# DESIGN, ANALYSIS & MANUFACTURE OF A SAFE LOW COST CHAFF CUTTER

A Final Year Project Report

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**SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING**

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In Partial Fulfillment
of the Requirements for the Degree of
Bachelors of Mechanical Engineering

by

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# ABSTRACT

Rising human injuries owing to unsafe Chaff Cutters among farmers is an increasing concern in Pakistan. Chaff cutters are the leading cause of agricultural injuries (50-65%). Injuries are mostly the upper limb amputations. Victims usually are the young people leaving them unable to work. The main reason is the non-existence of any kind of safety mechanism in the locally available chaff cutters. Designing and manufacturing of a chaff cutter that meets the requirements of safety and capacity while keeping it affordable for the local people is the requirement not only on the humanitarian basis but it also targets a vacuum in the local industry. The purpose of this project is to design a chaff cutter of required capacity, equipped with a safety mechanism and within affordability range of the locals. A Chaff cutter is a mechanical device used to chop forage into small pieces of desired size before for livestock and Cattles. Using Market surveys and literature review, this study analyzed the existing chaff cutters, the threat they are to the safety of their operator and the problems faced by their operator. After that we proposed a new improved design to overcome these challenges. A detailed description of material selection for blades, fodder roller, frame, casings, as per International standards is also included for ensuring a sustainable and reliable operation of hay or straw cutting along with optimum efficiency and longevity. New methods were developed to design and manufacture a safe low-cost Chaff cutter of the capacity competitive to the ones already in use and using low-cost alternatives for the mechanical systems. Chaff cutter was modelled and analyzed using a CAD software by taking trails to amend the detected errors.



***Keywords:*** *chaff cutter, human injuries, fodder, compact design, safe, low cost.*

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# ORIGINALITY REPORT

Chaff Cutter - FYP

ORIGINALITY REPORT

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## ABBREVIATIONS

| | |
|---|---|
| CAD | COMPUTER AIDED DESIGN |
| GDP | GROSS DOMESTIC PRODUCT |
| IFCN | INTERNATIONAL FARM COMPARISON NETWORK |
| HPFM | HUMAN POWERED FLYWHEEL MOTOR (HPFM) |
| RPM | REVOLUTION PER MINUTE |
| HRC | HARDNESS, ROCKWELL, C SCALE |
| FR | FEED ROLLERS: |
| FH | FEED HOPPER: |
| FEA | FINITE ELEMENT ANALYSIS |
| FCR | FODDER CUTTING MACHINE |
| MP | MOTOR POWERED |
| HPFM | HUMAN POWERED FLYWHEEL MOTOR |
| AFEM | ARECA FIBER EXTRACTION MACHINE |
| FOFM | PEDAL OPERATED FLYWHEEL MOTOR |
| STM | SWARAJ TOKA MACHINE |
| MPCC | MOTOR POWERED CHAFF CUTTER |

## NOMENCLATURE

| | |
|---|---|
| RPM | Revolutions per minute |
| $\tau$ | Yield Strength |
| $T_{max}$ | Torque shaft can sustain |
| FOS | Factor of safety |
| C | Center to center distance between pulleys |
| $D_1$ | Pulley 1 diameter |
| $D_2$ | Pulley 2 diameter |
| GS | Galvanized Steel |

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# CHAPTER 1: INTRODUCTION

## 1.1 MOTIVATION

A Chaff cutter is a mechanical device used to chop forage into small pieces of desired size for livestock and Cattle.

Pakistan is basically an agricultural country based on the individuals work in this area and the proportion of agricultural products it distributes around the world. The natural resource base of Pakistan is quite large and has a great worth which covers different environmental and climatic zones. Thus, the potential for producing various kind of agricultural products is present in Pakistan. Economic growth of Pakistan has drastically affected by agriculture. (CORPORATION, n.d.) Around 27 percent of the total area of Pakistan is under cultivation. Area under cultivation is only 22.51 million hectares of Pakistan's total area which is 79.6 million hectares. Provincial wise the Punjab which is the biggest and cultivated province of Pakistan covers 13.01 million hectares land, while Sindh and Khyber Pakhtunkhwa provinces have 7 and 1.09 M hectares, respectively. On the other hand, Baluchistan which is an arid desert and mountainous has only 0.49 M hectares. Agricultural sector has been remained an essential and vital part of Pakistan's economy for the last many decades. Agriculture accounts for 21% of Pakistan's total GDP. 41% of the total labor force is being employed by agriculture and is an important sector of Pakistan's economy. Almost three-quarter of the country's population is being supported by this sector. Agriculture plays an important role in generating overall economic growth, ensuring food security, reducing poverty by employing 50 percent of the labor force to bear their expenses, move the country towards industrialization and come up with the biggest share of foreign exchange earnings. Various businesses are associated with agriculture sector, for instance, sugar production, vegetable farming, livestock and fish farming and many more. (Ajaz, n.d.)

During 2012-2013, the contribution of livestock to agriculture value added was 55.5 percent, while to the national GDP it was around 11.8 percent. However, these figures rose steadily to 55.9% and 11.8% in the following period between 2013 and 2014. Cattle, sheep, buffalo, camel, goat, mules and horses come in the livestock category these live stocks not only produce milk and meat but also provide wool, hair and fats. However, the major products among mentioned are milk and meat. (Sheep and Goats, n.d.)

More than three-quarter of the country's population has a land of less than 5 acres. Those land lords may earn a good amount of money from dairy farming. Livestock has an important role since two to three cattle or buffaloes and five to six goats or sheep are being raised by around 35 million people in their homes and these contribute about 20 to 25 % of their total income.

According to IFCN dairy report 2014, Pakistan is the 3$^{rd}$ largest milk producing country around the globe in terms of the total tradable while milk. Main milk producing animals in Pakistan are cattle and buffaloes however, many other animals can also produce milk like camel, sheep and goat etc. More than 61% of the total milk produced in Pakistan is being produced by buffaloes which constitutes 47% of the national population of dairy animals in Pakistan. However, cattle on the other hand, produces 35% of the total milk. Both buffaloes and cattle contribute more than 96% to the tradable white milk produced in the country. In the last decades the total population of the livestock has increased drastically from 113 million (1998-1999) to 125 million (2002-2003) which accounts for a total increase of 12 million per year. According to economic survey of Pakistan livestock sector the cattle's population in Pakistan was around 170 million in the period of 2013-2014. Animal feeding plays a crucial role in increasing livestock growth.

Feeding animals is one the most important factors in animal husbandry. Cutting fodder into little piece would ease or aid in providing suitable fodder for livestock. People living in the rural areas of Pakistan usually have one or more cows, buffaloes and sheep in order to meet milk requirements and earn some money. Feeding fodder to animals greatly affect the production of milk. In some areas Pakistan people feed their animal by giving fodder whiteout cutting down into small pieces. Which ultimately affect animal digestion system and wastage of crops and fodder. In order to ensure complete consumption of fodder, fodder must be cut down into little piece with aid of any cutting device. By doing so, animal will eat more efficiently.

A Chaff cutter is a mechanical device used to chop hay or straw into small pieces of desired size before being mixed with other forage for livestock and Cattles. Figure 1 depicted the manual operated or human operated chaff cutter which was used to chop hey or straw into little pieces. These kind of chaff cutters needs either human power or animal power in excess amount to be operated owing to which it was quite laborious and needs lots of time. These Chaff cutters need physical efforts to be operated. Livestock population has increased significantly over the last decades. Electric motor operated machineries were of utmost importance for an increased production and less physical efforts and this reason led to revolution in machineries and thus motor operated Chaff cutters introduced in the market.

Figure 1-a: Manual operated fodder cutter

Figure 1-b:Motor operated fodder cutter

**1.2. PROBLEM STATEMENT**

Motor operated Chaff cutters facilitated the human and helped in increased production of fodder. However, this led to many injuries in farmers owing to no safety mechanism in existing Chaff cutters. With the introduction of motors in Chaff cutters not only the proportion of injuries has increased significantly but also percentage of death grew drastically. RPMs of motor driven chaff cutters are almost 10 times the RPMs of hand driven ones thus reducing the reaction time to stop the blade by 10 times. Almost all are still stopped by manually cutting off the power and have no safety mechanism for prevention of contact. During the period of only 15 months 73 patients were reported with injuries owing to motor operated Chaff cutters in Jinnah hospital Lahore. Due to significant growth in injuries and deaths owing to existing Chaff Cutters, it is considered as life taking or one of the most dangerous machines in Pakistan.

The problem we identified behind such huge number of chaff cutter injuries is that at first the local chaff cutters do not have any kind of safety or preventive features. Secondly, the relatively safer options available in the market are too costly due to being imported and thus are out of the affordability range of the locals. So, the reason behind the local people not buying the safer chaff cutters is the non-availability and high cost of the imported ones available.

## 1.3. SUMMARY:

- There is no safety mechanism in the locally made chaff cutters and have an exposed blade. Even these unsafe chaff cutters when assembled by local industry has an unjustifiable cost.
- The imported chaff cutters are too costly and not easily available either.

So, our problem statement is

***"Our goal is to design a chaff cutter of required capacity, equipped with a safety mechanism and within affordability range of the locals."***

## 1.4. OBJECTIVE:

The main objective of this study includes:

**1)** Designing and development of a compact sized and safe Chaff cutting machine.
**2)** Keeping the machine low cost, ensuring safety of the operator.
**3)** Making the machine with the operational capacity competitive to the market.
**4)** Ensuring our machine will not fail; Static stress, fatigue, buckling and other analysis.
**5)** Performance evaluation and economic feasibility of newly developed machine.
**6)** Providing a detailed manufacturing plan for the machine

# CHAPTER 2: LITERATURE REVIEW

Chaff cutting systems have interested researchers for a long time. In this section some of the prominent works that lead to the development of fodder cutting system have been discussed. The research has been arranged in a chronological order starting from simple Manual operated chaff cutters and simple Motor operated and gradually reaching single phase motor operated chaff cutters.

## 2.1 BRIEF OVERVIEW OF CHAFF CUTTER RESEARCH:

Chaff cutters have been in use since ancient times but the biggest drawbacks of using chaff cutters for forage cutting was their low efficiency and production rate. But in the past few decades, with improvement in technology, chaff cutter performance has improved drastically. Literature is available on this topic but for brevity some extensive reviews are cited here. (Bandiwadekar et al., 2016) performed a review on design and development of cutting machine. (Singh et al., 2017) presented a review on mechanism and various applications of human powered flywheel motor. (Khodke et al., 2018) summarized and reviewed technological development and performance to make grass cutting machine more efficient and cost effective.

### 2.1.1 Modernization in Chaff Cutters:

The study regarding modernization of machines has been carried out by (C. et al., 2011). Increasing demand for meat and milk in the people around globe has led to the urge of growing its production described by authors. Further, the issue of providing suitable fodder to animals or livestock is mainly faced by local farmer usually in the winter season. Main sources are the hay or straw and maize for the fodder which are usually extracted from Paddy Rice however its quality has been compromised. Providing farmers with suitable and better-quality forage is one the main problems. Manually operated chaff cutters need more human or animal power and consume more time. Owing to which many local farmers feed livestock by providing forage without cutting into small pieces in form of crops which ultimately led to around 15 to 20% wastage of fodder. To avoid wastage of fodder and tackle these challenges, the Power Straw and Fodder Chopper (PSFC) was developed and manufactured.

### 2.1.2. Injuries due to Local Chaff Cutters

Even though this machine aids in cutting forage into little pieces however, due no safety mechanism it leads to many injuries among the users. These injuries were mostly cutting of arms, limb and fingers. The following table shows the ***breakdown of agricultural injuries caused by different machines. Table (a)***

Table 1. Injuries due to Local Chaff Cutters

| | |
|---|---|
| Chaff Cutter | 45 (65%) |
| Rotavater | 6 (8.7%) |
| Thresher | 6 (8.7%) |
| Sugarcane Juice extractor | 3 (4.3%) |
| Maize Thresher | 3 (4.3%) |
| Tractor | 3 (4.3%) |
| Harrow blade | 3 (4.3%) |

*Sample 69,* (Faisal et al., 2015)

"Total number of cases in period under study was 69. There were 63 (91.3%) male and 6 (8.9%) female (Ratio 10.56:1). Mean age was calculated to be 24.4 years. Forty-five (65%) cases were due to Fodder chopper (Toka)"

Table 2 Types of injuries by chaff cutters

| **Site of injury** | **Total** |
|---|---|
| Right Upper limb | 125 (63.7%) |
| Left upper limb | 25 (12.7%) |
| Right lower limb | 18 (9.18%) |
| Left lower limb | 12 (6.12%) |
| Head and neck | 13 (6.6%) |
| Groin | 3 (1.53%) |

*Sample :196* **Pattern of Fodder Cutting** (Faisal et al., 2015)

This table shows the types of injuries chaff cutters are causing in Pakistan. Right upper limb constitutes about 63.7% of the total followed by left upper limb (12.7%), right lower limb (9.18%), left lower limb (6.12%), Head and neck (6.6%) and groin (1.53%). So, it is clear that right upper limb is the most commonly affected part.

A study published in the Journal of Pakistan Orthopaedic Association evaluated the **severity of the upper limb injuries** due to fodder cutter machines in southern Punjab.

The results of the study are:

"

- No patient affected by hand driven Toka machine was received.
- In this study 73 patients affected by power-driven Toka machine injury were received during these 15 months period. Out of these 32 were male and 41 were females. Fifty-six patients were below the age of 30 years, and 17 patients were above 30 years.

- All patients sustained injuries to the upper limbs. Left limb was involved in 28 (38%) patients and right upper limb was involved in 41 (56%) patients and 4(5%) patients have bilateral upper limb injuries.
- According to severity of injuries 24 (32%) patients having digits level injuries, 22(30%) patients having palm level injuries including wrist, 15 (20%) patients have distal forearm injuries, 11(15%) patients have proximal forearm injuries and 03 (4%) patients having injuries in the arm.

"

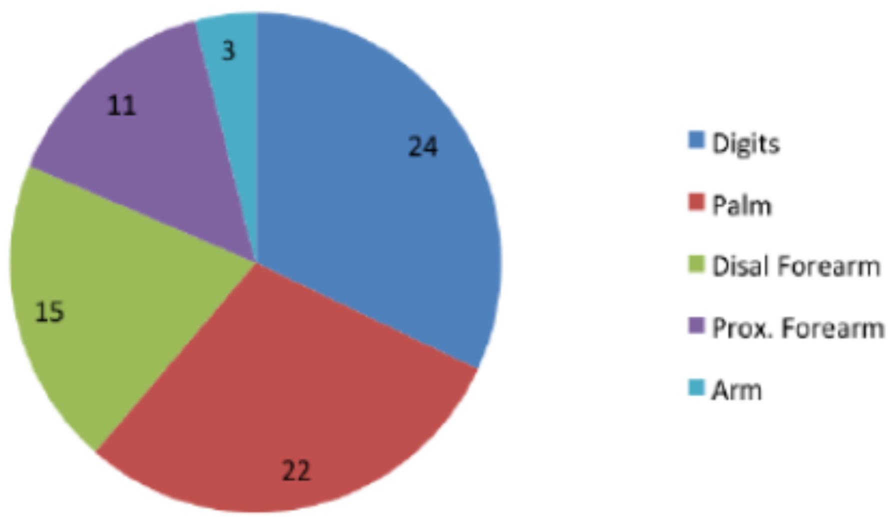


Figure 2(a)- Pie chart showing injuries

Upon studying the types of injuries caused by chaff cutters we observed that most of these injuries are of upper limb and among them the major portion is of the upper right limb and the second one being the left upper limb.

So, the affectees are left with their working arm harmed or amputated. The study of the severity of injuries Chaff cutters have inflicted from the data published by Pakistan Orthopedic Journal, we noticed that most of these injuries are amputations ranging from forearm to digit level injuries. Even the digit level ones leave the operator unable to work properly. So, chaff cutters are harming the working arms of the people who only know to work with their arms, and thus have a major impact on their livelihoods and working capacity.

### 2.1.3. Market Survey

We conducted a market survey of the existing chaff cutters in Pakistan to get an idea of the machines available in the market which are causing these problems. We found out that only the open-wheel type Chaff cutters are being manufactured Pakistan which are available in both hand operated and motor operated versions. These have an exposed blade and lack any kind of safety features. There are relatively safer options available in the market but the problem with them is first they are not available in most of the rural areas or even the towns nearby and even if available they're not affordable for them.

Upon checking the chaff cutters available online, we found some of the options and their prices as listed below. Even the simple manual driven chaff cutter is costing Rs.20,000 and the same chaff cutter **driven by motor costs Rs.32,000**. This is only the price of the open wheel chaff cutter. The relatively safer options available in the market which are **imported are costing from Rs.50,000 to Rs.200,000** depending upon their capacity.

Figure 2(b): Local Chaff cutter

Figure 2-c: Imported Chaff Cutter

## 2.2. OVERVIEW OF HUMAN POWERED FLYWHEEL MOTOR (HPFM):

A detailed design of experimental set up for establishing empirical relationship of forage cutting phenomena for chaff cutter energized by human powered flywheel motor has been proposed by (P.B.Khope, 2013). This system is quite practicable for pumping using flywheel's muscular energy and stored energy in flywheel can be used for various applications. Thus, establishing empirical relations for human powered chaff cutters was decided by using the mentioned concept. Developing these kinds of machines using complete theoretical method is far more challenging and unpredictable, therefore, experimental methodology was implemented. There are three main subsystems of this experimental set up. (i) Human powered flywheel motor (HPFM) in other words energy unit. (ii) Torques amplification gears and clutch. (iii) Chaff cutter i.e., process unit. A detailed design of experimental set up which can be used to perform various experiments in order to establish experimental formulation of forage cutting phenomenon for Chaff cutter which is energized by HPFM. Forage can be cut down into little pieces by using this cutter and resulted fodder was meant to be eaten up by livestock. It is proposed that the energy can be stored in the flywheel by using paddling system which converts and transmit human energy into it by using bicycle mechanism. Cutting of forage is energized by the rotational kinetic energy stored in the flywheel. The speed of flywheel which was observed in the result of 1 minute paddling and using a gear ratio of 1:2 was 350 RPM. After 1 minute of paddling the driver stopped further driving it. It was observed that flywheel shaft stopped or came to rest after 25 minutes of free running.

### 2.2.1. OVERVIEW OF CHOPPING MACHINE:

A project on "Methodology for Design & Fabrication of Portable Organic Waste Chopping Machine" had been carried out by (Hande & Deshpande, 2014), in their research work. Firstly, tray and feeding was used for uniformly feeding of organic waste. Secondly, electric motor used to rotate shaft at a speed of 1440 rpm using pulleys as drive system which created impact shear using shearing blades and thus leading to cutting of organic waste by chopping drum. Due to effects of impact, tensile and friction in the cutting process organic waste was also cut inside the chopping house. Concave holes of the sieve served as exit of the cutter through small pieces of fodder come out.

### 2.2.2. OVERVIEW OF ARECA FIBER EXTRACTION MACHINE (AFEM):

A project on Fabrication of areca fiber extraction machine has been carried out by (Naik et al., 2014), in their research work. Areca husk has fiber which can be extract from it using this machine. Major components of this machine are motor which is an alternating current 3 phase 5 hours power (HP) motor, and drive shaft. Both motor and drive shaft are connected directly. Outer casing is used to cover the driven shaft. A rectangular duct which situated at the side of the driven shaft casing is served as storage for fiber to come out from it. Two bearing have been used to support the driven shaft it also has blades. Modifying the blade design of coconut husk decorticating machine resulted in the design of the blades which are on the drive shaft.

### 2.2.3. OVERVIEW OF PEDAL OPERATED FLYWHEEL MOTOR (POFM):

The study regarding pedal operated flywheel motor to serves as an energy source for forage cutter has been carried out by (Zakiuddin & Modak, 2010). Due to energy crisis in the developing countries, they felt the urge of developing pedal operated flywheel motor which can be used as an energy source for fodder cutting machine. Further, it is proposed that it is better to use-conventional energy as a source for powering forage cutting machine. People with less technical skills can easily use this machine according to authors. Manpower is used to drive the flywheel and maximum speed it can reach is 600 rpm. This study proposed a pedal operated flywheel motor which consists of shaft, gear and flywheel. However, the problem with this is that it is also man operated chaff cutter.

## 2.3 OVERVIEW OF MOTOR-POWERED CHAFF CUTTER (MPCC):

(Bandiwadekar et al., 2016) proposed a new design for cutting fodder into small piece this new design is much safer and need less efforts as compared to the conventionally available chaff cutters according to them. This machine is specially designed for small to medium based operation since the power supply is much lower than locally available machines and it is for those farmers who just only feed their livestock daily. A comparison was made between this new design and the traditional "Kadba kutti" machine dimension wise. It needs less energy and the power supply is single phase and is much safe since moving parts has been covered. Further, it is said that conventional cutting machines are prone to wear and tear owing old cutting technologies while this one need less or no sharpening of blades.

### 2.3.1. INJURIES RELATED TO MPCC

(Ch et al., n.d.) Conducted research in the southern Punjab Pakistan, on the injuries associated with the fodder cutter machine and determined whether male or female are more victim of such injuries. A total of 73 patients of both genders were examined over the duration of 15 months between Jan 2014 and March 2015. Female and children were more prone to Chaff cutter injuries and the proportion of it was 56%, while the proportion of men got injured was 41%. Further, 69 patients out of 73 were reported with an upper limb amputation, however, bilateral limb injuries were involved in only 4 patients. It is concluded that injuries related to Chaff cutters are common among the users among which females and children were more prone to such injuries along with males. A campaign on national level should be launched to spread awareness among the farmers regarding the danger associated with fodder cutter machine.

### 2.3.2. PROBLEMS IN MPCC:

Singh et al. (1997) conducted research on the problems related to chaff cutting machines and to make them more productive. Major issue with existing fodder cutters was to feed the forage in a small amount otherwise it will be discharged without being cut down into little piece which results in the wastage of fodder. If the feeding hay or straw is too large or small in amount, then the machine usually could not cut it properly and the forage needs to be forced into blades physically which put hands in danger and hands of the user become more prone to injuries. While the new modified fodder cutter is much faster and safer than the existing ones since there is no need to push straw or hay into machine manually. Another problem with conventional machine was to sharpen the blade again and again. For this it has to take out of the machine. Serrated blades were proposed for modified cutter owing to which it would last longer. New teeth can cut if old one get worn out. The proposed chaff cutter may have more capacity and require less power to be operated as compared to the existing ones. Inclined feeding channel could help in making feeding process automatic with less human efforts.

### 2.3.3 PERFORMANCE EVALUATION OF FODDER CUTTING MACHINES

The performance of fodder cutting machine was evaluated by Lazaro et al. (1990), using various parameters. Chaff cutter was designed, manufactured and its performance evaluated by considering pulleys of various diameters in terms of Chopping capacity(kg/hr), Throughput capacity(kg/hr), Chopping recovery (%), Machine efficiency (%) and Percent loss (%). Cutting capability and size of cut was significantly affected by pulley's diameter. Machine efficiency has increased drastically with increasing diameter of pulley the bigger the pulley the better the result and efficiency of cutting machine. Regarding throughput capacity and chopping it was observed that 5-inch diameter pulley resulted in highest capacity and speed as compared to 3- and 4-inches diameter pulleys. However, chopping recovery and percentage loss was the highest at 3-inch diameter pulley and has the slowest speed among the three pulleys. Further, in terms of Machine efficiency the highest efficiency was observed by using 5-inch diameter pulley and has the fastest speed among the three treatments. Length of cut of hay or straw is proportional to the machine's speed, to get forage of larger cut blades should be rotating at a lower rpm while for shorter length of cut it must rotate at higher speed. High speed resulted in low loss and suitable output. High efficiency and capacity could be obtained at higher speed.

### 2.3.4 OVERVIEW OF SWARAJ TOKA MACHINE (STM):

(Karunya et al., 2016) carried out study on "Swaraj Toka" to evaluate it and make a **power operated fodder** cutter machine using various machine speeds and types of blades for cutting para grass having different proportions of moisture content. The speeds under which "Swaraj Toka" was evaluated were 10, 12 and 14 cm/s. serrated edge and straight edge blades were used to evaluate the mentioned machine. Moisture content in hay or straw was 51.3%, 56.25% and 63.13%. Higher machine speed and moisture content of hay resulted in improved efficiency of chopping machine. At 14 cm/s machine speed and 63.13% moisture content the maximum efficiency 85.1% was observed both speed and moisture content were higher among all the three treatments. On the other hand, minimum machine efficiency was obtained at lower chaff cutter speed of 10 cm/s and lower hay's moisture content (51.3%). Regarding blade edge, efficiency was higher for serrated edge blade which was 85.1%, while straight edge blade witnessed a maximum efficiency of 66.4% which is 18.7% lower than the serrated edge blade. In terms of capacity, maximum was 471 kg/h whereas the lower capacity of the machine was 309 kg/h. For straight edge blade, maximum and minimum length of cuts were 2.24 cm and 1.84 at a moisture level of 51.36% and 63.13% respectively. In conclusion, high speed of fodder cutter, higher level of moisture of para grass and serrated edge blade could lead to a maximum cutter's efficiency however, there is an inverse relation between moisture level and forage cut. With serrated edge blade energy consumption of fodder cutter was lower (4.3 $kWhMg^{-1}$) and energy consumption was proportional to both machine speed and para grass's moisture content.

### 2.3.5. TESTING PROCEDURE FOR MPCC:

The procedures for testing **motor powered chaff cutter** has been discussed by (KANKAL et al., 2016) in their research. Assessment and measurement performance of the motor-powered fodder cutter was assessed at "Department of Farm Power and Machinery, Dr. PDKV, Akola. Further, Dairy and Animal Husbandry Department, PDKV, Akola" was used to taking test trail of the cutter. Two crops were used as forage i.e., ginni crop and dry Sorghum. It was concluded that ginni crop's feed rate was higher than dry Sorghum owing high level of moisture in ginni crop which also strengthen the statement made by (Karunya et al., 2016) that moisture content is proportional to higher feed rate. Similarly, quantity of cut was more for ginni crop and power consumption for it was found low. Energy consumed per unit quantity of cut was also higher for ginni crop than dry Sorghum. Moreover, machine's performance index observed to be less for dry Sorghum as compared to its counterpart. Overall, it was observed that higher level of moisture in crops lead to better performance of the chaff cutter.

## 2.4. SUMMARY

Through a review of the literature and previous studies on the chaff cutters it was found that there are problems related to design, power supply, safety, and cost. Such as previous chaff cutters have open flywheel, feeding channel and fodder roller which cause injuries to user's hands. Open flywheel chaff cutters can cause injuries even if it is not in operation. Usually, children play with it and harm themselves with blade's sharp edge. Further, Chaff cutters available in Pakistan's commercial market are open flywheel and are expensive.

It can be concluded from this literature review that large amount of recent work has been dedicated to the development of Chaff cutters and their optimization. These devices in particular can greatly decrease the size and cost of chaff cutters. The use of cylindrical blades in fodder cutters has also shown a lot of promise. Further, it is concluded that the modern trend in cutting technology is towards compact size. Compact sizing and cylindrical blades have been shown to greatly enhance the overall performance of Chaff cutters by (Karunya et al., 2016) While (Bandiwadekar et al., 2016) showed that it greatly improves cutter's effectiveness. For fodder cutter, the use cylindrical blades started in the last decades, but the topic remained stagnant for a many years. However, recently the area has once again gained importance. In terms of physics of cutting the forages, many theories and models have been proposed to explain the phenomena, each with its merits and demerits. At present no theory can comprehensively explain the reason for low production and capacity in cutting process.

Research in this field is still ongoing but this study shows that the processes has made tremendous progress in recent years and has great potential to compete with commercial chaff cutting machines.

# CHAPTER 3: METHODOLOGY

The methodology of our project is divided into the following parts:

**1-** Figuring out possible solutions and choosing the most suitable option
**2-** Detailed Design of our chaff cutter (parts & mechanisms)
**3-** Calculations related to feasibility of design & capacity
**4-** Choosing suitable materials (acc. to cost & operation)
**5-** Designing electrical circuit and choosing motor
**6-** Analysis of the design
**7-** Detailed manufacturing plan

### 3.1. Figuring out possible solutions and choosing the most suitable option

Ensuring safety of the chaff cutters is the primary objective of our project and we looked into several options to achieve it. First, we looked into the option of stopping the blade when a hand approaches it to prevent the contact. The options in the stopping the blade were:

- **Power Trigger:** Cutting the power of the chaff cutter by detecting the IR radiations emitted by hand in the vicinity of the blade by a PIR sensor.

  **Defects:** Even when the power to the blade is cut after detecting the hand, the blade does not stop but continues the movement due to its inertia and will still be dangerous for the hand. Moreover, the sensors equipment is fragile and needs maintenance and also increases the cost significantly.
- **Stoppage mechanism for blades:** The second option we considered was the stoppage mechanism for the blades in addition to the power trigger. The Process was influenced by the stopping mechanism used in table's saws known as SawStop. It uses a destructible caliper and the caliper mashes into the teeth of the rotating blade after being triggered by

the electrical disturbance caused by the contact with hand. The idea was to mount a stoppage add-on of similar fashion.

Figure 1: Stoppage mechanism for blades

**Defects:** The major difficulty with this was the custom designs and sizes of the flywheels used in the local chaff cutters. And another one was that in the flywheel there are usually 3 to 4 blades unlike sawstop which has numerous teeth. So, with the flywheels being used in the market the mounting mechanisms had no teeth to latch onto. This mechanism would not be feasible due to its cost too.

- **Preventive features & new blade design (The chosen option):** After careful evaluation of the first two we considered another option to ensure the safety and this one was preventive features and new blade design. The idea was to basically prevent the hand of the operator from reaching the vicinity of the blade. To achieve that we proposed the new design of blade i.e. drum cutting assembly and preventive features which include warning rollers, Blade guard, Feed channel and output tray.

❖ **Drum cutting assembly:** The reason of opting for the drum cutting assembly was to make the blade compact without reducing its operational capacity. The blade had to be made compact so it could be properly guarded and enclosed in the blade guard.

- **Preventive Features:** The preventive features include the warning rollers, Blade guard, output tray and feed channel. This will fully enclose the machine and will prevent the hand from getting near the blade and cause injuries.


Figure 2: Preventive features

The compact drum cutting assembly along with the preventive features ensure the safety of our chaff cutter

**3.2. Detailed Design of our chaff cutter (parts & mechanisms):**

Our final design is a fully enclosed chaff cutter with drum cutting assembly. There is a system of pulleys for power transmission from motor to the shaft. We chose a single-phase Ac induction motor of 1hp and 3000rpm. The frame is of angled iron and the shaft is held radially by bearings which are supported by bearing holders mounted on the frame. The blade assembly is mounted on the shaft with a keyway so there is no relative motion between shaft and blade. Blade assembly is held by retaining rings to ensure there is no axial motion between shaft and blade either. This type of drum cutting assembly is opted to make the blade compact so it can be properly enclosed, without decreasing the operational efficiency. There is a stationary shear plate mounted on the frame which provides grip to the fodder so that it is cut properly by the blade. The warning rollers at the entrance of feed channel ensures that the hands of the person feeding the fodder to the machine stay out of it at the same time it helps in supporting and moving the fodder to the plate The feed channel the covering and the output channel are made up of galvanized iron sheets due to their easy forming ability and low cost.

**Final design without Blade guard**

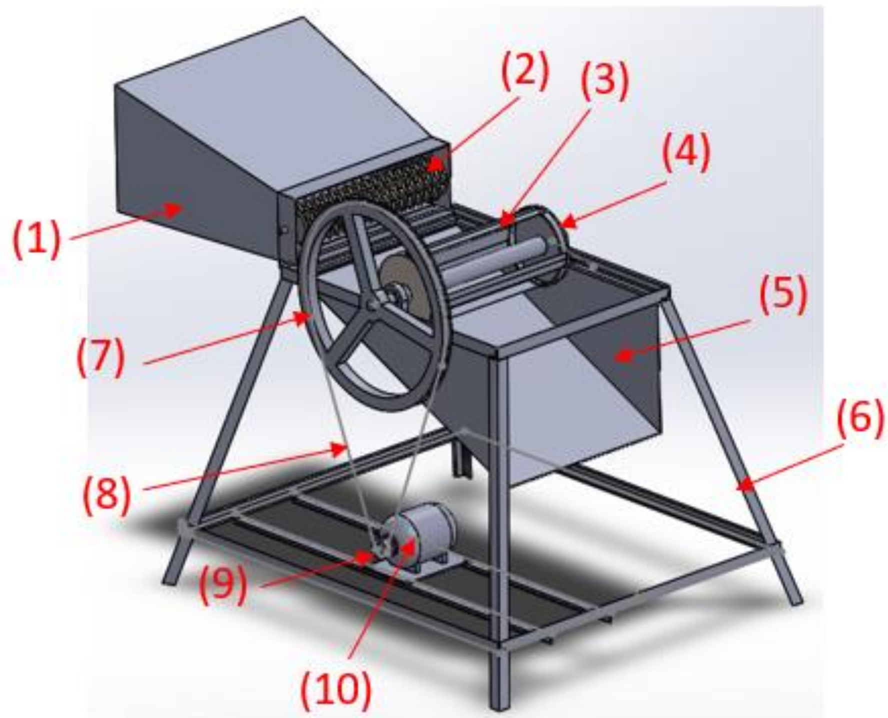


Figure 3: Final design without Blade guard

**(1)** Feed channel

**(2)** Warning rollers

**(3)** Blade

**(4)** Blade holder

**(5)** Output tray

**(6)** Stand

**(7)** Shaft pulley

**(8)** V-belt

**(9)** Motor pulley

**(10)** Motor

**Final Design**

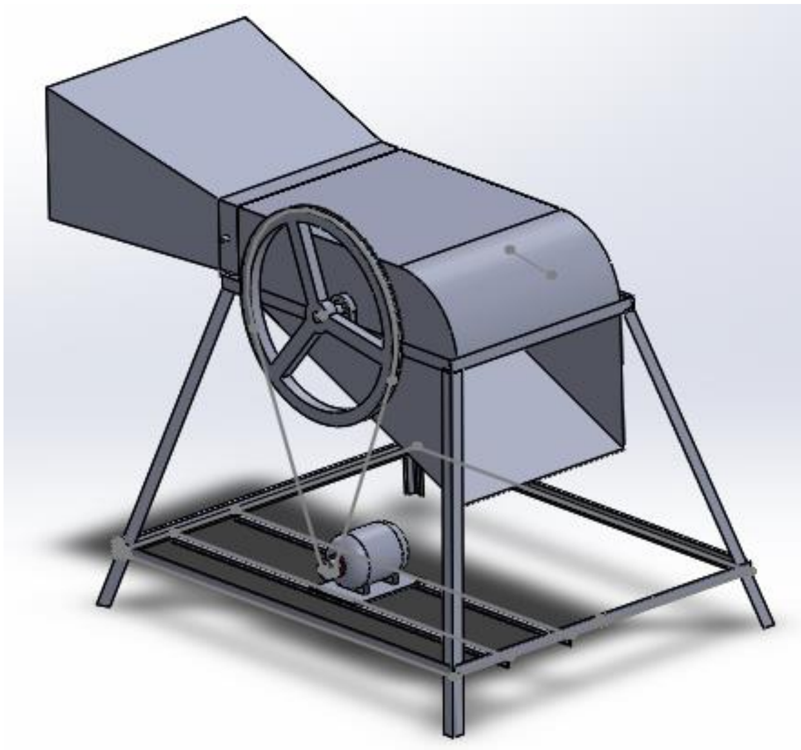

Figure 4: Final Design

**3.3. Calculations related to feasibility of design & capacity**

- **Required RPM at shaft:** We calculated the required RPM by fixing the chaff length and feed rate.

  Chaff length = l = 10cm = 0.01m ; Feed rate = v = 15cms$^{-1}$ ;

  Angle between two successive blades = θ = 90° = π/2 rad

  Delay time = t = Fodder size / Feed rate = l / v = 0.0667

This is the required delay time between two successive hits of the blade which are 90° apart. So, our required shaft RPM is

$\theta/t = 23.5619449 \text{ rads}^{-1} = 225$ RPM

- **Pulley ratio :**

  Pulley ratio = Motor RPM / Shaft RPM = 3000 / 225 = 1/13.33 ≈ 1:13

- **Required Shaft diameter:**

  Yield strength of EN8 = 280 MPa = $\tau$

  Power = P =745.7 W

  Shaft RPM = N = 225 RPM

  Required Shaft diameter = d

  Operational torque = Top

  Torque shaft can sustain = $T_{max}$

  Factor of safety = 2

  $T_{max} = 2\, T_{op}\, ;\ P = \frac{2\pi N\, Top}{60}$

  $T_{op} = \frac{745.7*60}{225(2\pi)}$

  $T_{op} = 30.85$ NM

  $T_{max} = 2\, T_{op} = 61.7$ NM

  $T_{max} = \tau(\pi/16) * d^3$

  $61.7 = 280*10^6*(\pi/16)* d^3$

  ⇒ d = 10.39 mm

- **Shear stress on shaft key:**

  Shaft radius = r = 0.005 m

  Key length = l = 0.4 m ; Key width = x = 0.005m ; Shaft RPM = $\omega$ = 225rpm ;

  P = 745.7W

  Shaft torque = T

  $P = T^* \omega$

$745.7 = T*(2\pi/60)(225)$

$T = 745.7(60)(13)/(2\pi*1800)$

$T = 30.875$ Nm

$T = F.r$

$F = (30.87/0.005) = 6171.4$ N

Area of key for shear $= x*l = 0.005*0.4 = 2*10^{-3}\ m^2$

$\tau$ = shear stress = F/A

$\tau = (6171.4/2*10^{-3}) = 3.085$ MPa

$T < T_{yield} = 280$ MPa

- **Force required to cut the fodder:**

Max force required to cut the fodder = 90N ((Sathish et al., 2020))

Torque of shaft = T = 30.857

r = 62.5 mm = Distance between blade and centre of shaft

$T = F*r$ ;  $F = T/r = 30.857/62.5*10^{-3}$

Force available at blade = 493.712N > 90N

So, all types of fodder will be cut easily by our machine.

- **Length of V-belt:**

$L = 2C + \pi (D_1 + D_2) / 2 + (D_2 - D_1)^2 / 4C$

L = Belt length

C = Center to center distance between pulleys = 0.5m

$D_1$ = Pulley 1 diameter = 0.03m

$D_2$ = Pulley 2 diameter = 0.39m ⇨ L = 1.74m

### 3.4. Operational Capacity of Chaff cutter:

Although the operational capacity of chaff cutters is calculated experimentally but we tried to get an approximation of it by using feed rate and rpm of our machine and the approximate density of the fodder (500kg/m^3).

Approximate feed rate = v = 0.15m/s
Effective height of blade cut = h = 40mm = 0.04m
Width of the blade = w = 300mm = 0.3m
Area of the cut = A = h x w = 0.012 sqm
Volume rate = v x A = $1.8 \times 10^{-3}$ $m^3/s$
Approximate capacity = Volume rate x Density = 2160 kg/hr
The approximate operational capacity of our chaff cutter is almost twice the operational capacity of the local chaff cutters.

### 3.5. Choosing suitable materials and components (acc. to cost & operation)

Suitable materials had to be chosen for different parts of the machine. Our selection criteria was feasibility and cost.

**Table 3 materials and components (acc. to cost & operation)**

| **Parts** | **Materials** |
|---|---|
| Stand | Angle iron (Hot rolled carbon steel) |
| Feed channel/Blade guard/Output tray | Galvanized Steel sheets (GS-14-0785) |
| Shaft/Blade assembly | Medium carbon steel (EN8) |
| Blades | High carbon steel |
| Warning rollers | Nylon 6.6 |

*Table 3-a*

**Specifications of Pulley and Bearing:**

Internal diameter of pulleys = 10mm

External diameter of motor pulley = 30mm

External diameter of shaft pulley = 390mm

Bearing 6000 (as the dynamic load on our bearing 4000N < 4500N)

### 3.6. Designing electrical circuit and choosing motor:

The electrical circuit for our machine was designed using Matlab.

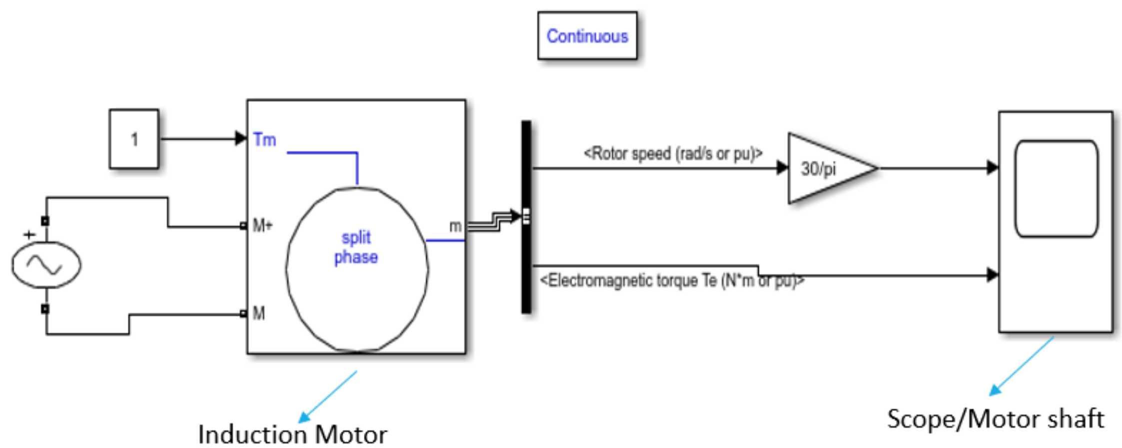


Figure 5: Electric circuit

The motor we chose was single phase AC induction motor of 1hp and 3000rpm.

from the left it shows single phase AC supply which is connected to induction motor which gives output in the form of rpm and torque which is connected to the scope simulated for the motor shaft. We calculated the rpm to be around 3000 from the feed and chaff length. And made an estimation of required force at the blade from the published study (*Reference 3-a*). After that we calculated the required torque and then the required power. The motor closest to our requirement was 1hp 3000rpm motor. Single phase because we are designing chaff cutter mainly for the domestic use which have single phase AC supply.

### 3.7. Analysis of the design

The analysis criteria was set up keeping in view the components used and the operating conditions of the Chaff Cutter. The analysis has been discussed under Design Validation Study in Chapter 4. Here we are going to discuss the key points identification for analysis and how the analysis studies were set up.

To identify the key points, we take a step back and look again at our objective which is focused both on cost and feasibility. Then there are hidden or unmentioned objectives such as reliability and long-life of the Chaff Cutter. Now evaluating These objectives against our components, we conclude that the key components are:

**1)** Motor

**2)** Pulley Ratio

**3)** Stand

**4)** Blades

**5)** Bearings

**6)** TorquethroughAssembly

Let's discuss each.

#### 3.7.1 Motor:

The motor we have chosen is a single phase AC Induction 1 Hp, 3000 RPM.

The max torque transmitted to the blades is 31Nm, which in our case provides a force of 539 N at the Blades for the Cutting Action. This force is greater than the cutting force and hence the Motor is perfectly adequate for the design.

### 3.7.2. Pulley Ratio:

The Pulley Ratio of 1:13 is a perfectly feasible ratio and the components for that are commercially available. As has been shown under design validation study, the pulley can also transmit the torque without any alarming stresses.

### 3.7.3. Stand:

The Stand is made up of angle iron rods which are welded together to form the structure. The stand needs to hold the weight of the whole assembly on top of it without failing. It is a constant force acts on the stand regardless of whether the Chaff Cutter is being operated or not.

### 3.7.4. Blades:

Forces act on the blade during the cutting process. These forces are cyclic. So the blade should neither fail due to yielding nor due to Fatigue. Other than cutting forces, Some pebble or rock mixed with the feed can also cause a high impact force on the blade. The blade should not break and fly off due to that force. These studies have been performed under design validation study.

### 3.7.5. Bearings:

On the 2 bearing, a bearing load of 245.25 and 147.15 acts respectively. Which is much lower than the rated load capacity of the bearing.

### 3.7.6. Torque through Assembly:

The Assembly can transmit the torque from the motor onto the blades without failing as has been detailed under Design Validation study.

### 3.8. Detailed Manufacturing plan:

The parts of the chaff cutter and the methods to assemble them together are discussed below. The parts of our machine are as follows:

- **Frame**
- **Shaft**
- **Blade holder**
- **Blade**
- **Warning rollers**
- **Pulleys and belts**
- **Bearings, bearing holders & retaining rings**
- **Motor housing**
- **Feed channel and blade guard**

- **Frame**

The first step in the manufacturing will be to make a stable frame which will not only hold our drum cutting assembly but also provide a solid base to make our machine stable and less prone to vibrations. So, keeping in mind the strength we require and the weight we require at the base of the machine we opted for angle iron as our base unit. We need a total of 14 angle iron parts of 1m or closest dimension available in market.

They'll be cut to the required dimensions by cut off wheel or chop saw. Then these angle iron parts will be welded together. The upper 4 angle iron bars will be joined by a coped joint to form a rectangular structure.



Figure 6: figure 3-f

The support angle iron bars will be inclined to the angle set in dimensions and its face will be made flat relative to the flat bottom of upper rectangular structure angle iron bars and will be welded at all 4 sides in the same way.

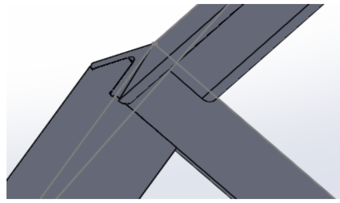

Figure 7: Figure 3-g

Then 4 angle iron bars will be welded to these supports near the base and at 4 edges to form a rectangular structure. 2 angle irons will then be welded along the length on this base rectangular structure such that their flat end is on the upper side, here motor will be clamped. An iron plate will be mounted by nut and bolt on the upper rectangle to act as a shear plate.

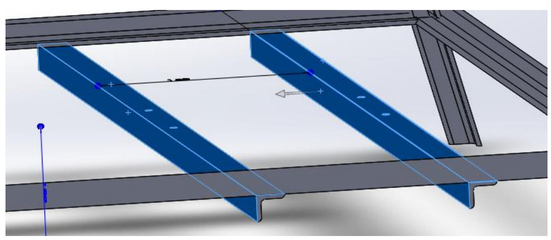

Figure 8: Figure 3-h

There will be a total of 8 holes drilled in this frame. 2,2 on the two opposite angle irons along the length to hold the bearing holders and 2,2 on the two parallel angle irons at the bottom to hold the motor plate. The final shape of the frame will be like this:

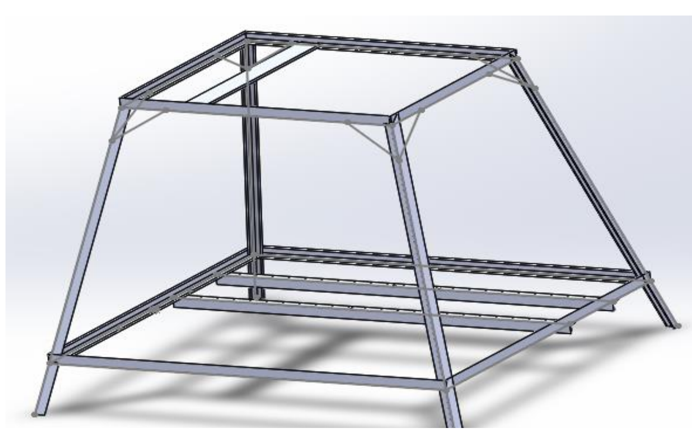

Figure 9: Figure 3-i

- **Shaft**

The EN8 medium carbon steel shafts are available in the market we'll be reducing them to our dimensions by turning and step turning and then cutting keyways in the shaft for holding blade holder and pulley at the end by a keyseat. This material is easily machinable. The lower diameter ends will be going through the bearings and with a pulley attached at the end.

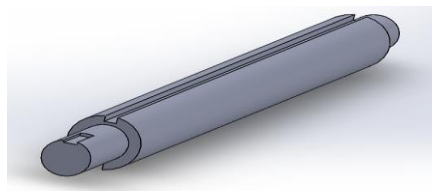

Figure 10: Figure 3-j

- **Blade holder**

We have designed our blade holder to be mounted on the shaft through a keyway-keyseat. So, our blade holder is a hollow shaft of medium carbon steel with keyway inside of it.

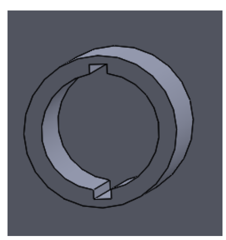

Figure 11:Figure 3-k

This hollow shaft has a disc which is welded on it from two sides. This disc has an elongated boundary edge and with holes drilled in it to mount the blades. There are hollow shafts available in the market but we can take the closest shaft available in the market and reduce it to our required diameter by turning and then drilling a hole in it according to our dimensions and then broaching in a keyway through it. The discs holding the blades will be welded on this hollow shaft and the blades will be mounted on them by nuts and bolts.

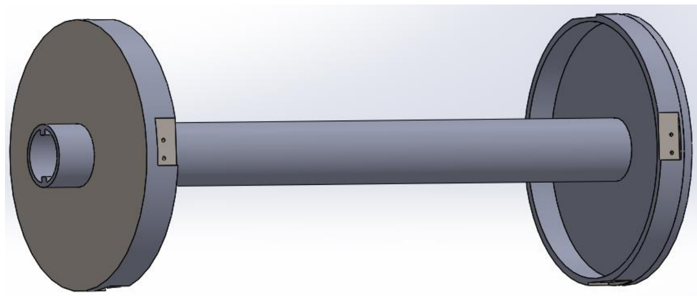

Figure 12: Figure 3-l

- **Blade**

  We will be using high carbon steel straight blades. We will not be making them ourselves as high carbon steel has poor machinability. They're available in the market in different dimensions and we can get the ones of our dimensions custom made too. We have to make sure the dimensions of the blade and holes are perfectly according to design and the cutting edge is sharp. This blade will be mounted on the blade holder by nuts and bolts.

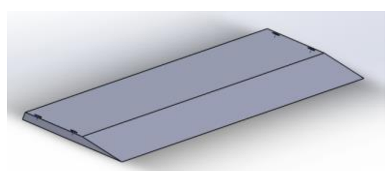

Figure 13: Figure 3-m

- **Warning rollers**

  We will use Nylon 6.6 warning rollers which will be held by a metallic assembly and mounted on the frame from the feeding side. Nylon rollers of various dimensions are available in market. They are easily machinable so we can cut them to our exact dimensions by a lathe machine. The rollers are not powered and will be free to roll on a cylindrical rod passing through them to hold them in place. The key point here is the distance between the warning rollers, it should not be enough to let the hand pass through them. There are Nylon rollers available in the market too, but we may not use them as our rollers are not powered. We may put the steel rod through the nylon rod to exact fit of the bore and make the rod and nylon rod move as a single unit with bearings at the end but preferably to cut the cost, the hollow Nylon rods will be freely rotating over the metallic rod passing through them to hold them in place.

Figure 14: Figure 3-n

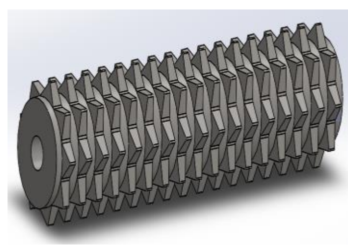

Figure 15: Figure 3-o

- **Pulleys & Belt**

  We can have any pulleys with inner diameter of 10mm, we just have to make sure the two pulleys we get have an outer diameter ratio of 1:13 to each other. The pulleys will be mounted at the end of the shafts by a keyway keyseat.

Figure 16: Figure 3-p

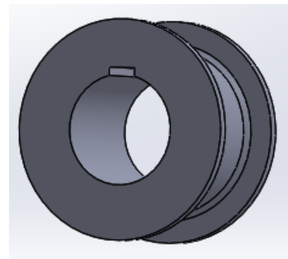

Figure 17: Figure 3-q

A rubber belt of 10mm thickness and 1.74m length will be used.

- **Bearings and Bearing holders and retaining rings**

  Two 6000 ball bearings will be used at two ends to hold the shaft radially. Retaining rings will be put to constraint the axial movement of the shaft. The bearing holders of inner diameter 26mm is required which will be mounted by nut and bolts at the two ends of the angle iron frame along its width to hold the shaft.

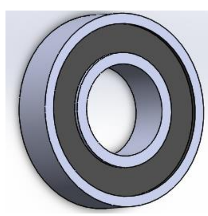

Figure 18: Figure 3-r

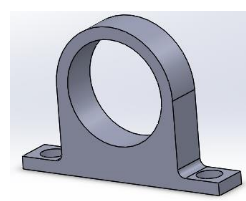

Figure 19: Figure 3-s

- **Motor housing**

  Motor will be mounted by nut and bolt to the plate which will be welded on the two parallel angle iron bars at the bottom. The motor shaft will be connected to the pulley by the keyway keyseat and with the help of the belt wrapped on it will transmit the power to the driven pulley and thus the shaft.

- **Feed channel and blade guard**

  The sheet metal we will be using is GS-14-0785. Its thickness is 2mm and we will be making the feed channel and blade guard from it by sheet metal operations. The sheet metal is formed into the desired shape and they're bent from the edges and the holes are punched in these bent edges to join them with other sheets to make the desired shape. The holes of two sheets are aligned and they are joined by screws and fasteners. The feed Channel will be connected to the blade guard sheet and to the frame from the bottom with the help of screws and fasteners. The blade guard will also be mounted on the angle iron frame by screws. The output tray will have its three sides connected to the angle iron frame to make an output tray with downward slope.

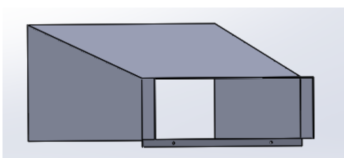

Figure 20: Feed channel

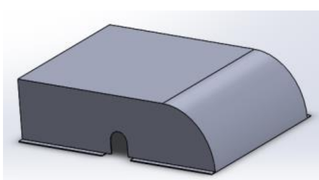

Figure 21: Blade guard

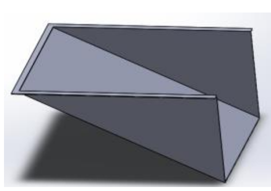

Figure 22: Output tray

### 3.8.1. Engineerig drawings of parts:

**Bearing holder:**

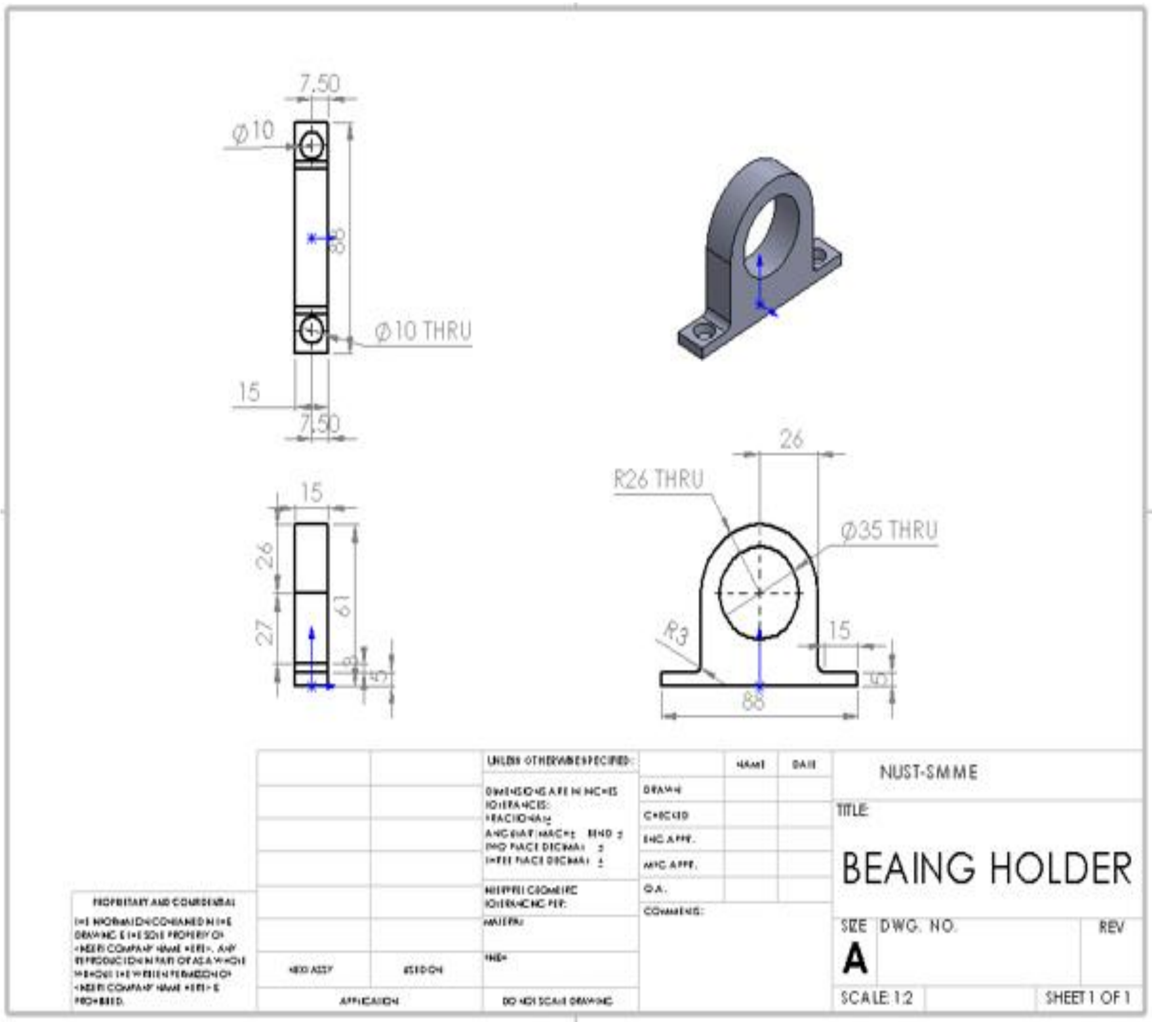


Figure 23: **Bearing holder**

**Blade Shaft:**

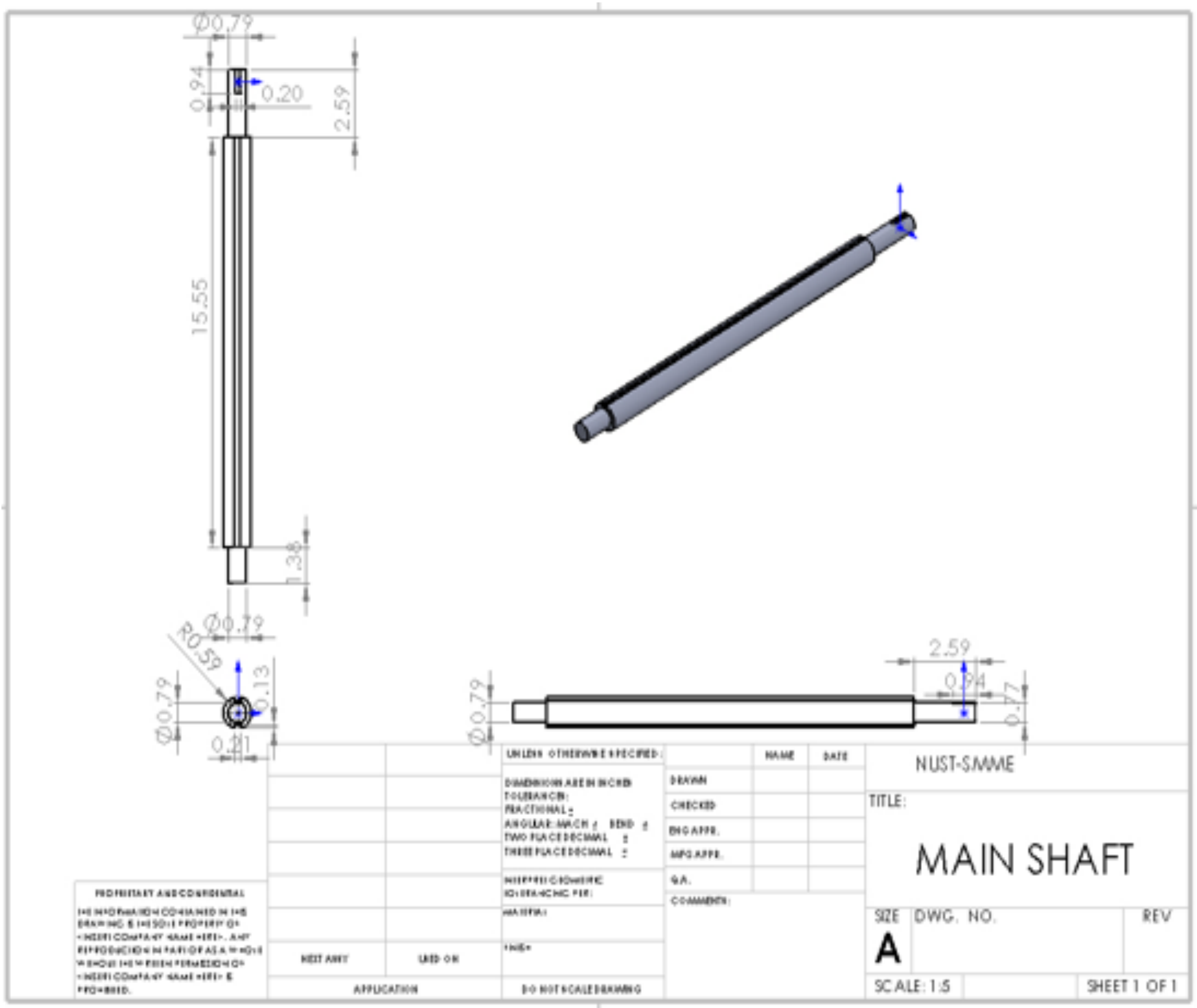


Figure 24: **Blade Shaft:**

**Stand:**

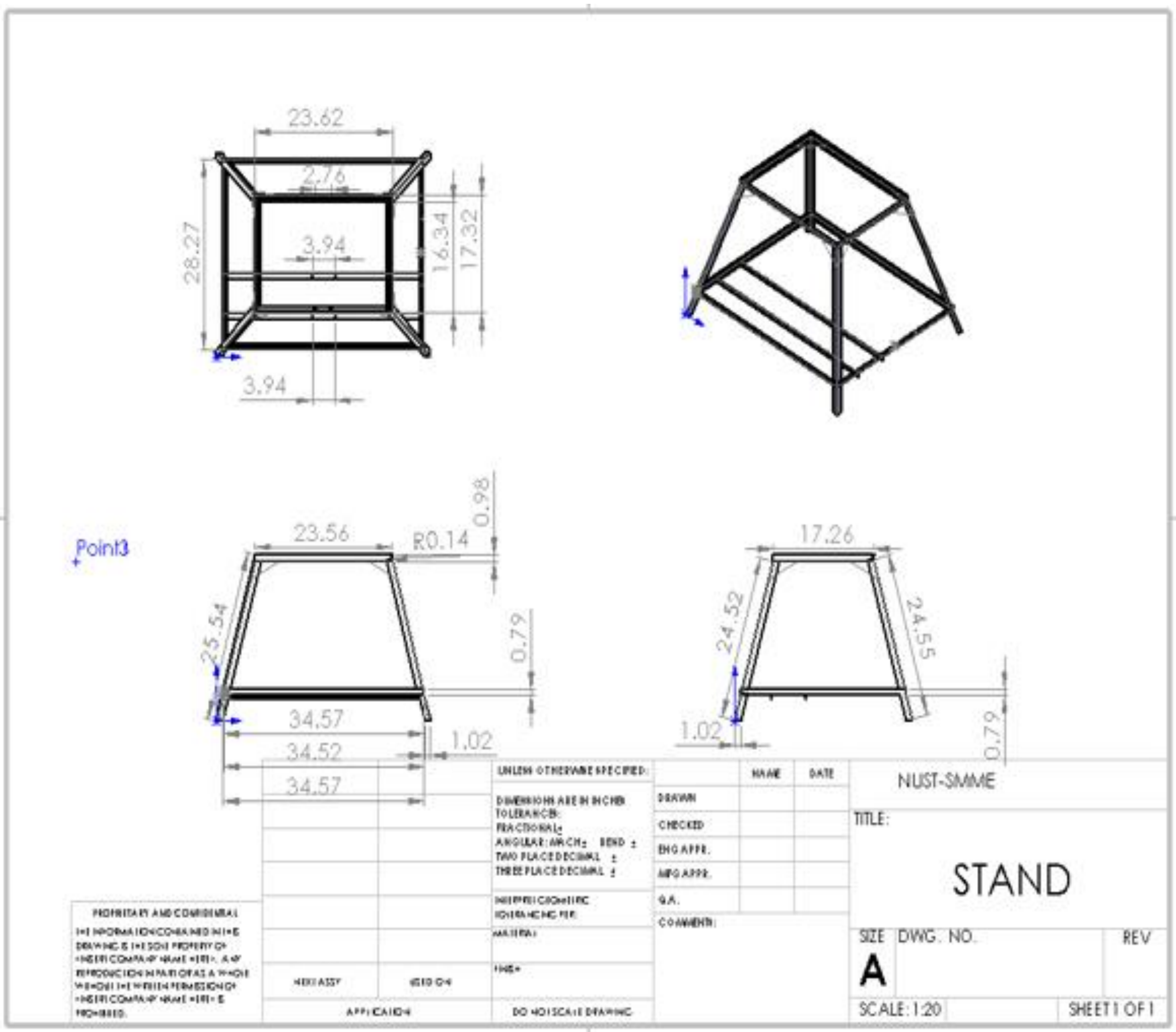


Figure 25: **Stand**

**Blade guard:**

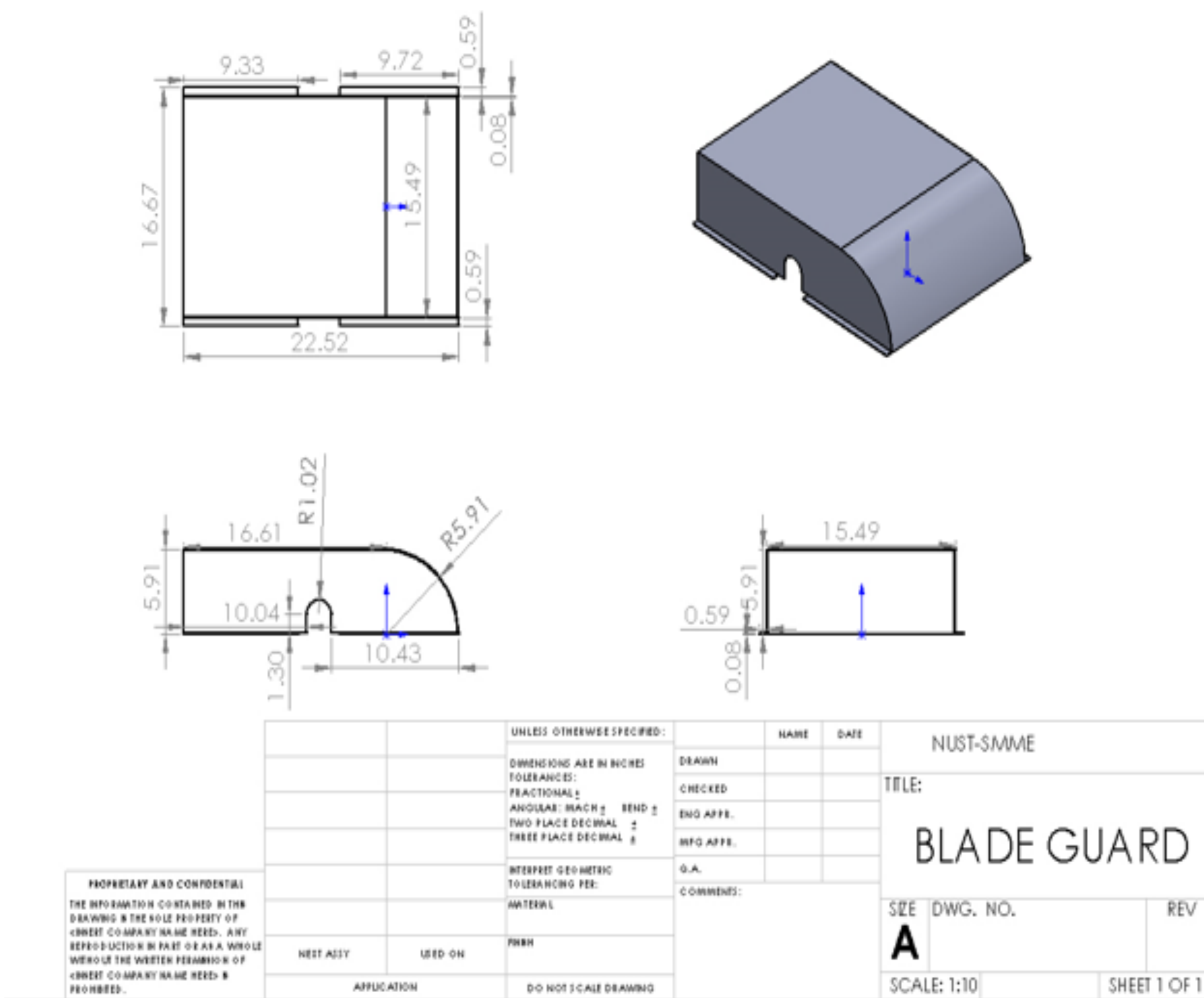


Figure 26: Blade guard:

**Feed channel**:

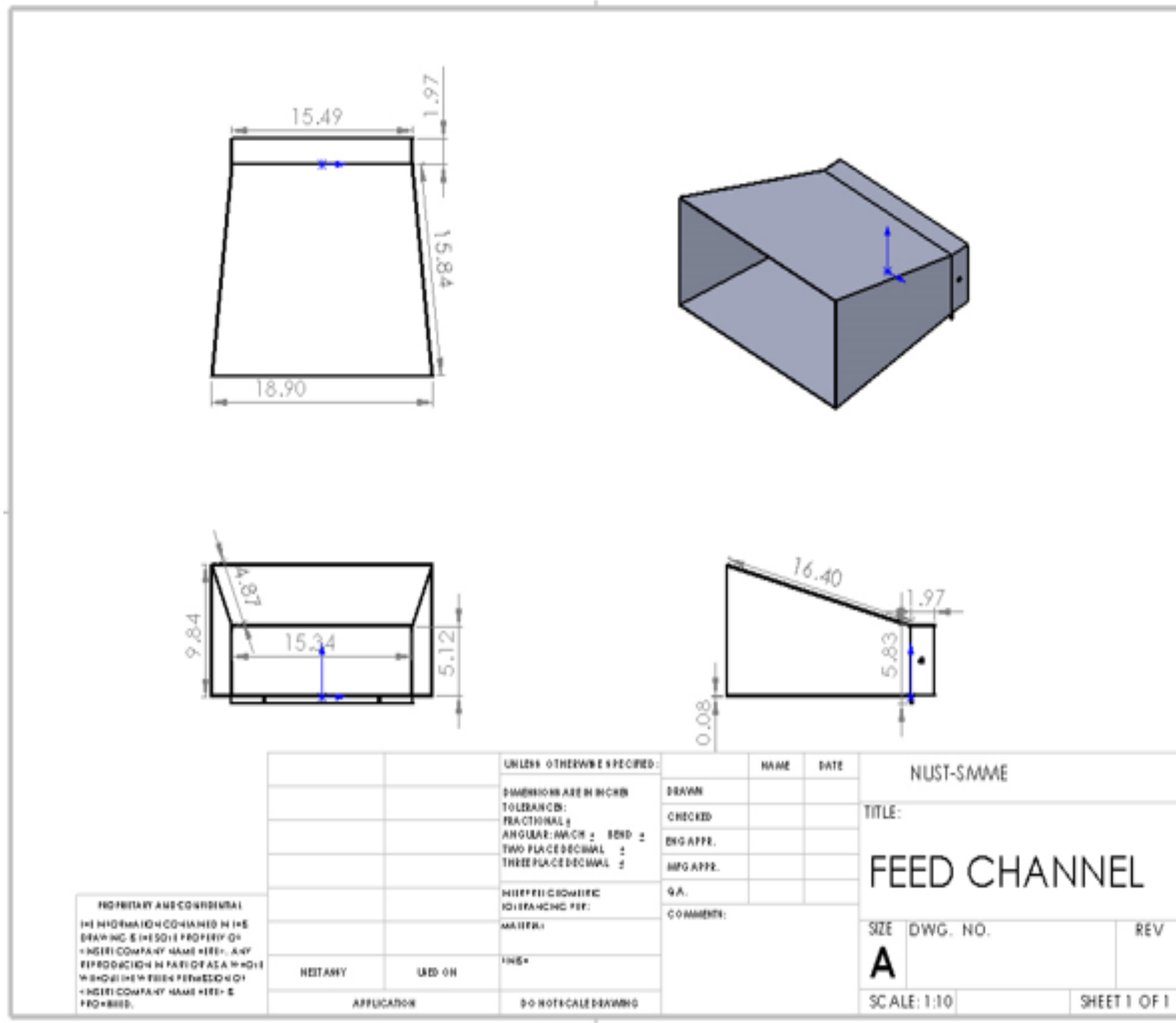


Figure 27: Feed channel

**Output Tray:**

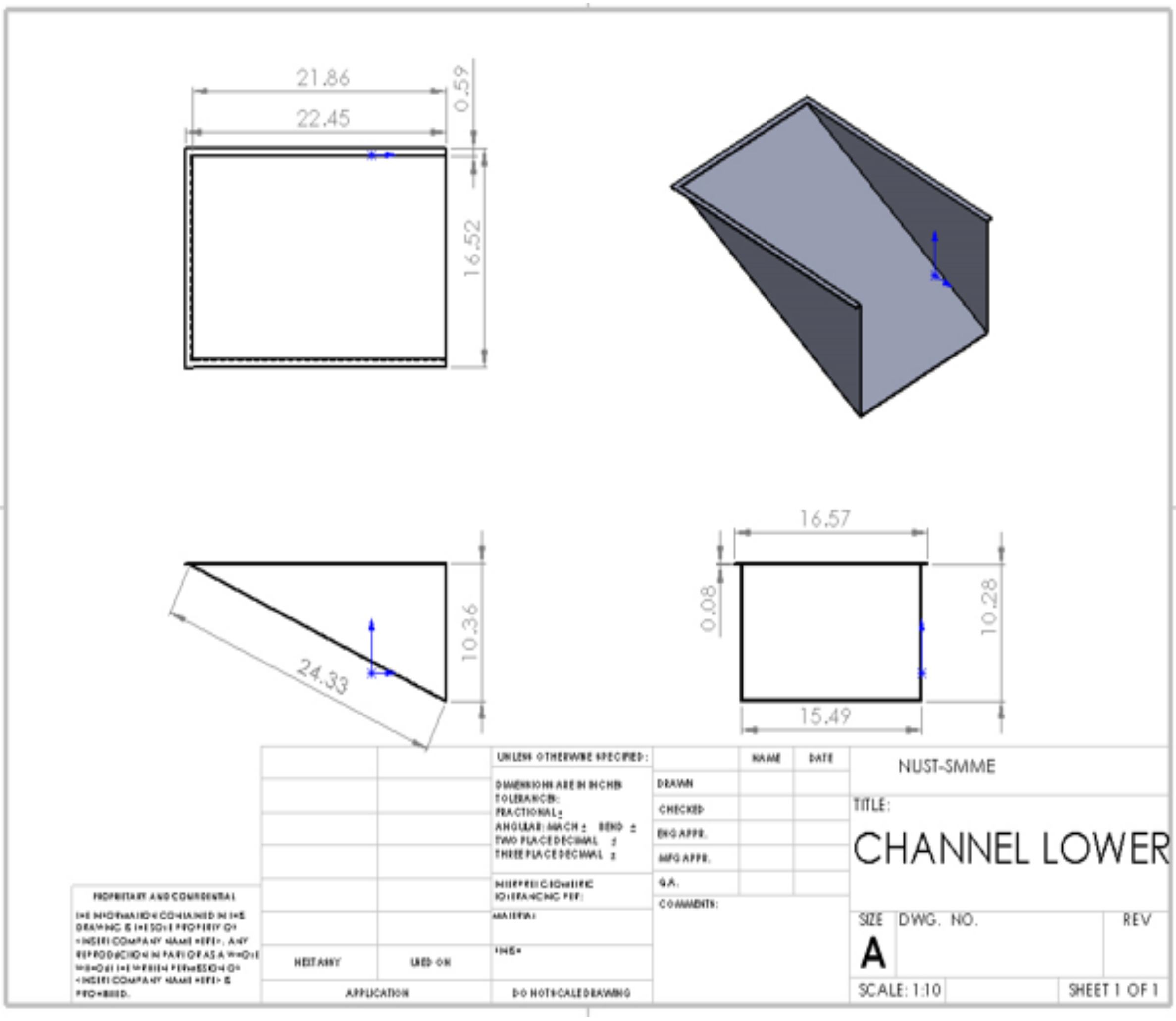


Figure 28: Output Tray

# CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter shows the results of our work. We verified our design against our design objectives as well as against the industry standards. Our design had to accomplish the defined objectives for it to be a valid design and fruitful outcome.

### 4.1. Defining the Validation Criteria

To define the criteria for our validation, we considered our objectives analytically. The objective is to make Chaff Cutter in low Cost. This Low Cost Cutter had to compete with Chinese as well as Japanese imported models.

To make a marketable product that can compete with the Imported Models, we had to make a better design that accomplishes the tasks at a low cost. Our product had to be better than the imported model on 3 different fronts.

- **i)** Cost
- **ii)** Safety
- **iii)** Reliability

Let us analyze and discuss each of these.

#### 4.1.1. Cost

In a developing country like Pakistan, cost is very critical. People can't afford to pay for an expensive product. The increase in Cost will lead to the Chaff Cutter being only purchased by Large Agricultural Organizations. This does not serve farmers that we are trying to serve. They are the people that are getting injured. And if they can't afford the product, they'll have to use the Low Cost Locally manufactured Open Fly-Wheel Chaff Cutter that is the cause of injuries in the first place.

So in terms of Cost, we couldn't afford to be expensive than the Locally Manufactured unsafe Open Fly-Wheel Chaff Cutter. To cut the cost, we had to stick with a basic design and utilize the parts that are already available in the local industry in abundance. So all the components that we've chosen in our design are industry standards that are readily available in the local market.

To Keep the Cost low, we made some simple yet effective design choices. So First we chose to not include sensors in our Chaff Cutter, implementation of which would have required not only the sensors themselves, but the housing for the sensors that had to be isolated from the moisture effects of the Chaff Cutter to prevent short circuit and also to increase the life of the components because moisture and electricity don't mix well, and additional components such as a braking mechanism that the sensor would have triggered. But that would have increased the cost. So, we used these low cost components.

### 4.1.2. Cost Analysis

Table 4: Cost Analysis

| Component | Approx. Cost |
|---|---|
| 1hp 3000RPM Motor | Rs.15,000 |
| 4 Blades | Rs.2000 (500/blade) |
| Angle iron | Rs.2500 (125/kg) |
| GI 14-gauge sheets | Rs.3500 (175/sq ft) |
| Pulleys | Rs.1000 (500/piece) |
| Belt | Rs.500 |
| Bearings, Bearing housing | Rs.1500 |
| Shaft | Rs.1000 |
| Total | Rs.27,000 **< 32,000 (Cost of local open wheel cutter)** |

This Cost analysis has been done by surveying the local market. It includes all the major components we require. Motor is the most expensive component. We are able to reduce the cost to such a level that it is even lower than the Open Fly-Wheel Chaff Cutter that leads to many injuries. The imported Chaff Cutter costs more than Rs 60,000. So it puts us in a very Good Place with regards to cost.

## 4.2 Safety:

We considered different ways of making it safer. We considered using sensors that would detect that the hand is getting close to the blade or comes into contact with blade, and then the sensor would trigger a braking mechanism such as a disk brake mounted onto the Chaff Cutter. But the usage of sensors would have not only increased the cost but also made the design delicate. So, we used low cost- alternatives as follow:

**Warning Rollers:**

They serve to not prevent the hand from reaching the blades but also helps the user to stay vigilant. It does a Secondary Task and that is to allow for proper feeding of the fodder to the blades.

**Sheet Metal:**

Simple Sheets of Metal have been used to cover the Blades. These Sheets are easy to install and can be removed easily for cleaning purposes but serve to greatly reduce the risk of injury during operation.

**Feeding Channel:**

Feeding Channel has been designed so that the hand of the user does not have to get any close to the blade It isolates the blade from the hands of the user. In Open Fly-Wheel Chaff Cutters, the feeding channel is also open. But we have used a close feeding channel to reduce the risk of injury.

## 4.3 Reliability:

One thing that was common to both the local as well as the imported Chaff Cutters was that they were reliable. They made use of reliable components and reliable mechanisms. We our Chaff Cutter also had to be reliable for it to be a marketable product.
Keeping in view the task that the Chaff Cutter performs, we set up a reliability criterion

to ascertain that our design was able to hold its own. So, we included four types of reliability tests.

**4.3.1 Stand can sustain the weight:**

This is fundamental to the Chaff Cutter to ascertain whether what size of angle iron we should use. It the base fails, then everything else fails. So, the base had to be strong and over-desgined.

For this test, we've applied the total load of 65 Kg on our stand. The load is distributed between the members of the stand. The weight of the Blade Assembly acts on the bearings and has been added as a bearing load. The weight of the Motor acts on the Lower Members where motor will be housed.

Initially we were using 3x3x20 Angle Iron Rods. They were able to hold the weight of the whole assembly. But to deliberately over-design it, we used 5x5x20 Angle Iron Rods. The cost difference between the two rods is negligible as they are standard sizes but the reliability is increased by a lot.

The total weight in our Chaff Cutter is 65 Kg.

Shown below(Fig A1), is the result of the analysis performed on a 5x5x20 Chaff Cutter. The color scheme accurately represents that the stresses are much lower than the UTS of the material (180Mpa). We see that the max stress = $2.412 \times 10^5$ which is much less than 10^8(UTS). This stress is important for the four legs of the Chaff Cutter that are in axial load.

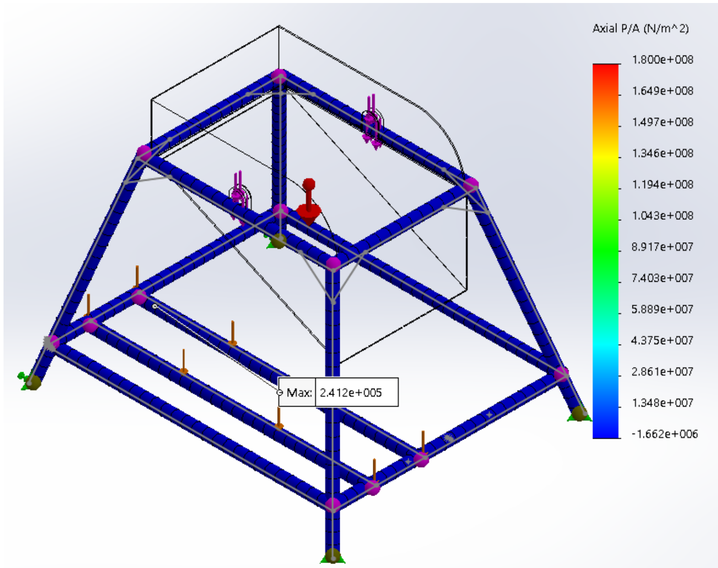


Figure 29: ) Axial Load Diagram for vertical members A-1

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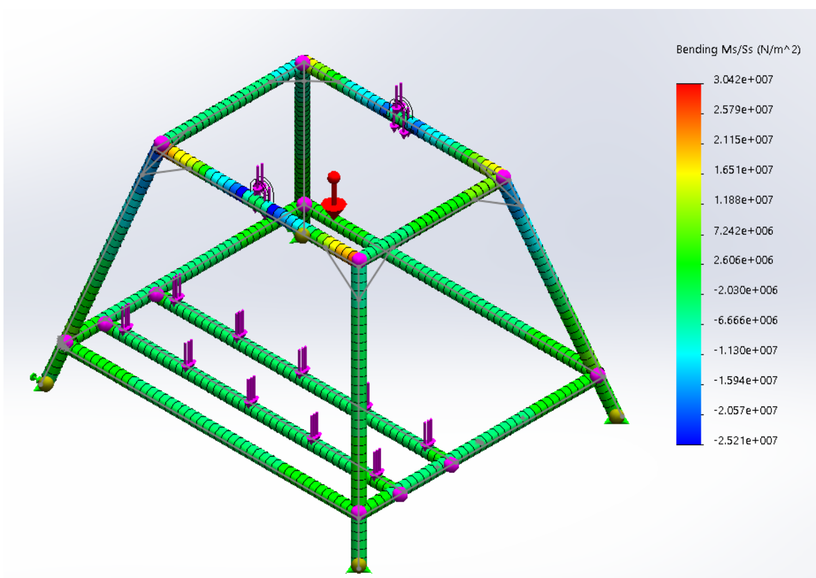


Figure 30: Bending Load for horizontal members A-2

Fig A2, shows the bending stress on the Stand. This stress test is important for Members on which load in being applied perpendicular to their direction. So, the Top Rectangular Structure of the Stand as well as the Bottom structures where the motor will be housed are the important parts. We see that the bending stresses are of the order of $10^6$ which is lower than the UTS of our material.

### 4.3.2 Blades can sustain sudden impact.

The impact test is important because in practical use of Chaff Cutter, Pebbles can get fixed with the feed and these small rocks lead to degradation of the blade and can even cause blade failure. So our blade should not fail on striking these pebbles.

For this test, we calculated the tangential velocity of the blade tip which comes out to be 1.81 m/s. The rock can be considered stationary since the feed velocity is very low compared to this tangential velocity. We've used a method to work out the force equivalent of this impact on the blade.

For a 100 g pebble, with a blade velocity of 1.81 m/s, the impact force comes out to be 278.6 N.

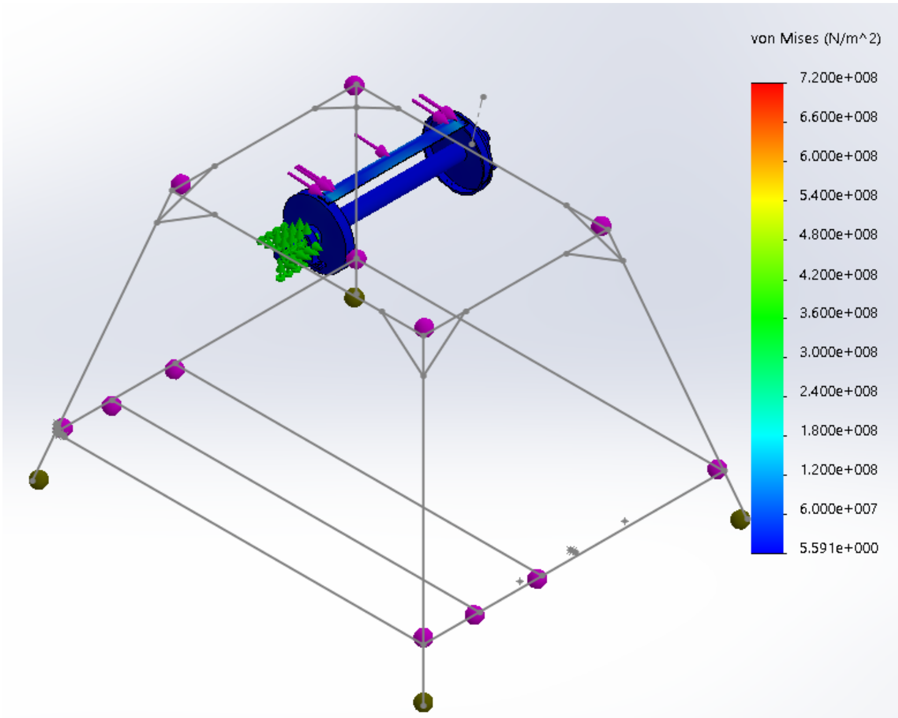


Figure 31: Shows the stress due to impact of rock on blade A-3

Fig A3 shows the impact stress test. The deformations are only local that don't break the blade. The UTS of blade is 720 MPa.

### 4.3.3 Fatigue due to cutting action.

Cutting action for every blade happens about 4 times every second. This means there is a cutting force that gets applied to the tip of the blade 4 times every second. During a period of 1 hour, there will be 14,400 cycles of this force. So the stress cycles are high enough in number for fatigue to be a possible mode of failure.

Fortunately, the cutting force is very small and hence the stresses caused by it are very small. The Cutting Force when the blade is sharp enough has been derived to be 250N. This force also gets transmitted to the Shaft on which the blades revolve. Due to the cutting force of 250N, the cyclic torque on the shaft comes out to be 18Nm. And as there are 4 Blades on the shaft and this torque appears during cutting action of every blade, so the number of cycles per interval of time is 4 times greater than on the blade. The Shaft is not hollow and is firm enough to handle this small torque without failing. So, we considered fatigue for both of these components.

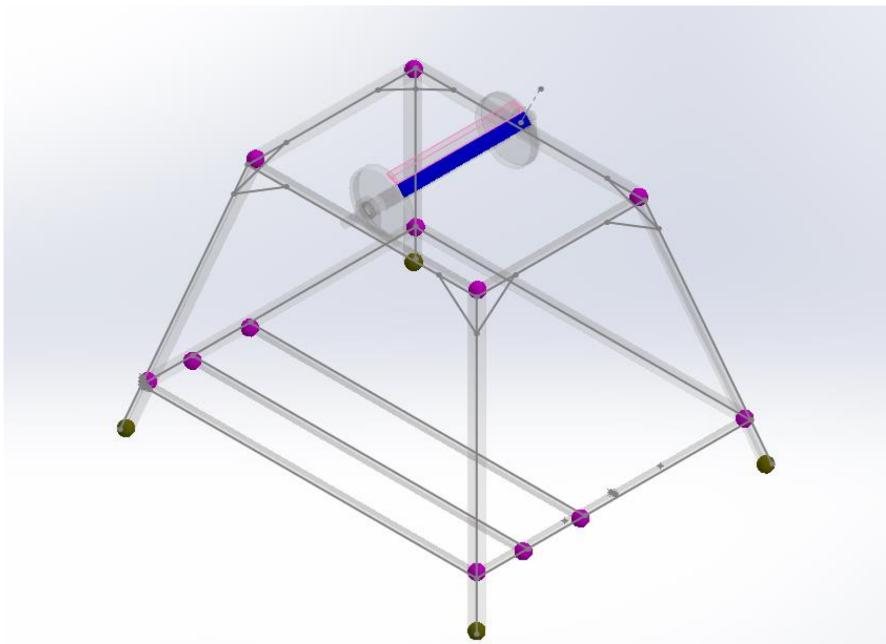

Figure 32: Shows the Fatigue Result for Blade A-4

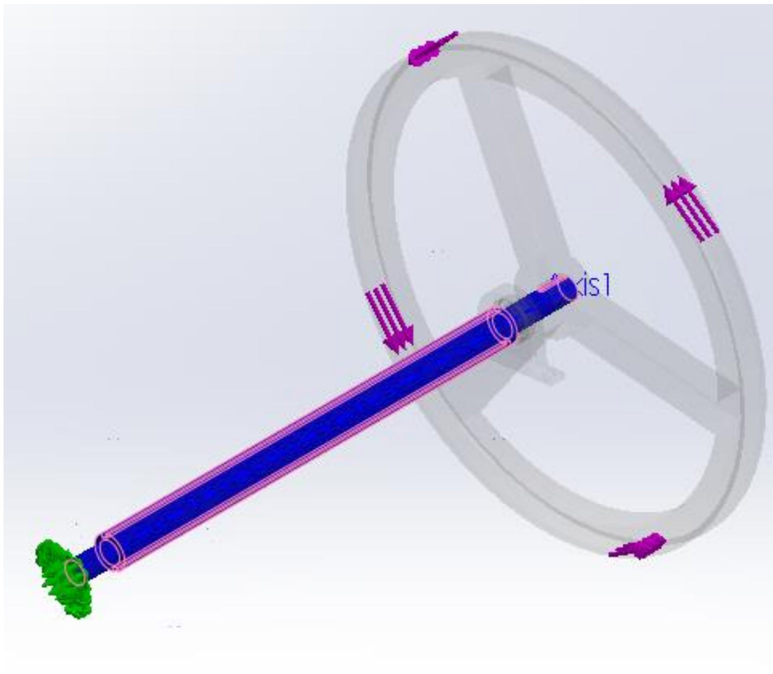


Figure 33: Fatigue Result for Shaft A-5

**Figure A4** shows the fatigue results for a single blade. The test was performed considering a single blade on which the cyclic force of 250N acts. The test shows that fatigue won't be a mode of failure for this part.

**In Figure A5**, the Fatigue test for the Shaft on which the cutting torque acts has been performed. The shaft has been considered to be stationary on the end away from the pulley while torque acts on the driving pulley. This transmits the torque into the shaft and can be used to accomplish the same result as if the force was acting through the blades onto the shaft. The results shows that fatigue is not a mode for failure for the shaft.

### 4.3.4 Shaft can sustain motor torque.

The cyclic loading on the shaft is only 18Nm. But the max torque of motor that can act through the pulley and onto the shaft is 31Nm. So in this test we checked if the Shaft will be able to sustain the whole torque applied by the motor without failing. This load is not cyclic like in the fatigue case but will be a rare scenario where the whole torque will shaft on the shaft.

Now the shaft is thicker in the center and thinner at the edges where it fits into the bearings. So, at the thinner edges, the torque will cause more stress. The shaft is considered to be locked at the other edge for that torque builds up on the shaft without turning it. The UTS for the shaft is 241Mpa.

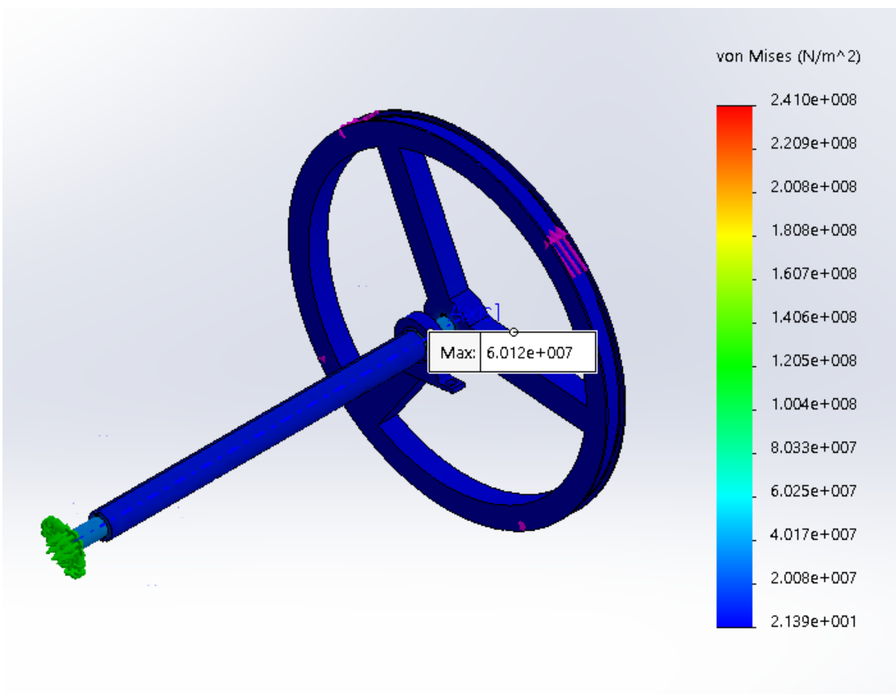


Figure 34: Torque by the motor onto the shaft assembly A-6

Fig A-6 shows the torque of 50 Nm acting through the pulley onto the shaft. To incorporate a factor of safety, instead of applying 31Nm of torque, 50 Nm of torque has been applied. As expected, the stress on the thinner end of the shaft where it connects to the pulley is the higher stress. The max stress also exists in this region. The Max Stress comes out to be $6.012x10^7$ which will not cause any yielding or failure of the shaft.

# CHAPTER 5: CONCLUSION AND RECOMMENDATION

Extensive work has been done that ranges from requirement studies to feasibility studies to market surveys all the way up to manufacturing plan. This work can act as a steppingstone for anyone that intends to improve upon the design of local chaff cutters and make them safer.

There are some key points that we are have been able to identify during this project which we'll highlight here.

## 5.1. Better Chaff Cutters can be manufactured locally.

Our market research shows that all the components that make a better chaff cutter are locally available and being manufactured locally. Everything including motor, bearing, blades, Stand and Pulleys are readily available in the local industry.

These are some very basic components that make up a Chaff Cutter.

In Gujranwala, we have a big industry where motors are manufactured. There are many sheet metal industries scattered throughout the country. Pulleys are being manufactured in local hardware industry.

## 5.2. Better Chaff Cutters can be made economical.

Right now, the better and safer option in the market are the Chinese or Japanese imported models. For international freight, the shipping fees for Chaff Cutters are high due to their weight and size. They are very expensive due to import duties and shipping fees. The Chinese imported models cost upwards of Rs 60000 which is out of the range of the everyday consumer.

The design characteristics that make those Chaff Cutters safer and more effective aren't expensive rather smart characteristics that can be incorporated into a Chaff Cutter design locally for a very low Cost. Cutting the cost all the way from 60,000 to 30,000 for the Chaff Cutter.

### 5.3. Reduction of injuries:

Survey shows that Smart cheap components like Sheet Metal Covering, Warning Rollers and Inlet Channel make the Chaff Cutters much safer. Greatly reducing the risk of injury. Consider the warning roller for instance, it a small piece of nylon that costs less than 200 rupees but helps to keep the users vigilant and thus reducing injury.

A single Metal Sheet of 36” x 96” is adequate to envelope the chaff cutter greatly reducing injuries.

The key points highlighted above focus only on the Chaff Cutter. But the same concept applies to various big industries and a wide range of useful products that can be manufactured locally. The local Engineering and manufacturing industry has a lot of room for improvement and they are all very simple and basic improvements that will make the industry and the economy so much better. Chaff Cutter is a very basic product in terms of where engineering and technology stands today. And we already have all the resources for such basic products. Taking one at a time, we can move towards self-sustainability.

### 5.4. Recommendations:

Design is an iterative process which can always be improved upon. With our objective being low cost and feasibility, we’ve left out some possible improvements. The improvements possible on this design, include but not limited to our recommendations. The recommended improvements are:

#### 5.4.1. Automatic Feed:

We have used manual feed in our design. The reason being that the automatic feed would require some new arrangement or design that tackles the possible injuries that can occur due to automatic feed. Automatic Feed uses very high torque which tends to pull the users hand along with the fodder which causes finger, hand and arm injuries. Possible solution would be to use chain drive instead of crushing rollers for feed. The chain will be powered in this case instead of rollers which will give the user a $2^{nd}$ chance to remove their hand.

### 5.4.2. Braking Mechanism:

To improve the Chaff Cutter and further reduce injuries, breaking mechanisms can be used that will act as a fail-safe. If the smart design fails, the braking mechanism kicks in that stops the blade. We have left out braking mechanisms due to increased cost and unsatisfactory results.
The Braking Mechanism would consist of the basic 2 mechanisms. Detection and Trigger Mechanism.

### 5.4.3 Stoppage Mechanism.

Detection mechanism will consist of sensors of some form that will sense the impending injury as the hand gets close to the Rollers or Blade ad will trigger the stoppage of blade to prevent impending injury.
For Stoppage Mechanism, a system that doesn’t break the blade would be better than a one time system that breaks or damages the blades. A disk brake coupled with a trigger and a hydraulic system that applies instant braking force would be required. The Motor Bike disk brake is strong enough the stop the blade instantly.

### 5.4.4. Addition of Pulverizer:

The Japanese model uses a system of meshes and trays that allows not only the fodder to be chopped but also can be used for grinding pulses commonly known as a pulverizer. The addition of pulverizer will make the chaff cutter multipurpose which will make grinding of Wheet, Pulses and Spices possible using the same Chaff Cutter.

### 5.4.5 Using Gears:

Gears can be utilized instead of pulleys to make the design more compact. Pulleys are cheaper and more readily available but they take up more space than a gear. Gears will allow for torque and rpm control in a more compact design.

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# APPENDIX I:BENDING ANALYSIS OF FRAME

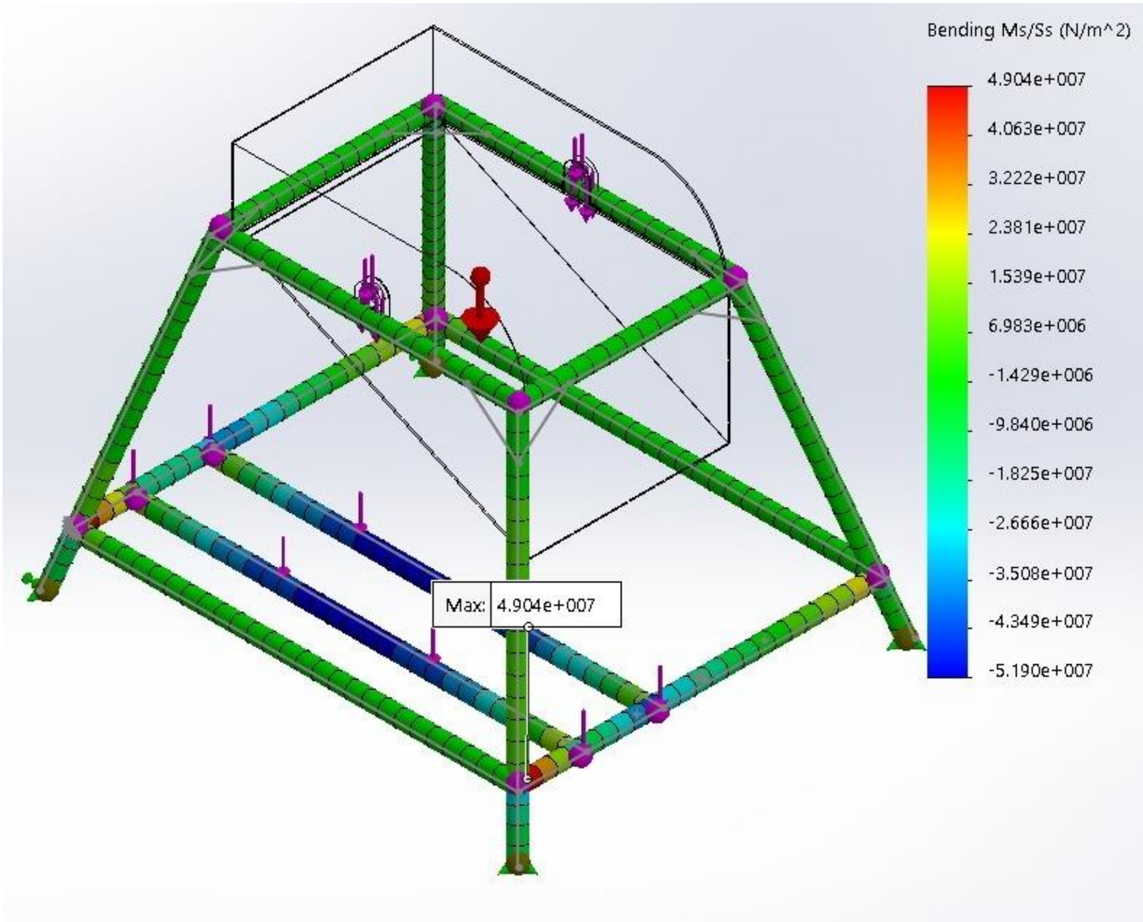


Figure 35: BENDING ANALYSIS OF FRAME

# APPENDIX II: SHEAR STRESS IN THE BEAM

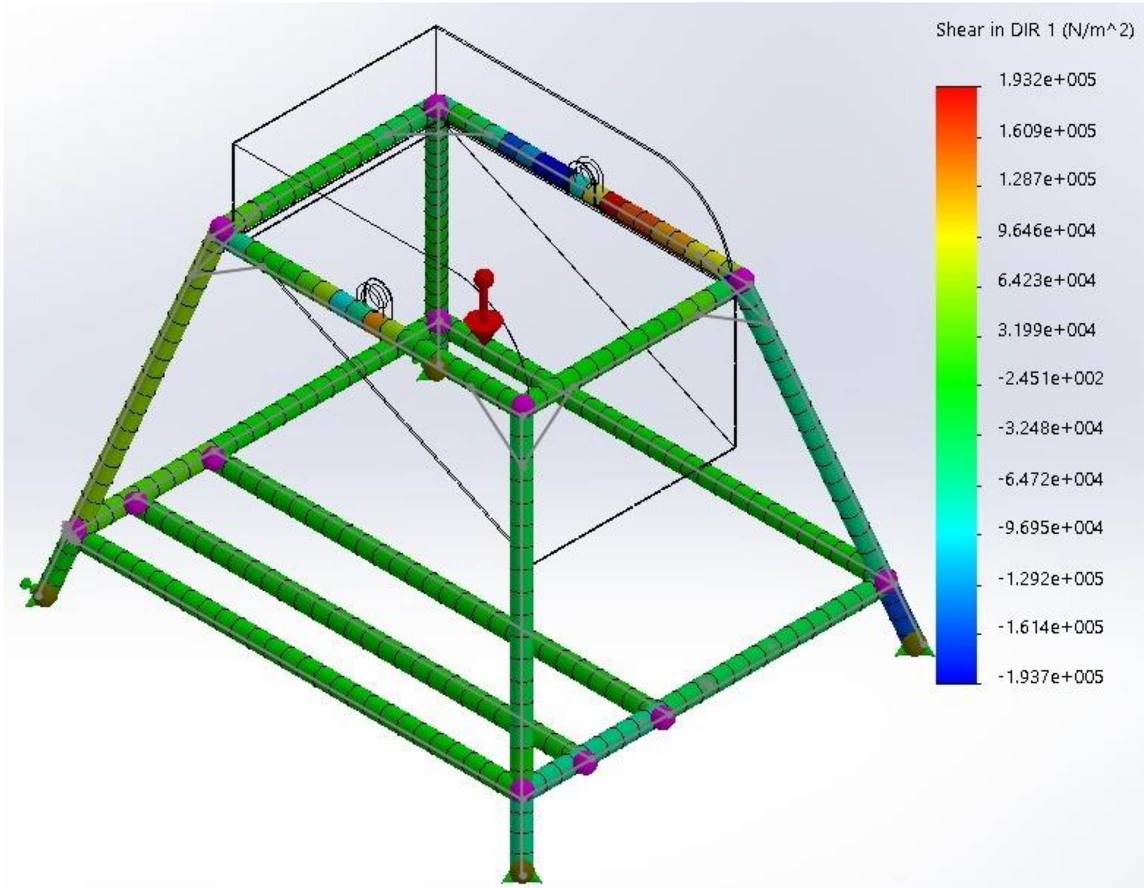


Figure 36: Shear stress in the beam