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Design and Fabrication of Agricultural Reaper Machine

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Abstract* — This research paper is based on reaper and binder machine. It performs cutting and binding simultaneously. Reaper machine is a harvesting tool which cut crop and windrow it on the field. The main components of reaper are header, power source and transmission and frame.During operation in the field we face the problem of arm for binder which transmits the motion from the base mechanism to the fingers which collects the paddy. Therefore, mechanical harvesting such as reaping with reaper, binders and combine harvesters are becoming popular. It is intended that design of the paddy harvesting machine should be durable, reliable, simple and easy to maintain. In this research paper, the designs of reaping gear box and carrier chain system are described. In the reaping mechanism, gear box plays an important role. Thus, the design calculations of bevel gears are calculated and suitable gears and materials are being selected.

Indexed Terms - Reaper, binder machine, Bevel gearsbinders, combine harvester, reaping gear box

I. INTRODUCTION

Harvesting is an operation carried out after the maturityof crop. It includes the cutting of crops and binding the straws. There are four types of technologies available for cereal crops in India. Traditional using hand tools like sickle, Using manual reaper, Self-propelled reaper and binder machine, Modern technology using combine harvester.

Reaper and binder machine is manufactured by BCS Company. The physical construction is divided into three parts: steering mechanism, Engine mounting and cutting and binder mechanism.

A mechanical reaper is an agricultural device which reaps crops mechanically and lays down the stems into small bundles, providing an alternative to using laborers to gather in crops by hand at harvest time. Harvesting is one of the most intensive operations in production sequence. With the introduction of new and high yielding rice varieties, the problem of harvesting have increased because of the greater amount of crops that has to be handled. In most rice growing countries in the tropics and in the world as a whole; harvesting is commonly done manually by sickle.

Rice is the most important cereal and staple food consumed in Myanmar. At this present, it is a transmission from hand farming age to this modern power farming age. Rapidly increasing population requires growing more food. Since more land is under cultivation, the only way to increase production is to increase yield and grow more than mono crop. Since the cultivation of summer paddy was initiated in 1992-1993 and extended with the support of irrigation scheme in summer season.

In double or triple cropping areas, the harvesting of the first crop corner is so close together. Most Myanmar farmers use traditional methods such as manual harvesting with sickles. Total labour requirement of traditional harvesting is 30 to 60 man hours per acre where cutting and laying alone requires 25 to 30 man hours per acre with the grain losses up to 6% for a week delay and 11% for a 10 day delay. During peak harvesting season and due to increase of agricultural labour, farmers have to face great difficulties in timely harvesting their crops. Timely harvesting of crop is of extreme importance. Therefore farmers handled effectively with machines. The use of a mechanical reaper to increase labour productivity and rice production may help alleviate this bottle neck.

II. MAIN COMPONENTS OF PADDY REAPER

The paddy reaper is powered by a 5 hp petrol engine. Power from the engine is transmitted by means of the v-belt and pulleys to an input shaft and then through a set of bevel gears. The output shaft of bevel gearbox is connected to the transmission bevel gear box with a couple of universal joints. The output of transmission bevel gear box rotates the carrier chain system and provides the reciprocating motion on the cutter bar. After cutting, the star wheel passes the cut crop to the right outlet and drives the star wheels.

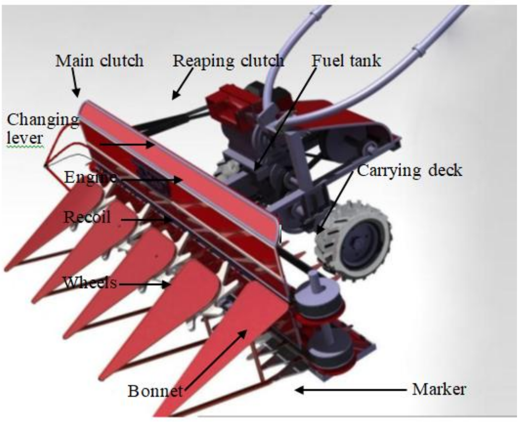

Fig. 1 Assembly of paddy reaper

The basic components of paddy reaper are
1. Air cooled 4 cycle gasoline engine
2. Gear box
3. Reaping blade assembly
4. Conveyor chain assembly
5. Tire
6. Driving clutch bevel box
7. Reaping gear box

The assemblies of the paddy reaper are shown in Fig. 1.

III. MAIN COMPONENTOF REAPING MECHANISM

Reaping mechanism is composed by three main parts.
1. Reaping gear box
2. Cutter bar assembly
3. Carrier chain system

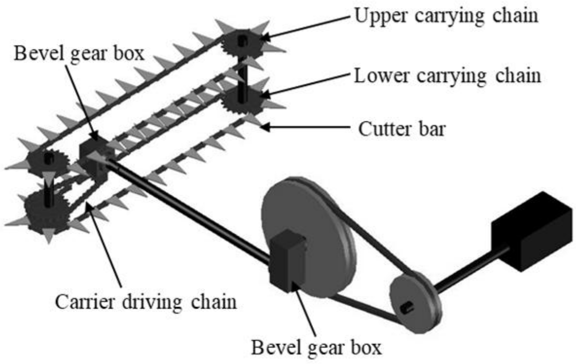

Fig. 2 Assembly of reaping mechanism

There are two gear boxes in reaper; main gear box and reaping gear box. Main gear box is driven by gasoline engine with belt and clutch pulley system. Power is transmitted from the main gear box or driving mechanism, through the reaping gear box to the crank arm, then to the cutter bar. Rice sticks coming from four guide paths are cut by the cutter bar [4].

IV. DESIGN OF BEVEL GEAR

Bevel gears are used to transfer motion between non parallel shafts, usually at 90˚ to one another as shown in Fig. 3.

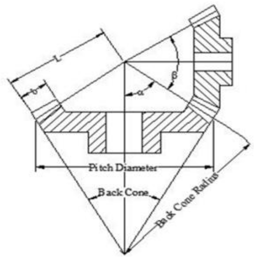

Fig. 3. Bevel gear geometry [1]

The mounting of bevel gear is critical if satisfactory performance is to be achieved. Most commercial gears have a defined mounting distance. If the gear is mounted at a distance smaller than the recommended mounting distance, the teeth will likely bind. If mounted at a greater distance there will be excessive backlash, causing noisy and rough operation.

A. Force on Straight Bevel Gear

The transmitted load acts tangential to the pitch cone and is the force produces the torque on the pinion and the gear. The torque, M_t can be computed produces from the known power transmitted and the rotational speed (rpm).

$$M_t = \frac{9550 \times kW}{rpm} \tag{1}$$

Then, using the pinion, for example, the transmitted load is

$$F_t = \frac{M_t}{r_m} \tag{2}$$

Where r_m is mean radius of the pinion. The value of r_m can be computed from

$$r_m = \frac{D_p}{2} - \left(\frac{b}{2}\right) \sin\beta \tag{3}$$

The pitch diameter D_p is measured to the pitch cone and its large end. The radial load acts toward the center of the pinion (F_{rp}), perpendicular to its axis, causing bending of the pinion shaft.

$$F_{rp} = F_t \tan\alpha \cos\beta \tag{4}$$

The axial load acts parallel to the axis of the pinion F_{ap}, tending to push it way from the mating gear. It causes a thrust load on the shaft bearings. It also produces a bending moment on the shaft because it acts at the distance from the axis equal of the gear.

$$F_{ap} = F_t \tan\phi \sin\beta \tag{5}$$

The value for the forces on the gear can be calculated by the same equations shown here for the pinion, if the geometry for the gear is substituted for that of the pinion.

B. Stress in Straight Bevel Gear Teeth

It may base on the Lewis equation. It should be noted that the tooth tapers and becomes smaller in cross section as it converges to the apex of the cone. The Lewis equation is modified as follows to correct for this situation.

$$F = S\,b\,y\,\pi\left[\frac{L-b}{L}\right]m \tag{6}$$

Where,

S = allowable bending stress, N/m^2
y = form factor based on the formative number of teeth and the type of tooth profile
L = the cone distance, m
b = the face width of the gear, m
m = the module based on the largest tooth cross section

For ease of manufacture and satisfactory operation of bevel gears, it is recommended that the face width b limited to between L/3 and L/4, where L is the cone distance. In general we will design the face width close to, but never greater than, L/3. When the diameter is known, it is convenient to use the modified Lewis equation in this form:

$$\frac{1}{my} = \frac{sb\pi}{F}\left(\frac{L-b}{L}\right) \tag{7}$$

When the diameter is unknown, it is convenient to use the following form of the Lewis equation:

$$S = \frac{2M_t}{m^2\,b\,\pi\,y\,m}\left(\frac{L}{L-b}\right)$$

This equation will yield a value for the actual stress in terms of m after making the following substitutions:

The allowable stresses, S, for the average conditions may be taken as

$$S = S_0\left(\frac{6}{6+V}\right) \text{for cut teeth or}$$

$$S = S_0\left(\frac{5.6}{5.6+\sqrt{V}}\right) \text{for generated teeth}$$

Where S_0 is the endurance limit of the gear material for released loading, corrected for average concentration. An approximate value for S_0 is 1/3 of ultimate strength, based on an average value for stress concentration. V is the pitch line velocity, in m/s.

The limiting wear load, F_w, may be approximated from

$$F_w = F_t + \frac{21V(L\text{-}b)}{21V+\sqrt{bC+F_t}}\left(\frac{L}{L-b}\right) \tag{8}$$

The dynamic load, F_d , which is the transmitted load plus an incremental load due to dynamic effects, may be approximated from

$$F_d = F_t + \frac{21V(bC+F_t)}{21V+\sqrt{bC+F_t}} \tag{9}$$

Note that F_0 and F_w are allowed values which must not be exceeded by the dynamic load.F_d must be $\leq F_w$. F_d must be $\leq F_0$.

V. CUTTER BAR ASSEMBLY

The cutter bar consists of two basic component parts. A movable bar to which are riveted knives what are called reaping cutter and a stationary bar to which are attached with rivets what are called corresponding cutter bar. The corresponding cutter separates the cut crops into portions which are cut by the reaping cutter with reciprocating motion driven by carrier chain system [3].

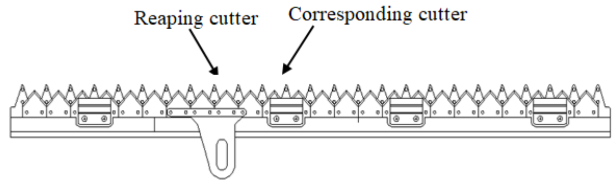

Fig. 4 Cutter bar assembly

The cutter bar assembly consists of (5) main parts. They are

1. Knife clip
2. Knife head
3. Slide plate
4. Reaping cutter
5. Corresponding cutter

The cutter bar assembly is shown in Fig. 5.

VIII. DESIGN OF CARRIER CHAIN SYSTEM

The objective of carrier chain system is the rice sticks of after cut that are carried out by mean of chain and star wheel. Sprocket of reaping gear box drives the vertical shaft, which composes three sprockets. One is to rotate the shaft and others are for the two carrying chains. The three types of chain are carrier driving chain, lower carrying chain and upper carrying chain. The most common type of chain is roller chain, in which the roller on each pin provides exceptionally low friction between the chain and sprockets. A standard single-strand roller chain is used in carrier driving chain. A double pitch roller chain is used in upper carrying chain and lower carrying chain [3].

The chain length L' in pitch numbers, for a given distance C'in pitch numbers, is exactly.

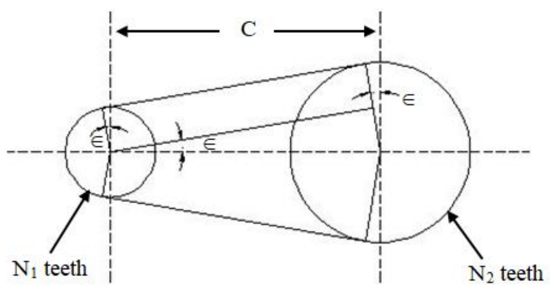

Fig.5 A typical chain drive

$$L' = 2C'\cos\epsilon + \frac{(N_1+N_2)}{2} + \frac{(N_2-N_1)\epsilon}{\pi} \tag{10}$$

Where,

$$\epsilon = \arc\sin\frac{\frac{1}{\sin\alpha_2}-\frac{1}{\sin\alpha_1}}{2C'} \tag{11}$$

Since, ϵ is generally small, it is sufficient in most cases to use the approximation .Then $\epsilon = \frac{(N_2-N_1)}{2C'}$

$$L' = 2C' + \frac{(N_1+N_2)}{2} + \frac{S}{C'} \tag{12}$$

Where,

$$S = \left[\frac{N_2-N_1}{2\pi}\right]^2$$

The actual chain length is

$$L = L'p$$

And the actual sprocket center distance

$$C = C'p$$

It is recommended that C' lie between 30 and 50 pitches. If the center distance is not given, the designer is free to fix C' and to actuate L'.

The sprocket diameters are

$$D_i = \frac{P}{\sin\alpha_i} \tag{13}$$

IX. DESIGN PROCEDURE OF REAPING MECHANISM

The reaping mechanism design procedure is divided into two parts. Firstly, calculate the power from the engine to the bevel gear box. The second is to calculate the chain length for carrier chain system. The bevel gear module, diameters, face width and number of teeth are calculated for two bevel gear box. The chain number, number of teeth, center distance and speed for the carrier chain system are used as input data and the diameter of sprockets and chain length are calculated.

VI. DESIGN CONSIDERATION AND RESULT

In this paper, design calculation of power reaper is using 3.727 kW engine power and 3600 rpm of engine speed and calculated all parts of reaping gear box and carrier chain system.

Engine power	=	3.31 kW
Losses	=	10%
Gear Material	=	AISI 5160 OQT 400
S_o	=	740 MN/m^2
BHN	=	627
E_p,E_g	=	207×10^9 N/m^2
ϕ	=	20° Full Depth

The results that are calculated for 3.729 kW and 3600 rpm of engine for bevel gear in reaping gear box are shown in Table I , Fig.6and chain length for carrier chain system are shown in Table II.

TABLEI. RESULTS OF BEVEL GEAR IN REAPING GEAR BOX

Detail	Pinion(A)	Gear(B)	Pinion(C)	Gear(D)
Material	AISI 5160 OQT 400	AISI 5160 OQT 400	AISI 5160 OQT 400	AISI 5160 OQT 400
S_u	2220 MPa	2220 MPa	2220 MPa	2220 MPa
BHN	627	627	627	627
Module	2.5	2.5	2.5	2.5
ϕ	20º Full Depth	20º Full Depth	20º Full Depth	20º Full Depth
Type of Cut	Precision Cut	Precision Cut	Precision Cut	Precision Cut

TABLE II.RESULTS DATAOF CARRIER CHAIN SYSTEM

Detail	Driving Carrier Chain		Lower Carrier Chain		Upper Carrier Chain	
Chain No.	ANSI NO. 40		ANSI NO. C2040		ANSI NO. C2040	
No. of Sprocket	2		2		2	
No. of Teeth	9	21	21	21	21	21
Speed (rpm)	975	419	419	419	419	419
Pitch (mm)	13	13	25	25	25	25
Size Dia: (mm)	D_1	D_2	D_1	D_2	D_1	D_2
	38	86	86	86	86	86
Center Distance (mm)	458		1200		1200	
Required Chain Length (mm)	1105		2655		2655	

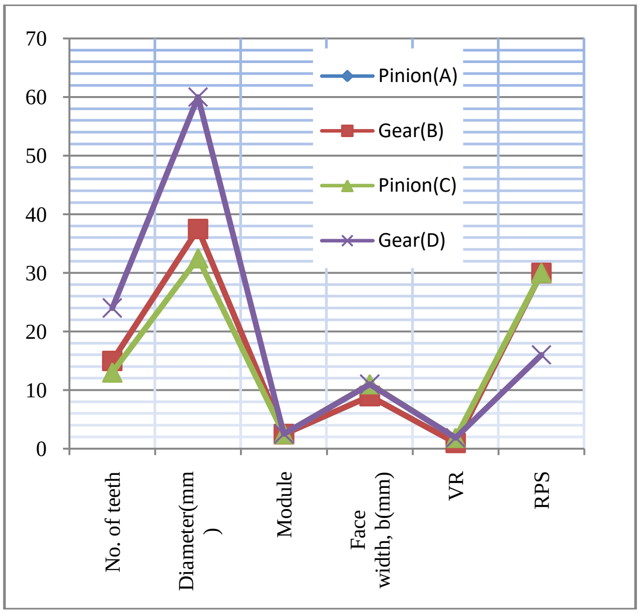

Fig.6. Result Data of in reaping gear box

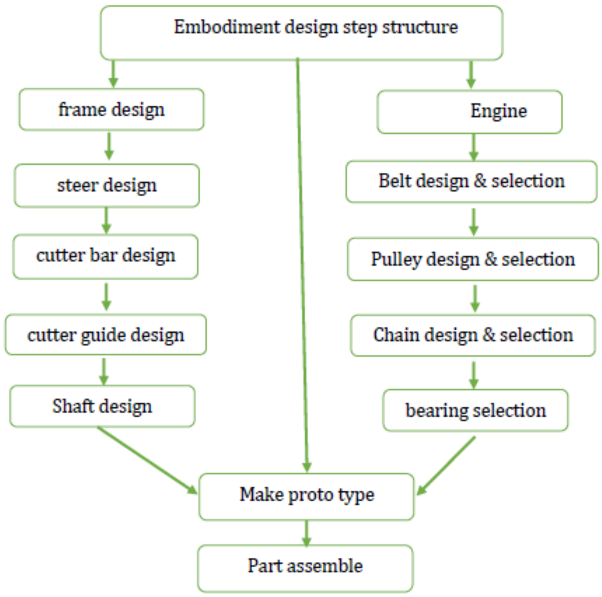

Fig. 7. Design and Construction procedure of Proto type Reaper Machine

VII. CONCLUSION

This paper has been mainly studied the design of reaping mechanism of paddy reaper with engine power 3.729 kW and input speed 3600 rpm with an average operating speed of 29.5 m/min. The required gear ratio, the module, the face width and the number of teeth are calculated for the design of reaping gear box. The required chain number, diameters of sprockets, center distance and required chain length are calculated for carrier chain system. The overall performance of paddy reaper was quite satisfactory on compare with man power and machine power. Normally one person can reap one acre in 5 days but with machine it only needs 1/4 day. Fuel consumption is about 4 litres/acre for gasoline engine.

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