Design and Fabrication of Small-Scale Sugarcane Harvester

By

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"Design and Fabrication of Small-Scale Sugarcane Cutting Machine"

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Muhammad Hassaan Siddique & Dawood Khalid

Under our supervision and in our opinion, it is fully adequate, in scope and quality, for the degree of B.S. Mechanical Engineering from Pakistan Institute of Engineering and Applied Sciences (PIEAS).

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Head, Department of Mechanical Engineering

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Dedication

This report is dedicated to the parents of both authors, who taught them well despite having financial problems. It is also dedicated to the authors' teachers, especially Dr. Kamran Rasheed Qureshi and Dr. Abdul Basit.

Acknowledgment

First of all, thanks to Allah Almighty, who has blessed us with many abilities while we have not even requested any of these, so we can do this. After that, we acknowledge our parents and teachers who supported us morally and technically, especially our supervisor Dr. Kamran Rasheed Qureshi, who helped us at every step.

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Abstract

The purpose of this project was to design and fabricate a small-scale sugarcane cutting machine. Doing so would be helping Pakistan's agricultural sector to replace the human labor force with machines and ultimately increase its productivity. Despite the thorough adoption of machines in Western countries, harvesting is primarily done in Pakistan by laborer. Most sugarcane harvesters cost tens of thousands of dollars, and small farmers are not capable of buying them. This work was centered on the fabrication of low-cost machine and mainly targeting small farmers. The design was mainly centered around two ideas, cutting and guiding the sugarcane to the side. Power calculations also played an important role in the design process and were done for all parts. CAD model of the design was made in CREO, and stress analysis was done in ANSYS workbench. Several challenges were faced during the manufacturing of the machines, which are discussed in detail along with their solutions. Chassis was made of mild steel square tubes and angle iron was used to make the rest of the body. The machine was finally fabricated, and tested successfully.

Chapter 1: Introduction

This chapter discusses the background, objectives, scopes and thesis organization of the Final Year Project titled "Design and Fabrication of Small-Scale Sugarcane Cutting Machine."

1.1 Background

Sugarcane is tropical grass composed of water, fiber and sugar. It is considered to be the most cultivated crop worldwide. Sugarcane is almost cultivated in almost 90 countries around the globe on almost 13 million hectares of land with the production of nearly 1.3 billion tons [1]. Pakistan produces a large portion of this production. Pakistan produces around 46 million tons of sugarcane, which makes it the 5th largest sugarcane producer in the world, including countries like Brazil, India, China, and Thailand [2].

Sugar is found nearly in every product. For example, it is used in every bakery product, soft drink and many others products. Nearly, 75 percent of sugar produced is obtained from sugarcane [3].

1.1.1 Harvesting

Harvesting is the process of cutting or gathering the fully ripened crops from the soil. There are many types of harvesters available in the market depending on the crop to harvest. The machine used to harvest sugarcane is known as a sugarcane harvester. Similar to the other harvesters for other crops, the sugarcane harvester also reduces the manual labor hence, also proving to be more economical rather than conventional methods.

1.1.2 Commercially Available Harvester

There are different commercially available harvesters in the market. Their functions and prices vary from each other. Some harvesting machines are used to cut, chop, transmit, leaves strip and for separating cane and leaf. But it costs more than 60,000 USD which cannot afford by most farmers working on a small-scale producing 100kg per hectare through their land.

1.1.3 Sugarcane Harvesting Techniques in Pakistan

Mostly like other developing countries, sugarcane is harvested in two ways in Pakistan. These techniques are:

- By machinery
- By human laborer

1.1.3.1 Harvesting by Machinery

The first technique by which sugarcane is harvested by harvesting through sugarcane harvesters, as shown in Figure 1-1. In developed countries, sugarcane is harvested through machines, but its process is not so common in the case of developing countries like Pakistan. These machines are much efficient that they can easily harvest an acre of sugarcane in just 1-2 hours. This type of harvesting has the following downsides;

- Skilled labor is required for operating such heavy machinery.
- Higher initial cost
- Higher maintenance price
- Not applicable on small farms.

Figure 1-1: Sugarcane harvesting through machines [4]

1.1.3.2 Harvesting by Human Labor

The second technique is using human labor which is the most common method of harvesting crops in Pakistan. The price of a laborer for harvesting the sugarcane is 20-25 rupees per kilogram of the crop. For example, if an acre is 1000kg, the price of labor would come out to be 20000-25000 rupees. Figure 1-2 shows human laborer harvesting sugarcane. This process has the following downsides:

- Time-consuming process
- Expensive for farmers
- Shortage of labor (caused by a few following reasons)
  - During peak seasons, there is natural shortage of labor
  - Industrialization
  - Lower wages for laborer in the agricultural sector in the society
  - Better non-farm opportunity

Figure 1-2: Manual sugarcane harvesting [5]

1.2 Motivation

Agriculture is considered to be the backbone of Pakistan's economy. A large percent of Pakistan's economy is directly or indirectly dependent on agriculture. About 38.5

percent of the labor force is employed in the agricultural sector [6]. Agricultural sector contributes about 18.5 percent to the country's Gross Domestic Product (GDP.). In this highly competitive environment, we require more productivity. To fulfil the future demands, the agricultural sector requires improvement in farming techniques and equipment at an economical cost. By using new agricultural techniques and machinery, human labor would replace or reduce to some degree.

Increasing population growth shows an increase in food demand, and to meet these upcoming demands, the agriculture sector requires better farming techniques and equipment. Labor wages are increasing due to the increase in demand for agricultural machines in Pakistan. Despite the increase in labor wages, most Pakistani farmers cannot afford harvesters for specific crops. Most of our harvesting techniques involve manual labor which lowers the yield and efficiency of our agricultural sector. Due to this most people are moving towards better-earning opportunities.

1.3 Objectives

The purpose of this project was to make a low cost, small-scale sugarcane cutting machine. The main objectives of the present project were:

- To design various parts of a small-scale sugarcane cutting machine using CREO;
- To perform analysis using ANSYS for various parts of the machine;
- To fabricate a sugarcane cutting machine with the available material at PIEAS.

1.4 Scope

The design proposed in this project is not limited to either internal combustion engines or electric motors but it can run on any source of energy. This machine is capable of harvesting an acre of sugarcane in just 3 hours. All the design calculations were done to make a small-scale sugarcane cutting machine, which may not be applicable for medium or large-scale machines. This machine design is only applicable for sugarcane cutting. This project was done under a limited budget of 50,000PKR.

1.5 Thesis Organization

This thesis consists of five chapters. Chapter 1 covers the introduction, which contains the background, motivation, objectives, and scope of the project. Chapter 2 contains a literature review, and it includes a brief overview of all the literature studied for the design of sugarcane cutting machines. This chapter also presents some information about commercially available machines. Chapter 3 covers the design methodology and also includes the calculations done for the design of a small-scale sugarcane cutting machine and enlightens the decision-making processes that had been undertaken for this project. Chapter 3 also contains the simulation analysis and 3D modelling of the sugarcane cutting machine. Chapter 4 discusses the fabrication part in thorough details. Chapter 5 covers the discussion about the FEA results, fabrication and the sustainability aspect of the project. Conclusion and future recommendations are discussed at the end of the thesis.

Chapter 2: Literature Review

Literature was reviewed to gather knowledge about the properties of sugarcane and to learn about the previous design approach for the design of small-scale sugarcane cutting machines. Furthermore, commercially available machinery and their respective properties were also studied.

2.1 Mechanical Properties of Sugarcane

Before designing the cutting machine for sugarcane, it is important to find the mechanical properties of sugarcane. It includes the cutting force and energy requirements for the cutting of sugarcane.

M. P. Awathale, G.D. Shelke, S.S. Borikar, and A.P. Khanate studied the mechanical properties of the sugarcane which influence the performance of the unit operation in a harvester. For the design of the cutter, cutting force is very important. Researchers found the cutting resistance ranging from 29N to 106N [7]. These values vary at different nodes. So, the cutting force requirement in this project was selected to be 106N.

According to Suleiman Samaila [8], sugarcane harvesting requires a lot of labour. The latest mechanization of this process relies heavily on foreign machines which makes it difficult to get needed spare parts. Therefore, making a sugarcane cutting machine on our own would make the country self-sufficient, it is very important to have preliminary data on the energy required for cutting sugarcane. The test result reveals that 15.71 Joules to 23.83 Joules are needed to cut the base of sugarcane.

2.2 Commercially Available Sugarcane Cutting Machine

Figure 2-1 shows a sugarcane harvester model 4GL-1 from Anon [9]. This machine can cut, chop, transmit, strip leaves, and separate cane and leaf. Although, it is an excellent machine it costs more than 60,000 USD which most of the farmers cannot afford in Pakistan.

Figure 2-1: Whole stalk sugarcane harvester [9]

Sugarcane Harvester Austoft 4000 is also an excellent piece of machinery for harvesting sugarcane. Although, this machinery is an excellent performer for harvesting sugarcane it costs more than 120,000 USD, which again cannot be afforded by most of the farmers in Pakistan. Figure 2-2 shows the Autosoft 4000 sugarcane harvester.

Figure 2-2: Autosoft 4000 sugarcane harvester [4]

2.3 Design of Sugarcane Cutting Machines Available in Literature

S. Shankar et al., did the mechanization of small-scale sugarcane harvesting machines [10]. The design of this work is more compact, and it looks like a trolley in the shopping complex. The main components in their design are controllers such as Arduino and linear actuators. The machine uses ultrasonic sensors and four-channel relays. There are two ultrasonic sensors on the machine. One measures the ground level and the other sensor measures the height of the linear actuator. The ground-level measuring sensor sends the feedback signal to the Arduino. The Arduino controls the linear actuator. The DC motor which was used in this project provided a torque of 4.5 Kg. The motor was coupled with the linear actuator. A circular cutter which is of 220 mm diameter was attached to the D.C. motor. A 24-volt battery with a current value of 7 Amps was used as a power source for the complete setup. When the machine is taken into the field, the ultrasonic sensors start to send the signals to the Arduino and the linear actuator varies its height depending on the ground level. The fabricated machine is shown in Figure 2-3

Figure 2-3: Fabricated machine [10]

V. Jamadar et.al., also developed a sugarcane cutting machine. In their paper, an attempt was made to design and manufacture a small semi-automatic sugarcane cutter by fabricating it locally [11]. The design was very simple and can be fabricated with local fabricators. According to the authors, "Both AC and D.C. power can be used, depending upon the availability of power or even an I.C engine can be used." The machine was simple, as shown by the CAD model given in Figure 2-4

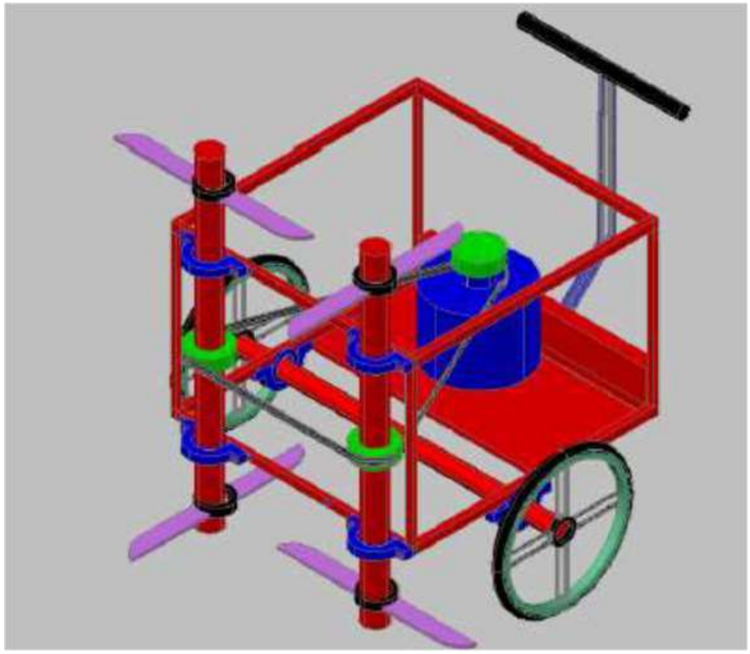


Figure 2-4: CAD model [11]

S.Siddaling and B.S.Ravaikiran also made a small-scale sugarcane cutting machine to reduce the efforts of the farmer and increase the efficiency of the agricultural products [12]. Figure 2-5 shows the CAD model of their proposed design.

Figure 2-5: CAD model [12]

This machine can cut the lower and upper portions of sugarcane containing leaves. This machine requires much lesser maintenance as compared to the other commercially available machines. Figure 2-6 shows the manufactured model of the design.

Figure 2-6: Manufactured design [12]

Chapter 3: Design Methodology

In this chapter, the design methodology and different aspects of the design are discussed. After briefly studying the literature, it was noted that all the designs were lacking the ability is moving sugarcane out of the way of the machine to sideline them for stocking.

3.1 Previous Design

Figure 3-1 shows the CAD model of the previous design. The previous design consisted of two parts:

- Front part
- Rear part

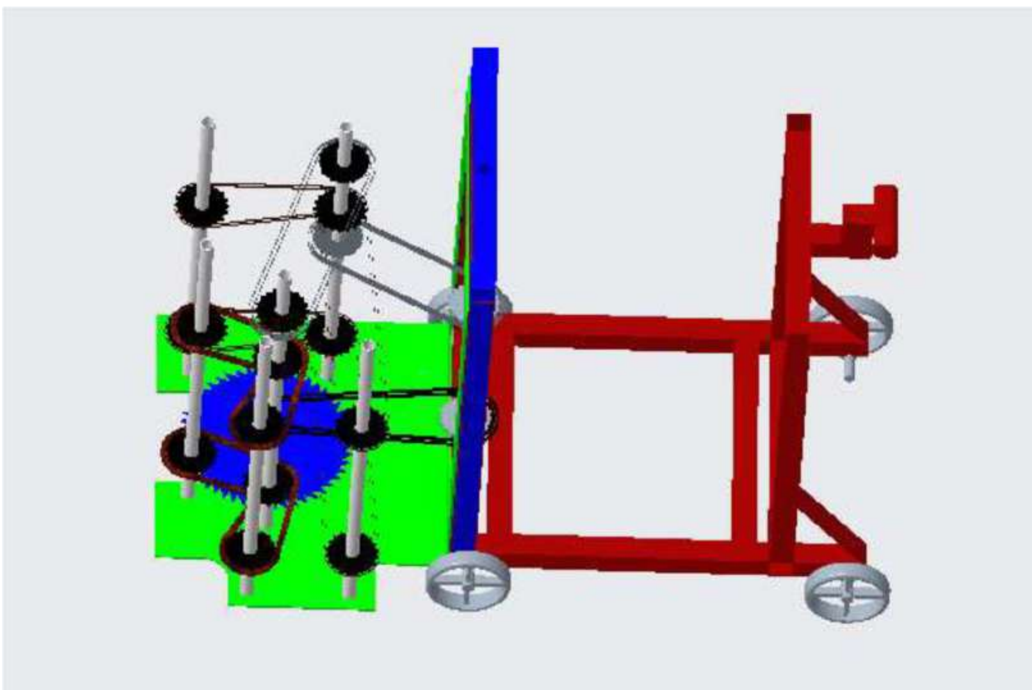


Figure 3-1: Assembly diagram of the previous design

3.1.1 Front Part

The front part consisted of a cutting blade having the following parts

- Cutter base
- Cutter
- Sprocket

- Mild- steel rods
- Chains

The guide vane mechanism consisted of a sprocket-chain mechanism. It is shown in Figure 3-2.

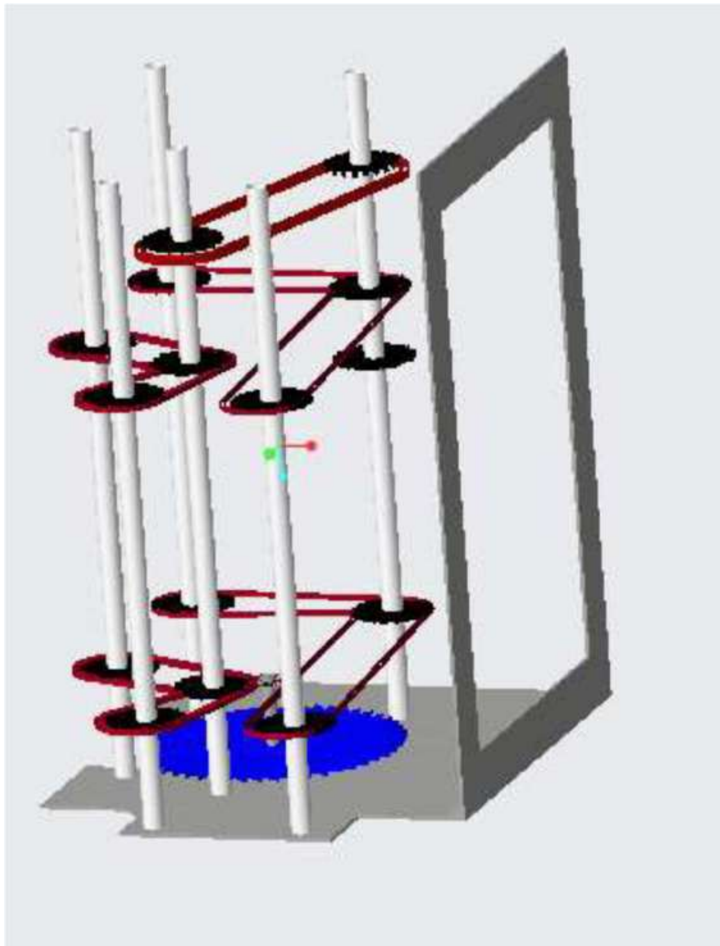


Figure 3-2: Front part assembly

3.1.2 Rear Part

Figure 3-3 shows the rear part assembly. The rear part consisted of the following parts:

- Chassis
- Tire-axle assembly

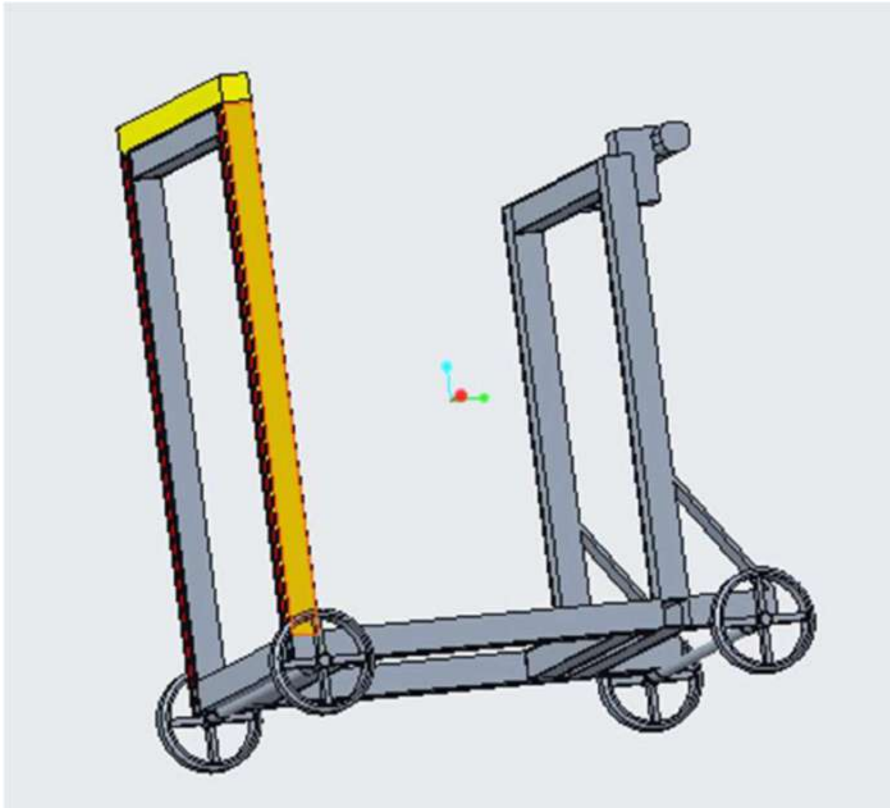


Figure 3-3: Rear part assembly

3.2 Reasons for Design Rejecting the Previous Design

The previous design was rejected due to following reasons:

- Guide-vane mechanism unable to work
- The mass of the designed machine was nearly 172 kg.
- Unbalanced shaft
- High power was required to move the machine

3.3 New Design

The design approach was to make a self-propelling sugarcane cutting machine with an estimated cost of 55,000 PKR.

Sugarcane should be moved to the side once the machine has cultivated it. If the machine does not move the sugarcane out of the way, it will run over it and ruin it. In some form or another, all commercially available machines push sugarcane out of the machine's path after cutting it, but no small-scale machine could do so.

3.4 Design Calculations

Design calculation involves the design of the following:

- Cuter selection and power consumption
- For cutter shaft
- Power requirement to drive machine
- Wheel shaft
- Forces on side-frame of machine

3.4.1 Cutter Selection and Power Consumption

The cutter was purchased from the market. Due to the bending of sugarcane structure is placed in front and cutter blade at the end of the frame, the cutter is attached to a shaft above it. It cannot be below driven by blade because there would still be 1 inch of sugarcane left above ground and placing the shaft below the cutter would make it stuck in the sugarcane. Figure 3-4 shows the assembly of new design.

$$\text{Force required to cut sugarcane} = 106 \text{ N}$$

$$\text{Diameter of cutter} = 12 \text{ in} = 0.3048 \text{ m}$$

$$\text{Required torque} = 106 * \frac{0.3048}{2}$$

$$\text{Required torque} = 16.15 \text{ Nm}$$

Cutting rpm is in the range of 750 rpm

$$\text{N} = 750 \text{ rpm}$$

The power required by the cutter to run is:

$$\text{P} = \frac{2 * \pi * 750}{60} * 16.15$$

$$\text{P} = 1268.76 \text{ W} = 1.27 \text{ KW} = 1.7 \text{ hp}$$

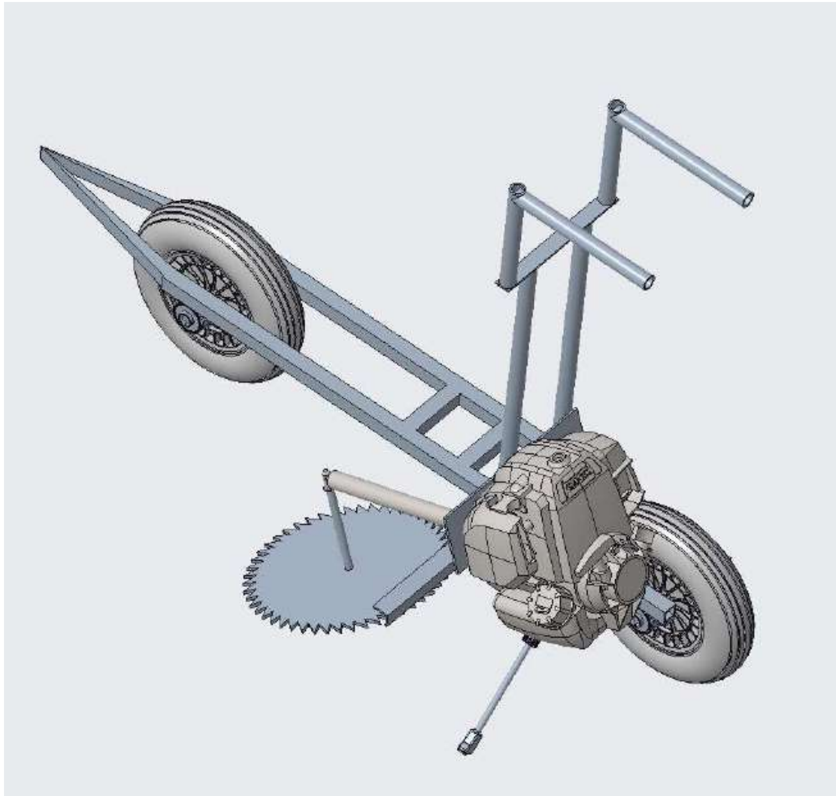


Figure 3-4: Cutter power

3.4.2 Design Calculation for Cutter Shaft

The material used for the cutter shaft was mild steel [13].

$$\text{Tensile strength} = Sy_t = 150\ \text{N/mm}^2$$

$$\text{F.O.S} = 3$$

According to the maximum shear stress theory

$$\text{Max. shear stress} = \frac{0.5 * Sy_t}{\text{F.O.S}} \tag{3.1}$$

Putting the value in the equation (3.1)

$$Sy_s = \frac{0.5 * 150}{3}$$

$$Sy_s = 25\ \text{N/mm}^2$$

Calculating the diameter of the shaft

$$T = \frac{\pi}{16} * d^3 * Sy_s \tag{3.2}$$

Putting the values in equation (3.2)

$$20.574 * 10^3 = d^3 * \frac{\pi}{16} * 25$$

$$d^3 = 4191.3 \text{ mm}^3$$

$$d = 16.12 \text{ mm}$$

To prevent material failure, we took;

$$d = 20 \text{ mm}$$

$$T = \frac{\pi}{16} * d^3 * Sy_s'$$

$$20.574 * 10^3 = \frac{\pi}{16} * 20^3 * Sy_s'$$

$$Sy_s' = 6.706 \text{ N/mm}^2$$

As

$$Sy_s' < Sy_s$$

So, the present design is in a very safe region.

3.4.3 Power Required to Drive Machine

The power required to drive the machine was calculated by performing the following calculations [14].

The total weight of the sugarcane machine was:

$$\text{Mass} = 50 \text{ Kg}$$

$$\text{Normal force} = N = mg$$

$$N = 50 * 9.8$$

$$N = 490 \text{ N}$$

For calculation of frictional forces on the wheels:

The coefficient of friction between tire and surface varies from 0.4-to 0.7 [15].

$$\mu = \frac{0.4 + 0.7}{2}$$

$$\mu = 0.55$$

So,

$$f_s = \mu * N \tag{3.3}$$

Putting values in equation (3.3)

$$f_s = 0.55 * 490$$

$$f_s = 269.5 \text{ N}$$

$$\text{Diameter of tire} = 14 \text{ in.}$$

For calculating torque on the wheels:

$$\text{Torque} = r * f_s \tag{3.4}$$

$$T = \frac{14}{2} * 269.5 * 0.0254$$

$$T = 47.917 \text{ Nm}$$

Normal walking speed of a human being is:

$$\text{Speed} = 3.6 \text{ Km/h} = 1 \text{m/s}$$

Using this speed to calculate the power to drive wheel shaft:

$$v = r * \omega \tag{3.5}$$

$$\omega = \frac{v}{r} = \frac{1}{7 * 0.0254} = 5.624 \, rad/s$$

Using equation (3.6) to calculate the power to propel machine:

$$P = T * \omega \tag{3.6}$$

$$P = 269.5 \text{ W}$$

Total power to drive sugarcane cutting machine= 269 W+1270 W

=1539 W=2 hp

3.4.4 Calculations for Wheel Shaft

To calculate the diameter of the wheel shaft:

$$\mathcal{T}_a = 0 \text{ lbf} \cdot \text{in } T_m = 49 \text{ N} \cdot \text{m} = 49 \text{ J}$$

$$M_a = 30 \text{ J} = 30 \text{ J } M_m = 0 \text{ lbf} \cdot \text{in}$$

the values from tables A 15-9 & A 15-8 were taken from Shigley [16]

$$25 \cdot 9.8 = 245$$

$$K_{ts} = 1.5$$

$$K_t = 1.7$$

From figure 6.20, and 6.21 Shigley, [16]

$$q = 0.64 \quad q_{shear} = 0.66$$
$$K_f = 1 + \bar{q} \cdot (K_t - 1) = 1.448$$
$$K_{fs} = 1 + q_{shear} \cdot (K_{ts} - 1) = 1.33$$
$$S_{ut} = 650 \text{ MPa}$$

$$T_a = 0 \text{ lb.in} \quad T_m = 49 \text{ N.m} = 49 \text{ J}$$

$$M_m = 0 \text{ lb.in} \quad M_a = 30 \text{ N.m} = 30 \text{ J}$$

By taking values from tables A15-9 &15-8 of Ref. [16]

$$25 * 9.8 = 245\ N$$

$$K_t = 1.7$$

$$K_{ts} = 1.5$$

From figure 6.20, 6.21

$$q = 0.64$$

$$q_{shear} = 0.66$$

$$K_f = 1 + q * (K_t - 1) = 1.448$$

$$K_{fs} = 1 + q_{shear} * (K_{ts} - 1) = 1.33$$

$$S_{ut} = 650 \text{ MPa} \quad S_y = 250 \text{ MPa}$$

$$S'_e = 0.5 * S_{ut} = 3.25 * 10^8 \text{ Pa}$$

$$a = 1.58 \quad b = -0.085$$

a & b from table 6.19 of Ref. [16]

$$K_a = 0.28 \qquad \text{ground finish}$$

$$K_b = 0.76990$$

$$K_d = K_c = K_f = 1$$

$$K_e = 0.814$$

$$S_e = k_a \cdot k_b \cdot k_c \cdot k_d \cdot k_e \cdot k_f \cdot S'_e = (5.703 \cdot 10^7)\ \text{Pa}$$

$$A := \sqrt{4(K_f \cdot M_a)^2 + 3(K_{fs} \cdot T_a)^2} = 86.88\ \text{J}$$

$$B := \sqrt{4(K_f \cdot M_m)^2 + 3(K_{fs} \cdot T_m)^2} = 112.878\ \text{J}$$

$$d = \left(16 \cdot \frac{n}{3.14} \cdot \left(\frac{A}{S_e} + \frac{B}{S_y}\right)\right)^{\frac{1}{3}}$$

By putting values,

$$d = 25\ mm$$

$$\sigma_{max}\left(\left(32 \cdot K_f \cdot \frac{M_a}{\pi \cdot d^3}\right)^2 + 3 \cdot \left(16 \cdot K_{fs} \cdot \frac{T_m}{\pi \cdot d^3}\right)^2\right)^{\frac{1}{2}} = (8.922 \cdot 10^3)\text{psi}$$

3.4.5 Forces on the Side Frame of Design

To calculate the forces on the side

$$\text{diameter of the sugarcane} = d = 22.1\ \text{mm}$$

$$moment\ of\ area = I = \frac{\pi}{64} * d^4 = 11709.52\ mm^4$$

$$Elastic\ Modulus = E = 2288.33\ N/mm^2$$

i) Force on the top bar of the Frame

$$P = \frac{3 * E * D * I}{l^3} \tag{3.7}$$

Deflection for the upper bar is 50 mm and the length is 625 mm

By putting values in the equation (3.7), we get

$$P = 16.5\ N$$

ii) Force on the Lower bar of the frame

$$P = \frac{3 * E * D * I}{l^3}$$

Deflection for the upper bar is 25 mm and the length is 400 mm

By putting values in the equation (3.7), we get

$$P = 31.4\ N$$

3.5 CAD Model

CAD model is used to communicate easily about one's design, as well as to create, optimize, and analyze it. PTC Creo Parametric was used to create a CAD model of a small-scale sugarcane cutting machine, which was then used for stress analysis. This topic includes a full explanation of how the model was created, and all other relevant information as well.

3.5.1 Various Parts

The design used for cultivating sugarcane is made up of several different parts. It should also be noted that the titles of the sections included in this thesis were provided by the authors of this thesis. As a result, the names in no way imply that they represent the names of all the parts used worldwide.

3.5.1.1 Cutter Blade

The cutter is a commercially available 12-inch tip cutter that is driven by a shaft attached to the engine. For cutting sugarcane, the cutter is to be rotated at a speed of 750 RPM. The CAD model of the cutter blade is shown in Figure 3-5.

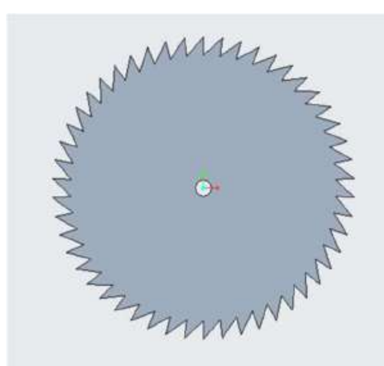


Figure 3-5: Blade cutter CAD model

3.5.1.2 Engine

A 2-stroke, 52cc, delivering 2hp power engine was used because it has a lower weight to power ratio. Figure 3-6 shows the CAD model of the standard engine.

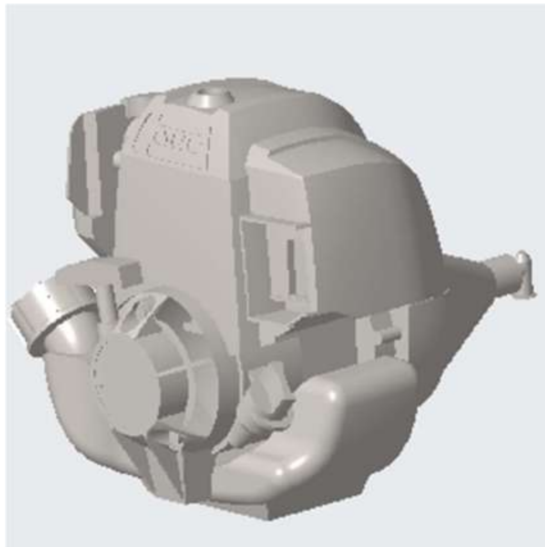


Figure 3-6: Engine assembly

3.5.1.3 Tire-Axle

A tire-axle assembly is made up of a tire and an axle. The design of the sugarcane cutting machine contains four such assemblies. As a result, two tires and two axles were required in total. Figure 3-7 shows the CAD model of axle-shaft.

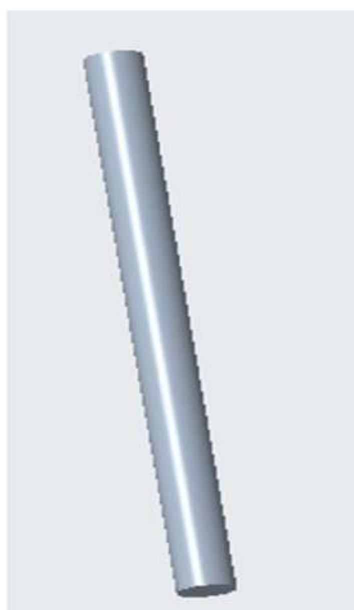


Figure 3-7: Tire-axle

3.5.1.4 Wheel

Commercially available 14-inch tires with a thickness of 3.5-inch were used. The tires usually run-on low speed. Figure 3-8 shows the CAD model of the tire.

Figure 3-8: 14-inch wheel

3.5.1.5 Frame

The frame is shown in Figure 3-9. This frame guides the sugarcane towards the blade. In addition to that, it bends the sugarcane out of way to be cut so that it does not get damaged by the tire of the machine.

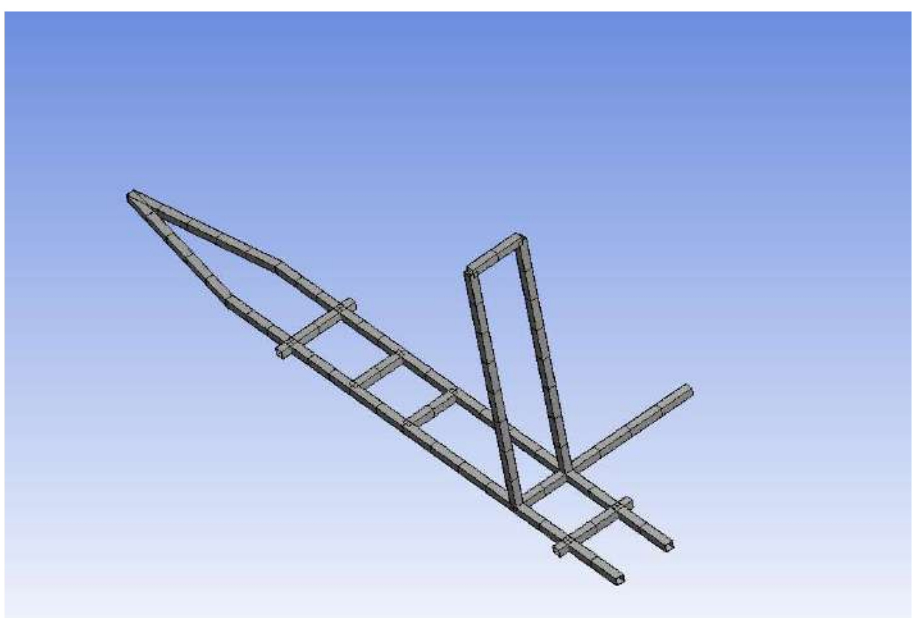


Figure 3-9: Frame design

3.5.1.6 Bearing

The deep groove ball bearing W 61905-2RS1 was used for the wheels. The bearing had a bore diameter of 25mm, having a width of 9mm. The basic dynamic load rating C is 6.05 kN. Figure 3-10 shows the CAD model of bearing.

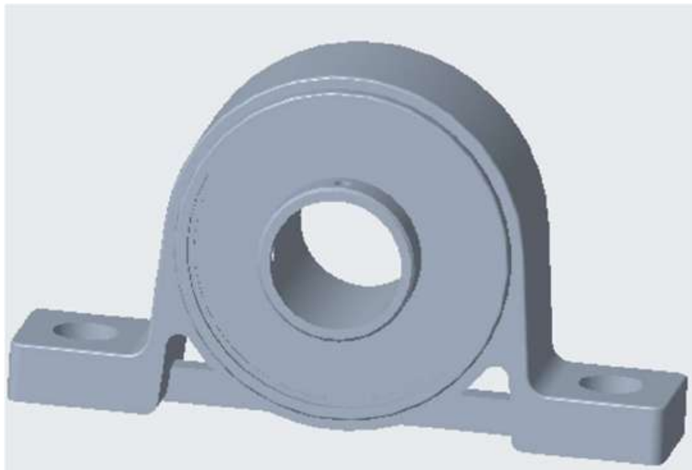


Figure 3-10: W61905 bearing

3.5.2 Assembly

Final assembly was obtained by assembling all parts which have been discussed in detail in previous in this chapter. Figure 3-11 shows the final assembly of the sugarcane cutting machine.

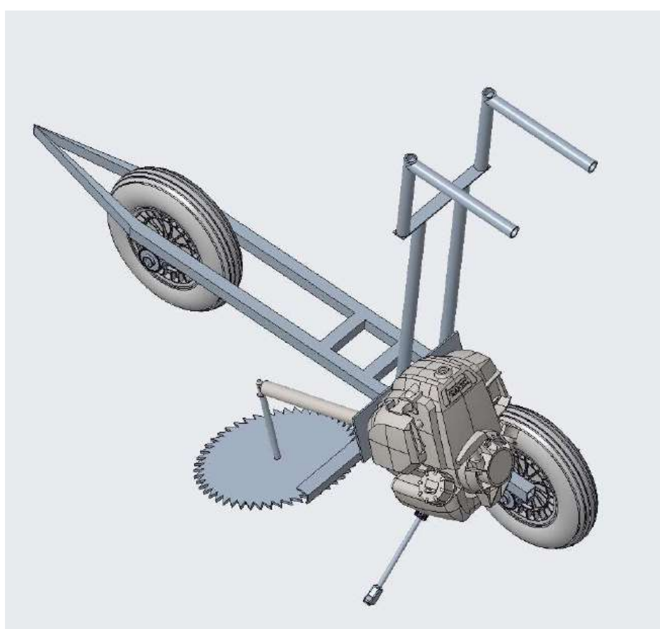


Figure 3-11: Assembly diagram

3.5.3 FEA Analysis

FEA simulation is a cost-effective way to see if the planned machine or some structure is feasible or not [17]. It is primarily concerned with the calculation and measurement of the loads that are applied to the structure [18]. This analysis measured and quantified the effects of forces on a small-scale sugarcane cutting machine. It was one of the most critical indicators of a machine's ability to withstand the various types of forces it will encounter during its regular operation [19].

ANSYS workbench was used for the F.E.A. analysis. The simulation provided us with firsthand knowledge about the strength of the sugarcane cutting machine. The subsection ahead discusses the complete detail of how the FEA analysis was done.

The FEA analysis was run for:

- Frame
- Blade shaft
- Wheel shaft

3.5.3.1 Procedure for Frame

The frame was the most crucial part of our design. The geometry of the frame was added in the ANSYS workbench and meshing was done followed by the application of forces and finally, simulation was run to get results. The line body of the frame was imported.

3.5.3.2 Meshing Settings for Frame

The meshing portion was completed in the second phase. Since it could not be argued that the computer used to conduct this simulation had very limited computational capabilities. As a result, the meshing was performed as finely as possible while remaining within the bounds of the computational power available.

The meshing was done to obtain the most accurate results possible with our computer. Although the mesh type was coarse but keeping in mind the computing power of the computer, the analysis was done. This analysis should not only be considered reasonable but a good one. The number of mesh elements was almost 116. It is shown in Figure 3-12.

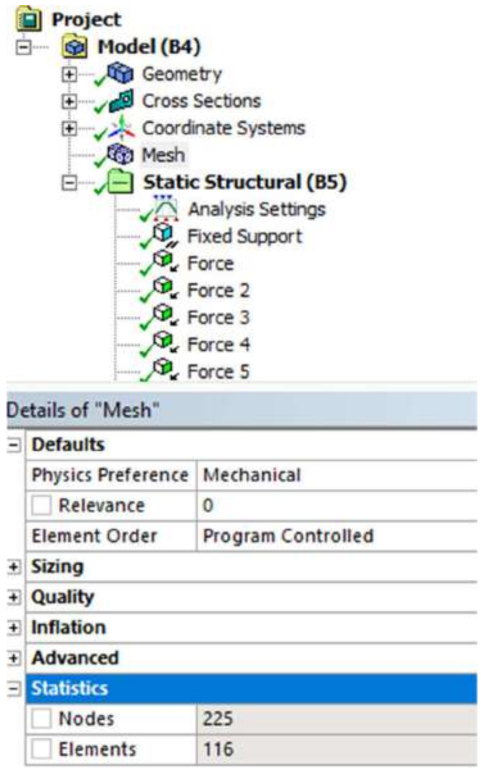


Figure 3-12: Meshing setting

3.5.3.3 Boundary Conditions for Frame

All the forces applied were calculated above and applied to the specific location. This can easily be seen in Figure 3-13.

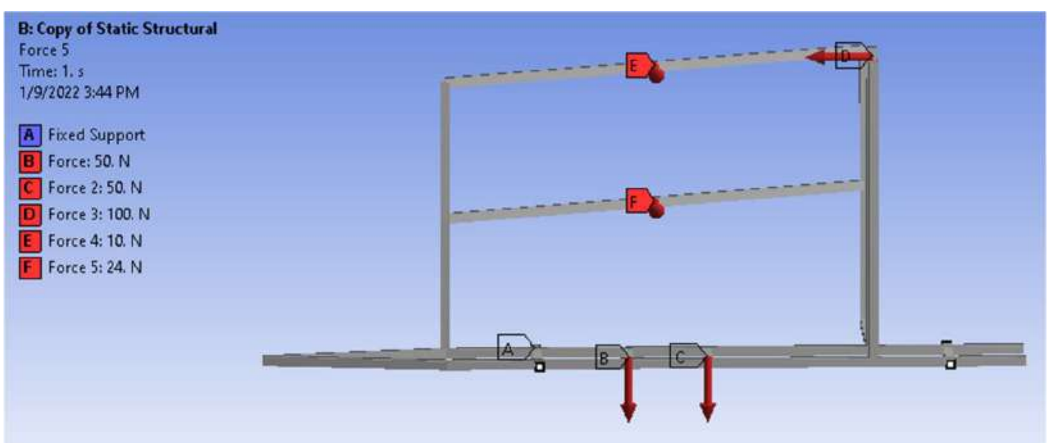


Figure 3-13: Applied force on frame

3.5.3.4 Stresses on Frame

One of the main concerns was the maximum limit of stress that the sugarcane cutting machine would have to bear, which was also quantified in the analysis. Values of maximum combined stresses were noted using this analysis, which can be seen in Figure 3-14.

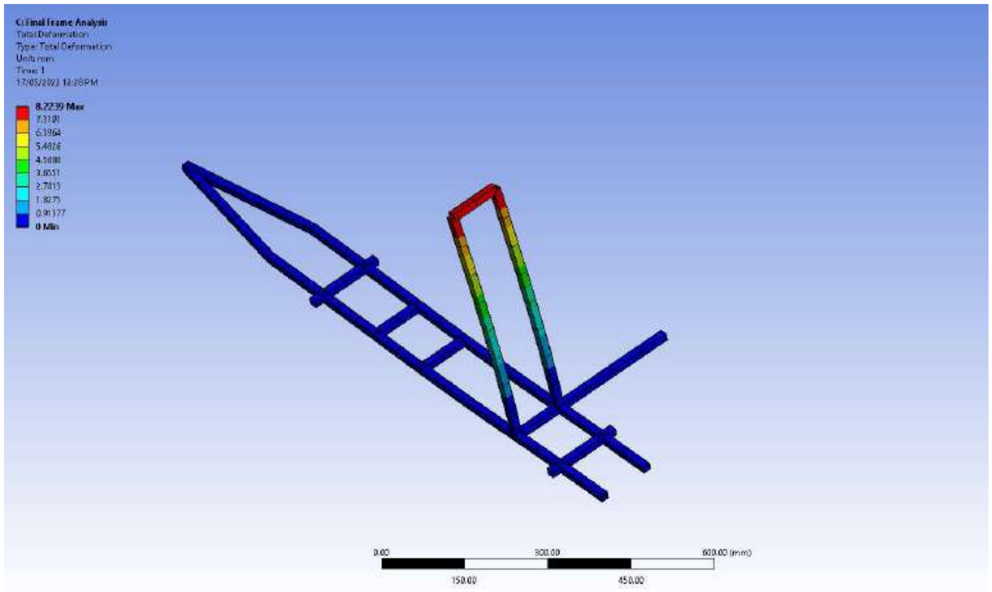


Figure 3-14: Stress analysis of frame

3.5.3.5 Deformation on Frame

Deformation determines how an object will deform under the forces applied to it. As a small-scale sugarcane cutting machine has several forces acting on it, it is important to know how it will deform under them. Deformation results from the analysis are shown in Figure 3-15.

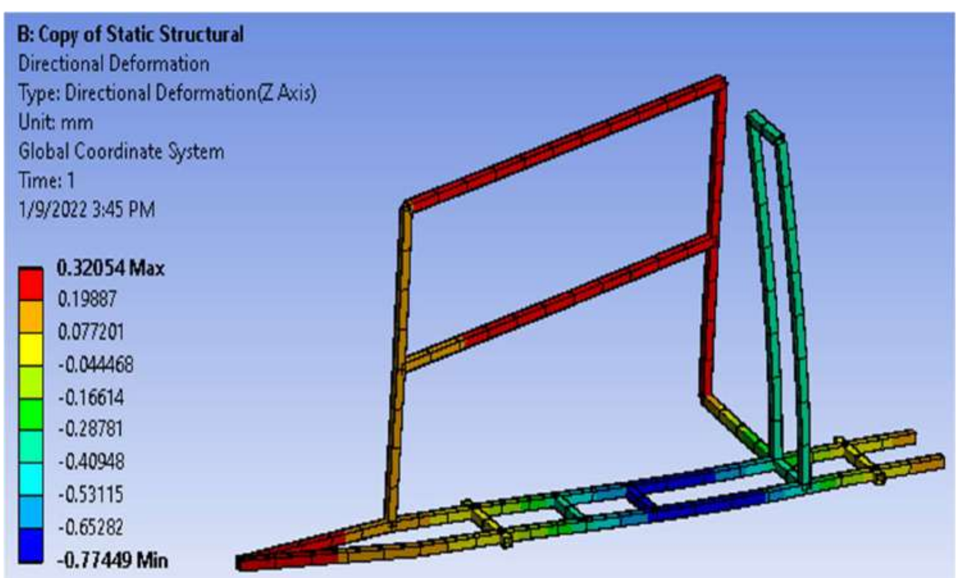


Figure 3-15: Directional deformation for frame

3.5.3.6 Conclusion about Frame

The results for all of the structural analysis performed on the sugarcane cutting machine shows that:

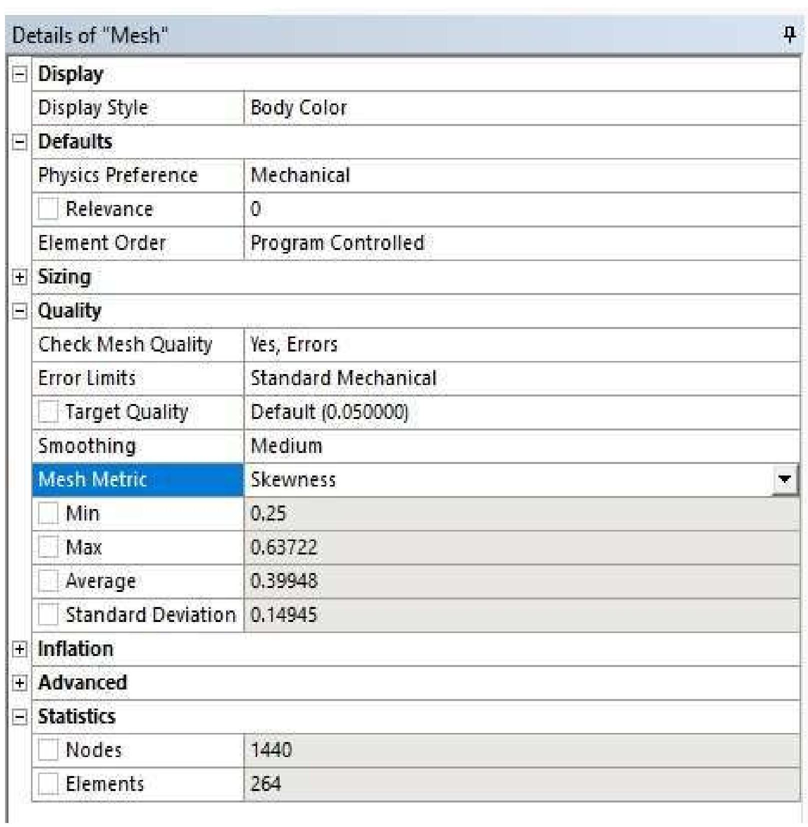
- The maximum deformation was lesser almost 1.2 cm.
- The maximum stress recorded in the structure was more than 3 times lesser than the yield stress value.
- The factor of safety had a minimum value of 3.77.

3.5.3.7 Procedure for Blade Shaft

The blade shaft was the second crucial part of our design. The geometry of the blade shaft was added in the ANSYS workbench and meshing was done followed by the application of moments and finally, simulation was run to get results.

3.5.3.8 Meshing for Blade Shaft

For meshing, the multizone hex-dominant was used. The number of elements generated through this mesh setting was 264. These settings are shown in Figure 3-16:



Details of "Mesh"

Display	
Display Style	Body Color
Defaults	
Physics Preference	Mechanical
Relevance	0
Element Order	Program Controlled
Sizing	
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Skewness
Min	0.25
Max	0.63722
Average	0.39948
Standard Deviation	0.14945
Inflation	
Advanced	
Statistics	
Nodes	1440
Elements	264

Figure 3-16: Mesh settings for blade shaft

3.5.3.9 Boundary Condition for Blade Shaft

All the moments applied were calculated above and applied to the specific location. These boundary conditions are shown in Figure 3-17.

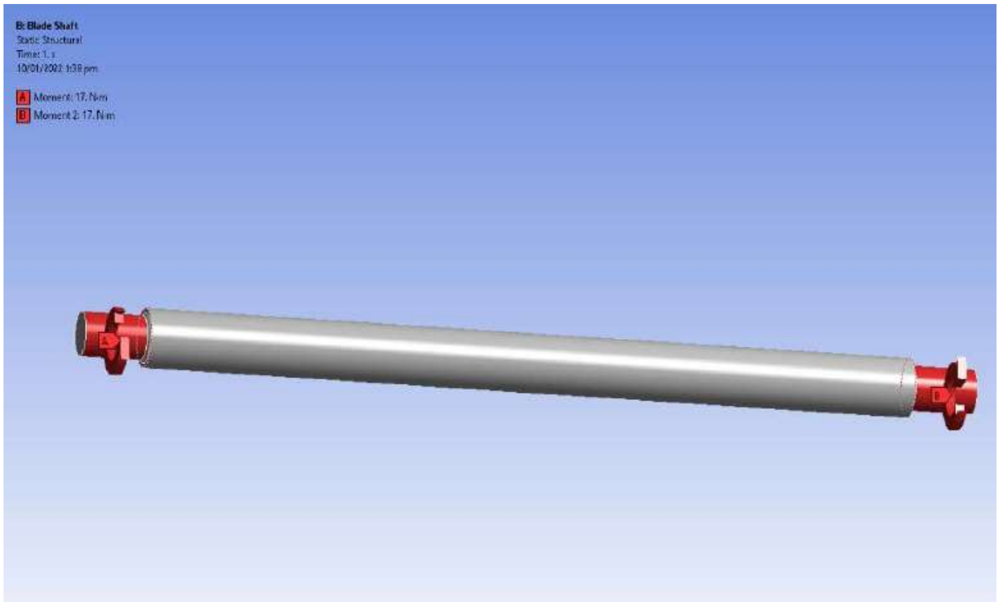


Figure 3-17: Boundary condition for blade shaft

3.5.3.10 Equivalent Stress on Blade Shaft

The equivalent stress was noted after running the analysis. This is shown in Figure 3-18.

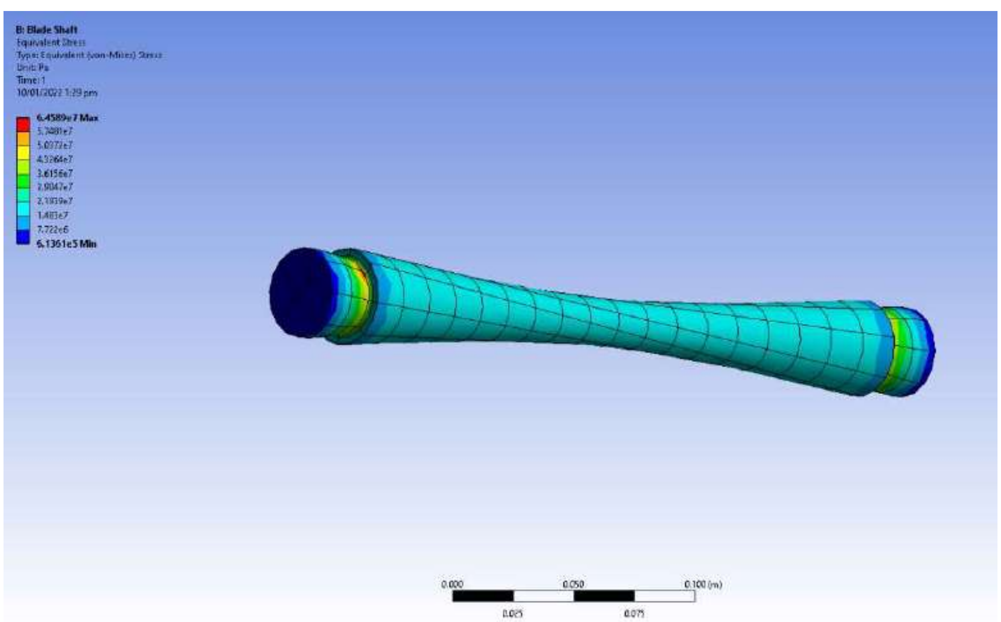


Figure 3-18: Equivalent Stress on blade shaft

3.5.3.11 Factor of Safety for Blade Shaft

The factor of safety is simply a number that shows how much stronger a system is than it needs to be for an intended load. It is the ratio of the strength of material to a maximum applied force. The factor of safety was also measured in the analysis and the minimum factor of safety was 3.8 which is shown in Figure 3-19.

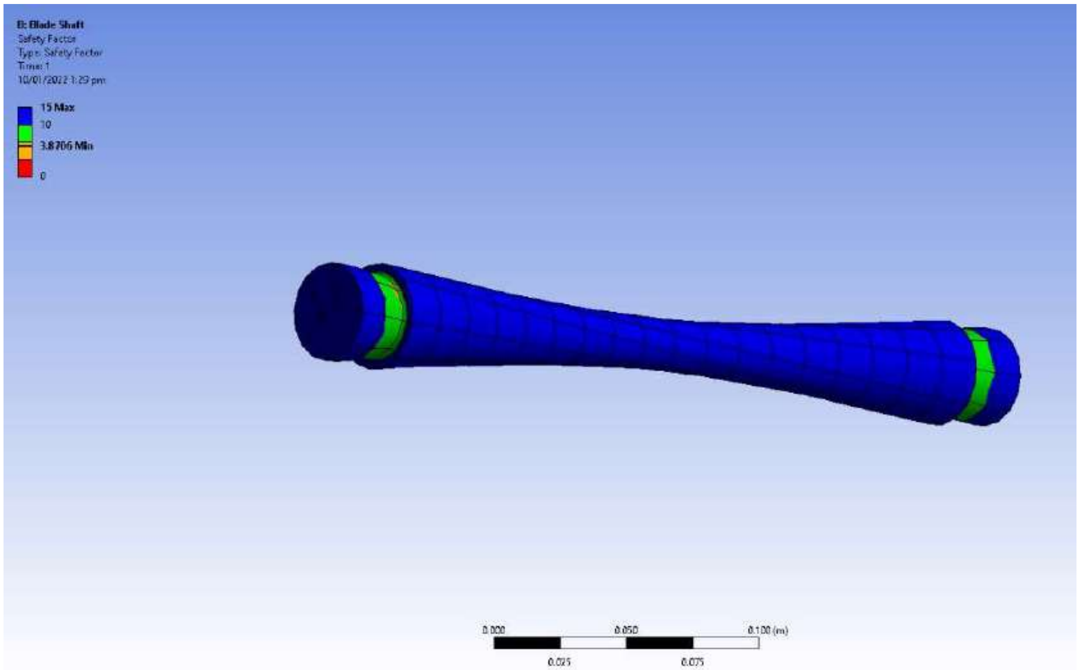


Figure 3-19: Factor of safety for blade shaft

3.5.3.12 Procedure for Wheel Shaft

The wheel shaft was the third crucial part of our design. The geometry of the blade shaft was added in the ANSYS workbench and meshing was done followed by the application of moments and finally, simulation was run to get results.

3.5.3.13 Meshing for Wheel Shaft

For meshing, coarse meshing was selected. The number of elements generated through this mesh setting was 294 which is shown in Figure 3-20.

Initial Size Seed	Assembly
Transition	Fast
Span Angle Center	Coarse
Automatic Mesh ...	On
Defeature Size	Default
Minimum Edge L...	49.8730 mm
Quality	
Inflation	
Advanced	
Statistics	
Nodes	1586
Elements	294

Figure 3-20: Meshing for wheel shaft

3.5.3.14 Boundary Conditions for Wheel Shaft

The boundary condition for the wheel shaft was only the moment at its end which is shown in Figure 3-21.

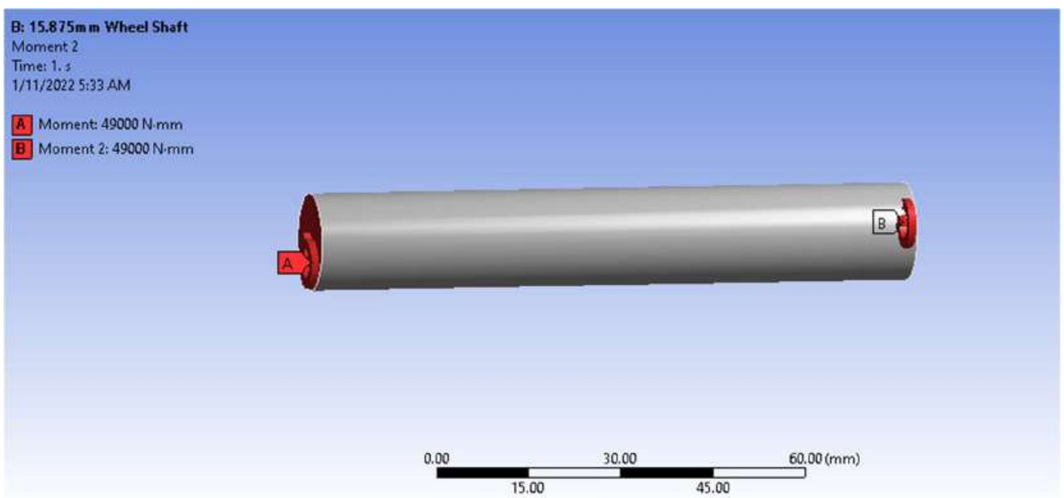


Figure 3-21: Boundary conditions for wheel shaft

3.5.3.15 Deformation for Wheel Shaft

Deformation determines how an object will deform under the boundary condition. Deformation results from the analysis are shown in Figure 3-22.

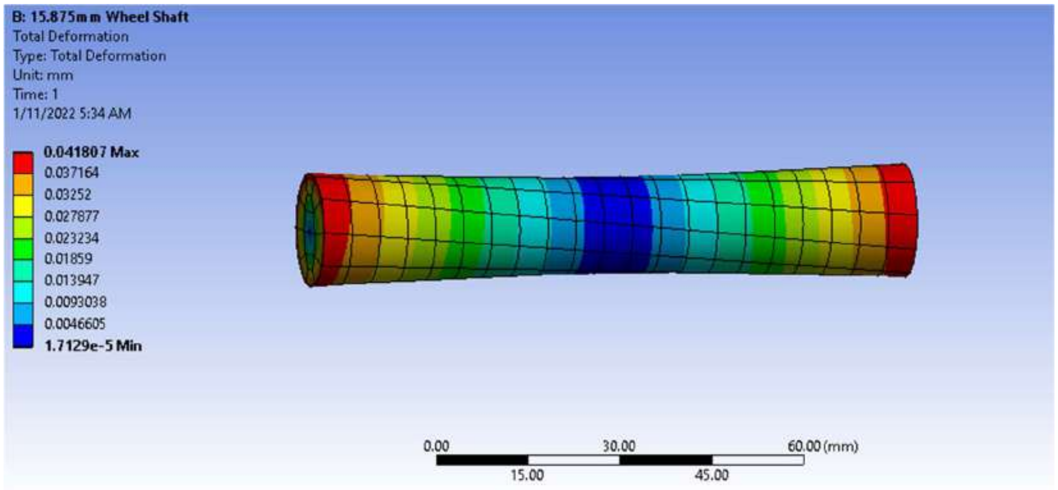


Figure 3-22: Deformation for wheel shaft

3.5.3.16 Equivalent Stress for Wheel Shaft

The equivalent stress was noted after running the analysis. This is shown in Figure 3-23.

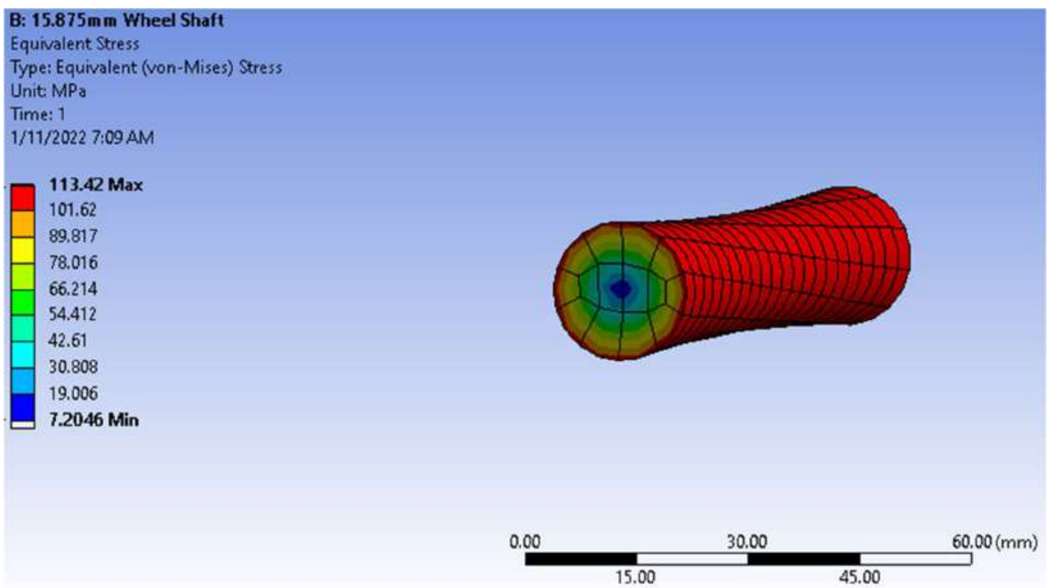


Figure 3-23: Equivalent stress for wheel shaft

3.5.3.17 Factor of Safety for Wheel Shaft

The factor of safety for wheel shaft was also measured in the analysis and the minimum factor of safety was 2.2 which is shown in Figure 3-24.

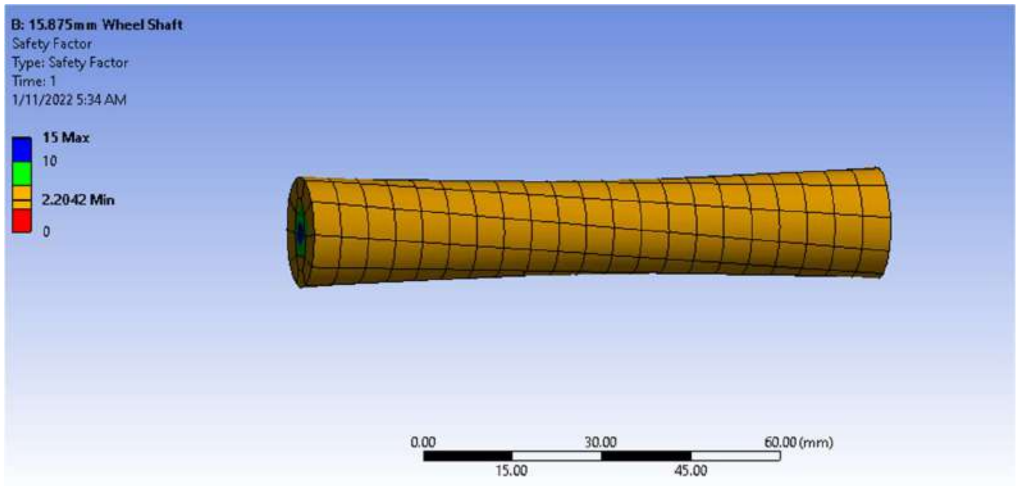


Figure 3-24: Factor of safety for wheel shaft

3.5.3.18 Procedure for Blade

The blade was among the crucial part of our design. The geometry of the blade was added to the ANSYS workbench and meshing was done followed by the application of moments and finally, simulation was run to get results.

3.5.3.19 Equivalent Stress on Blade

The equivalent stress came out to be 19 MPa. This is shown in Figure 3-25.

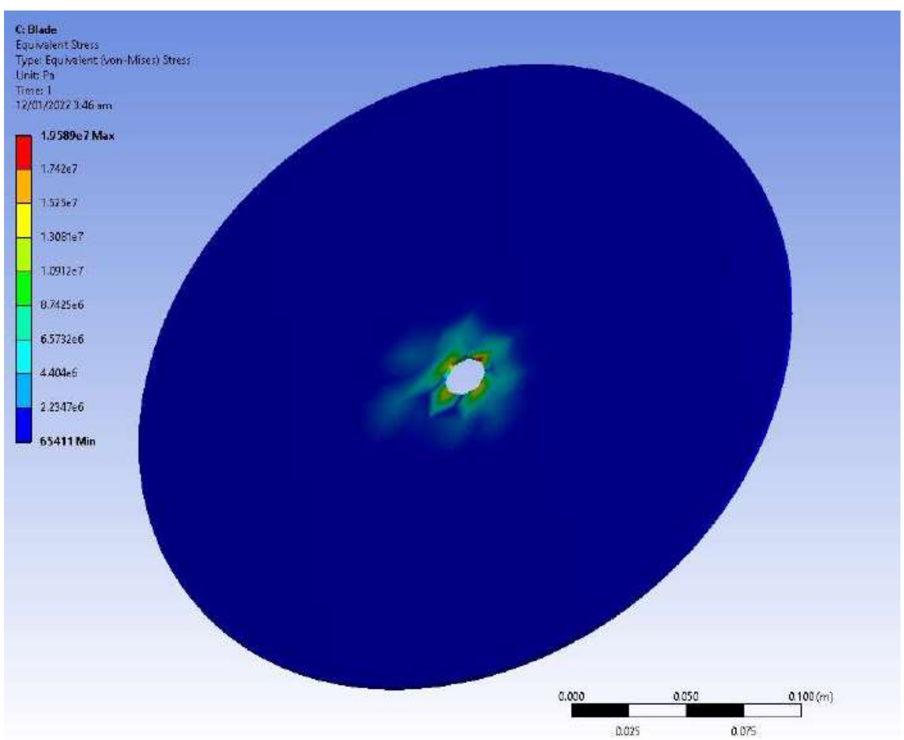


Figure 3-25: Equivalent Stress on blade

3.5.3.20 Factor of Safety for Blade

The factor of safety for blade was also measured in the analysis and the minimum factor of safety came out to be 12. This is shown in Figure 3-26.

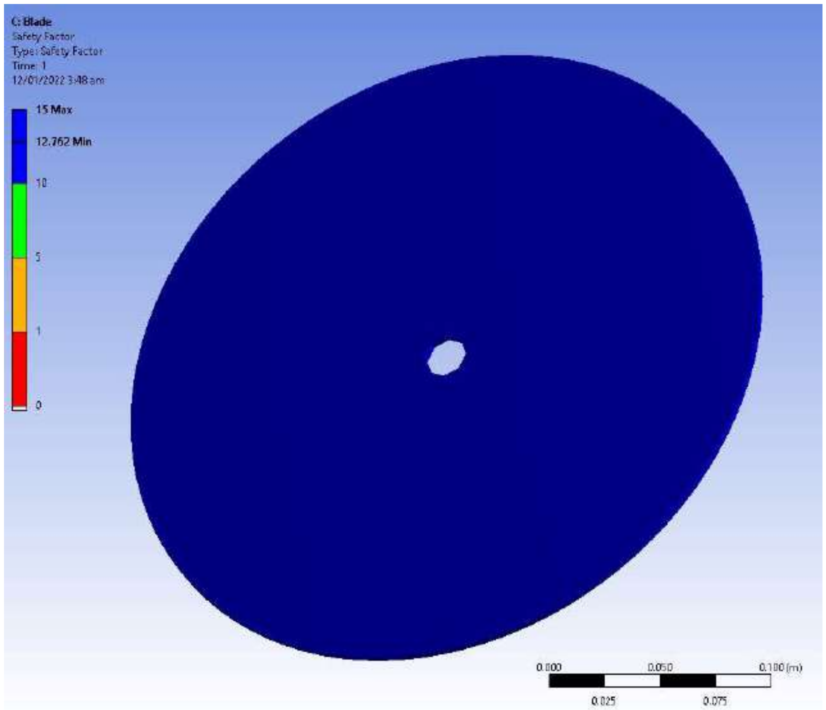


Figure 3-26: Factor of safety for blade

Chapter 4: Fabrication of the Machine

This chapter discusses all the details about how the design was fabricated and assembled, what the problems were, and how they were resolved. Fabrication of the machine started with the manufacturing of the front part, a complex part of our design.

4.1 Fabrication and Machining Processes

Before discussing the manufacturing and assembly of the machine, it is necessary to cover different fabrication and machining processes used in the manufacturing of small-scale sugarcane cutting machines.

4.1.1 Facing Operation

Facing in machining is a basic operation that can be performed on a lathe machine and milling machine, both involve removing material to produce varying machined parts. Facing is commonly used in C.N.C. machines and boring and it refers to the process of removing material from the end and/or shoulder of a workpiece. It uses a facing tool to produce a flat, smooth surface perpendicular to the rotational axis of the workpiece. If the stock has a hole in the center, a half-center is used to stabilize and support the workpiece as shown in Figure 4-1.

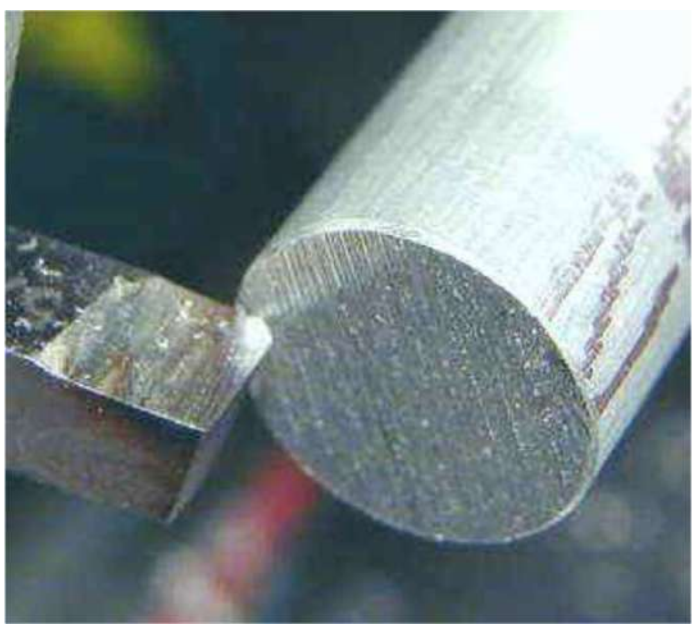


Figure 4-1: Face operation

Speeds and feeds, dimensions and material of cutting tool, types of material to be machined and the method of workpiece clamping will affect the quality and effectiveness of facing operation on the lathe machine [20].

After the workpiece is fixed on the C.N.C. lathe and the facing tool is mounted into the tool holder of the lathe carriage, the tool will feed perpendicularly across the part's rotation axis, to cut the workpiece to the required length accurately. C.N.C. machines can provide power feed instead of hand feed to obtain a smoother surface finish.

4.1.2 Cut-off Operation

In parting or cut-off operations, the objective is to efficiently and securely separate one part of the workpiece from the other. To achieve this, a straight cut is made to a depth that equals the radius of a bar, or workpiece. Figure 4-2 shows the cutoff operation on a lathe machine.

Figure 4-2: Cut-off operation [21]

4.1.3 Turning Operation

Turning is the most common lathe machining operation. During the turning process, a cutting tool removes material from the outer diameter of a rotating workpiece as shown in Figure 4-3. The main objective of turning is to reduce the work piece's diameter to the desired dimension. There are two types of turning operations, rough and finish.

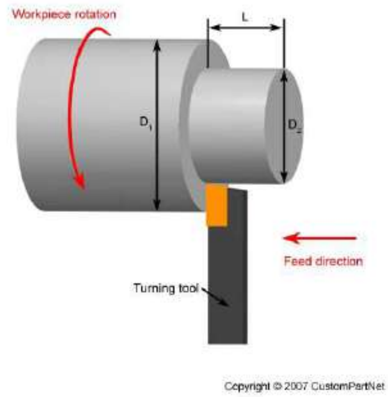


Figure 4-3: Turning operation

4.1.4 Surface Finishing

Surface finish, also known as surface texture or surface topography, is the nature of a surface as defined by the three characteristics of lay, surface roughness, and waviness. It comprises of small, local deviations of a surface from the perfectly flat ideal (a true plane). On a lathe, the surface finish is done by keeping feed rates very low. It is shown in Figure 4-4.

Figure 4-4: Finished surface

4.1.5 Drilling

Drilling is a cutting process that uses a drill bit to cut a hole in a circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multi-point. The bit is pressed against the workpiece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the workpiece, cutting off chips (swarf) from the hole as it is drilled.

4.2 Cutter

There were different types of cutters available in the market, for example, tip cutter, edge cutter etc. 10-inch tip cutter was purchased from the market and used for fabrication because a tip cutter is commonly used for sugarcane cutting. The tip cutter is shown in Figure 4-5.

Figure 4-5: Tip cutter

4.3 Engine

The engine to drive the cutter shaft was a 2-stroke engine. It delivered the power of 2-horsepower. The Engine was not directly connected to the shaft but through a cup piece. The 2-stroke engine was used due to its lightweight and high power to weight ratio. Figure 4-6 shows the engine used.

Figure 4-6: 2-Stroke engine

4.4 Accelerator

The accelerator was used to control the clutch and the speed of the blade. The accelerator was simply mounted on the handle and the wires were connected to the engine. The Figure 4-7 shows the accelerator used.

Figure 4-7: Accelerator

4.5 Handle

The handle was connected to the frame to push the machine and steer the machine. The handle was mounted with the accelerator to keep it a user-friendly experience. The handle was made up of hollow tubes of aluminum. Figure 4-8 shows the handle used.

Figure 4-8 :Handle

4.6 Base Frame

The base frame was made of 1 x 1-inch hollow rectangular pipes. The pieces were joined together by arc welding. Figure 4-9 shows the base frame.

Figure 4-9: Base frame

4.7 Clutch Cup

The clutch cup converted the clutch part motion of the engine to the rotary motion of the shaft. It was mounted on the engine through a plate to place the engine at an angle. Figure 4-10 shows the clutch cup used.

Figure 4-10: Clutch cup

4.8 Gear Head

The gear head was used to transmit power from the shaft to the blasé. It consists of bevel gears inside it. The blade was simply fastened in the front part of gear head. Figure 4-11 shows the gear head.

Figure 4-11: Gear head

4.9 Blade Shaft

The blade shaft was used to transmit power between the gear head and the clutch cup. It contains gear teeth on both ends which go through the clutch cup to the gear head. The shaft was almost 5 ft. long. So, it was cut to keep it to our design considerations. Figure 4-12 shows the blade shaft used.

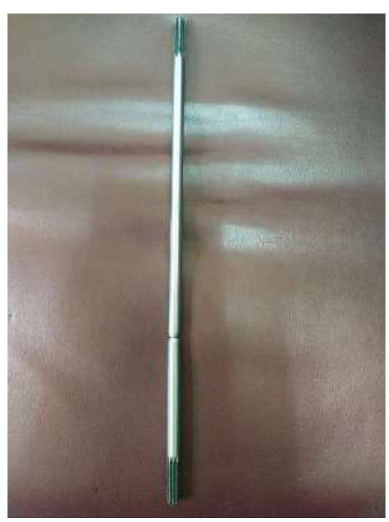


Figure 4-12: Blade shaft

4.10 Metal Plate

A metal plate of mild steel was used to place the engine. It was 14-in. long, 12-in. wide and has a thickness of 4mm. the piece was cut through it to move the clutch cup through it to place the engine. The metal gas cutting technique was used to cut the centre hole of 84-mm diameter. and 4 small holes of 6mm were made to place bolts in it [22]. It is shown in Figure 4-13:

Figure 4-13: Metal plate

4.11 Wheel

The wheel used to move the whole machine and it is 14-inch in diameter and 4-inch wide. Figure 4-14 shows the wheel.

Figure 4-14: Wheel

4.12 Assembly

The parts were assembled at their designated places and finally, the machine was fabricated successfully. Figure 4-15 shows the assembled machine.

Figure 4-15: Assembled machine

4.13 Cost Economic Estimates

This section discusses the economic cost of our project. This includes the cost of all the parts and materials required for the project. This section is further divided into the initial estimate and final expenditures

4.13.1 Initial Assessment

The budget proposal which was given earlier is shown in Table 4-1.

Table 4-1: Initial assessment

Serial no.	Name	Specifications	Quantity	Price/unit	Price
1	Mild Steel Square Pipe	10' x 1"	1	1500	1500
2	Mild Steel Angle Iron	12' x 1"	1	1750	1750
3	Steel Pipe	10' x 1"	2	1850	3700
4	Wheel	14"	3	2300	6900
5	Wheel Shaft	6"	3	500	1500
6	Engine	2-Stroke	1	19500	19500
7	Bearing	20mm	4	1100	4400
8	Metal Sheet	5' x 4'	1	4100	4100
9	Driving Shaft	15mm	1	850	850
10	Gearbox		1	1550	1550
11	Sprocket		4	900	3600
12	Accelerator		1	1050	1050
13	Gears		4	800	3200
14	Chain		1	1750	1750
Total					55350

4.13.2 Final Expenditures

After purchasing all the parts and completing the project, the final expenditures are given in Table 4-2.

Table 4-2: Final expenditure

Serial No.	Name of Item(s)	Specification	Qty.	Price
1	Hex Bolt	6 mm x 75 mm	8	120
2	Angle Iron	1" x 1"	20'	2010
3	Wheel Barrow	14"	2	2300
4	Pipe	26 mm Dia.	5'	800
5	Tip Cutter Blade	10" Dia.	1	600
6	Stand	Mild Steel	1	200
7	Petrol Engine	2-Stroke	1	9000
8	Handle for Engine	Aluminum	1	1000
9	Front Gear		1	800
10	Clutch		1	800
11	Steel Rod		1	500
Total				18130

Chapter 5: Results and Discussion

This chapter explains the results of the project alongside necessary discussion and comments about the project.

The initial design in this thesis covers the designing and manufacturing of self-propelled machines but because of a shortage of funds, the design was changed from self-propelled to push propelled. This removed a lot of components from the machine-like gearbox, etc. This ultimately reduces the price. This simplified the rear part of the machine while keeping the front part more or less the same.

5.1 FEA Analysis

The geometry of the frame was added to the ANSYS workbench and meshing was done followed by the application of the force and finally, a simulation was run to get the results. For the frame, the line body was generated in ANSYS and material was assigned to it.

The computer used to conduct this simulation had very limited computational capabilities. As a result, the meshing was performed as finely as possible while remaining within the bounds of the computational power available. The meshing was done to obtain the most accurate results possible with our computer. Although the mesh type was coarse but keeping in mind the computing power of the computer, the analysis was done.

The results for all of the structural analysis performed on the sugarcane cutting machine shows that:

- The maximum deformation was lesser almost 0.3 mm.
- The maximum stress recorded in the structure was more than 3 times lesser than the yield stress value.
- The factor of safety had a minimum value of 3.77.

Analysis showed that the maximum stress value was 90 MPa in the side frame .which was facing the weight of the sugarcane. Also, the front part of the frame faced the maximum force which was expected since this part would be facing the field and pushed through the crops. Since the maximum stress value was 90 MPa. Therefore, the material stays well within safe limits.

Results of the analysis show that the maximum deformation was lesser almost 0.3 mm. Maximum deformation occurred at top of the side frame since most of the forces were acting on it. It is known from theory that for a cantilever beam, maximum deformation occurs at the free end of it. This theoretical fact is consistent with the analysis of this design. The maximum stress recorded in the structure was more than 3 times lesser than the yield stress value. The factor of safety has a minimum value of 3.77. All of these values show that the design was in a safe range.

5.2 Fabrication Analysis

While manufacturing the machine. Most of the standard parts were chosen to keep the maintenance as easy as possible. The most difficult part was to drill a hole of 84mm dia. Since no such tool was available, the experienced workers tried to build a tool specifically for this drill. But unfortunately, that tool could not hold for long and broke down. So, this problem was solved by using the gas cutting metal technique which created a lot of clearance issues for the mounting of the engine. The part was ground after gas cutting. Also, the tool for teeth creation was not available in the workshop, the problem was tackled by cutting the shaft into two parts and welded together by TIG-welding.

5.3 Sustainability Aspects of the Project

The sustainability of any project is an important aspect. This project has economic, environmental and social impacts, which are discussed in detail in the following subsections.

5.3.1 Economic Impact

Agriculture is the backbone of Pakistan's economy and it employs about 50 percent of the Pakistani labor force but still contributes little to the total G.D.P. of Pakistan. In a lot of foreign countries, agricultural yield is much higher than in Pakistan. This is mainly because of the use of modern agricultural machines and techniques, which are not being used in Pakistan. The biggest barrier to adopting these machines is price. Most sugarcane harvesters cost around 20,000$ making it very difficult for small farmers to purchase them. This project mainly centers on low prices. This design of sugarcane cutting machine can be fabricated in less than 25,000 PKR. This price tag makes it affordable for even very small farmers. This machine frees or reduces farmers' manual labor ultimately allowing them to be more productive. The introduction of cheaper agricultural machines can affect every second Pakistani.

5.3.2 Environmental Impact

This machine is designed so that it can be operated by an electric motor or engine. This gives people the option to select green energy over fossil fuels but without necessarily forcing them to go for one. The machine manufactured in this project had an electric motor, making its carbon emissions zero.

5.3.3 Social Impact

In today's world, we require more productivity. Population growth in Pakistan shows an increase in food demand, and to meet this demand, the agriculture sector requires better farming techniques and equipment. The problem with this solution is the introduction of cheaper agricultural machines that would increase agricultural yield. An increase in yield will improve farmers' lifestyles and fulfil the ever increasing food demand in Pakistan.

Conclusion

The sugarcane cutting machine designed and fabricated in this project checks all the objectives of this project. First of all, the commercially available machines were studied, followed by a detailed study of previous works on these projects. The design philosophy in this project was to point out and solve existing problems in previous machines made by various researchers. Two problems pointed out were the machine's inability to move the cutter's height or ground clearance and the lack of any guide vanes mechanism. It was also found that the force required to cut sugarcane varies from 20 to 106 N. Based on these, a machine was designed which has three main parts i.e.

- Frame
- Blade shaft
- Metal plate

The frame has all the components attached to it. Most of the parts were welded on it. The cutting of material was a problem to create the sharp corner at its front part and imperfection were there because of inexperienced workers. The most difficult part was to drill a hole of 84mm diameter. Since no such tool was available, the experienced workers tried to build a tool specifically for this drill. But, unfortunately, that tool could not hold for long and broke down. So, this problem was solved by using the gas cutting metal technique which created a lot of clearance issues for the mounting of the engine. The part was ground after gas cutting. Also, the tool for teeth creation was not available in the workshop, the problem was tackled by cutting the shaft into two parts and welded together by TIG-welding.

The power required to cut sugarcane was almost 1.4 kW. Stress analysis of part which has all forces acted on it was done in ANSYS and maximum stress, maximum deformation and a minimum factor of safety were found. All of these indicated that the material was well within safe limits.

Manufacturing was started with the fabrication of the front part, and it turned out to be a lot more complicated than expected. All parts were manufactured in mechanical workshop according to the drawing of the CAD model. Due to imperfections on the shafts, their alignment was affected. Overall, all the objectives of the project were completed which were stated at the very start of the project.

Future Recommendations

Certain improvements can be made in this work. Some of them are listed below:

- The machine fabricated in this work was a push propelled machine. This can be modified to turn into a self-propelled machine.
- It can be equipped with replaceable gear head and blades for other crops.

Working on these areas would ease the sugarcane harvesting process, allowing farmers to be more productive.

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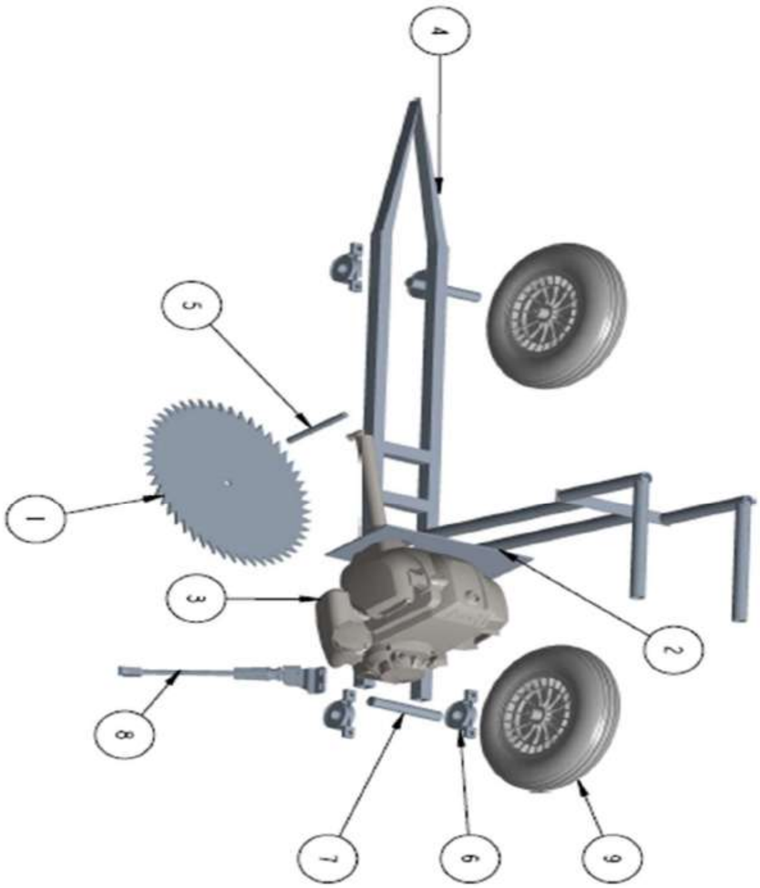
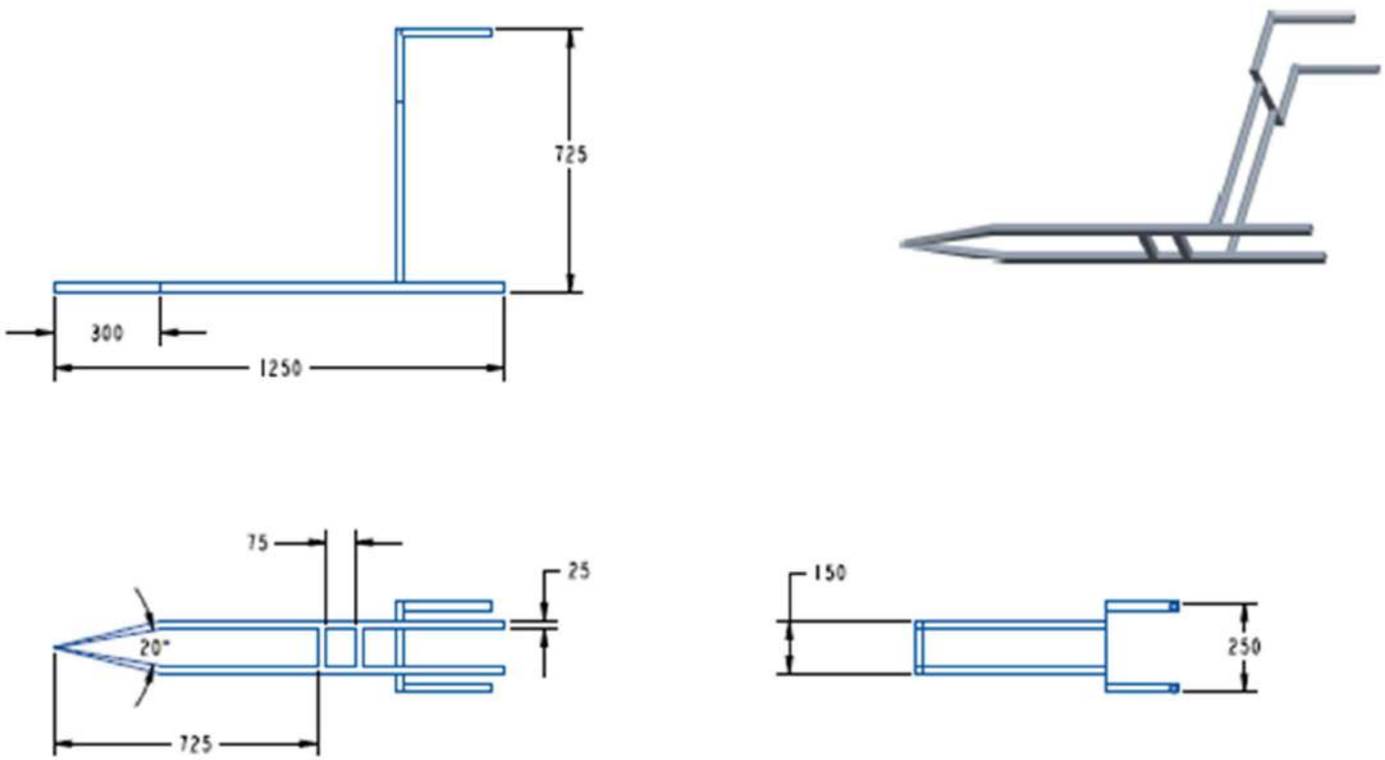
Appendix



	Sugarcane Harvester				
Made by	Dawood, Hassan	Drawing Title	ASSEMBLY	Scale	0.150
checked By	Dr. Kamran	Part title	HP_ASM_REV	Size	A3
Session	2018_2022	Model type	ASSEM	units	mm

ITEM NO	PART NUMBER	QTY
1	Cutter Blade	1
2	Engine Mounting Plate	1
3	Engine	1
4	Frame	1
5	Blade Shaft	1
6	Bearing	4
7	SHAFT	2
8	Stand	1
9	Wheel	2



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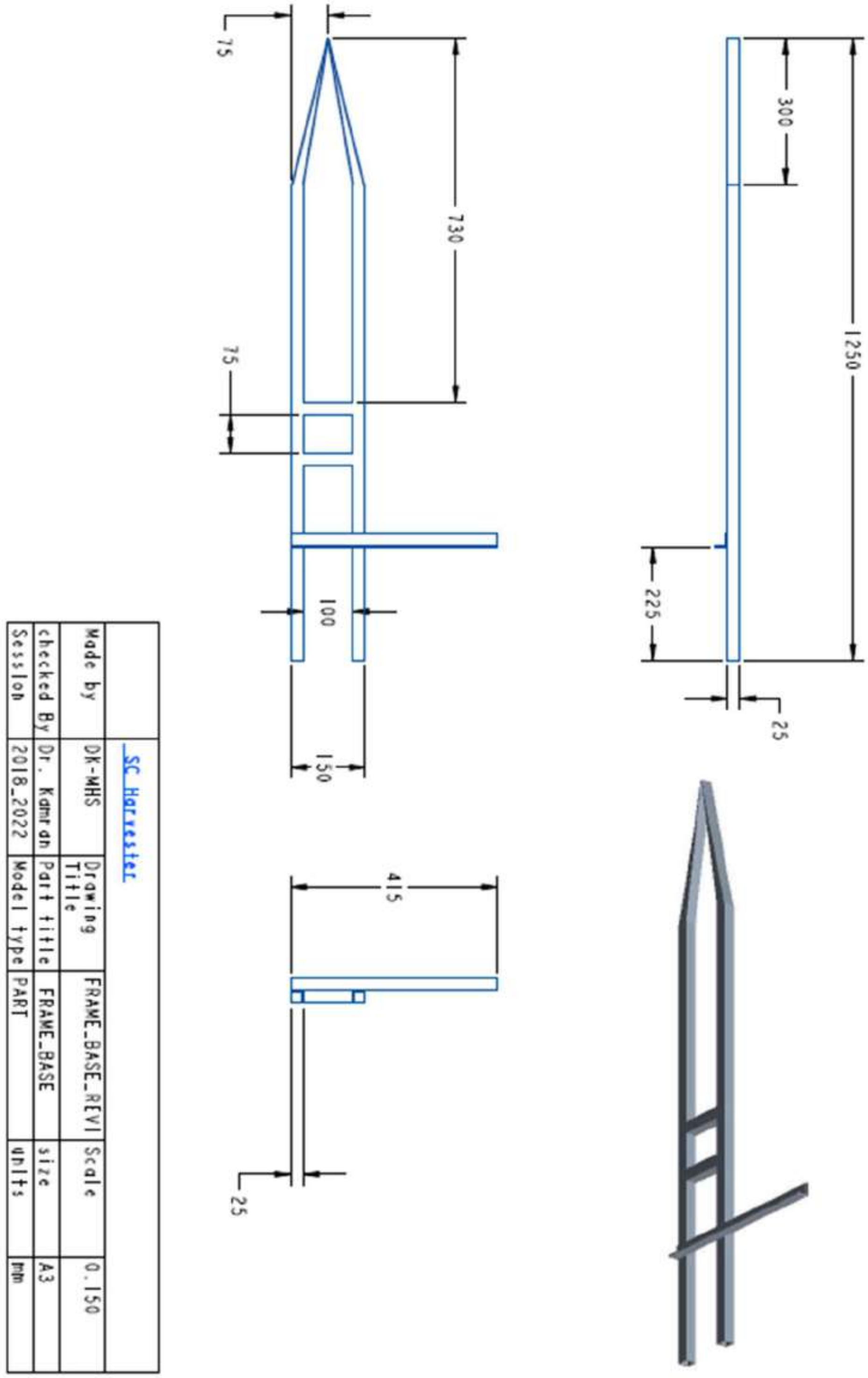
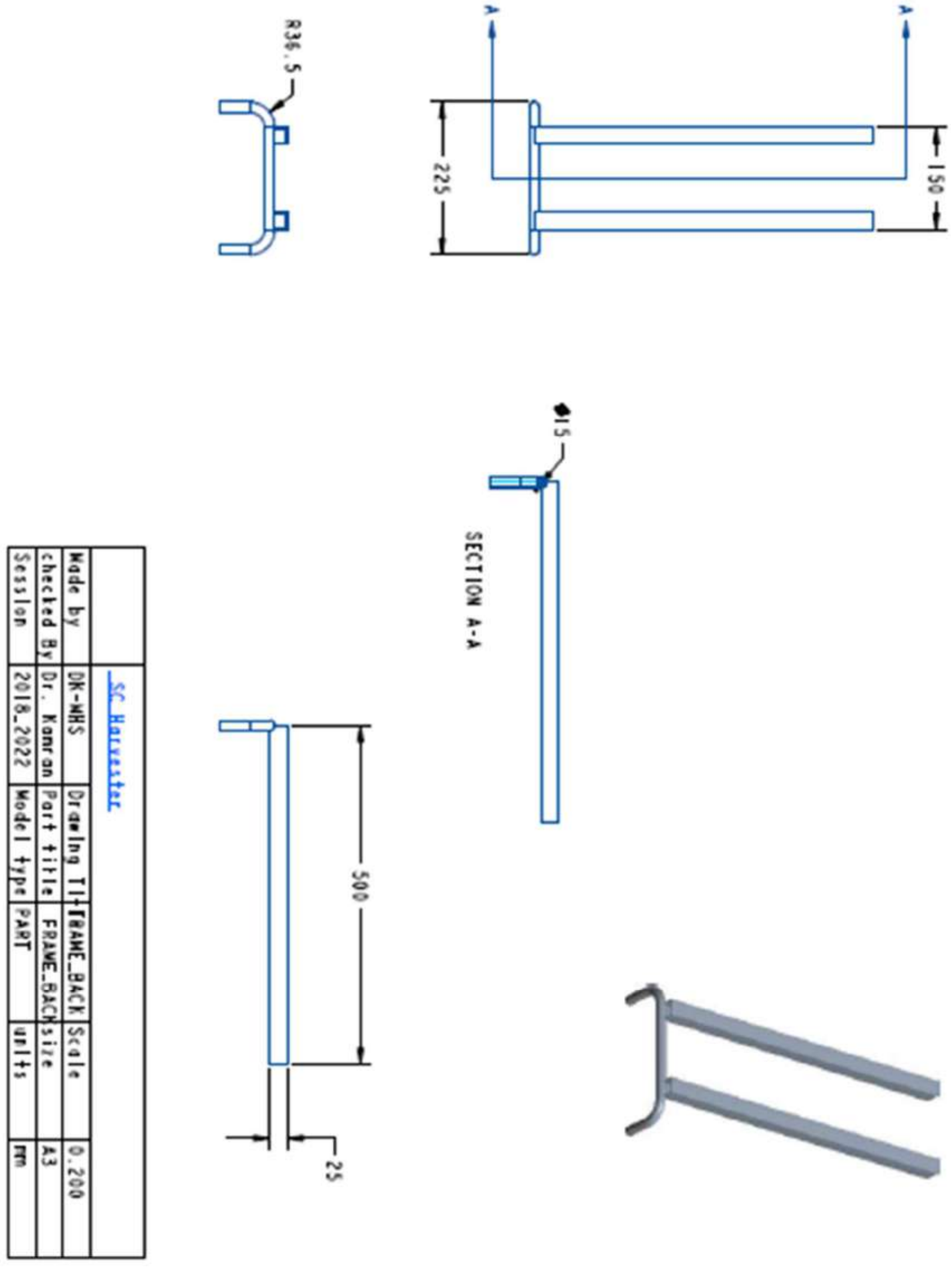
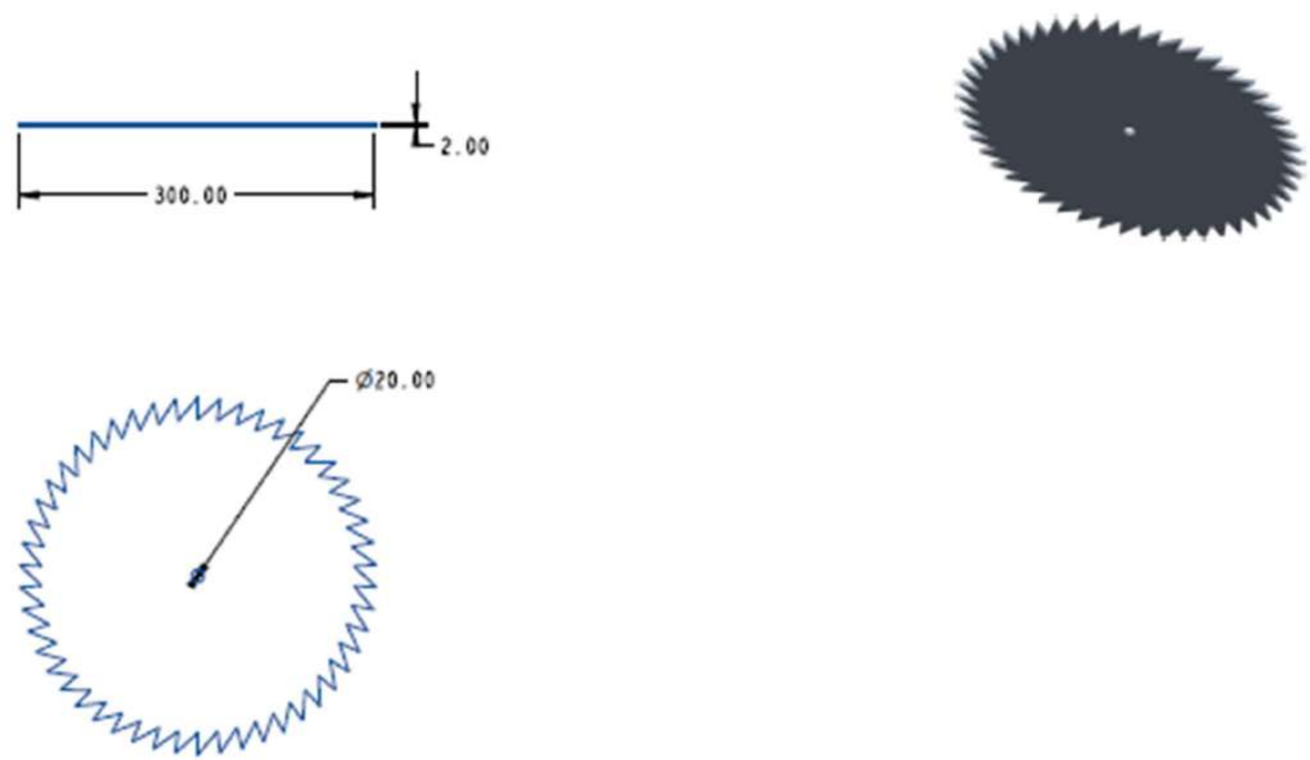
checked By	Dr. Kamran	Part title	Frame	size	A3
Session	2018_2022	Model type	PART	units	mm

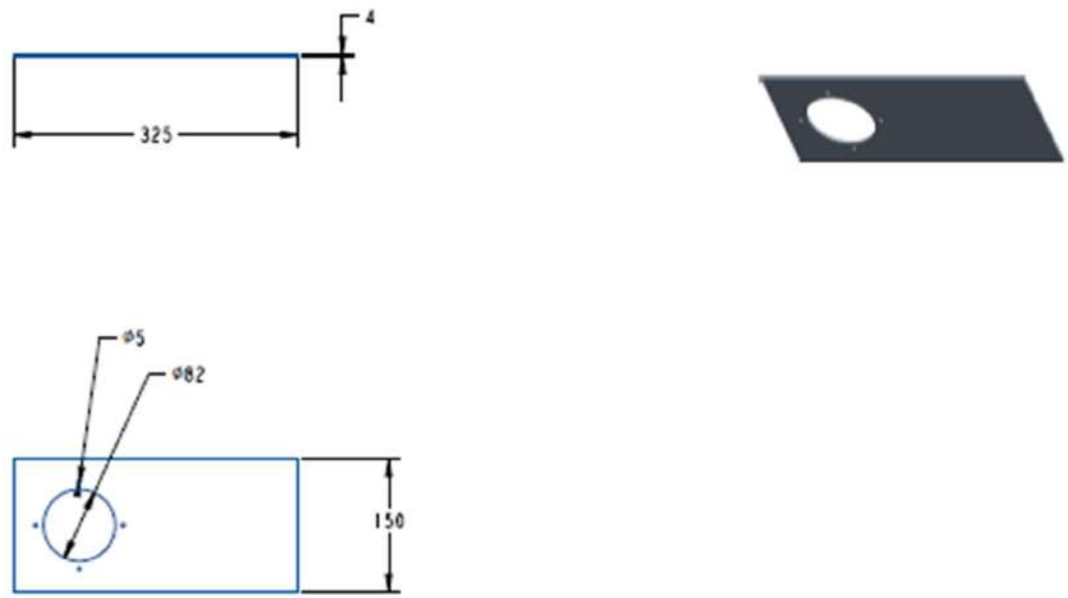

75
730
75
100
150
415
25
300
1250
225
25
SC_Harvester
Made by
DK-MHS
Drawing Title
FRAME_BASE_REV1
Scale
0.150
checked By
Dr. Kamran
Part title
FRAME_BASE
size
A3
Session
2018_2022
Model type
PART
units
mm



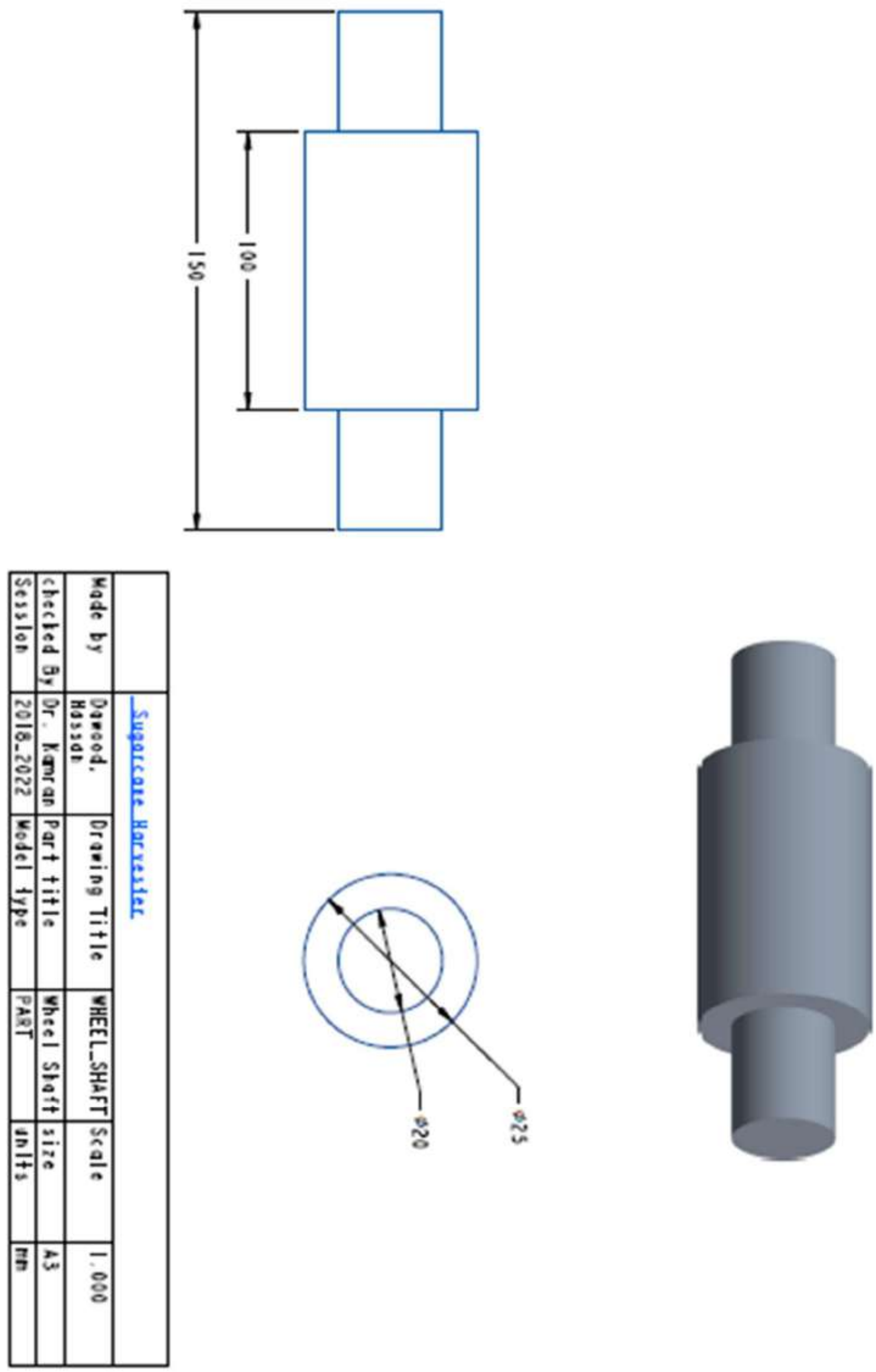
150
A
A
225
R36.5
Φ15
SECTION A-A
500
25
SC Harvester
Made by
DK-WHS
Drawing TI
FRAME_BACK
Scale
0.200
checked By
Dr. Kamran
Part title
FRAME_BACK
size
A3
Session
2018_2022
Model type
PART
units
mm



	Sugarcane Harvester				
Made by	Dawood, Hassan	Drawing Title	BLADE	Scale	0.250
checked By	Dr. Kamran	Part title	CUTTER_BLADE	size	A3
Session	2018_2022	Model type	PART	units	mm



	Sugarcane Harvester				
Made by	Dawood, Hassan	Drawing Title	PLATE	Scale	0.250
checked By	Dr. Kamran	Part title	ENGINE_SUPPORT_PLATE	size	A3
Session	2018_2022	Model type	PART	units	mm


150
100
Ø25
Ø20
Sugarcane Harvester
Made by
Dawood, Hassan
Drawing Title
WHEEL_SHAFT
Scale
1.000
checked By
Dr. Kamran
Part title
Wheel Shaft
size
A3
Session
2018_2022
Model type
PART
units
mm

Vita

Muhammad Hassaan Siddique

Muhammad Hassaan Siddique is a student of B.S. Mechanical Engineering of the batch BSME 18-22. He had a keen interest in physics and mathematics from an early age and was interested in the understanding working of different things. This led him to pursue Mechanical Engineering at PIEAS. In Mechanical Engineering, he worked on several C.E.P.s and fabricated different projects. After realizing the difference between Pakistani and foreign countries' agricultural techniques. He decided to make these machines and methods affordable for Pakistanis. He plans to continue to use his mechanical engineering knowledge to make new, better and cheaper products.

Dawood Khalid

Dawood Khalid is a Mechanical Engineering student of batch 18-22 in PIEAS. His interest in problem-solving led him to pursue Mechanical Engineering. During BS degree, he worked on many challenging projects & complex engineering problems which motivated him to pursue the goal of making cheaper farming equipment. In future, he plans to do further work on projects related to machine design.