Design Calculation of Agricultural Reaper

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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 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 = shear stress \times c/s area ......(for 1 stalk)

F = 3 \times 706.85

F = 2121 N

Stroke of cutting = 80mm

Radius of crank = 80/2 = 40mm
Torque = Cutting Force × radius of crank

Torque = 2121 × 0.04

Torque = 84.84 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 rpm

Power = \( \frac{2\pi N T}{60} \)

Power = 1.42 hp = 1066.13 watt

Power ≈ 1.5 hp

3.3 Selection of Belt Drive

N1 = 1440 RPM

D1 = 52 mm

D2 = 104 mm

\[ \frac{N_1}{N_2} = \frac{D_0}{D_1} \]

\[ N_2 = 240 \text{ rpm} \]

Power to be transmitted = 1.12 kW

Service factor = \( F_s' \) = 1

Designed Power = \( F_s' \times \) Power to be transmitted

= 1 × 1.12

= 1.12 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 mm, D = 304.8 mm, d = 50.8 mm

\[ x = c = 452.906 \approx 453 \text{ mm} \]

\[ \sin \alpha = \frac{R_1 - R_2}{x} \]

\[ \alpha = 16.28^\circ \]

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

\[ \theta = 2.57 \text{ rad} \]

3.4 Forces on Bevel Gears

\( z_1 \) = no. of teeth on pinion = 13

\( z_2 \) = no. of teeth on gear = 26

\( d_1 \) = dia. of pinion = 52 mm

\( d_2 \) = dia. of gear = 104 mm

\[ m = \text{module} = 4 \text{ mm} \rightarrow m_p = \frac{\sigma_p}{\varepsilon_p}, \ m_g = \frac{\sigma_g}{\varepsilon_g} \]

Material : 50C4

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

Surface hardness = 400 BHN

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

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

\[ m_t = 47746.48 \text{ Nmm} \]

\[ \tan \gamma = \frac{D_2}{D_1} = \frac{52}{104} \]

\[ \gamma = 26.56^\circ \]
\[ r_m = \frac{D_p}{2} - \frac{b \times \sin \alpha}{2} \]
\[ A_o = \left[ \left( \frac{D_p}{2} \right)^2 + \left( \frac{D_p}{2} \right)^2 \right]^{\frac{1}{2}} \]
\[ A_o = 58.13 \text{mm} \]
\[ S_b = m b Y \sigma_b \left[ 1 - \left( \frac{b}{A_o} \right) \right] \]
\[ S_b = 3700 \text{ N} \]

Wear strength
\[ Q = \frac{z_g}{z_d + z_p \tan \gamma} \]
\[ Q = 1.6 \]

Material constant (k)
\[ k = 0.16 \left( \frac{BHN}{100} \right)^2 \]
\[ k = 2.56 \text{N/mm}^2 \]

Dynamic load by Buckingham’s equation
\[ S_w = \frac{0.75 D_p b Q k}{\cos \gamma} \]
\[ S_w = 3571.82 \text{ N} \]

Error for gear with 4mm module is (e) = 0.0125
\[ V = \frac{\pi D_p N_p}{60 \times 10^3} \]
\[ V = 0.6534 \text{ m/s} \]

C = deformation factor for 20° full depth with pinion & gear of steel
\[ C = 11400 \text{ N/mm}^2, P_t = 2009.53, b = 10 \text{mm} \]

By interpolation
\[ P_d = \frac{21 V (c e + c b + p_t)}{21 V + \sqrt{(c e + c b + p_t)}} \]
\[ P_d = 819.038 \text{ N} \]

Effective load, \( C_s = 1.25 \)
\[ P_{eff} = (C_s P_t) + P_d \]

\[ \sigma_b = \frac{S_{ut}}{3} = \frac{750}{3} = 250 \text{ N/mm}^2 \]
\( P_{\text{eff}} = 3037.738 \text{ N} \)

Factor of safety (bending failure)

\[ f_s = \frac{s_b}{P_{\text{eff}}} \]
\[ f_s = 1.21 \]

Factor of safety (pitting failure)

\[ f_s = \frac{s_w}{P_{\text{eff}}} \]
\[ f_s = 1.17 \]

3.5 Main Shaft Design

50C4 material, \( S_{yf} = 460 \text{ Mpa} \)

\( \tau_{\text{max}} = \frac{0.5 \times S_{yf}}{f_{os}} \)
\( \tau_{\text{max}} = \frac{0.5 \times 460}{f_{os}} \)
\( \tau_{\text{max}} = 76.667 \text{ Mpa} \)

\( M_t = \frac{60 \times 10^6}{2 \pi N} \)
\( M_t = 44563.384 \text{ Nmm} \)

\( \frac{P_1}{P_2} = e^{\mu \theta} \)
\( \mu = 0.25 \)

\( \frac{P_1}{P_2} = e^{0.25 \times 2.97} \)
\( \frac{P_1}{P_2} = 1.9 \)

\( M_t = (P_1 - P_2)R_1 \)
\( (1.9P_2 - P_2)152.4 = 44563.384 \)

\( P_2 = 324.9 \text{ N}, P_1 = 617.31 \text{ N} \)
Shaft 1 (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

\[ R_C \times 270 - P_T \times 430 = 0 \]
\[ R_C = 3533.48 \text{ N} \]

\[ R_A = 1314.78 \text{ N} \]

Bending Moment at C

\[ M_C = P_T \times 160 \]
\[ = 2218.7 \times 160 \]
\[ M_C = 354992 \text{ N.mm} \]

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

\[ M_{B(\text{max.})} = \sqrt{115571.2^2 + 354992^2} \]
\[ M_{B(\text{Max})} = 373330.9823 \text{ Nmm} \]
\[ M_T = 44563.384 \text{ Nmm} \]

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

\[ K_b = 1.5 \quad k_t = 1.0 \]

\[ d^3 = \frac{16}{\pi \tau_{\text{max}}} \times \sqrt{(K_b \times M_{B(\text{max.})})^2 + (K_t \times M_T)^2} \]
\[ d = 33.417 \text{ mm} \]
\[ d = 35 \text{ mm} \]
Shaft 2

Shaft 2 (Vertical Plane)

\[ \Sigma f_y = 0 \]
\[ P_T - R_B - R_C - 2121 = 0 \]
\[ R_B + R_C = 2218.7 - 2121 \]
\[ R_B + R_C = 97.7 \text{ N} \]

Moment at A = 0
\[ R_B + 100 + R_C \times 400 - 2121 \times 500 = 0 \]
\[ 100 \times R_B + 400 \times R_C = 1060500 \]
\[ R_B = -3404.733 \text{ N} \]
\[ R_C = 3502.433 \text{ N} \]

Bending Moment at A = D = 0

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
\[ R_B \times 100 + 400 \times R_C - 2121 \times 500 = 0 \]
\[ 100 \times R_B + 400 \times R_C = 1060500 \]
\[ R_B = -225.573 \text{ N} \]
\[ R_C = 2707.64 \text{ N} \]

Bending Moment at A = D = 0

Bending Moment at B
\[ M_B = R_C \times 300 - 2121 \times 400 \]
\[ = 2707.64 \times 300 - 2121 \times 400 \]
\[ M_B = -36108 \text{ N.mm} \]
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

\[
M_{B(max)} = \sqrt{1899129.92 + 212100^2}
\]

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

\[
M_T = 89126.76 \text{ N.mm}
\]

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

\[
D^3 = \frac{16}{\pi \tau_{max}} \sqrt{(K_d \times M_{B(max)})^2 + (K_t M_T)^2}
\]

\[
D = 57.53 \text{ mm}
\]

\[
D = 60 \text{ mm}
\]

3.6 Selection of Bearing

Shaft 1

\[
F_i = R_i = 1314 \text{ N}
\]

\[
L_{10h} = 40000 \text{ h}
\]

\[
n = 240 \text{ rpm}
\]

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

\[
L_{10} = \frac{62 \times 240 \times 40000}{10^6}
\]

\[
L_{10} = 576 \text{ million revolution}
\]

\[
C = P(L_{10})^{1/3}
\]

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

\[
C = 10932.92
\]

d = Inner diameter

D = Outer Diameter

B = Axial width

\[
d = 35 \text{ mm}
\]

\[
D = 62 \text{ mm}
\]

\[
B = 9 \text{ mm}
\]

Code: 16007

\[
F_i = R_e = 3533 \text{ N}
\]

\[
L_{10h} = 40000 \text{ h}
\]

\[
n = 240 \text{ rpm}
\]

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

C = 576 million revolution
\[
L_{10} = \frac{60 \times 240 \times 40000}{10^6}
\]

\[
L_{10} = 576 \text{ million revolution}
\]

\[
C = P(L_{10})^{1/3}
\]

\[
C = 3533(576)^{1/3}
\]

\[
C = 29395.74
\]

d=60mm  
D=95mm  
B=21mm  
Code: 6307  

**Shaft 2**

\[
F_r = R = 3404 \text{N}
\]

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

\[
L_{10} = \frac{60 \times 120 \times 40000}{10^6}
\]

\[
L_{10} = 288 \text{ million revolution}
\]

\[
C = P(L_{10})^{1/3}
\]

\[
C = 3502(288)^{1/3}
\]

\[
C = 23126.69
\]

d=60mm  
D=95mm  
B=21mm  
Code: 6307

4. **Results**

Motor= 1.5HP  

Diameter of Shaft 1= 35 mm (50C4 Steel)  
Diameter of Shaft 2= 60 mm (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**

![CAD Model Image]
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