

Design Calculation of Agricultural Reaper

Saurabh Patil¹, Mayur Deore², Bhimashankar Swami³, Omkar Bhabad⁴

¹⁻⁴B.E Students, Mechanical Engineering, Dr. D. Y. Patil Institute of Engg. Management And Research, Pune, Maharashtra, India.

Abstract - In this project, our work is to study the various methods used by farmers during harvesting, various types of machinery available for harvesting to develop and design an effective mechanism for the same. Though there are various types of machinery available in the market but these are too expensive. The scope of this project is to design an economical reaper & analyze the problems faced by farmers. The goal is to identify and optimize the mechanism appropriate for such conditions. This project tends to provide the design and development of manually or mechanically operated reaper machine

Key Words: Scotch Yoke Mechanism, Reaper.

1. INTRODUCTION

India is an agricultural-based country. Our economy also depends on agricultural products. Nowadays tremendous changes have occurred in conventional methods of agriculture like seed plantation, irrigation system, pesticides, and spray used. For developing our economic condition, it is necessary to increase our agricultural productivity and quality also.

Recently India has seen a shortage of skilled labor available for agriculture. Because of this shortage, the farmers have transitioned to using harvesters. These harvesters are available for purchase but because of their high costs, they are not affordable. However, agriculture groups make these available for rent on an hourly basis. But the smallholding farm owners generally do not require the full-featured combine harvesters. Also, these combine harvesters are not available in all parts of rural India due to financial or transportation reasons. Thus, there is a need for a smaller and efficient combine harvester that would be more accessible and also considerably cheaper. The mission is to create a portable, user-friendly, and low-cost mini harvester.

Considering the requirements of the current situation, the idea was created to prepare a cheap machine and reduce the labor required to cut crops. This machine has the capability and the economic value for fulfilling the needs of farmers having small landholdings. This

machine is cost-effective and easy to maintain and repair for the farmers. The machine model is designed based on the demand for a compact and economical reaper. This demand is taken into consideration by consulting farmers in person, for their problems and requirements. Considering the present scenario of corn harvesting, we decided to prepare a corn reaper model with a compact construction that will be most suitable for farmers having small land for agriculture. The machine prototype will be economical and most convenient for cutting corn stalks and other similar plants having the same or less shear strength than corn.

1.1 Problem Statement

To design and develop a cost effective mechanism to harvest corn crops for small scale farmers in India.

1.2 Objective

- To formulate an idea to suit our required functionality that is to reap the crops.
- To fabricate the design and the selected material which are cost effective

2. Methodology

With the demand for the grains on rise, the aim was to fabricate affordable reaper collector for increasing the economy of small scale farmers. For the fulfilment of this aim, it is decided to follow following steps:

- Interview the local farmers who have small scale land holding and enquire about the harvesting practices and the crops produced and emerging trends in crop harvesting.
- Interview agricultural equipment manufacturers to get information about various equipment that are available and are in demand.
- Refer various international papers in small scale harvesters produced earlier.
- Design of reaper collector harvester.

A. Conducting Interviews with Farmers and survey of field:

The design of this machine was to be based on the demand for a compact and affordable harvester. This demand could have been seen only with personal interaction with small scale farmers. Most of the farms in or near Pune and Nashik city are small scale farms. The purpose of this visit was to see and enquire about the harvesting machines that are being used by the farmers.

B. Surveying Agricultural Machines Manufacturer:

We took information about the manufacturability for the harvester. The following questions were focused to get a generalized idea about the various types of manufacturing equipment.

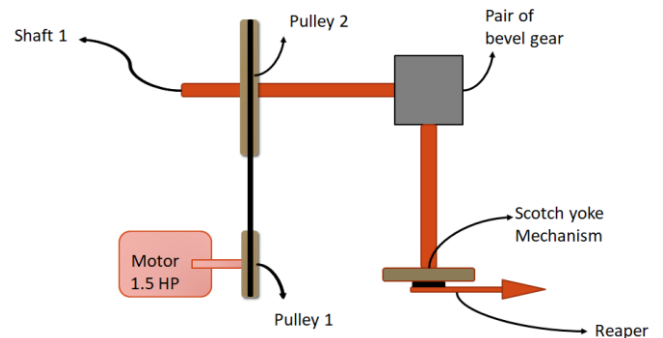
Taking into account the present scenario of corn harvesting we decided to prepare a model of corn harvester with compact construction which will be mostly suitable for farmers having small land for agriculture. The machine prototype will be economical and most convenient for cutting corn stalks and other similar plants having same characteristics as corn.

2.1 Components

The Components used are

1. Motor
2. Pulleys
3. Shafts
4. Bevel Gears
5. V-Belt
6. Scotch Yoke Mechanism
7. Cutter Blades

2.2 Schematic Diagram



3. Design procedure

3.1 Selection of Mechanism

Translating cutter are more advantageous than round cutter as it can take more stalks for cutting. Also less power will be required as compared to round cutter.

So, we decided to use 2 plates of blades with the help of **Scotch yoke mechanism.**



3.2 Selection of Motor

Diameter of corn stalk = 30mm

$$c/s \text{ area} = \frac{\pi}{4} \times 30^2 = 706.85 \text{mm}^2$$

$$\tau = \frac{F}{A}$$

Shear stress = 2.11Mpa (for 30° bevel)....from UTM testing

Consider shear stress = 3Mpa

$$F = \text{shear stress} \times c/s \text{ area} \quad \dots\dots(\text{for 1 stalk})$$

$$F = 3 \times 706.85$$

$$F = 2121 \text{N}$$

Stroke of cutting = 80mm

Radius of crank = 80/2 = 40mm

Torque = Cutting Force × radius of crank

$$\text{Torque} = 2121 \times 0.04$$

$$\text{Torque} = 84.84 \text{ Nm}$$

[velocity for cutter bar = 0.5m/s]

$$v = \omega \times r$$

$$0.5 = \omega \times 0.04$$

$$\omega = 12.5 \text{ rad/sec}$$

$$\omega = \frac{2\pi N}{60}$$

$$N = 120 \text{ rpm}$$

$$\text{Power} = \frac{2\pi NT}{60}$$

$$\text{Power} = 1.42 \text{ hp} = 1066.13 \text{ watt}$$

$$\text{Power} \cong 1.5 \text{ hp}$$

3.3 Selection of belt Drive

$$N_1 = 1440 \text{ RPM}$$

$$D_1 = 52 \text{ mm}$$

$$D_2 = 104 \text{ mm}$$

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

$$N_2 = 240 \text{ rpm}$$

$$\text{Power to be transmitted} = 1.12 \text{ kW}$$

$$\text{Service factor} = F_a = 1$$

$$\text{Designed Power} = F_a \times \text{Power to be transmitted}$$

$$= 1 \times 1.12$$

$$= 1.12 \text{ kW}$$

V-Belt A Section is considered.

Centre distance

$$L = 2c + \pi \left(\frac{D+d}{2} \right) + \frac{(D-d)^2}{4c}$$

By trial and error $L = 1500 \text{ mm}$, $D = 304.8 \text{ mm}$, $d = 50.8 \text{ mm}$

$$x = c = 452.906 = 453 \text{ mm}$$

$$\sin \alpha = \frac{R_1 - R_2}{x}$$

$$\alpha = 16.28^\circ$$

$$\theta = (180 - 2\alpha) \times \frac{\pi}{180} \text{ rad}$$

$$\theta = 2.57 \text{ rad}$$

3.4 Forces on Bevel Gears

$$z_1 = \text{no. of teeth on pinion} = 13$$

$$z_2 = \text{no. of teeth on gear} = 26$$

$$d_1 = \text{dia. of pinion} = 52 \text{ mm}$$

$$d_2 = \text{dia. of gear} = 104 \text{ mm}$$

$$m = \text{module} = 4 \text{ mm} \rightarrow m_p = \frac{d_p}{z_p}, m_g = \frac{d_g}{z_g}$$

Material : 50C4

$$\text{Ultimate tensile strength } (S_{ut}) = 750 \text{ N/mm}^2$$

$$\text{Surface hardness} = 400 \text{ BHN}$$

$$m_t = \frac{60 \times 10^6 \times \text{kw}}{2 \times \pi \times N_p}$$

$$m_t = \frac{60 \times 10^6 \times 1.12}{2 \times \pi \times 240}$$

$$m_t = 47746.48 \text{ Nmm}$$

$$\tan \gamma = \frac{D_p}{D_g} = \frac{52}{104}$$

$$\gamma = 26.56^\circ$$

$$r_m = \frac{D_p}{2} - \frac{b \times \sin \gamma}{2}$$

$$r_m = \frac{52}{2} - \frac{20 \times \sin 26.56}{2}$$

$$r_m = 21.52 \text{ mm}$$

$$P_t = \frac{M_t}{r_m}$$

where,

$P_t =$ tangential force, $P_r =$ radial force, $P_a =$ axial force

$$P_t = \frac{47746.48}{21.52}$$

$$P_t = 2218.7 \text{ N}$$

$$P_r = 2218.7 \times \tan \alpha \times \cos \gamma$$

$$P_r = 2218.7 \times \tan 20 \times \cos 26.56$$

$$P_r = 722.32 \text{ N}$$

$$P_a = P_t \times \tan \alpha \times \sin \gamma$$

$$P_a = 361.07 \text{ N}$$

Calculation for beam strength (for pinion)

$$z_p' = \frac{z_p}{\cos \gamma}$$

$$z_p' = 14.53$$

For 20 full depth involute system

Teeth 14 = lewis factor = 0.276

Teeth 15 = lewis factor = 0.289

By interpolation

Lewis form factor (γ) = 0.282

Bending stress

$$\sigma_b = \frac{S_{ut}}{3} = \frac{750}{3} = 250 \text{ N/mm}^2$$

$$A_o = \left[\left(\frac{D_p}{2} \right)^2 + \left(\frac{D_g}{2} \right)^2 \right]^{\frac{1}{2}}$$

$$A_o = 58.13 \text{ mm}$$

$$S_b = m b Y \sigma_b \left[1 - \left(\frac{b}{A_o} \right) \right]$$

$$S_b = 3700 \text{ N}$$

Wear strength

$$Q = \frac{z_g}{z_g + z_p \tan \gamma}$$

$$Q = 1.6$$

Material constant(k)

$$k = 0.16 \left(\frac{BHN}{100} \right)^2$$

$$k = 2.56 \text{ N/mm}^2$$

$$S_w = \frac{0.75 D_p b Q k}{\cos \gamma}$$

$$S_w = 3571.82 \text{ N}$$

Dynamic load by buckingham's equation

Error for gear with 4mm module is (e) = 0.0125

$$V = \frac{\pi \times D_p \times N_p}{60 \times 10^3}$$

$$V = 0.6534 \text{ m/s}$$

C = deformation factor for 20° full depth with pinion & gear of steel

$$C = 11400 \text{ N/mm}^2, P_t = 2009.53, b = 10 \text{ mm}$$

$$P_d = \frac{21v(ceb + p_t)}{21v + \sqrt{(ceb + p_t)}}$$

$$P_d = 819.038 \text{ N}$$

Effective load, $C_s = 1.25$

$$P_{eff} = (C_s P_t) + P_d$$

$$P_{eff} = 3037.738 \text{ N}$$

Factor of safety (bending failure)

$$f_s = \frac{S_b}{P_{eff}}$$

$$f_s = 1.21$$

Factor of safety (pitting failure)

$$f_s = \frac{S_w}{P_{eff}}$$

$$f_s = 1.17$$

3.5 Main Shaft Design

50C4 material, $S_{yt} = 460 \text{ Mpa}$

$$\tau_{max} = \frac{0.5 \times S_{yt}}{fos}$$

$$\tau_{max} = \frac{0.5 \times 460}{3}$$

$$\tau_{max} = 76.667 \text{ Mpa}$$

$$M_t = \frac{60 \times 10^6}{2\pi N}$$

$$M_t = 44563.384 \text{ Nmm}$$

$$\frac{P_1}{P_2} = e^{\mu\theta}$$

$$\mu = 0.25$$

$$\frac{P_1}{P_2} = e^{0.25 \times 2.97}$$

$$\frac{P_1}{P_2} = 1.9$$

$$M_t = (P_1 - P_2)R_1$$

$$(1.9P_2 - P_2)152.4 = 44563.384$$

$$P_2 = 324.9 \text{ N}, P_1 = 617.31 \text{ N}$$

shaft 1 (Vertical plane)

$$\Sigma f_y = 0$$

$$R_A + P_1 + P_2 + R_C + P_R = 0$$

$$R_A + R_C + 324.9 + 617.31 - 722.32 = 0$$

$$R_A + R_C = -219.89$$

Taking Moment at A=0

$$P_1 + P_2 = 942.21 \text{ N}$$

$$(P_1 + P_2) * 70 + R_C * 270 - (722.32 * 430) = 0$$

$$942.21 * 70 + R_C * 270 - 722.32 * 430 = 0$$

$$R_A = -1125.97 \text{ N}$$

$$R_C = 906.08 \text{ N}$$

Bending Moment

$$M_A = M_D = 0$$

Bending Moment at B

$$M_B = -R_C * 200 + P_R * 360$$

$$= -906.08 * 200 + 722.32 * 360$$

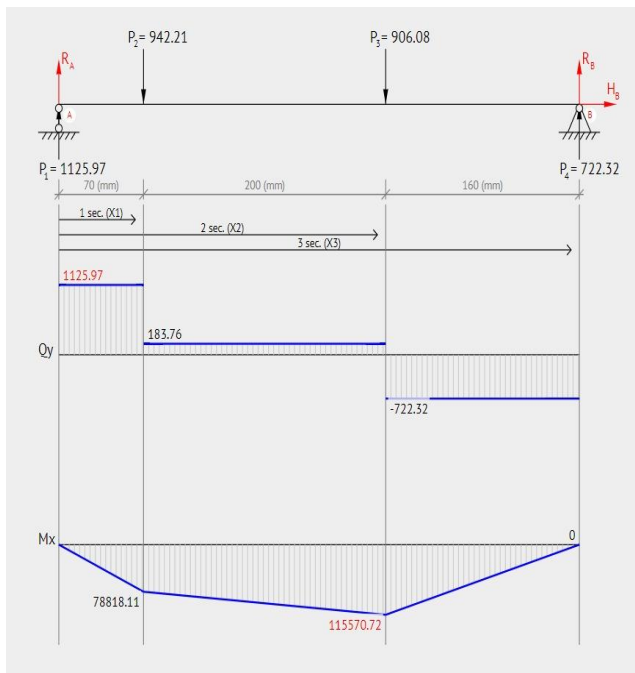
$$M_B = 78819.2 \text{ N.mm}$$

Bending Moment at C

$$M_C = P_R * 160$$

$$= 722.32 * 160$$

$$M_C = 115571.2 \text{ N.mm}$$



Shaft 1 (Horizontal Plane)

$$\Sigma f_y = 0$$

$$-(R_A + R_C + P_T) = 0$$

$$R_A + R_C = 2218.7 \text{ N}$$

Moment at A = 0

$$R_C * 270 - P_T * 430 = 0$$

$$R_C = 3533.48 \text{ N}$$

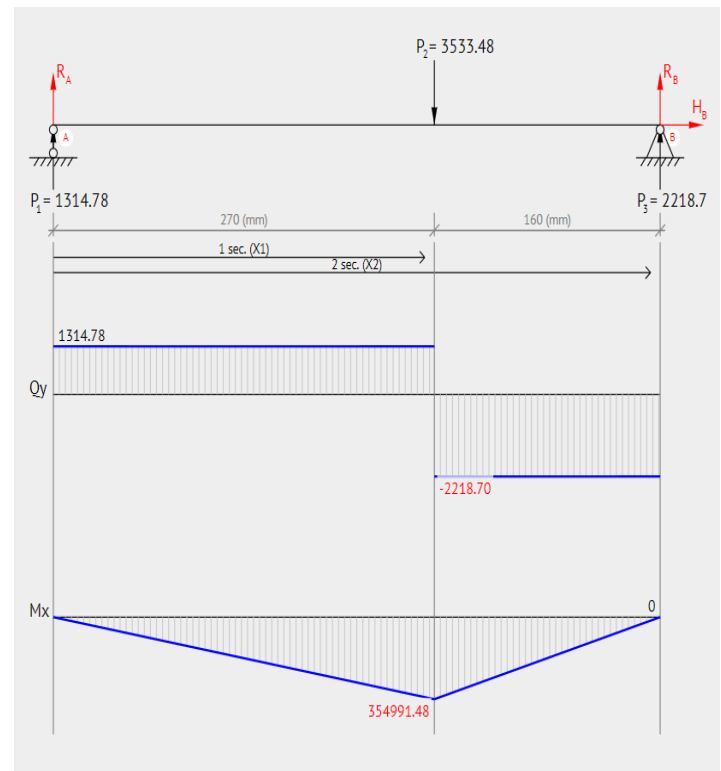
$$R_A = 1314.78 \text{ N}$$

Bending Moment at C

$$M_C = P_T * 160$$

$$= 2218.7 * 160$$

$$M_C = 354992 \text{ N.mm}$$



Shaft 2 (Vertical Plane)

$$M_B = 78819.2 \text{ N.mm}$$

$$M_C = 115571.2 \text{ N.mm}$$

Horizontal Plane

$$M_C = 354992 \text{ N.mm}$$

Taking Maximum Bending Moment

$$M_{B(max)} = \sqrt{115571.2^2 + 354992^2}$$

$$M_{B(Max)} = 373330.9823 \text{ Nmm}$$

$$M_t = 44563.384 \text{ Nmm}$$

$$\tau_{Max} = 76.667 \text{ N/mm}^2$$

$$K_b = 1.5 \quad k_t = 1.0$$

$$d^3 = \frac{16}{\pi \tau_{max}} \times \sqrt{(K_b \times M_{b(max)})^2 + (K_t M_t)^2}$$

$$d = 33.417 \text{ mm}$$

$$d = 35 \text{ mm}$$

Shaft 2

Shaft 2 (Vertical Plane)

$$\Sigma f_y = 0$$

$$P_R - R_B - R_C - 2121 = 0$$

$$R_B + R_C = 2218.7 - 2121$$

$$R_B + R_C = 97.7 \text{ N}$$

Moment at A = 0

$$R_B * 100 + R_C * 400 - 2121 * 500 = 0$$

$$100 * R_B + 400 * R_C = 1060500$$

$$R_B = -3404.733 \text{ N}$$

$$R_C = 3502.433 \text{ N}$$

Bending Moment at A = D = 0

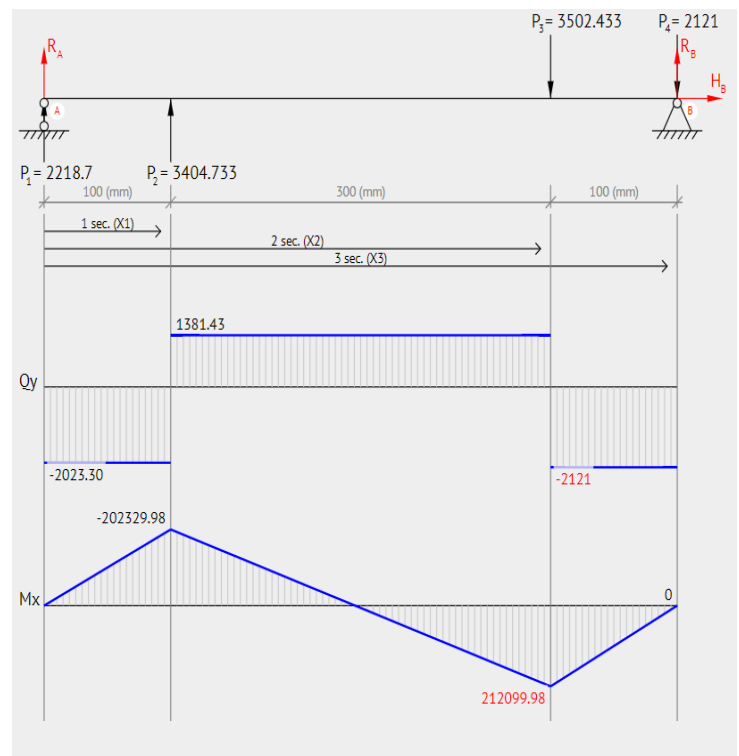
Bending Moment at B

$$M_B = 202329.98 \text{ N.mm}$$

Bending Moment at C

$$M_C = 2121 * 100$$

$$M_C = -212100 \text{ N.mm}$$



Shaft 2 (Horizontal Plane)

$$\Sigma f_y = 0$$

$$P_T - R_B - R_C + 2121 = 0$$

$$R_B + R_C = 2121 + P_T$$

$$R_B + R_C = 2482.07 \text{ N}$$

Moment at A

$$R_B * 100 + 400 * R_C - 2121 * 500 = 0$$

$$100 * R_B + 400 * R_C = 1060500$$

$$R_B = -225.573 \text{ N}$$

$$R_C = 2707.64 \text{ N}$$

Bending Moment at A = D = 0

Bending Moment at B

$$M_B = R_C * 300 - 2121 * 400$$

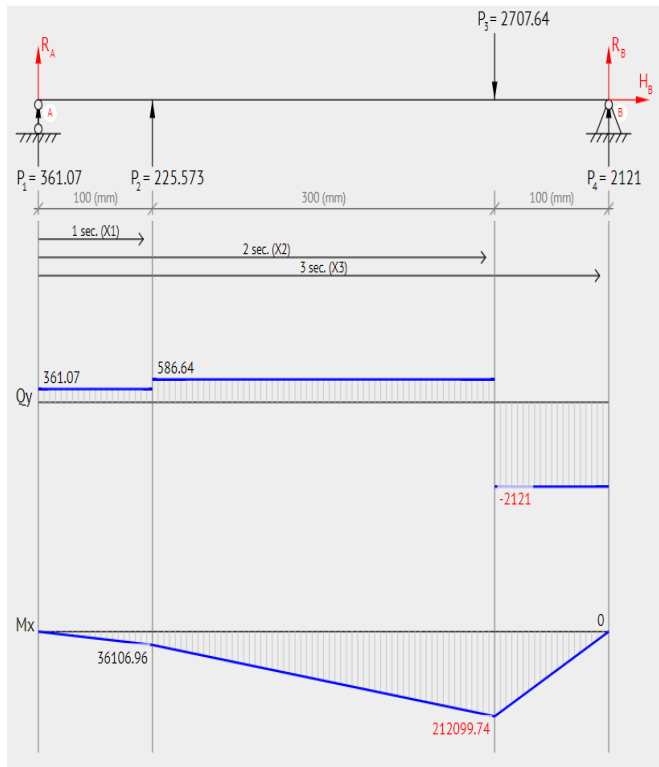
$$= 2707.64 * 300 - 2121 * 400$$

$$M_B = -36108 \text{ N.mm}$$

Bending Moment at C

$$M_C = -2121 \times 100$$

$$M_C = -212100 \text{ N.mm}$$



Vertical Plane

$$M_B = 202329.98 \text{ N.mm}$$

$$M_C = -212100 \text{ N.mm}$$

Horizontal Plane

$$M_C = -212100 \text{ N.mm}$$

$$M_B = -36108 \text{ N.mm}$$

Taking Maximum Bending Moment

$$M_{B(max)} = \sqrt{1899129.9^2 + 212100^2}$$

$$M_{B(max)} = 1910937.149 \text{ N.mm}$$

$$M_T = 89126.76 \text{ N.mm}$$

$$\tau_{max} = 76.667 \text{ M/mm}^2$$

$$D^3 = \frac{16}{\pi \tau_{max}} \times \sqrt{(K_b \times M_{b(max)})^2 + (K_t M_t)^2}$$

$$D = 57.53 \text{ mm}$$

$$D = 60 \text{ mm}$$

3.6 Selection of Bearing

Shaft 1

$$F_r = R_A = 1314 \text{ N}$$

$$L_{10h} = 40000 \text{ h}$$

$$n = 240 \text{ rpm}$$

$$L_{10} = \frac{60nL_{10h}}{10^6}$$

$$L_{10} = \frac{60 \times 240 \times 40000}{10^6}$$

$$L_{10} = 576 \text{ million revolution}$$

$$C = P(L_{10})^{1/3}$$

$$C = 1314 \times (576)^{1/3}$$

$$C = 10932.92$$

d = Inner diameter

D = Outer Diameter

B = Axial width

$$d = 35 \text{ mm}$$

$$D = 62 \text{ mm}$$

$$B = 9 \text{ mm}$$

Code: 16007

$$F_r = R_c = 3533 \text{ N}$$

$$L_{10h} = 40000 \text{ h}$$

$$n = 240 \text{ rpm}$$

$$L_{10} = \frac{60nL_{10h}}{10^6}$$

$$L_{10} = \frac{60 \cdot 240 \cdot 40000}{10^6}$$

L_{10} = 576 million revolution

$$C = P(L_{10})^{1/3}$$

$$C = 3533(576)^{1/3}$$

$$C = 29395.74$$

d = 60mm

D = 95mm

B = 21mm

Code: 6307

Shaft 2

$$F_r = R_A = 3404N$$

$$L_{10} = \frac{60nL_{10}h}{10^6}$$

$$L_{10} = \frac{60 \cdot 120 \cdot 40000}{10^6}$$

L_{10} = 288 million revolution

$$C = P(L_{10})^{1/3}$$

$$C = 3404(288)^{1/3}$$

$$C = 22479.52$$

d = 60mm

D = 95mm

B = 18mm

Code: 6012

$$F_r = R_c = 3502N$$

$$L_{10} = \frac{60nL_{10}h}{10^6}$$

$$L_{10} = \frac{60 \cdot 120 \cdot 40000}{10^6}$$

L_{10} = 288 million revolution

$$C = P(L_{10})^{1/3}$$

$$C = 3502(288)^{1/3}$$

$$C = 23126.69$$

d = 60mm

D = 95mm

B = 21mm

Code: 6307

4. Results

Motor = 1.5HP

Diameter of Shaft 1 = 35mm (50C4 Steel)

Diameter of Shaft 2 = 60mm (50C4 Steel)

V-Belt A section (Rubber Belt)

Shaft 1 Bearing

Code: 16007

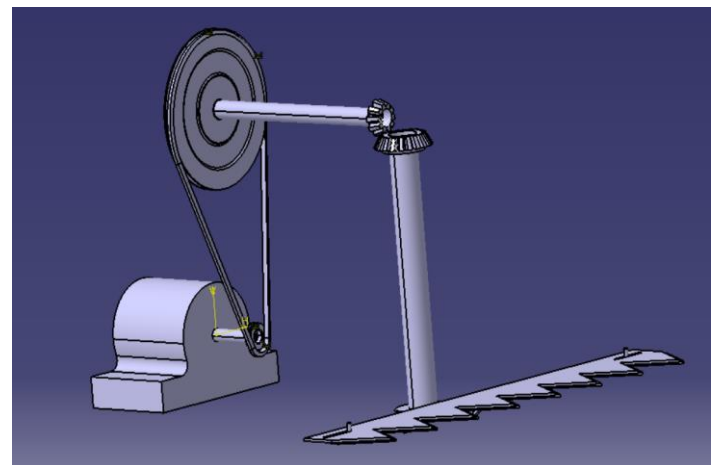
Code: 6307

Shaft 2 Bearing

Code: 6012

Code: 6307

5. CAD Model



REFERENCES

1. Performance Evaluation of Self Propelled Reaper Binder for Harvesting of Wheat Crop. by Anurag Patel^{1*}, Rajkishor Singh, Prabhakar Shukla and S.C. Moses. In this paper we get to know that the total grain losses in manual harvesting were extremely high 119.5 kg ha^{-1} as compared to reaper harvesting 18.5 kg ha^{-1} .
2. Design and Fabrication of Agricultural Reaper Machine. by khin ohnmar Normally one person can reap one acre in 5 days but with machine it only needs $1/4$ day.
3. Economic analysis for self-propelled reaper binder over manual harvesting. by -Shashank Singh Average fuel consumption of self-propelled reaper binder was found 0.8 l/h . Pay back periods of self-propelled of reaper binder was found at 539.25 h or 102.46 ha .
4. Energy Requirement for Cutting Corn Stalks. By - M. Azadbakht Cutting energy increases as the moisture content increases.
5. Performance Evaluation of Reaper--cum--Binder for Harvesting of Soybean and Rice By - Ashutosh Tripath Harvesting grain loss in rice and soyabean is 1% and 19% respectively.