A New Design for Grain Combine Thresher

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ABSTRACT

One of the problems facing the combine holders in Iran for years has been the thresher cylinder with one piece passing through shaft. The problem has arisen ever since domestic make buckled shaft has been used. Buckle is too much to recover by simple machining. As such, disassembling the cylinder is a breath taking, time consuming and expensive task to do. On the other hand, manual welding in factory to join the thin plates to rather thick tubing cause undercutting. This research was performed to cope with both problems by designing a suitable threshing cylinder for Iran namely the 3 piece cylinder. A tube was installed to carry the plates. The plates unlike similar cylinders are not welded to the tube but bolted to specially designed flanges. The flanges are welded to the tubing instead, which eliminates the undercutting phenomena. The two piece shafts on the sides, the long and the short are joined to the tubing by simple flanges and studs. Putting down the cylinder is as easy as un-screwing 12 bolts and screws. Bolting the plates to the flanges makes the mechanism indispensable. Any damaged plate can be removed for repair or replacement. The similar three piece cylinders are rather disposable type because the flanges are welded the plates. The cylinder was designed successfully. Auto Cad software was used for the design. The vibration consideration and calculations indicated a critical speed way beyond the operating speed to avoid resonance.

Key Words: Threshing; John deere; Grain combine; Cylinder

INTRODUCTION

Changing over the grain thresher cylinder with other types say rice or peas has been a cumbersome task with the one shaft through thresher type. The task is costly and time consuming. Statistics show that 13.5 kg ha^{-1} of wheat is lost for every day of delay in harvesting (Behroozi, 2001). It is greater for Soya and some other agricultural products. Few manufacturers have developed and installed a 3 -piece shaft thresher type for the remedy (CLAAS Dominator 116 CS Combine Catalogs, Germany). This type although solves the problem but there is still another matter to be considered specially for the third world country and that is, changeability or repair of the thresher plates when needed. The plates in the existing threshers are welded to a carry tube, which makes them dispensable if a plate is damaged, since the plate is not replaceable or repairable. In the new design presented in this paper however, the plates are not welded to the carry tube but rather bolted to a special star flange. Removing the plates thus, is possible and simple just by un-screwing the nuts. Repairing in the third world countries; unlike the developed ones; is cheaper than replacing the whole outfit.

A second problem also exists with this type of design and that is undercutting phenomena. The thin plate should be welded to the carry tube by automatic welders and special electrodes. The device is seldom used in developing countries. The welding in these countries is performed manually using regular electrodes, which inevitably causes undercutting (Anonymous, 2004). The weld thus usually cracks even in the factory and before testing (Fig. 1). Much

more when it is put to work. The objective of this research was to design and develop a new 3 -piece thresher with renewable or repairable plates.

MATERIALS AND METHODS

The single shaft cross through the thresher cylinder in grain combines (Fig. 2) has long been used in most combines (John Deere, Combine Catalogs, USA). To replace the thresher for different crops, the thresher must be dismantled. To do so, the shaft must be brought out first; a task, which is hard to do on all threshers of this type. The shaft after working for some time expands and sticks to the holder, making it hard to pull out.

A few manufacturers have switched to 3 -pieces cylinders (Fig. 3) but yet many are still using the one shaft with the problems explained above. The existing 3 -pieces cylinder on the other hand, has its shortcoming or may say it can be improved by making it repairable. The 3 -pieces cylinders has the plates welded to the carry tube. This configuration makes the cylinder a disposable cylinder. On the other hand, if any one of the plates is broken or damaged, it can not be replaced or repaired but the whole outfit has to be replaced.

Fig. 4 shows a perspective view of the designed 3 -pieces thresher. It is composed of the following parts (Fig. 5): 1. carry tube, 2. tube flanges, 3. star flanges, 4. shaft flange, 5. plates, 6. 2 -piece shaft.

Star flanges are welded to the tube at determined spaces. Welding is no problem because the flanges and the tube have enough thickness. Undercutting will not occur.
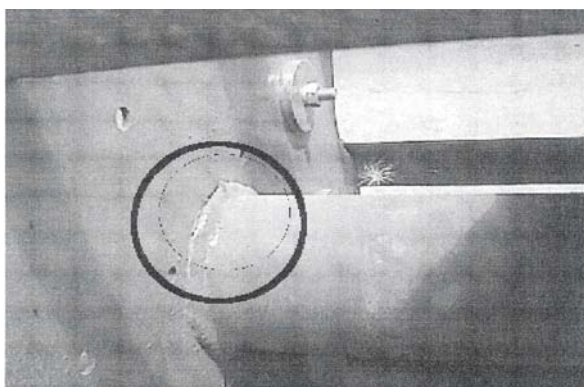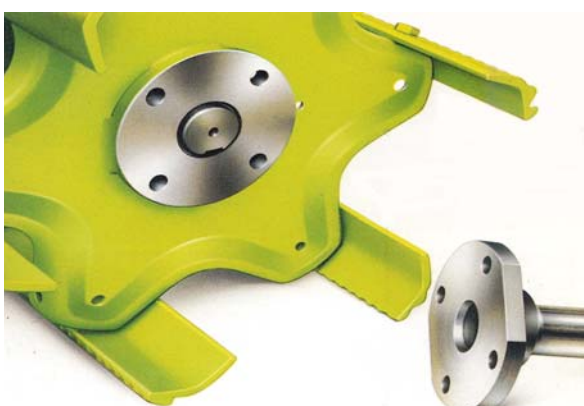
Fig. 1 A sample of Cylinder Crack

Fig. 2 Cylinder with one piece passing through the shaft

Fig. 3. Three piece Cylinder

Fig. 4. A perspective view of the designated cylinder
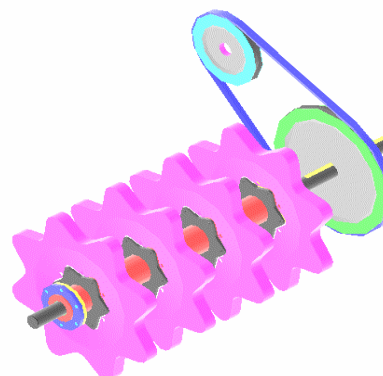
Fig. 5. Parts of the 3-piece shaft thresher

1. carry tube	4. shaft flange
2. tube flange	5. plate
3. star flange	6. 2-piece shaft
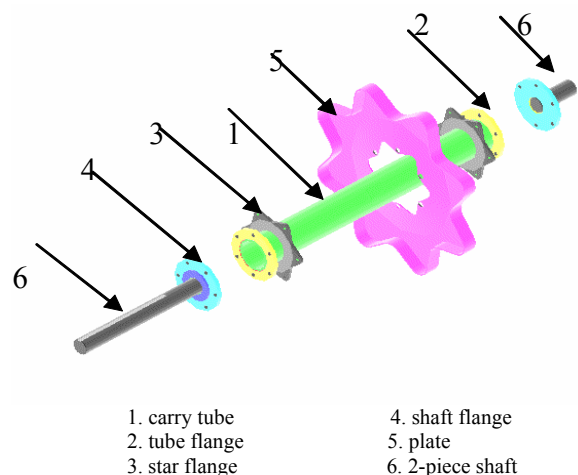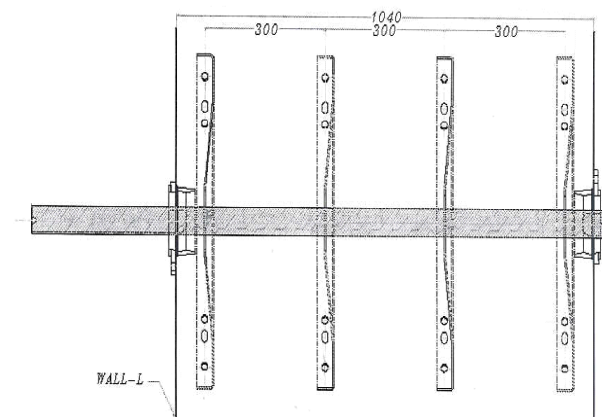
Fig. 6. Plate spacing should reduce to 240 mm

The same star shape is cut out at the center of each plate with enough tolerances to pass over the star flanges. After placing the plate, it will be rotated 30° for the plate and flange holes coincide and bolted together (Behroozi, 2004).

Two round flanges are welded to the tube, one at each end. Again, no undercutting phenomenon occur here either.

The thresher cylinder is now ready. Two shafts, a small and a long each is welded to a round flange. These flanges are exactly the same as those welded to the tube and fastened together by six screws.

Comparing to the pass through shaft thresher (John Deere 955 Combine Upgrading, John Deere Co., Germany),

the plates spacing is shortened by 60 mm from 300 mm to 240 mm (Fig. 6) to provide enough space for the tube and shafts flanges.

To determine the forces imposed on the tube, an estimation of wheat feeding rate was needed. The highest mean yield in Iran provinces is given (Anonymous, 1992-2001). The feed rate is calculated as follows (Behroozi, 2001):

$$Q = Y V w c / 36000 \qquad (1)$$

Where: q = feeding rate, kg/s, Y = yield, tons/ha

V = forward speed of combine, km/h

W = width of cut of combine, m, e = field efficiency,

Forward speed seldom exceeds 4.5 km h^{-1} but yet it will be considered 6 km h^{-1} to account for exceptionally higher yields than 4 tons h^{-1}. The working width of the combine is 3.75 m and the expected farm efficiency is 70%. Taking the 4304 ton ha^{-1} yield (Popov *et al.,* 1986) and replacing these figures in the equation 1:

$$q \approx 2 \text{ kg/s} \qquad (2)$$

To thresh this rate of crop a force F is needed, which is a function of cylinder linear speed as well as the friction coefficients between the crop- crop and crop-metal (Popov *et al.,* 1986).

Thus,

$$F = Fc + Fr \qquad (3)$$

Where: F = the force needed for threshing crop, N

Fc = impact force of the cylinder, N, Fr = friction force, N

The impact force Fc may be calculated from eq. 4 below;

$$Fc = q (V2 – V1) \qquad (4)$$

Where: V2 = speed of the threshed crop as it exits the cylinder, m/s

V1 = speed of the crop as it enters the cylinder, m/s

V2 is proportional to the linear speed of the cylinder (V);

$$V2 = aV \qquad (5).$$

The coefficient a, is an empirical figure depended upon cylinder length, straw humidity, shape of rasp bar, feed rate and physical properties of the threshing unit. For a thresher of 0.8 m in length, humidity of 15 - 25%, feed rate of 3.5 kg/s, the coefficient a, has been determined equal to 0.70 - 0.85 (Hall *et al.,* 1981). The linear speed of the cylinder has also been determined equal to 15 - 37 m/s (Behroozi, 2004). Inserting equation (5) in equation (4):

$$Fc = q (aV - V1) \qquad (6)$$

Fc is dependent upon many factors such as the friction coefficient, type of breakage of the straw, the intense of threshing and etc. It is however proportional to the total force necessary to thresh the crop, F;

$$Fr = f F \qquad (7)$$

The coefficient f, for rasp bar type cylinders is equal to 0.65 - 0.75 and for finger type equal to 0.7 - 0.8. Inserting equations 6 and 7 in equation 3;

$$F = q (aV - V1) + f F \qquad (8)$$

And therefore,

$$F = [q (aV - V1)/(1 - f)] \qquad (9).$$

Required power for threshing, P1 in watts, may be obtained by multiplying both sides of equation (9) by V;

$$P1 = FV = [q (aV - V1)/(1 - f)] V \qquad (10).$$

The total power for the threshing is more than what is shown in equation (10). Power is also needed to overcome the air resistance against the rotation of the cylinder and the friction force in bearings. This power is calculated from equation 11, below:

$$P2 = AV + BV^3 \qquad (11)$$

The first term after the equal sign is due to friction and the second term is for air resistance. A and B are two coefficients. Coefficient A is determined as 0.85 - 0.90 N per 100 kg mass of rasp bar type thresher cylinder and 5 - 5.5 N per 100 kg mass of finger types. Coefficient B for cylinder diameters of 550 mm is equal to 0.065 Ns^2/m^2 per m of cylinder length of rasp bar type and 0.045 Ns^2/m^2 for finger type. The total required power is then:

$$P = P1 + P2 = [q (aV - V1)/ (1 - f)] V + AV + BV^3 \qquad (12)$$

Substituting the least value for V1 but the maximum for other components yields;

$$P = 11.75 \text{ kW}$$

and for a design coefficient of 1.5 the total power requirement is:

$$P = 11.75 \text{ x } 1.5 = 17.6 \text{ kW} \qquad (13).$$

Tube diameter was calculated from the following classic equation (Hall *et al.,* 1981).

$$do^3 = \frac{16}{\pi S_s (1 - k^4)} \sqrt{\left[C_m M + \frac{\alpha F_{do}(1 + K^2)}{8} \right]^2 + (C_t T)^2} \qquad (14)$$

Where

do = tube outside diameter, mm, K = do/di

Di = tube inside diameter, mm, M = bending moment, Nmm

Ss = permissible shear stress, N/mm2,

T = torsion moment, Nmm

Cm, Ct = coefficients (Hall *et al.,* 1981).

The second term inside the radical sign is due to tension, which does not exist in this case and thus is set to zero. To calculate the moments, the imposed forces must first be determined as follows:

1. Horizontal forces, which are reaction to the threshing force and friction. These forces may be calculated from the total power requirement.

2. Vertical forces due to the weight of the components such as: rasp bars, plates, star flanges, tube flanges, tube, power transmission pulley, shaft flanges, short and long shafts.

The weight of the existing components was known but the un-known weight of the others such as star flanges, shaft flanges and etc. were obtained from AUTO CAD software.

Power is transmitted to the cylinder by V-belt pulleys at an angle of 30° angle with respect to the horizon. The tight and slack side tensions were calculated from the following equation (Behroozi, 2000);

$$P = (T1 - T2) V/1000 = T n/9549 \qquad (15)$$

Where: P = total design power = 17.6 kW

T1, T2 = tensions on the tight side and slack side of the V belt, N, V = linear speed of the belt, m/s

T = Torque, Nm, n = rotational speed, rpm

From which Tx (horizontal vector component) and Ty (vertical vector component) were determinant at a 32° angle (Behroozi, 2004). Resulting bending and torsion moments were 315357 N mm and 357580 N mm, respectively. Substituting these values and Cm = 3, Ct = 3 [11] Ss = 55N/mm2, K = 0.89 (for standard tubes) in the equation 14;

$$Do = 70.7 \text{ mm} \qquad (16)$$

The nearest standard tube diameter to choose was 101.6 mm outside diameter with 90.4 mm inside.

Critical speed was calculated from the following equation (Thomson, 1998):

$$\omega = \sqrt{\frac{g \sum My}{\sum My^2}} \qquad (17)$$

Where
ω = critical speed, rad/s
M = weight, N, y = deflection, mm
g = gravitational acceleration, 9.81 m/s2
With E = 2.1 x 10^6 N/mm^2 for steel and calculated I= 5.23 x 10^7 mm^4, a value of 317 rad/s = 3042 rpm was obtained for critical speed which is way beyond the 1160 rpm, operating speed.

RESULTS AND DISCUSSION

A summary of calculation results is shown in Table 1. The new thresher design production cost is about the same as the customary but with the following advantages:
1. Ease of dismantling the thresher cylinder
2. Saving time for replacing or repairs. The time saved

considering it in the harvest season is very valuable to the farmer and combine operator
3. This new design is repairable which is highly favored especially in the developing countries; whereas, the other 3- piece designs are not.

REFERENCES

Anonymous, 1992-2001. *Statistics on Iran Agriculture.* Ministry of Agriculture, Tehran, Iran

Behroozi Lar, M., 2000. *Design of Agricultural Machinery (Translation).* Azad University Press, Tehran, Iran

Behroozi Lar, M., 2001. *Farm Power and Machinery Management (Translation).* University of Tehran, Iran

Behroozi Lar, M., 2004. Report on the Optimization of 955 John Deere Grain Combine: a. Replacing the Flat Drive belt to V-type belt. University of Tehran, Iran

Hall, A.S. *et al.,* 1981. Theory and Problems of Machine Design. Schaum's Outline Series. McGraw Hill Book Co., New York, USA

Iran Combine Manufacturing Co., 2004. Pamphlets and Information. John Deere Combine Catalogs, John Deere. 955 Combine upgrading. John Deere Co., Germany

Popov, I.F., N.I. Kienen and V. Asakun, 1986. Agricultural Machines. A.A.Balkema –Roterdan, New Delhi

Thomson, W.T., 1998. *Vibration Theory and Application.* Prentice Hall, Inc., Englewood Cliffs, N.J. USA

Table I. Physical dimensions of the designed components. (Steel specific mass = 7850 kg/m^3)

Component name	OD mm	ID mm	Length/thickness mm	Volume mm^3	Material type	Length mass Kg/m	No.	Unit weight N	Total weight N
Plate	600	star	4.2	1018.5	Steel plate		4	81.74	314.4
Star flange	226	101.6	10	206.7	CK45		4	15.9	63.6
Tube flange	166	50	12	152	CK45		2	11.8	23.6
Shaft flange	101.6	90.4	12+5	228	CK45		2	1 7.6	35.6
Tube	50		860	1452.5	ST37	13.19	1	111.28	111.28
Tall shaft	50		45	865	CK45	15.4	1	68	68
Short shaft			120	225	CK45	15.4	1	19.6	19.6
Rasp bar			1000	weighted	Cast iron		8	54	422
Total									1067.7
Pulley				weighted			1	245.25	245.25