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TRACTOR OPERATED DRIP LATERAL COILING MACHINE

KARALE D.S., KANKAL U.S.* AND KHAMBALKAR V.P.

Department of Farm Power and Machinery, College of Agricultural Engineering and Technology, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola, MS
*Corresponding Author: Email-uskankal@gmail.com

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Abstract- Drip lateral coiling is very difficult job to make the bundle in the field. At the present coiling operation is done by hand and in this method there is chance to twist and damage the laterals. During placing and coiling the laterals, the labour has continuous to bend often and often to collect and coil, which increases drudgery in operation. Besides these constrains the efficiency of manual coiling and decoiling is very poor and improper coiling and decoiling increased the damage to the laterals and reduces the life of the laterals. In order to overcome these problems, Department of Farm Power and Machinery, Dr. PDKV, Akola has made an attempt to design and develop power operated coiler.

Keywords- Drip, design, coiler, hand, tractor, machine, pulley, shaft.

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Introduction

Drip irrigation system is the most important mechanized irrigation input of the row crop. Most of the crop of Vidarbha is row crop and drip play important role in recent crop production, in the row crop, the lateral to be placed in between the rows, is a major hurdle during sowing, intercultural, harvesting etc. As the laterals are of P.V.C. pipes (16 mm) it is prone to damage, if not handled carefully. To achieve the proper utilization of this mechanization input, it is to be placed before sowing and to be removed before harvesting [1]. These jobs are to be done carefully, skillfully to avoid the damages due to folding of tube during handling, and to make the suitable bundle to store properly. It is very difficult to make the bundle in the field during collection of the laterals from the field. Hand pulling and coiling twist and damage the laterals. Similarly, for placing and coiling the laterals, the labour has to continuous bend often and often to collect and coil the laterals, which increases drudgery in operation. Besides these constrains the efficiency of manual coiling and decoiling is very poor and improper coiling and decoiling increased the damaged to the laterals and reduces the life of the laterals [4]. Department of Farm Power and Machinery was developed a manually operated drip lateral coiler. Now days the demand from the farmers towards the power operated coiler is more for more efficient and timely work due to shortage of labour. Keeping the above facts in mind the present investigation was undertaken to design and develop a tractor operated lateral coiler.

MaterialsandMethods

The tractor operated drip lateral coiler was designed according to the agronomical parameters and power source. Agronomical parameters *viz.* row spacing, height of crops etc. were consider while design the machine. The speed of operation is mainly affected the design of the machine.

Power requirement: The PTO power requirement of drip lateral coiler was calculated the formula [3].

PTO power of tractor = horse power x 75/100
= 35x75/100
= 26.25 hp

Selection of power source: As per PTO power requirement a 35 hp tractor was selected for operating the drip lateral coiler. On the basis of the requirement of the lateral in fields which are already laid out. The coiler is designed with suitable mechanism for coiling the laterals mechanically.

Design of power transmission system: It is necessary to reduce speed, which is given to transmission shaft by PTO shaft. PTO shaft speed in ideal condition is 220 rpm, which is not suitable for coiling drip lateral pipe by coiler, and to understand all condition and situation for coiling drip lateral pipe, speed of reel or coiler should be about 40 RPM, which is more suitable for effective coiling of drip lateral pipe.

Selection of belt and pulley: In most of the agricultural machine, flat belt drive is mostly used. In tractor operated drip lateral coiler, belt and pulley was selected for power transmission because it is cheapest and low maintenance cost is required than other hydraulic, chain and gear drives. Also belt drives slip when if more tension is increase due to any abstraction in coiling, which prevents the braking of lateral.

The B section flat belt drives were selected for power transmission. The power from PTO section is made available with the help of double grove pulley of B section belts from which the power was made available to the reels of the coiler with the help of single grove pulley with B section Belts.

Speed of the Coiler reels: The power transmission system was designed to reduce PTO shaft speed from 220 RPM to 40 RPM in two stage is given below. Speed reduction was done in two stages are given below:-

Speed at counter shaft: In first gear reduction belt and pulley has been selected. Assume diameter of driver is 12.5 cm. with speed ratio 0.44 to 1 [2].

$$\text{Speed ratio} = \frac{D_1}{D_2}$$

Where,
D_1= dia. of first driver pulley. cm
D_2 = dia. of second driven pulley, cm

$$0.44=\frac{12.5}{D_2}$$
$$D_2=28.40cm$$

Available corresponding pulley was 30 cm diameter hence it was selected.

$$\frac{Speed\ of second\ driven\ pulley(N2)}{speed\ of\ first\ driver\ pulley(N1)}=\frac{diameter\ first\ driver\ pulley(D1)}{diameter\ of\ second\ driven\ pulley(D2)}$$

$$\frac{N_2}{N_1}=\frac{D_1}{D_2},\frac{N_2}{220}=\frac{30}{12.5}=N_2=92rpm$$

The speed of Counter shaft is 92 rpm

Speed at main shaft:
In second stage of speed reduction assume diameter of driver is 7.5 cm with speed ratio 0.42 to 1.

Speed ratio $=\frac{D_3}{D_4}$

Where,

D_3 = dia. of third driver pulley. cm
D_4 = dia. of forth driven pulley. Cm

$$0.42=\frac{7.5}{D_4}$$
$$D_4=17.84cm$$

Available corresponding pulley was 17.5 cm diameter hence it was selected.

$$\frac{Speed\ of fourth\ driven\ pulley}{speed\ of\ third\ driver\ pulley}=\frac{diameter\ thired\ driver\ pulley}{diameter\ of\ fourth\ driven\ pulley}$$

$$\frac{N_4}{N_3}=\frac{D_3}{D_4},\frac{N_4}{92}=\frac{7.5}{17.5}$$
$$N_4=39.49rpm, N_4=40rpm$$

The speed of main shaft is 40 rpm.

Speed of Reels: From main shaft to reels power transmitted with the help of bevel gears with a ratio of 1: 1 hence speed of reel 40 rpm.

Length of open belt for power transmission to PTO attached pulley to counter shaft:-
Length belt length is calculated as following formula, [4].

$$L=\frac{\pi}{2}(D_1+D_2)+2X+\frac{(D_1-D_2)^2}{4X}$$

Where,

D_1 = 12.5cm = dia. of smaller pulley (Driver pulley)
D_2 = 30cm = dia. of larger pulley (Driven pulley)
X = 35cm = distance between centre of pulley

$$L=\frac{3.14}{2}(12.5+30)+2\times35+\frac{(12.5-30)^2}{4\times35}$$
$$L=138.9cm$$

Length of belt in first speed reduction stage was found 139 cm at which B55 size belt was chosen as per the availability in market.

Length of belt for counter shaft to main shaft: Length belt length is calculated as following formula,

D_3 = 7.5 cm (Driver pulley)
D_4 = 17.5 cm (Driven pulley)

$$L=\frac{\pi}{2}(D_3+D_4)+2X+\frac{(D_3-D_4)^2}{4X}$$
$$L=\frac{3.14}{2}(7.5+17.5)+2\times24+\frac{(7.5-17.5)^2}{4\times24}$$
$$L=88.29$$

Length of open belt in second speed reduction stage was found to be 88.29 cm at which B36 belt was chosen.

Design of reel: The reel of the coiler was designed using the data's available and necessary assumptions were made and were corrected by trial and error method [1]. The data's obtained are, the minimum permissible coiling diameter (D) = 0.5m The lateral pipe diameter (d) = 0.016m, The length of one lateral (l) = 200m Different height of the coil was assumed and tried in calculation and the height of the coil found to be suitable was h=25cm=0.25m. With the consideration of free boards of 5 cm, the height of the reel which come to be 30 cm.
As lateral pipe diameter (d) =0.016m. Therefore during coiling along the diameter there was two pipes and hence the total pipe diameter =0.016×2=0.032. No. of coil in 25cm high vertical flats $=\frac{h}{a}=\frac{25}{1.6}=15.42$ (Assuming no. of coils =15 no.).
In first revolution of the lateral the total length of pipes recoiled $=\pi DN$

Length of pipe recoiled up to that revolution

$$L_C=\pi\times0.5\times15, L_C=23.56cm$$

In second revolution of the lateral the length of the pipes recoiled was equal to the total length recoiled in first revolution.

$$L_{C2}=23.56+\pi(0.5+0.032)\times15$$
$$=23.56+\pi(0.532)\times15$$
$$=48.62$$
$$L_{C_3}=48.62+\pi(0.532+0.032)\times15$$
$$=48.62+\pi(0.564)\times15$$
$$=75.197m$$

Similarly, for other revolution also, in seventh revolution we get

$$L_{C7}=163.99+\pi(0.66+0.032)\times15$$
$$=196.59m$$

In the eighth revolution, L_{C8} = 230.70 m which is more than the length of the lateral (200 m). Hence adopting the seventh revolution (196.59m) hence was considered in the design.
To determine overall diameter of the reel, seventh revolution was assumed (0.692 m i.e. 0.7m) and the free board of 10 cm equally at the both side was considered. The overall diameter of the reel was come to be (0.70 + 0.20 = 0.90) i.e. 90 cm.

Design of main transmission shaft
Weight of each reel = 14.43 kg, weight of drip pipe of 200 m = 8.8 kg
Then, total weight of reel with pipe = 14.43 + 8.8 =23.23 kg
But consider some impact or jerk force acting on reel,
Then, consider total wt. = 30 kg
This load acts on the end of the transmission shaft at both side.
Bending moment at Point A of shaft,

$$M = W\times L$$
= 30×7.50 kg-cm = 22050 N-mm

Similarly, B.M. at point B,
B.M. at pt. B, M= 22050 N-mm

The tension on tight side and slack side of the first pair of the pulley is T_1 and T_2, respectively.
We know that,.

$\frac{T_1}{T_2} = e^{\mu\theta}$ (Assume μ= 0.3 = coefficient of friction)

$$\theta = (180 - 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right))\frac{\pi}{180} = (180 - 2\sin^{-1}\left(\frac{30-12.5}{2\times40}\right))\frac{\pi}{180} = 2.7 \text{ rad.}$$

Now, $\frac{T_1}{T_2} = e^{\mu\theta}, \frac{T_1}{T_2} = e^{0.3\times2.7} = 2.24$ So $T_1 = 2.24\ T_2$

Velocity of the belt:-

$$V = \frac{\pi D_1 N_1}{60} = \frac{3.14\times0.125\times220}{60} = 1.44 m/\sec$$

Maximum tension in belt:- $T = \sigma.b.t$

Where,

σ = shear stress of belt = 2Mpa =2X10^6 N/m^2

b = width of belt

= 15mm= 1.5cm =0.015m, t= thickness of belt = 10mm = 0.01m.

T = 2X10^6 X 0.015 X 0.01 = 300 N

Maximum tension in belt = 300 N, Mass of single belt = 0.2 kg, Mass of double belt m = 0.4 kg

Centrifugal tension in belt:- $T_C = mv^2 = 0.4 \times (1.44)^2 = 0.82$ N

Maximum tension in the belt was calculated by the following equations.

$$T = T_1 + T_C$$
$$300 = T_1 + 0.82$$
$$T_1 = 299.18 \text{ N}$$
$$\frac{T_1}{T_2} = 2.24$$
$$T_2 = \frac{T_1}{2.24} = \frac{299.18}{2.24} = 133.56N$$

Power transmitted by the shaft

$$P = (T_1 - T_2)v$$
$$P = (299.18-133.56) \times 1.44$$
$$P = 231.86 \text{ W}$$

Torque in by the main shaft,

$$T = \frac{P\times60}{2\pi N_4}$$
$$T = \frac{231.86\times60}{2\times3.14\times40}$$
$$T = 55.380N-m$$
$$T = 55380N-mm$$

Tension on the tight side and slack side is T_3 and T_4 respectively for second pair of pulley

$$\frac{T_3}{T_4} = e^{\mu\theta}$$

$$\theta = (180 - 2\sin^{-1}\left(\frac{D_4 - D_3}{2C}\right))\frac{\pi}{180}$$

$$\theta = (180 - 2\sin^{-1}\left(\frac{17.5-7.5}{2\times26.5}\right))\frac{\pi}{180} = 2.76 \text{ rad.}$$

$$\frac{T_3}{T_4} = e^{0.3\times2.76} = 2.3, T_3 = 2.3T_4$$

Power transmitted by the main shaft,

$$P = (T_3 - T_4)v$$
$$231.86 = (2.3T_4 - T_4)\times\frac{\pi D_4 N_4}{60}$$
$$231.86 = 1.3T_4\times\frac{3.14\times0.175\times40}{60}$$
$$T_4 = 486.86N$$
$$\therefore T_3 = 2.3\times486.86$$
$$T_3 = 1119.7N$$

Load on the main shaft,

$$W = T_3 + T_4$$
$$W = 1119.7 + 486.86$$
$$W = 1606.56N$$

As pulley is mounted at middle of main shaft hence bending moment of the shaft,

$$M = \frac{W\times L}{4}$$
$$M = \frac{1606.56\times850}{4}$$
$$M = 341394N-mm$$

Maximum bending moment is,

The equivalent twisting moment is,

$$T_e = \sqrt{M^2 + T^2}$$
$$T_e = \sqrt{341394^2 + 55380^2}$$
$$T_e = 345856.6N-mm$$

Whereas equivalent twisting moment is,

$$T_e = \frac{\pi}{16}\times\tau\times D_4^3$$
$$345856.6 = \frac{3.14}{16}\times56\times D_4^3$$
$$D_4^3 = 31470.12$$
$$D_4 = 30.5mm$$
$$D_4 = 3.05cm$$

Bending moment line diagram of main transmission shaft:

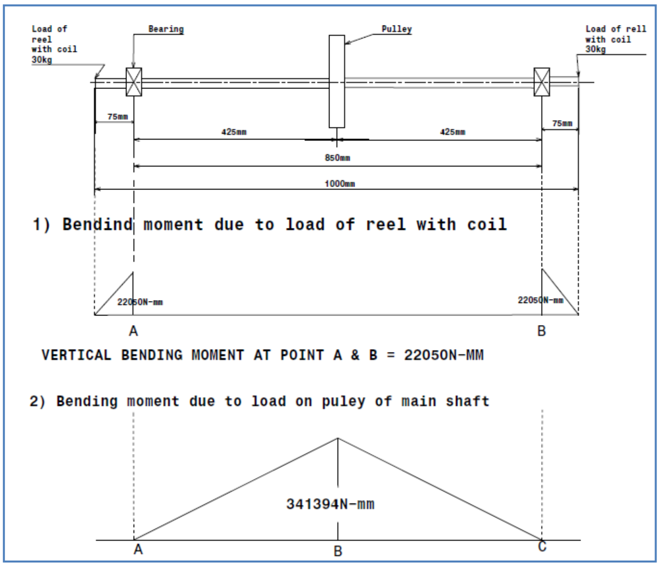

Fig-1 Bending moment line diagram of main transmitting shaft

Bending moment at point c is 341394 N-mm.

On the basis of the above bending moment diagram the diameter of the shaft should be 3.05 cm is suitable for the machine for safety. Therefore, the shaft dia. was taken as 3.1 cm. The details CATIA drawing of machine is shown in [Fig-1].

Development of drip lateral coiler

The prototype drip lateral coiler was fabricated based on the dimensions obtained from design. Machine is consists of main frame, power transmission system, reel, main transmission shaft. The details construction details of each components are as bellow.

Reel: In drip lateral coiler is consist of two reels. The diameter of outer ring and inner ring is 90 cm and 33 cm. The material used for the fabrication of these reel is mild steel. The power provided to reel by means of main transmission shaft.

Supporting disc plate: Supporting disc plate was provided in order to support the base of reel and which is made up from mild steel having diameter 18 cm attached with the bottom side at the center.

Flexible vertical flats: Flexible vertical flats are provided to hold the laterals. Eight flexible flats were welded at inner ring vertically for each unit at an in equal distance between two successive flats were mentioned. The constructional material of these flats was used as Mild steel. The size of flat is 35 cm in length and 4 cm in width. The portion is kept free to provide flexibility for the laterals to be taken out easily without much effort as these flats goes inner simply by pressing or load of the coiled during removing bundled. It is given a slight bend at the top portion 25cm from the base.

Transmission shaft: Solid MS shaft having a diameter of 3.1 cm was used in drip lateral coiler. The overall length of the shaft was 100 cm. DPI P205 bearing having base diameter of 2.5 cm provided at both end of the shaft.

Frame: The overall dimension of frame is 200x40 cm (LxB). The frame is made up of mild steel angle size 40x0.5 cm to give more strength to the structure and provide support to the reel.

Hitch: Three point linkage systems was provided for mounting and transportation of implement.

Bevel gear: The bevel gear is used for transmission in right angle of the power, which is received form belt and pulley system for rotating the reel. Two pair of bevel gear was used.

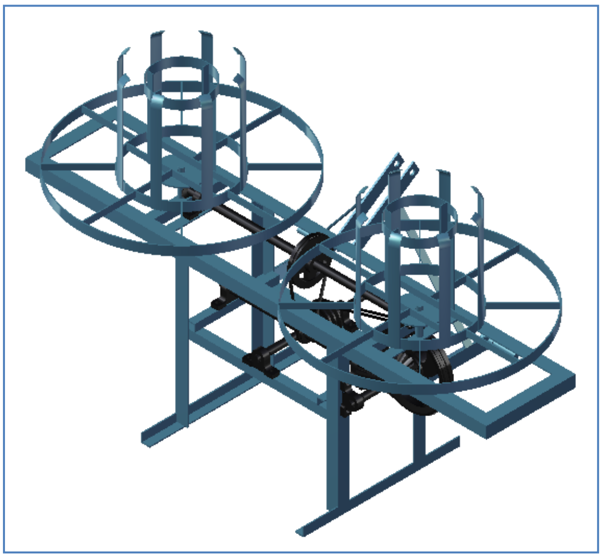

Fig-2 Isomeric view of tractor drawn drip lateral coiler machine

Fig-3 Prototype tractor drawn drip lateral coiler machine.

The specification of developed tractor operated lateral coiler is presented in [Table-1].

Table-1 *Specifications of tractor operated drip lateral coiler*

Sr. No.	Particulars	Details
1	Name of machine	Tractor operated drip lateral coiler
2	Overall dimension of machine (L× B×H)	200×94×115 cm
3	Weight of machine	110kg
4	Power source	35or below 35 hp tractor
5	PTO shaft speed (ideal)	220 rpm
6	Gear type	Bevel gear
7	Belt drive	Open flat belt drive
8	Bearing	Ball bearing
9	Details of machine component	
10	Frame dimension (L×B)	200×40 cm
11	No. Of reel	2
12	Size of shaft	100 cm in length with 4.8ϕ
13	Bearing (Pedestal)	205(8 in no.)
14	Pulley	4 (2 of double groove pulley and 2 of single groove pulley)
15	No. of open belt	3 (B section belt, two 55" and one 35")
16	No. of bevel gear	6 (4 of 20 teeth and 2 of 28 teeth)

Result and Discussion

The results pertaining to the design and development of tractor operated drip lateral coiler are presented in this section. Based on agronomic and machine parameters and specification of lateral, tractor operated drip lateral coiler was designed and developed. The details of functional parts of tractor operated drip lateral coiler are presented below.

Power source: Drip lateral coiler is operated on prime mover as a tractor. It was observed that the implement work satisfactory with 15 hp tractor.

Design of power transmission system

The power transmission system was designed to reduced PTO shaft speed from 220 rpm to 40 rpm on reel in 2 steps. Hence the speed was reduced from PTO to counter shaft and is observed 100 rpm at ideal speed of a tractor high neutral gear position of the tractor. It was observed that the calculated speed of counter shaft (92 rpm) which is lesser than the readings of tachometer that is 100 rpm this may due to the possibility of the ± 5% error in the tachometer reading due to instrumental error.

Length of open belt

Length of open belt was designed and found in first speed reduction unit was 139 cm. and second stage 88.29 cm. From the observation, the belt size of B 55 and B 36 was used for the power transmission system, which works satisfactory.

Design of power transmission shaft

Power transmission shaft was designed ant it was for PTO attached pulley and counter shaft of diameter 2.8 cm whereas for main shaft subjected to bending moment due to load on shaft calculated diameter is 3.05 cm which taken as 3.1 cm to sustain any jerk or impact load during the operation. It was observed that there was no deformation or any bending observed in the shafts. Hence, design diameter of the counter shaft within the limit and safe.

Design of reel

Reel was designed on the basis of lateral specification and speed of reel. Diameter of outer and inner ring was designed and it was 90 cm and 50 cm in diameter respectively.

Conclusions

From study of the drip lateral coiler following conclusions could be drawn

1. As per design of coiler a tractor at 540 PTO rpm suitable to drive the machine.
2. In power transmission system the speed of tractor PTO shaft, need to be reduced for the proper collection of drip laterals.
3. The diameter of outer and inner ring was 90 cm and 50 cm in diameter, respectively it is works satisfactory without bending or twisting of the drip laterals coils.
4. Increases the life of the drip laterals when using such machine for coiling the drip laterals.

Conflict of Interest: None declared

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