inserted in the hopper and grinded in the housing by means of blades under the guidance of the sieve and then the grinded materials pass through the outlet port. During this process the mass before grinding and after grinding was measured by weighing using digital balance. The performance evaluation of animal feed grinding machine was on the basis of:

1. Output capacity, (kg/h)
2. Grinding efficiency, (%)
3. Percentage loss, (%)
4. Length of cut, (mm)

3.10.1. Bulk density of wheat straw

The bulk density was found by taking wheat straw in a container of cylindrical shape Figure 3.29. The volume of the container was found by measuring diameter and height for cylindrical container. The weight of the container is found separately. The bulk density was calculated. Three samples were measured and the average of them was taken (Hesham, 2015).

Figure 3.29. Determination of bulk density of grinded straw

$$Bulk\ density = \frac{Weight\ of\ sample}{Volume\ occupied\ by\ the\ sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.8)$$

3.10.2. Moisture content of fodder

The oven dry method was used for determination of moisture content of straw Figure 3.30. The initial weights of straw samples were taken and weighed and then dried in hot electric oven at 105'C temperature for 24 hrs. The samples were then removed from the oven and weighed, then the dry samples were recorded. The percentage of moisture content (wet basis) was determined as follows:

$$M = \frac{(W1 - W2)}{(W1 - W3)} x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.9$$

Where: M = Moisture content in wet basis, (%)

W3 = mass of the empty dish, (g)

W1= mass of the material before drying, (g)

W2 = mass of the dried material, (g)

Figure 3.30. Measuring moisture content of the sample with oven method.

3.10.3. Output capacity

According to Ibrahim et al. (2017), the output capacity of the feed grinder machine was measured by weighting the amount of feed grinded in unit time.

$$\mathrm{Gc} = \frac{\text{Total mass of materials grinding(Kg)}}{\text{Total time taken (hr)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.10$$

3.10.4. Grinding efficiency

Grinding efficiency (Ge) was determined:

$$\mathrm{Ge} = \frac{\text{Mass of materials after grinding(Kg)}}{\text{Mass of materials before grinding(Kg)}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

3.10.5. Loss of straw

The percentage the loss of feed was obtained in the powder form after chopping of feed by grinder and the feed remained in the casing was considered as loss. Percentage loss of feed incurred during chopping of feed was expressed using;

Grinding loss (Gl) was determined Ibrahim et al. (2017),

$$\mathrm{Gl} = \frac{\text{Mass before grinding (Kg)} - \text{mass after grinding(Kg)}}{\text{Mass before grinding(Kg)}} \times 100 \ldots\ldots\ldots\ldots\ldots 3.12$$

3.10.6. Length of cut

The length of the feed grinded was mainly depends on the sieve diameter used. The cutting length of the feed after grinding operation was measured in mm by using category method. Category method of measuring the range of grinding in terms length of cut was the most preferable method of determining uniformity because there exist some deviation on the length of cut.

Grinded material was taken after the grinding operation. Randomly 1 kg samples were taken from each sieve diameter and weigh it and measure the length of variation with arrange of four categories to know the percentage of uniformity and also the length of the feed materials before grinding was measured to determine the uniformity.

Cutting length readings of less than 30mm, on the other side, are suitable straw length and appropriate for animal feeding, according to that categorization. The length of cut was calculated by following formula (Ismail et al. 2007).

$$Category\ (\%) = \frac{Straw\ weight\ of\ catagory\ in\ that\ sample\ (Kg)}{Total\ weight\ of\ the\ sample\ (Kg)} \times 100 \quad \text{...............3.13}$$

The percentage of the size reduction was obtained the length form the length before grinding and the length after grinding by the feed grinder; it is considered as a percentage of size reduction. Percentage size reduction of the feed was expressed by using the formula (Worku and Solomon, 2012).

$$\text{Percentage size reduction} = \frac{L_b - L_a}{L_b} \times 100 \quad \text{..(3.14)}$$

Where: L_b = Average length of the feed before chopping

L_a = Average length of the feed after chopping

3.11. Experimental Design

The experiment was set in RCBD having sieve diameter and blade types as main blocks, the moisture content and feeding rates as sub-block with three replications. The design was 2 by 2 and 3 by 3 replications with 2 levels of moisture content combinations, with three replicates giving 72 total experimental units (2 x 2 x 3 x 3 x 2 = 72). The treatments were two levels of sieve diameter (10 mm and 12 mm), three levels of feed rate (2.5kg, 5kg and 7.5kg) and two levels of moisture content (13.22 % and 24.63 %) as shown the Figure 3.31.

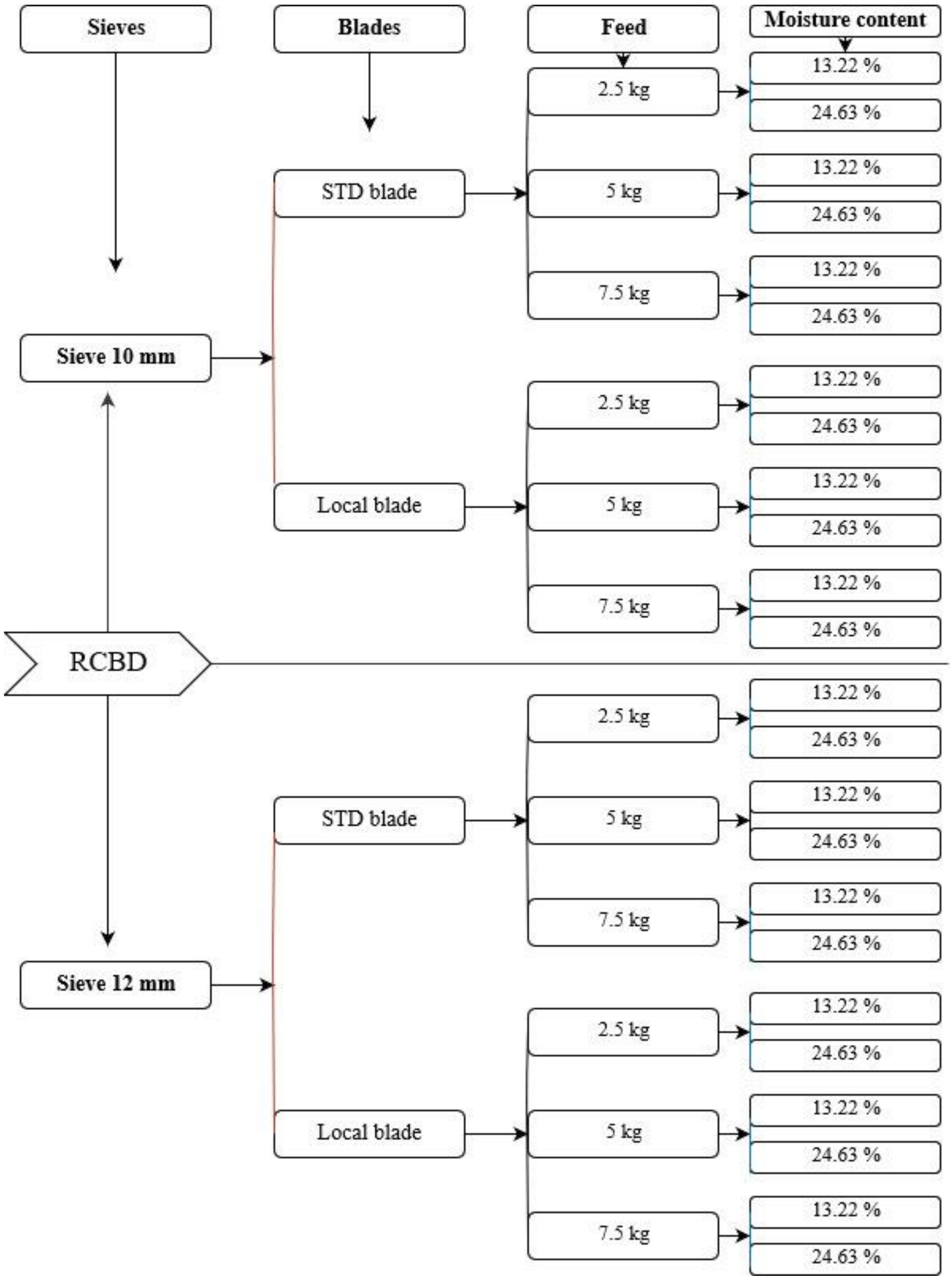


Figure 3.31. Experimental design flow diagram.

3.11.1. Independent variables

The independent variables are the sieve diameter (10 and 12 mm), blade type (standard blade from the market and locally manufactured blade at the workshop), feed (2.5kg, 5kg and 7.5kg) and the moisture content of the straw (13.22 and 24.63 of wet basis) which were selected and analyzed.

3.11.2. Dependent variables

Observations on each treatment were used to compute the different performance assessment metrics. Below are the dependent parameters for each treatment combination.

Length of cut, mm

Output capacity kg/hr

3.12. Cost Analysis

The overall investment cost of the feed grinder machine is, interest, cost of maintenance and accessories, cost of labour, and depreciation were used to estimate hourly operating costs of the feed grinder machine.

The new manufactured machine's operating cost was calculated in Birr (ETB). The machine's operating price is calculated and established in the appendix B and appendix D.

3.12.1. Fixed cost

The fixed cost was calculated by the following steps According to Makkar et al. (2020), the annual depreciation, interest, housing, tax and insurance was calculated as follows by equation 3.15, 3.16, 3.17, 3.18 and 3.19 respectively.

Depreciation

Depreciation is the loss of an asset's value owing to use, time, mileage, technology out dating or expiration, and other factors. The yearly basis depreciation was computed using equation 3.16.

$$D = \frac{C-S}{L} \quad \text{……………………3.15}$$

Where: D = Depreciation per hour (ETB.),

C = Capital investment cost (ETB),

S = Salvage value, assume 10% of the capital investment, ETB,

L = Life of the machine in years

Interest

Interest is calculated on the average investment of the machine were taking into deliberation the worth of the machine in the first and last year. The yearly interest on the investment can be calculated as equation 3.17.

$$I = \frac{C \times S}{2} \times \frac{i}{H} \qquad \text{………………………………………………………3.16}$$

Where: I = interest per hour, ETB/hr.,

i = Interest rate (10 % per year),

C = Capital investment cost (ETB),

S = Salvage value, 10% of the capital investment, ET

Housing, Taxes, Interest and Insurance

Each of the above titles was calculated as 1% of the initial cost of the machine.

Housing cost per hour (ETB.) = 1% of the initial cost of the machine..…… ..… ……...3.17

Taxes cost (ETB.) = 1% of the initial cost of the machine…………………….….…….….3.18

Insurance cost (ETB.) =1% of the initial cost of the machine…………………….………..3.19

3.12.2. Operating cost

The variable cost of the machine would be calculated by the following parameters.

a) Repair and maintenance cost

The repair and maintenance cost is a product of a machine's cost price and repair and maintenance percentage factor Makkar et al. (2020),

RMc = 2.5 % × capital investment per year…………………….…………….………………......3.20

b) Wages of the operators

Wages are calculated based on the actual wages of workers per hour.

The total cost of the operation per hour

The total cost of operating per hour of the feed grinder machine can be calculated by the summation of the fixed and variable cost per hour and calculated as equation 3.21.

Total operating cost per hour = fixed cost (ETB/hr.) + Variable cost (ETB/hr.) ………..…3.21

3.13. Working Principles of the Machine

The machine used a high speed rotating blade along the axis of the motor shaft. The cutter blade disc attached on the motor shaft and rotates in the housing guided by the sieve (Figure 3.32). The material is feed through the center of the rotor, by means of cylindrical hopper and it is augmented to high speeds before being passes through sieve. The feed material is grinded when it is sheared between the rotating blade and the fixed blades. The size of ground materials varies with the variation of the sieve diameter. Finally the grinded material passes through the casing to the outlet.

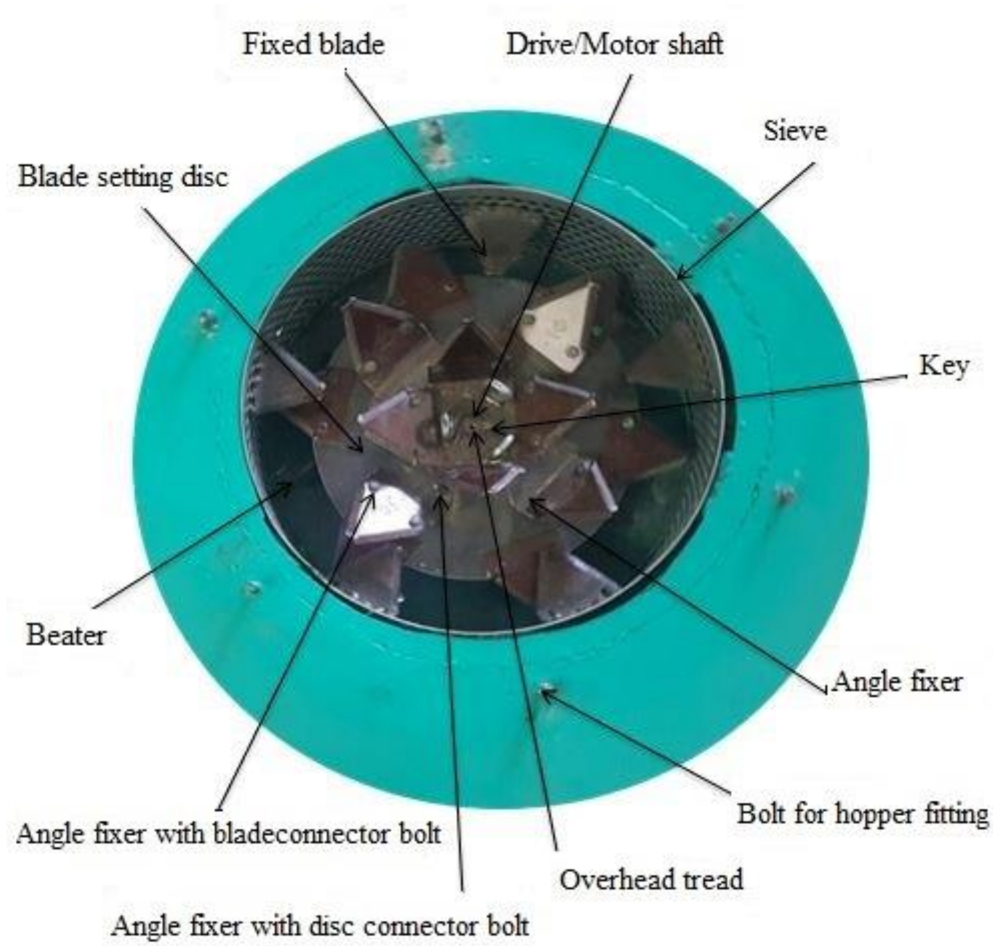


Figure 3.32. Fixed and rotating blade arrangement inside the housing

CHAPTER FOUR

4. RESULT AND DISCUSSION

In this chapter, the result relating to physical properties of feed grinder, design and fabrication of different component of feed grinder, performance evaluation of feed grinder machine for grind at different sieve diameter, and with numbers of blades and for grinding machine the factors that mainly influence the selection of raw material such as moisture content and physical characteristics of feed were analyzed and discussed.

4.1. Preliminary Evaluation of the Machine

Before conducting performance test of the feed grinder machine visual observation and operational checking machine defects at no loads was reported in Table 4.1.

Table 4.1. Symptoms to be checked visually and operationally

No	Parameter	Observation
1	Presence of unusual sounds during operations	None
2	Presence of knocking and vibration	None
3	Smooth running of the machine with is attachments	Very good
4	Any observed un usual wear on machine components	Not observed
5	Any observed loose on bolt and nuts	Not observed
6	Stability of the machine with its components	Stable

4.2. Physical Characteristics of Selected Feed

The different physical characteristics of selected feed was determined and represented.

4.2.1. Bulk density

The procedure followed to measure the bulk density of feed was explained under section 3.10.1 equations 3.8. The average bulk density was found to be 107.26 kg/m^3 after grinding Table 4.2 and the average bulk density was recorded as 26 kg/m^3 before grinding. This study shows that, the increments of the bulk density better indication of the feed for minimum storage area requirement.

Table 4.2. Sample bulk density of the straw

No.	Wight of the sample (kg)	Weight of sampler (kg)	Weight of straw (kg)	Volume of sampler (m^3)	Bulk density of straw(kg/m^3)
1	0.3096	0.2039	0.1057	0.001	105.7
2	0.3118	0.1995	0.1123	0.001	112.3
3	0.3074	0.2011	0.1063	0.001	106.3
4	0.3103	0.2024	0.1079	0.001	107.9
5	0.3074	0.2023	0.1051	0.001	105.1
6	0.3095	0.2032	0.1063	0.001	106.3
		Average			107.26

4.2.2. Moisture content

The procedure followed to measure the moisture content of the feed is explained under section 3.10.2 in equation 3.9. The average moisture content dry basis of the wheat straw early morning of the testing day was found to be 24.63 % while in midday of the testing day the average moisture content was 13.22 %. From the result, it was found the proper/efficient grinding has occurred in the moisture content of 13.22 %.

During carrying out the experiments, the conditions of the experimental materials were studied and different tests were conducted and results are tabulated in the Table 4.3 and Table 4.4 Samples were randomly taken for each material test and evaluated and recorded in which one sample was taken and inserted on the oven-dry in the early morning of the testing day and one sample was taken at the midday of the testing day in order to manage the moisture content.

In Table 4.3 is shown the moisture content in the early morning at 6 different samples was found to be 24.88%, 27.94%, 25.15%, 21.80%, 24.62% and 23.38% on a wet basis. In Table 4.4 is shown the moisture contents of six samples of 13.69%, 10.86%, 14.83%, 14.74%, 15.17%, and 10.05% wet basis. The average moisture content of the experiment was 13.22 % and 24.63% in the midday and in the early morning of the testing day respectively.

Table 4.3. Moisture content of wheat straw taken early morning of the testing day

Sample	Wt before oven dry (gm)	Wt after oven dry (gm)	Moisture Content Wb (%)
1	109.7	82.4	24.89
2	84.1	60.6	27.94
3	79.9	59.8	25.16
4	97.7	76.4	21.80
5	112.9	85.1	24.62
6	88.5	67.8	23.39
Average	95.47	72.02	24.63

Table 4.4. Moisture content of wheat straw taken midday of the testing day

Sample	Wt before oven dry (gm)	Wt after oven dry (gm)	Moisture Content Wb (%)
1	84.7	73.1	13.70
2	91.1	81.2	10.87
3	99.1	84.4	14.837
4	83.4	71.1	14.75
5	88.3	74.9	15.18
6	87.5	78.7	10.06
Average	89.02	77.23	13.23

4.2.3. Length of cut

The method followed to find out the grinding length of the feed grinded material was explained under section 3.10.6 by equations 3.13.

Table 4.5. Length of grinded straw for each sieve diameter

1 kg of grinded straw was taken for each sieve diameter.						
			Ranges			
Samples	<0.5cm	(0.6 – 1)cm	(1.1 – 2)cm	(2.1-3)cm	(3.1 -4)cm	(4.1 – 5)cm
Sieve 10	7%	13%	45%	14%	10%	8%
Sieve 12	5%	11%	51%	15%	9%	7%
Sieve 10 mm = 3% loss			Sieve 12 mm = 2% loss			

Effects of sieve diameters on grinding length of the feed were presented Table 4.5. It was observed that the average length of the cut varies in the range of 0.5mm to 50 mm. The minimum grinding length in both case 5 % of the feed out of 1kg sample were less than 0.5 cm and the maximum 7 % of length was greater than 4.1 cm but the maximum percentage was found greater than 45% was in a range of 1.1 to 2 cm in length of cuts. In both case the sieve diameters had less effect on length of cut.

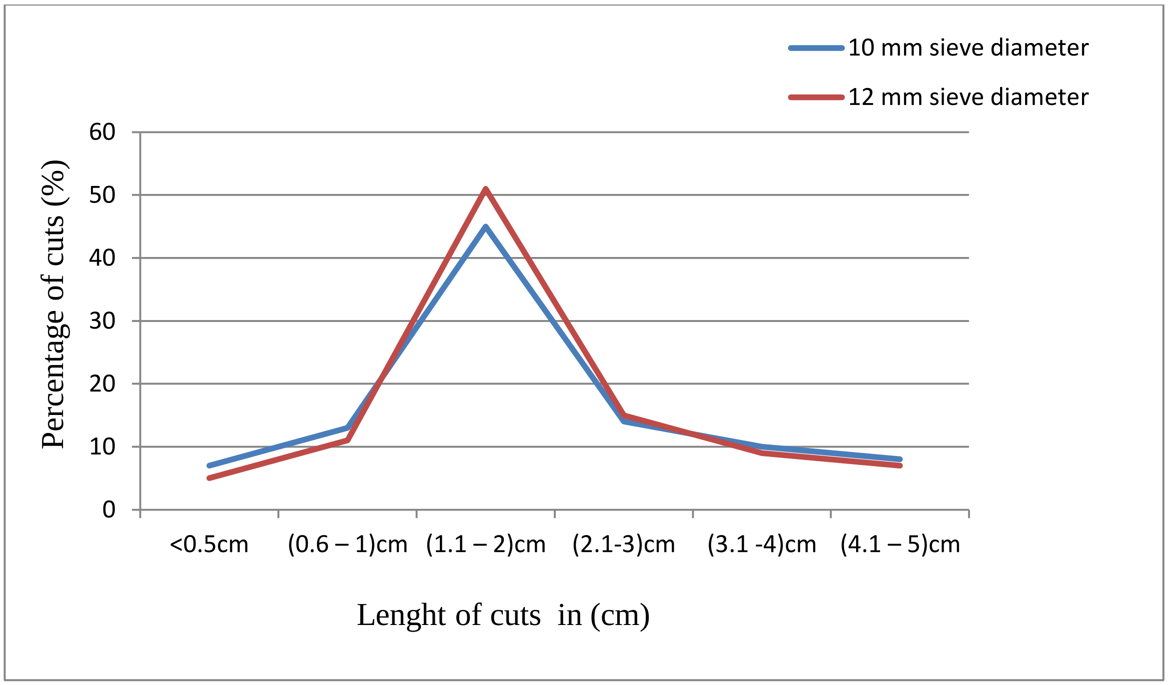


Figure 4.1. Percentage of feed cut distribution graph

The maximum percentage was found in the range of 1.1 to 2 cm length Figure 4.1 which is better for animal feed. This result is much better for total mixed ration and palatability. In dairy cattle, the length of forage particles has a significant impact on feed intake and rumen functionality (Kiggundu M, 2018). The mean chopping length was within the appropriate range from 1 to 4 cm, which is essential for healthy rumination and salivation (Moharrery, 2010). There are almost no significant variations among many of the means length of cut.

The percentage of reduction was explained under section 3.10.6 equations 3.14. From the sample taken the average length of the feed before grinding was measured, and it was 42.1 cm. The percentage reduction during grinding was from the above category, the minimum percent reduction was found from the maximum length of cuts of 5 cm that is 87.8%, and the maximum length of cut was found from the minimum length of cut 0.5 cm is 98.7%. This percentage reduction was found in the range of recommended size of range. FAO recommends from 1cm to 5cm is the better feed size for mixed rations. Therefore the size reduced by the feed grinder machine is fulfilling the required size for mixed rations.

4.2.4. Output capacity

The procedure followed to find the output capacity of the feed grinder machine was explained under sections 3.10.3 in equations 3.10. The effect of feed on 12mm and 10mm sieve diameters, on the output capacity of the feed grinder machine was presented in Figure 4.2 and Figure 4.3 respectively. The effect of moisture content on the output capacity of the feed grinder machine was presented in Figure 4.4 and Table 4.6.

Table 4.6. Variations of output capacity with different parameters

Feed (Kg)	Parameters							
	10 mm STD		12 mm STD		10 mm LCL		12 mm LCL	
	13.22%	24.63%	13.22%	24.63%	13.22%	24.63%	13.22%	24.63%
2.5	242.08	192.88	289.63	222.43	135.42	103.	171.15	130.17
5	230.70	178.96	270.83	220.18	120.53	93.02	133.71	102.14
7.5	195.841	169.32	220	171.30	86.23	76	93.16	81.67

STD = Standard blade LCL = Local blade 10 & 12 = Sieve diameter % = Moisture content

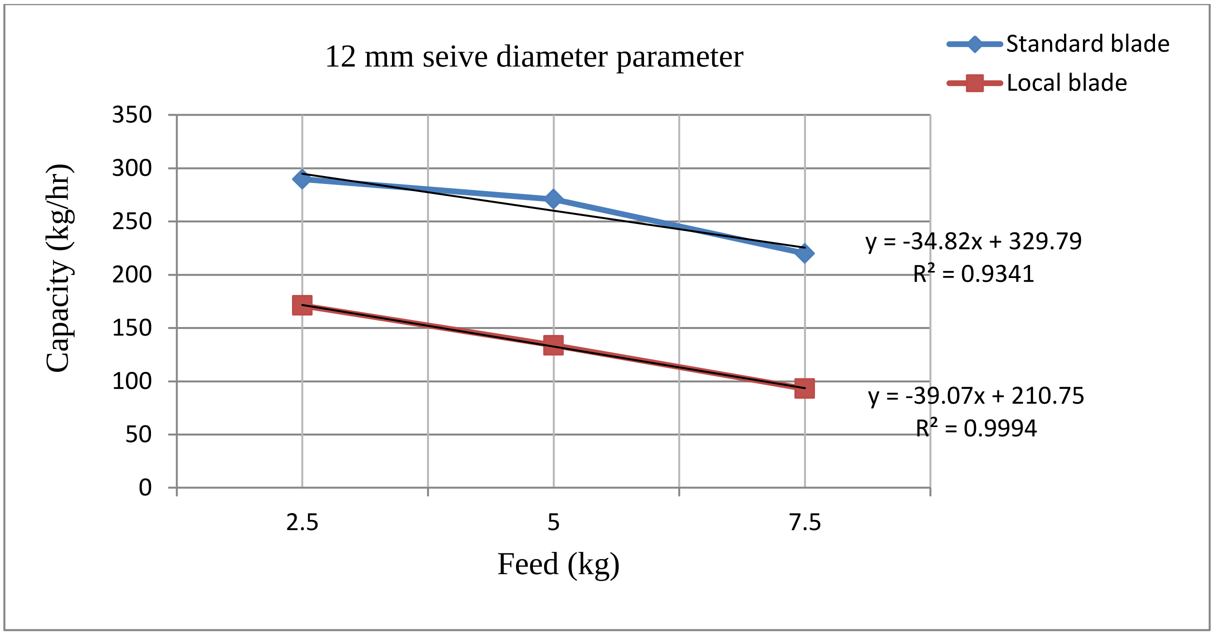


Figure 4.2. Effect of feed rate on output capacity with 12 mm sieve diameter

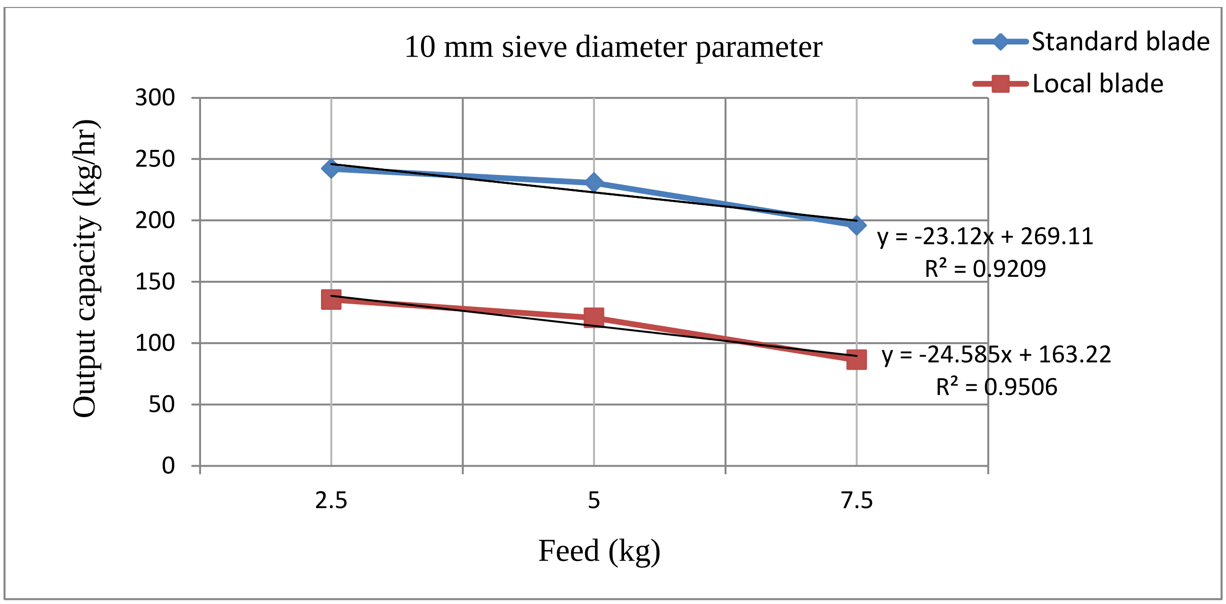


Figure 4.3. Effect of feed rate on output capacity with 10 mm sieve diameter

The influence of feed on the capacity of the machine's production for different observations varied with feeds of 2.5 kg, 5 kg, and 7.5 kg, as shown in Figure 4.2 and Figure 4.3. It was discovered that the samples gathered from two different sieve diameters have inverse relations, in which the output capacity declined as the feed increased.

For 10 mm sieve diameter the output capacity varied in the range of 195 kg/hr to 242 kg/hr for standard blade and 86 kg to 135kg locally fabricated blade in the shop. Similarly, for 12 mm sieve diameter the output capacity varied in the range of 219 kg/hr to 289 kg/hr for standard blade and 93 kg to 171 kg locally fabricated blade in the shop. In both cases, the minimum capacity was obtained for the feed of 7.5 kg. While the maximum capacity was obtained for the feed of 2.5 kg this was because as the feed increase the hoppers become full due to this reason the air inter into the radial grinding housing was limited and started sacking air from the outlet side.

The data in Figure 4.2 and Figure 4.3 showed, strong correlation between blade type and drum feed (kg) in all trials, with a high coefficient of determination (R^2 = 0.9341 and R^2 = 0.9994) were observed with standard blade and with locally manufactured blade for 12 mm sieve diameter on output capacity. While in 10 mm sieve diameter (R^2 = 0.9209 and R^2 = 0.9506) observed with standard blade and with locally manufactured blade.

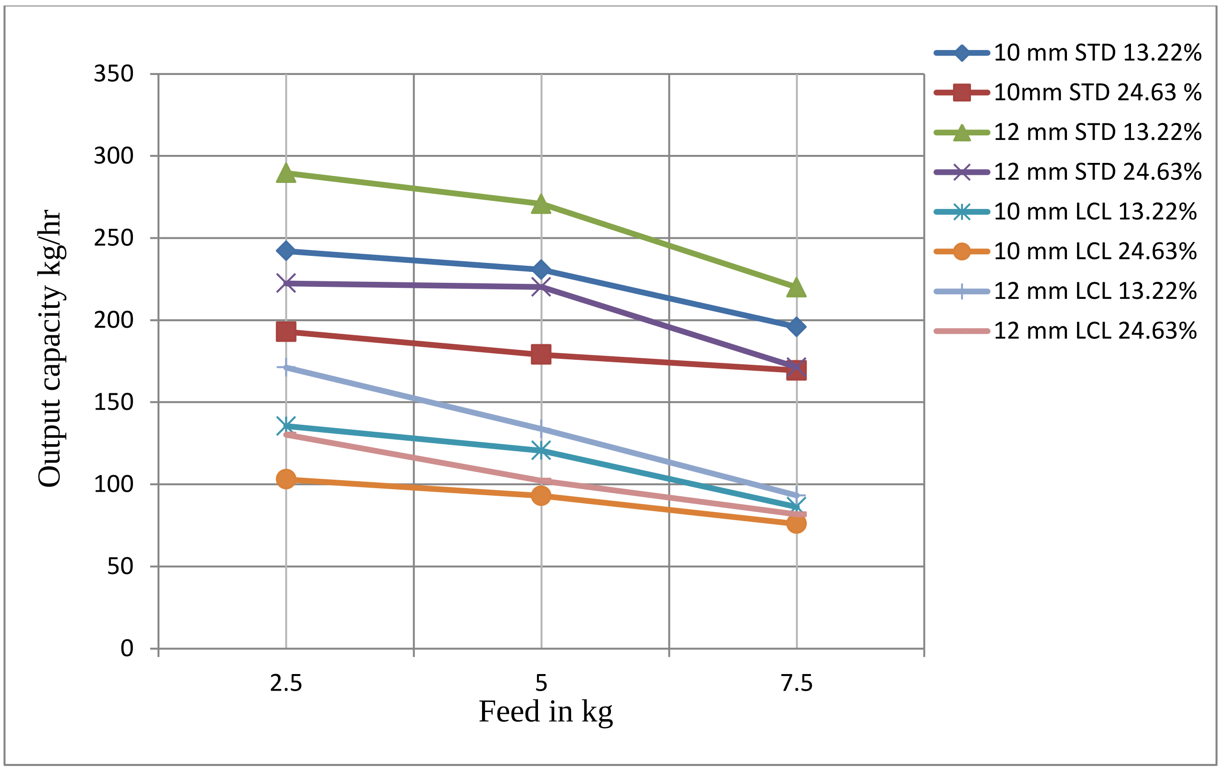


Figure 4.4. Effect of feed and moisture content on the output capacity

STD= Standard blade   LCL = Local blade   10 & 12 = Sieve diameter   % = Moisture content

Table 4.7. Effect of feed on output capacity ANOVA summary

ANOVA

Capacity (kg/hr)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29897.524	2	14948.762	4.035	.022
Within Groups	255605.630	69	3704.429		
Total	285503.154	71			

ANOVA significance level of feed rate on the output capacity in Table 4.7 showed that it is significantly affected because it is less than 0.05 alpha value or 95% confidence level. The detail result displayed in table 10 appendix C.

4.2.5. Loss of straw

The procedure followed to measure the grinding efficiency and the percentage loss of the feed grinder machine was explained under equations 3.11 and 3.12 respectively. Effects of the percentage of loss and grinding efficiency of the feed grinder were presented under the following table, Table 4.8.

Table 4.8. Average Percentage lose & grinding efficiency

Average Percentage lose & grinding efficiency				
	Sieve 10 mm		Sieve 12 mm	
Feed (kg)	Lose (%)	Efficiency (%)	Lose (%)	Efficiency (%)
2.5	8	93.33	6.6	95.6
5	9.3	90.6	7.3	92.6
7.5	6.6	92	4.4	93.2

The loss occurs in the form of clouds of dust, unmanageable small particle size, and left inside the casing during grinding. Compared to the loss caused by feeding the straw directly for animals without physical treatment, it was much less. This is happen by les area requirement for storage and feeding wisely. Feed lose and efficiency have a least effect on the machine capacity.

CHAPTER FIVE

5. CONCLUSION AND RECOMENDATION

5.1. Summary

The purpose of this research was to design, fabricate and evaluate the performance of animal feed grinding machine for farmers and different stakeholders who are participating on livestock production. The design of the machine was done through considering physical properties of straws, simplicity to operate, minimum space requirement, easiness to dismount machine components for transportation, ergonomics and cost. The overall dimensions of feed grinder were 1060 mm in length, 700 mm in width and 1200 mm in height. The fabrication also done under consideration of available materials and machine shops and the machine can be fabricated inexpensively everywhere in the country that has small workshops.

5.2. Conclusion

Machine performance evaluation was accompanied to conclude the effects of feed moisture contents, sieve diameters and the blade types on grinding capacity, length of cut and uniformity. Depending on the results the following conclusions were drawn:

- Grinding capacity has direct relationship with sieve diameter, and inverse relationship with moisture content and feed rate (Table 4.6).
- The length of cut slightly varies with the variations of sieve diameter.
- It grinds the feed uniformly, which is better for mixed ration.
- Sieve diameters have the least effect on uniformity of the output.
- It is long lasting because it is low maintenance demanding machine.

Therefore, the results imply that the feed grinder machine can grind the straw into the required size. According to the results gained from performance evaluation of the machine, it is concluded that the performance of the machine is highly acceptable with high viewpoint for spreading the technology.

5.3. Recommendation

The machine has a capacity which suits its purpose but it can be improved and modified to address for all farmers in the country. Due to time limitation and limited cost the issues that have to be addressed in the improvements of this machine in the future are:

- By using different types of sieves diameter, it is possible to obtain different size of feed length for different animal.
- The machine should be re-evaluated with more sieve diameters with different hay types.
- Incorporate feeding tray mechanism to reduce operators' fatigue and to control feeding rate.
- Incorporate a mechanism that helps to use tractor as a power source.

So, the developed grinder machine must suit technically and economically for Ethiopian small scale enterprise.

REFERENCES

1. AL-Gezawe, A.. (2016). Development f A Fodder Bales Chopper. Misr J. Ag. Eng., 33, pp 1255 -1272.

2. Arshdeep, S. Dhaliwal, I. S. and Dixit, A, (2011). Performance evaluation of tractor mounted straw chopper cum spreader for pady straw management. *Ind. J. Agr. Res* 21-29

3. Astanakulov, K., Gapparov, S., Karshiev, F., Makhsumkhonova, A., & Khudaynazarov, D. (2020). Study on preparation and distribution of forage by chopping coarse fodder. *IOP Conference Series: Earth and Environmental Science*, *614*(1), 012158

4. A.Yousif, L. (2013). Crop-machinery management system for field operations and farm machinery selection. *Journal of Agricultural Biotechnology and Sustainable Development*, 5(5), 84–90.

5. B. Malede, B. M. (2012). Role of Seeding rates and cutting stages on yield and quality of forage intercropping in the case of North Gondar zone, Ethiopia. *Lambert Academy Publishing, Germany*, pp. 56-73.

6. Bandiwadekar, C., Kamble, A., Garala, V., & Shaikh, Z. (2016). Review Paper on Design & Development of Chaff Cutting Machine. *International Journal for Scientific Research & Development*, 4(02), 235–237.

7. Basher, I. M. Zubiaru. .M & Garba, U. A (2010) Design construction and evaluation of a stoalk chopper. J res 1-7

8. Basiouny, M., & El-Yamani, A. (2016). Performance evaluation of two different hammer mills for grinding corn cobs. *Journal of Soil Sciences and Agricultural Engineering*, 7(1), 77–87.

9. Boldyreva, E. M. (2014). Current Challenges in Global Dairy Farming: Cattle Diseases.

   Journal of Dairy, Veterinary & Animal Research, 1(2).

10. Chander, M. (2010). Chaff cutters and fodder chaffing: a simple technology worth adoption In: Makkar, H. P. S (Ed) Successes and failures with animal nutrition practices and technologies in developing countries. *FAO Electronic Conference*. Roma, Italy: FAO Animal Production and Health.

11. Central Statistical Agency and the World Bank, (2011-12). Living standards measurement study–Integrated surveys on agriculture (LSMS-ISA. *Ethiopia Rural Socioeconomic Survey (ERSS).*

12. Du D D, Wang J. (2016). A review research on mechanics properties of crop stalks. Int J Agric & Biol Eng,; 9(6): pp 10—19.

13. Chevanan, N., Womac, A. R., Bitra, V. S., Yoder, D. C., & Sokhansanj, S. (2010). Flowability parameters for chopped switchgrass, wheat straw and corn stover. *Powder Technology*, *193*(1), 79–86.

14. Ebunilo p. O., o. A. (2010). Design and preliminary testing of a hammer mill with end-suction lift capability suitable for commercial processing of grains and solid minerals in nigeria. *International Journal of Engineering Science and Technology*, 1581-1593 .

15. Elfatih A. Arif, E. & Atef, A (2010). Evaluate the modified chopper for rice straw composting j applied sci 1125-1131

16. El-Haddad, W. Z. (2010). Developing and maximizing the performance of local threshing machine for small holding to suit chopping and shredding crops residues. Misr Journal of Agricultural Engineering, 27(4), 1588–1608

17. El-Khateeb, H.; Khodier, M. and Soliman, A. A. (2010). Performance of rice straw chopper and environment preservation. Misr J. Agric. Eng., 27(4): 1572- 1587.

18. Gizaw,S., Ebro, A., Tesfaye, Y., Mekuriaw, Z., Mekasha, Y., Hoekstra, D., Gebremedhin, B. and Tegegne, A. (2017). Feed resources in the highlands of Ethiopia: A value chain assessment and intervention options. LIVES Working Paper 27. Nairobi, Kenya: International LivestockResearch Institute (ILRI).

19. Heuzé V., Tran G., Nozière P., Bastianelli D., Lebas F., (2021). Straws. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/60 Last updated on March 26, 2021, 8:56

20. Hesham, A. Y. (2015). Redesign and Manufacture an Impact Crusher Hammer Mill Using Advanced Iron Casting. *Global journal of advanced research. Vol-2, Issue-7*, PP. 1196-1209.

21. Ibrahim, M., Ahmed, M., Habou, D., Misbahu, A., & Peter Mu'ar, K. (2017). Improvement on the Design, Construction and Testing of Hammer Mill. *American Journal of Engineering Research (AJER), Volume-6*(Issue-3), 139–146.

22. Ismail, Z., El-Banna, E., Ibrahim, M., & Shalaby, M. (2007). Evaluation of wheat straw chopping performance using a developed conical rotor. *Journal of Soil Sciences and Agricultural Engineering, pp.* 7333–7345.

23. J.N. Nwakaire, b. U. (2011). Design, construction and performance analysis of a maize thresher for rural dweller. *Nigerian Journal of Technology*, PP: 50-54.

24. Jenny Gustavsson, C. C. (2013). *The methodology of the FAO study: "Global Food Losses and Food Waste - extent, causes and prevention.* SIK - The Swedish Institute for Food and Biotechnology.

25. Jibrin M. U., A. M. (2013). Design and Development of a Crop Residue Crushing Machine. *International Journal of Engineering Inventions*, PP: 28-34.

26. K. S. Zakiuddin, J. P. (2010). Formulation of Data Based Ann Model for the Human Powered Fodder-Chopper. *Journal of Theoretical and Applied Information Technology, Volume 15, Issue 2*, Page104-108.

27. Karunya, M., Gowthami, E., Reddy, K.V.S.R., Pavani, I.S. (2015). Performance Studies On Power Operated Chaff Cutter With Paragrass Brachiariamutica.

28. Kassahun Gurmessa1, 2. T. (2016). Production and Utilization of Crop Residues in Horro and Guduru Districts, Western Ethiopia . *ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online)* , 77-84.

29. Kebede G, Ababa A, Feyissa F , Assefa G (2017). Review on Major Feed Resources in Ethiopia : Conditions, Challenges and Opportunities. Academic Research Journal of Agricultural Science and Research 5(3):176- 185.

30. Kiggundu M, Kato H, Komakech J and Mugerwa S, 2018. Design and performance evaluation of a NARO forage chopper prototype for smallholder dairying systems. International Research Journal of Engineering and Technology (IRJET).

31. Mady, M. A., Abdel-Hadi, M. A., Abd-Allah, Y. E., & Ali, M. F. (2015). A study on some engineering parameters of cutting and chopping machine for agricultural wastes. *Misr Journal of Agricultural Engineering*, *32*(4), 1775–1800.

32. Makkar, R., Aalam, B. E., Jain, M., & Wani, A. (2020). A Review of Cost Analysis Study of Farm Tractor. *International Journal of Current Microbiology and Applied Sciences*, *9*(3), 2914–2921.

33. M. V. Gudadhe, J. P. (2015). Design of Experimentation for the Formulation of an Approximate Experimental Model for HPFM driven Kadba Cutter,.

34. Moharrery, A., 2010. Effect of Particle Size of Forage in the Dairy Ration on Feed Intake, Production Parameters and Quantification of Manure Index 23, pp. 483–490

35. Moiceanu g, Gheorghe v, Paraschiv g, ion c.p. and Maican p (2012). Physical Characteristics of Miscanthus Plant and Power Demand at Grinding Process. Engineering for Rural Development Jelgava 24, pp 222.

36. Tegegne, A., & Feye, G. (2020). Study of Selected Livestock Innovations in Ethiopia. *SSRN Electronic Journal. Published.*

37. Tesfaye, A. C. (2007). Management and feeding systems of crop residues: the experience of East Shoa Zone, Ethiopia. Livestock Research for Rural Development. *Volume 19, Article #31.*

38. Thakur, R. (2019). Design & Fabrication of Portable Waste Shredder Machine for Domestic Compost. *International Journal for Research in Applied Science and Engineering Technology*, *7*(5), 1501–1504.

39. Zakiuddin, K.S. & Modak, J.P. (2010). Application of pedal operated flywheel motor as an energy source for fodder chopper.

40. Zhang, W. C. (2016). Physical and mechanical properties of modified wheat straw-filled polyethylene composites. *BioRes*, pp. 4472-4484.

41. Zhang, A. Yaning G. (2012). Physical Properties of Wheat Straw Varieties Cultivated Under Different Climatic and Soil Conditions in Three Continents. *American Journal of Engineering and Applied Sciences*, pp. 98-106.

42. Walli T.K, Garg M.R. and Makka H.P.S. (2012). Crop Residue Based Densified Total Mixed Ration. ISBN 978-92-5-107232-5. Food and Agricultural Organization of the United Nations 2002 Publication, pp

43. Worku Biweta and Solomon Tekeste.(2012). A Design Study of a Motor Driven Chopper for Chopping Crop Residue and Hay. The Journal of Mechanical Engineering, Vol. V, No. 3, 20122

APPENDIX

Appendix A. Fabrication process of the grinder machine.

Figure 1. Cutting of parts with its corresponding dimensions

Figure 2.Part welding and surface grinding

Figure 3. Welding of housing

Figure 4. Partial assembling of the machine on the frame

Figure 5. Weighing and tagging of cutter blade

Figure 6. Modification and fixing of the outlet of the machine

Figure 7. Pretest of the machine in order to check defects

Figure 8. Pretest and checking the condition of the output product

Figure 9. Painting machine parts separately

Figure 10. Assembling of the machine

Figure 11. Surveying the condition of the straw in the field

Figure 12. Gathering of straws for testing of the machine

Figure 13. Evaluating the performance of the machine

Figure 14. Checking of the conditions of the blades during evaluation

Figure 15. Straw sample after and before grinded

Figure 16. Sample taken to evaluate its parameter

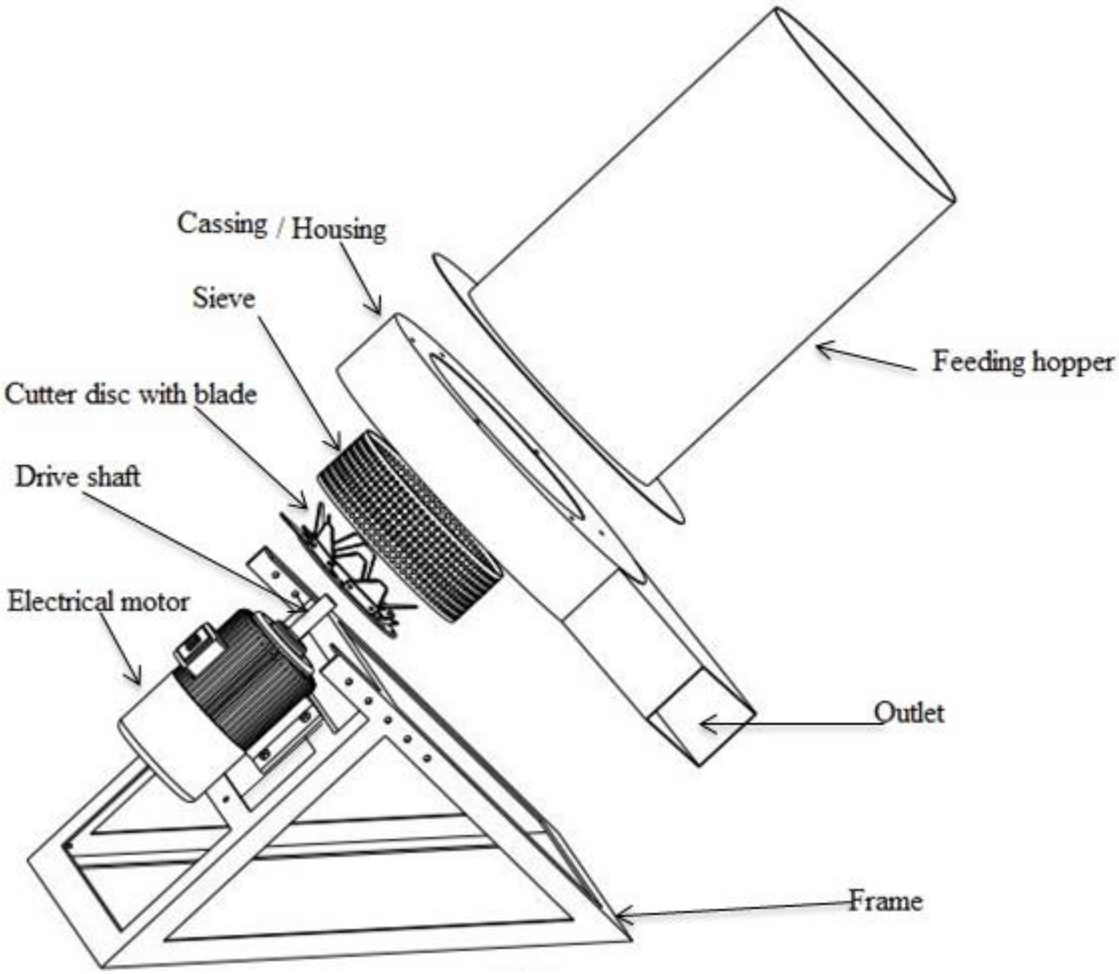


Figure 17. Explicit view of feed grinder machine

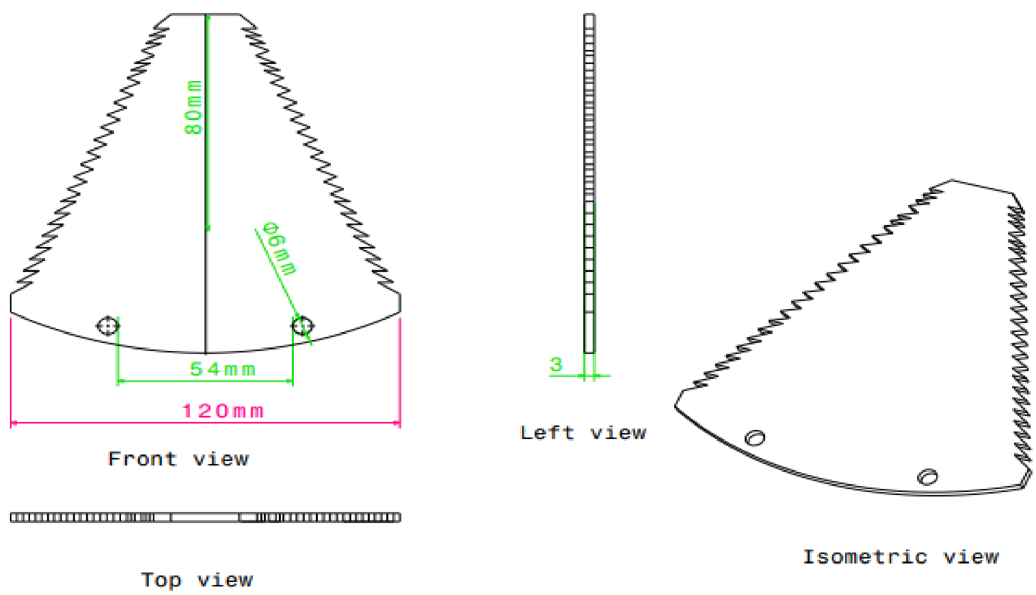


Figure 18. Detail view of the cutter blade

Appendix B: Production and operational cost

Table 1. Material cost for fabrications of grinding machine

No.	Materials list	Standard size	Quantity	Rate	Total price
1	Electrical motor	3.5 kW	1	10,500	10,500
2	Sheet metal 3 mm thick	$700x700\text{-}\pi 210^2$	336,639 mm^2	791	791.10
3	Sheet metal 5 mm thick	700 x 700	490,000 mm^2	1372	1372
4	Sheet metal 1 mm thick	1350 x 850 mm	1147500 mm^2	1090.28	1090.28
5	Sheet metal 2 mm thick	$600x600\text{-}\pi 210^2$	214853 mm^2	408.22	408.22
6	Sheet metal 2 mm thick	600x600 mm	360000 mm^2	684	684.00
7	Angle iron 5 mm thick	6000mm	1	2500	2500.00
8	Mild steel round	Ø50 mm x 50mm	1	97	97.00
9	Brass bearing	Ø50 mm x 20mm	1	150	150.00
10	Bolt and nut	M-12 x 50	12 Pcs	30	360.00
11	Bolt and nut	M- 14 x 100	4 Pcs	50	200.00
12	Bolt and nut	M- 6 x 20	46 pc	9	414.00
13	Electrodes	Ø3.2	2 package	345	690.00
14	Paint		2 liter	200	300.00
				Subtotal	19,557

Table 2. Machine and technical person cost for fabrication of the machine

No	Type of machine	Machine cost/hrs.	Working hours	Total cost	Labor cost/hrs	Working hrs.	Total cost
1	Lathe machine	200	2:00	400	62.5	2:00	125.00
2	Grinding machine	20	4:00	80	30.00	4:00	120.00
3	Universal cutter	150	1:00	150	50.00	1:00	50.00
4	Welding machine	50	4:00	200	30.00	4:00	120.00
5	Rolling machine	30	1:00	30	30.00	1:00	30.00
8	Drilling machine	40	2:00	80	30	2:00	60.00
9	Compressor	70	2:00	140	50	2:00	100
	Subtotal			1080		Subtotal	605
Total machine and labor cost							1685 ETB

Table 3. Cost summary

No.	Cost variables	Cost
A	Raw materials cost	**21,242**
B	Material wastages (2.5%)	531.04
C	Machine cost	1080
D	Technical person cost	605
E	Overhead cost 5% (C+D)	84.25
F	Profit 10% (A+B+C+D+E)	2354.23
G	Selling tax 15% (A+B+C+D+E+F)	3884.47
Selling price		29,781

Appendix C: Performance test data sheet

Table 4. Test data for 10 mm sieve diameter for the standard blade

Feed	Testing on midday (moisture was 13.22 wet basis)			Testing early morning (moisture was 24.63 wet basis)		
	Ending time(sec)	Time in hr	Capacity kg/hr	Ending time	Time in hr	Capacity kg/hr
2.5	34	0.0094	264.71	47	0.0131	191.49
	39	0.0108	230.77	47	0.0131	191.49
	39	0.0108	230.77	46	0.0128	195.65
Aver	37.33	-	242.08	-	-	192.87
5	73	0.0203	246.57	93	0.02588	193.55
	77	0.0214	233.76	101	0.0281	178.22
	85	0.0236	211.76	109	0.0303	165.14
Aver	78.33	-	230.70	-	-	178.97
7.5	132	0.0367	204.54	153	0.0425	176.47
	141	0.0392	191.49	159	0.0442	169.81
	148	0.0411	191.49	167	0.0464	161.67
Aver	140.33	-	195.85	-	-	169.32

Table 5.Test data for 12 mm sieve diameter for the standard blade

Feed	Testing on midday moisture was 13.22 wet basis			Testing early morning moisture was 24.63 wet basis		
	Ending time	time in hr	Capacity kg/hr	Endin g time	Time in hr	Capacity kg/hr
2.5	28	0.0078	321.43	37	0.0103	243.24
	31	0.0087	290.323	41	0.0114	219.51
	35	0.0098	257.143	44	0.01224	204.54
Aver	-	-	289.633	-	-	222.431
5	62	0.0173	290.323	77	0.0214	233.77
	67	0.0187	268.66	81	0.0225	222.22
	71	0.0198	253.526	88	0.0244	204.54
Aver	-	-	270.836	-	-	220.18
7.5	115	0.0320	234.786	142	0.0394	190.148
	127	0.0353	212.60	161	0.0447	167.708
	138	0.0383	212.60	173	0.0480	156.07
Aver	-	-	219.00	-	-	171.307

Table 6. Test data for 10 mm sieve diameter for the local manufactured blade

Feed	Testing on midday moisture was 13.22 wet basis			Testing early morning moisture was 24.63 wet basis		
	Ending time	time in hr	Capacity	Ending time	Time in hr	Capacity kg/hr
2.5	62	0.0172	145.16	81	0.0225	111.11
	67	0.0186	134.33	89	0.0247	101.12
	71	0.0197	126.76	93	0.0258	96.77
Aver	-	-	135.42	-	-	103.00
5	142	0.0394	126.76	188	0.0522	95.74
	148	0.0411	121.62	192	0.0533	93.75
	159	0.0442	113.21	201	0.0558	89.55
Aver	-	-	120.53		-	93.02
7.5	297	0.0825	90.91	341	0.0947	79.18
	315	0.0875	85.711	354	0.0983	76.278
	329	0.0914	82.07	373	0.1036	72.39
Aver	-	-	86.23	-	-	75.95

Table 7. Test data for 12 mm sieve diameter for the local manufactured blade

Feed	Testing on midday moisture was 13.22 wet basis			Testing early morning moisture was 24.63 wet basis		
	Ending time	time in hr	Capacity	Ending time	Time in hr	Capacity kg/hr
2.5	50	0.0139	180	65	0.0181	138.46
	55	0.0153	163.64	69	0.0192	130.43
	53	0.0147	169.81	74	0.0206	121.62
Aver	52.67	-	171.15	-	-	130.17
5	132	0.0367	136.36	171	0.0475	105.26
	134	0.0372	134.338	177	0.0492	101.69
	138	0.0383	130.43	181	0.0503	99.45
Aver	134.67	-	133.71	-	-	102.14
7.5	280	0.0777	96.43	322	0.0894	83.85
	295	0.0819	91.52	331	0.0919	81.57
	302	0.0839	91.52	339	0.0942	79.65
Aver	292.33	-	93.16	-	-	81.69

Table 8. Feed lose and grinding efficiency test result for 10 mm sieve diameter

Feed lose and grinding efficiency test result for 10 mm sieve diameter				
Treatment	Mass before grinding (kg)	Mass after grinding (kg)	Percentage lose (%)	Grinding efficiency (%)
2.5 kg	2.5	2.2	12	88
2.5 kg	2.5	2.3	8	92
2.5 kg	2.5	2.4	4	96
Average	2.5	2.3	8	92
5 kg	5	4.3	14	86
5 kg	5	4.7	6	94
5 kg	5	4.6	8	92
Average	5	4.53	9.33	90.6
7.5 kg	7.5	7	6.67	93.33
7.5 kg	7.5	7.1	5.33	94.67
7.5 kg	7.5	6.9	8	92
Average	7.5	7	6.67	93.33

Table 9. Feed lose and grinding efficiency test result for 12 mm sieve diameter

Feed lose and grinding efficiency test result for 12 mm sieve diameter				
Treatment	Mass before grinding (kg)	Mass after grinding (kg)	Percentage lose (%)	Grinding efficiency (%)
2.5 kg	2.5	2.3	8	92
2.5 kg	2.5	2.3	8	92
2.5 kg	2.5	2.4	4	96
Average	2.5	2.33	6.67	93.2
5 kg	5	4.4	12	88
5 kg	5	4.7	6	94
5 kg	5	4.8	4	96
Average	5	4.63	7.33	92.6
7.5 kg	7.5	7.2	4	96
7.5 kg	7.5	7.1	5.33	94.67
7.5 kg	7.5	7.2	4	96
Average	7.5	7.17	4.44	95.6

Table 10. Effect of feed on the output capacity

Multiple Comparisons

Dependent Variable: Capacity (kg/hr)

Tukey HSD

(I) Feeds	(J) Feeds	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2.5	5.0	17.086625	17.569930	.597	-24.99884	59.17209
	7.5	49.158958*	17.569930	.018	7.07349	91.24442
5.0	2.5	-17.086625	17.569930	.597	-59.17209	24.99884
	7.5	32.072333	17.569930	.169	-10.01313	74.15780
7.5	2.5	-49.158958*	17.569930	.018	-91.24442	-7.07349
	5.0	-32.072333	17.569930	.169	-74.15780	10.01313

*. The mean difference is significant at the 0.05 level.

Table 11. ANOVA analysis for different test parameter

12

SUMMARY	Count	Sum	Average	Variance
2.5 kg	8	1486.76	185.845	4006.183
5 kg	8	1350.1	168.7625	4389.759
7.5 kg	8	1103.521	137.9401	3658.173
13% 10mm STD	3	668.621	222.8737	580.4499
25% 10mm STD	3	541.16	180.3867	140.2949
13% 12mm STD	3	790.46	263.4867	929.3776
25% 12mm STD	3	613.91	204.6367	834.7656
13% 10mm LCL	3	342.18	114.06	636.3097
25% 10mm LCL	3	272.02	90.67333	186.3801
13% 12mm LCL	3	398.02	132.6733	1521.416
15% 12mm LCL	3	314.01	104.67	592.75

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	9431.220415	2	4715.61	46.74649	6.36E-07	3.738892
Columns	82966.53903	7	11852.36	117.4941	2.4E-11	2.764199
Error	1412.267519	14	100.8763			
Total	93810.02697	23				

Appendix D. Costs calculation

Depreciation

Depreciation is calculated with the following formula

$D = \frac{C-S}{L}$

D = Depreciation per hour (ETB.),

C = Capital investment cost (ETB), = 29,781

S = Salvage value, assume 10% (29,781) = 2,978

L = Life of the machine in years, assume it will use for the next 15 years

$D = \frac{29781-2978}{15}$

$\underline{D= 1786.8}$

Interest

Interest is calculated as

$$I = \frac{C \times S}{15} \times \frac{i}{H}$$

$$I = \frac{(29781 - 2978) * 0.1}{15}$$

$$\underline{I = 178.68}$$

Housing, Taxes, Interest and Insurance 297.87

Housing cost per hour (ETB.) = 1%(29,781) = 297.81

Taxes cost (ETB.) = 1% of the initial cost of the machine 1 %(29,781) = 297.81

Insurance cost (ETB.) =1% of the initial cost of the machine 1 %(29,781) = 297.81

Repair and maintenance cost

RMc = 2.5 % × capital investment per year (2.5 % x 29,781) = 744.52