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Effect of Round Spiked Threshing Cylinder Geometry on the Threshing Performance of Wheat Crop

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ABSTRACT

For wheat crop threshing, threshing cylinder with round spikes gave the maximum output capacity and threshing efficiency which were observed as 369.3 kg/h and 99.87% at tip diameter of 600 mm and spike thickness of 6 mm corresponding to maximum feed rate of 780 kg/h. The wheat straw size for maximum output capacity and maximum threshing efficiency were 22.67 mm at tip diameter of 600 mm and spike thickness of 6 mm corresponding to maximum feed rate (780 kg/h) in case of round spiked threshing cylinder. The maximum broken grain percent values were 0.833% at feed rate (507 kg/h) corresponding to tip diameter of 600 mm and spike thickness of 10 mm for round spiked threshing cylinder. For higher threshing efficiency, fine straw quality and minimum specific power consumption, round spiked threshing cylinder of 600 mm tip diameter and spike thickness of 6 mm gave best performance results with total grain loss within permissible limit. The spike thickness of 6 mm gave minimum broken grain loss with fine straw quality. But from mass manufacturing point of view, tip diameter of 600 mm and 8 mm round spike thickness will be appropriate for manufacturers. It also delivered good output capacity and threshing efficiency and fine straw quality.

1. Introduction

Nearly 90% of wheat threshers used in the country and the most common prime mover used for their operation is of 3-4 kW. These threshers have lower cylinder tip speeds, 25 m/s ensuring good viability of seeds. Spike tooth threshers are commonly used by farmers for wheat threshing due to its simplicity in design, low cost, low energy requirement and lower percentage of grain damage while producing *bhusa* of satisfactory quality. The machine parameters which affect the quality and efficiency of threshing are feeding chute angle, spike shape, size and numbers, cylinder type, cylinder diameter, concave size, shape and clearance. The intensity of impact of the spikes of the cylinder on the crop depends on the peripheral speed of threshing cylinder having a direct bearing on the threshing efficiency, grain damage and power requirement. The selection criteria for a spike tooth thresher includes the capacity, type, safety aspects, availability of spare parts, facilities for repair, source of prime-mover and suitability for different crops. Generally, the tip speed of the spikes range between 20-25 m/s. Crop is fed to the spike tooth thresher radially and is found to less accident prone as compared to syndicator type threshers. Anonymous (2002) mentioned criteria for selection of threshing cylinder on the basis of quality of straw and power requirement per ton of crop. Spike tooth type thresher used for threshing wheat had power requirement in the range of 1.65-2.74 kW/t of grain and produced fine straw quality. Average number of pegs provided were 46, 51 and 110 for 3.7 and 5.6 and 15 kW size of power threshers. The output capacity of a peg tooth type thresher was directly proportional to the number of peg tooth and the permissible feed per tooth. The permissible feed varied 0.025 to 0.04 kg/s per tooth. The number of teeth on the threshing cylinder was dependent upon its working length (Popav and Klenin 1975). AAI power thresher (3.7 kW) was designed and developed. The spike tooth type thresher had threshing cylinder of 456 mm diameter and 300 mm length.

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Forty-five spikes of 12.5 mm diameter and 75 mm length were fitted in nine rows. The thresher delivered threshing capacity of 208 kg/h and total grain losses of 0.5% for wheat. Pantnagar multi-crop thresher consisted of peg tooth type cylinder of 680 mm diameter and 1400 mm length. The spike teeth (120 no) of 18 mm diameter and 150 mm length were fitted. During field test, the thresher gave threshing capacity of 312 kg/h for wheat. PAU Wheat cum paddy thresher of 3.75 kW consisted of a spike tooth cylinder with eight rows of staggered spikes, the cylinder had three distinct portions. The machine had a threshing cylinder with round spikes arranged in 8 rows. The grain output of the thresher reported for wheat was 2 q/h. The CIAE multi-crop thresher of 3.75 kW, suitable for wheat and paddy, consisted of spike tooth cylinder, aspirator type blower and sieve shaker. The threshing cylinder diameter and lengths were 500 and 584 mm respectively. In the thresher ninety-two flat spikes of size 25x8x80 mm were provided. The threshing cylinder was fitted with forged spikes mounted on 8 bars in staggered fashion. For wheat, output capacity, threshing and cleaning efficiency were 276 kg/h, 99.84% and 99%, respectively at threshing cylinder speed of 19.3 m/s. CIAE multi-crop plot thresher consisted of spike tooth cylinder of 250 mm diameter and 250 mm length suitable for precision threshing of wheat. The results indicated 99.3% threshing efficiency, 93.4% cleaning efficiency and 29.5 kg/h output capacity. CIAE semi axial flow multi-crop thresher had threshing cylinder diameter of 540 mm and length of 740 mm. Seventy-two spikes of length 80 mm and 1.6 mm diameter were provided on threshing cylinder. At cylinder speed of 21 m/s, wheat output capacity was 350 kg/h. CIAE High capacity (15 kW) multi-crop thresher consisted of spike tooth threshing cylinder of 700 mm diameter and 1100 mm length. At 14.6 m/s threshing cylinder speed, the output capacity was1380 kg/h. ANGRAU power thresher consisted of threshing cylinder of 500 mm diameter and 610 mm length. It is suitable for threshing of wheat and other crops including paddy (Singh et al. 1997). During testing, the thresher gave cleaning efficiency of 98% and labour requirement of 9 man h/q. Banga et al. (1984) reported that the quality of straw increased with increase in cross- sectional area of spikes. Analysis of straw size index indicated that the material retained on the sieves did not reflect directly the length of the straw. Majumdar et al. (1985) reported straw quality of wheat (HDM 4530 variety) during evaluation of 3.7 kW spike tooth thresher. It was opined that the measure of straw quality was percentage of straw of 30 mm or lower size and that of the nodes. It was recommended that straw larger than 30 mm and the nodes should not be more than 30% and 3 respectively. It was found 89.1, 90, 92.5 and 95.7% of straw below 30 mm (by weight) at threshing cylinder speed of 550, 650, 750 and 850 mm, respectively. The nodes percent varied 4.9, 3.8, 3 and 2.7% at 550, 650, 750 and 850 mm, respectively. Lawrence et al. (1987) reported straw size of 14.45-25.1 mm and straw split of 63.39-94.01% at 8.89% moisture content and 99.49% threshing efficiency for threshing wheat using chaff cutter type thresher. At higher crop moisture content, grain breakage and power requirement were observed high and *bhusa* quality was poor. Das (1996) reported that the spike tooth (peg) thresher contributed 90% to the population of threshers because of simple design, easy fixing, threshing almost all the crops, superior quality of bruised straw (*bhusa)*, and ease in fabrication of cylinder drum. During the process of grain separation and straw grinding, the pegs were subjected to impact, fatigue and abrasion. The continuous rolling or sliding of hard particles over peg surface resulted into material loss at the peg tip. The continuous use of the thresher produced worn out pegs, which affected output and service life of the unit. With 200 h of annual use (4 q/h grain) or 150 tonnes of grain threshing, the thresher needs peg replacement once in three years. Therefore, with life span of 12 years, thresher pegs need to be replaced 3 times. The teeth of threshing cylinder strike and grasp the stem of crop and impart to them a velocity close to the peripheral speed of cylinder. The ears strike the teeth and are dragged into the space between its faces. During this action, the grain gets detached and the stem is crumpled and shredded. Three distinct operations can be identified within a threshing cylinder namely compaction, impact and shearing or rubbing. The crop receives only one impact at the entrance of the threshing cylinder, but is compressed repeatedly on its way to the exit (Clark et al. 1993). The physical properties *viz.* grain size, moisture content, angle of repose, bulk density, crushing load, and sphericity have effects on size of the separating mechanism, speed of the drum and size and profile of the threshing pegs and size of the screen respectively. Therefore, it is essential to standardize threshing cylinder geometry in same power range and introduce an efficient threshing system for wheat.

2. Material and Methods

The tip diameter of threshing cylinder, thickness of the spike and feed rate were included as independent parameters. The dependent parameters included were total power consumption, broken grain loss, total grain loss, threshing efficiency, cleaning efficiency, straw length of wheat, splitting of wheat straw, output capacity and specific power consumption. Relevant physical properties such as size of the wheat seed at initial moisture content, 1000 seed mass, true density, bulk density, porosity, terminal velocity, angle of repose, crushing load and static coefficient of friction were determined following the standard methods and techniques.

The survey details of power threshers revealed that almost in all sizes of thresher (3.7 to 18.5 kW), the main shaft size was of 50 mm diameter made from bright bar. Concave was made using 6 mm square MS bar. Pegs were generally made from MS flat having a length of 125 mm. The section size was either of 35x8 or 40x8 mm which played a key role in deciding desired geometry.

Round spiked threshing cylinder design

The threshing cylinder diameter varies from 445 to 610 mm for spike tooth drums when the number of bars M is six to eight (Klenin *et al*., 2001). The threshing capacity q_r of a given crop depends upon the length l_r of the flat bars, that is,

$$q_r = q_o l_r M$$

where,

q_o =allowable feed rate length of the flat bar in kg/s per meter and

l_r = length of the drum, m.

The round spiked plain pegs of 6, 8 and 10 mm diameters with 75, 100 and 125 mm length were fabricated from M.S round bar on a lathe. The side rings and central ring, hubs and spokes being of same size as fabricated for rectangular spiked threshing cylinder were reused for fitting MS flat rows bolted with round plain spikes. The bottom end of plain spikes were provided with threads for their easy fixing on bolts of 125 mm size welded on MS flat strips (25x5 mm size). These nuts were positioned at equal interval in staggered fashion on rows of MS flat strips to facilitate locking of plain pegs of desired length pegs. These MS flat strips were welded on side rings and central ring after inserting main shaft in the hub.

The spokes were welded between hub and side/central rings to provide strength to the threshing cylinder. The main frame was fabricated using 65 x 65 x 6 mm size MS angle. Two pieces each of 730, 1470 and 1600 mm lengths were cut and welded. Five MS angle pieces of 600 mm length and 65x65x6 mm size were cut. Eight pieces of MS flat of 65x65x6 mm size were cut of 850 mm length. The experimental set consisted of top set, motor base, frame sub assembly, bottom, vertical set, blower, threshing cylinder, two cleaning sieves. It was also equipped with torque pick up on fixed between coupling on drive shaft. A straw collection box was also provided of MS sheet of 1.6 mm size. Three types of tests namely test at no load; test at load for short duration and test at load for long duration were conducted for threshing of crop. No load test was conducted at recommended speed for threshing wheat without any load for 10 min to observe the power consumption of moving parts of the machine. The tests at load were conducted at maximum feed rate and recommended speed for threshing. For each test, parameters related to crop, machine, operator and ambient conditions were recorded. The parameters related to the performance of the machine were also recorded. The speed of the moving parts was observed by a hand tachometer thrice during each test and average values were reported. The feed rates were determined by weighing crop samples of 25 kg each on a platform balance and keeping near the machine before the start of test. The maximum feed rate at which no checking of cylinder / blower / sieve occurred at recommended speed was determined initially and feed rate was controlled by regulating the quantity of the crop fed in pre-calculated time. For measurement of energy consumption suitable energy meter was used. The power consumption was observed several times by connecting suitable watt meter and the minimum, maximum and average readings were recorded.

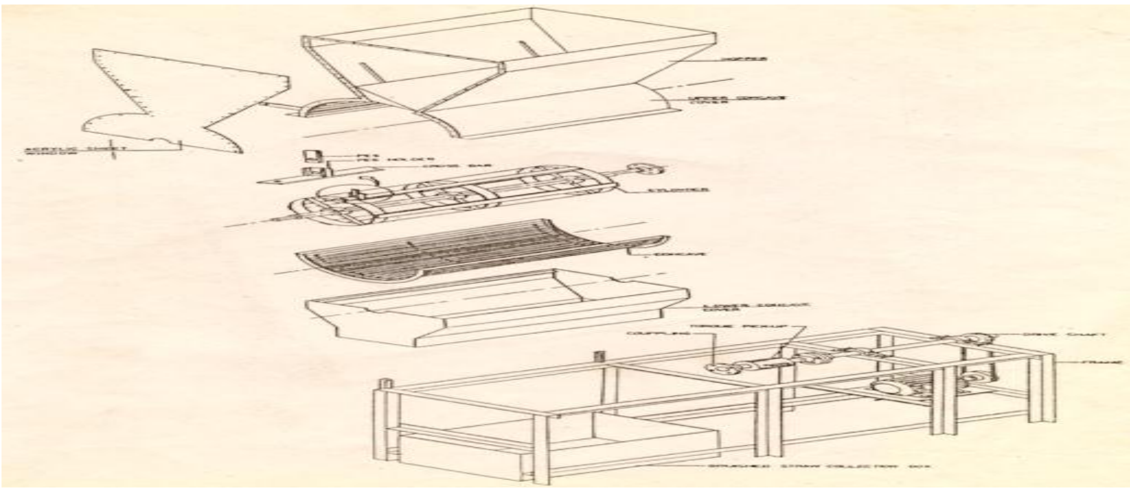


Figure 1. Sub-assemblies of Experimental set-up

During each test three sets of samples were collected at 20 minutes intervals from main grain outlet (for 30 s), sieve overflow outlet (30 s) and blower outlet (15 s) by using sampling bags and a nylon mosquito net. Stop watch was used for recording time. The grain and straw moisture were determined in accordance with IS: 4333 (Part II).The total grain mixture collected at sieve underflow during one hour test were also analyzed and quality of *bhusa* was also analyzed by taking 500 g sample. Microsoft Excel was used to perform analysis of variance (ANOVA) on the data to determine if significant effects of independent parameters were visible on various parameters of threshing performance of wheat crop.

3. Results and Discussion

It is evident from Figure 2. that at maximum feed rate, total power consumption increased with increase in tip diameter of round spiked threshing cylinder. The larger tip diameter consumed more total power due to more drag forces of longer spikes and higher peripheral speed. The minimum power consumption was 3.5 kW for tip diameter of 500 mm and spike thickness of 6 mm. There was increase in power consumption from 3.5 to 3.72 kW with the increase in tip diameter from 500 to 600 mm at the spike thickness of 6 mm. As the tip diameter increased from 500 to 600 mm, the power consumption increased from 3.58 to 3.92 kW and from 3.623 to 4.07 kW corresponding to spike thickness of 8 and 10 mm. At larger tip diameter of round spiked threshing cylinder, total power consumption is more, which is in conformity with the findings of Majumdar, et al. (1997). The coefficient of determination values are 0.9699, 0.8851 and 0.9989 which indicate that the tip diameter is significant positively correlated with total power consumption at maximum feed rate.

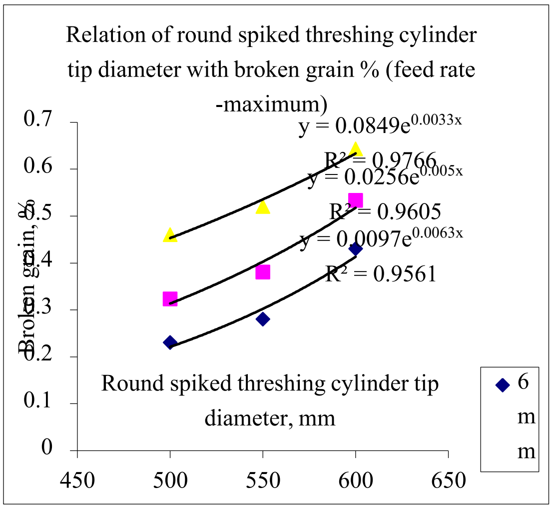


Figure 2. Relation of round spiked threshing cylinder tip diameter with power consumption (maximum feed rate)

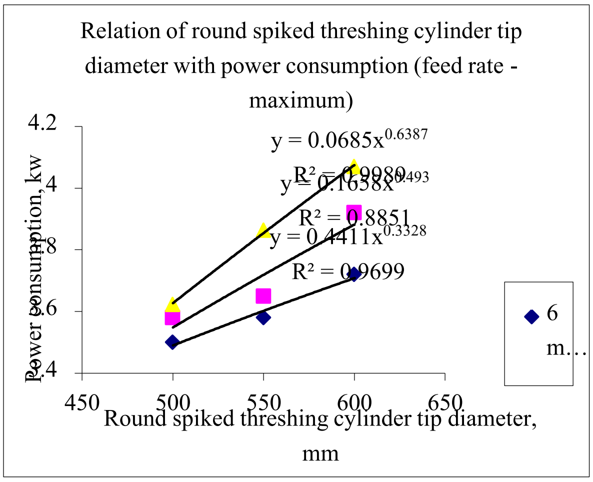


Figure 3. Relation of round spiked threshing cylinder tip diameter with broken grain loss (maximum feed rate)

It is evident from Figure 3. that the broken grain percent increased with the increase in tip diameter of round spiked threshing cylinder at maximum feed rate. The broken grain percent increased from 0.23 to 0.43% with the increase in tip diameter from 500 to 600 mm corresponding to spike thickness of 6 mm. The minimum broken grain percent was 0.23% at the tip diameter of 500 mm and spike thickness of 6 mm. As the tip diameter increased from 500 to 600 mm, the broken grain percent increased from 0.323 to 0.533% and from 0.46 to 0.643% corresponding to spike thickness of 8 and 10 mm. The coefficient of determination values vary from 0.9561 to 0.9766 which indicate that effect of tip diameter is positively correlated with broken grain loss at maximum feed rate.

It is evident from Figure 4. that increase in tip diameter of round spiked threshing cylinder increased total grain loss percent at maximum feed rate. Higher impact forces of greater length of spikes yielded more total grain loss percent. Total grain loss percent increased from 0.486 to 0.663% with the increase in tip diameter from 500 to 600 mm corresponding to spike thickness of 6 mm. As the tip diameter increased from 500 to 600 mm, there was increase in total grain loss percent from 0.576 to 0.74% and from 0.713 to 0.893% corresponding to spike thicknesses of 8 and 10 mm respectively. Minimum total grain loss percent was 0.486% for tip diameter of 500 mm and spike thickness of 6 mm. The coefficient of determination values varied from 0.966 to 0.9975 which show that the tip diameter is positively correlated with total grain loss percent. At larger tip diameter of round spiked threshing cylinder, more broken and lesser unthreshed grain were observed which increased total grain loss percent.

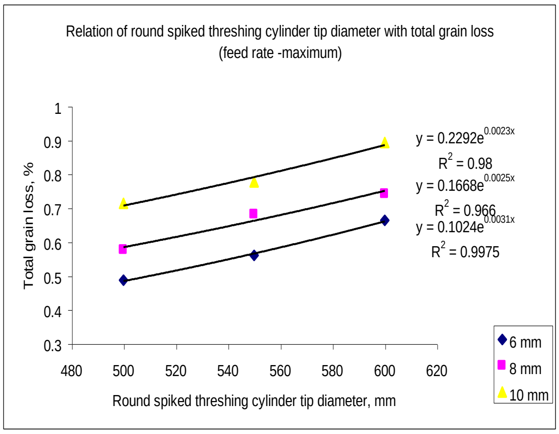


Figure 4. Relation of round spiked threshing cylinder tip diameter with total grain loss (maximum feed rate)

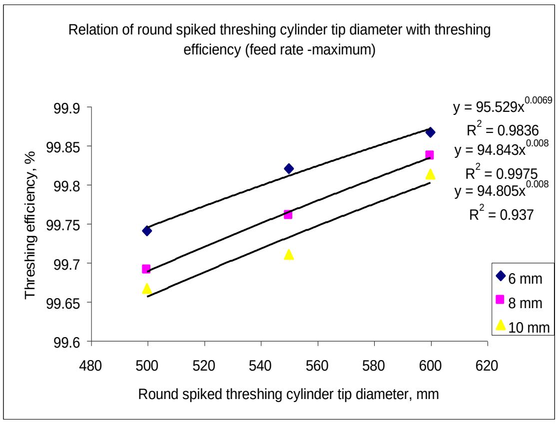


Figure 5. Relation of round spiked threshing cylinder tip diameter with threshing efficiency (maximum feed rate)

Figure 5. show that increase in tip diameter of round spiked threshing cylinder is increased threshing efficiency at maximum feed rate. Larger spike length gave more drag forces yielding more threshing efficiency. Threshing efficiency increased from 99.74 to 99.866% with the increase in tip diameter from 500 to 600 mm corresponding to spike thickness of 6 mm. As the tip diameter increased from 500 to 600 mm, the threshing efficiency increased from 99.69 to 99.836% and from 99.666 to 99.813% corresponding to spike thicknesses of 8 and 10 mm, respectively. Maximum threshing efficiency was 99.866% at the tip diameter of 600 mm and spike thickness of 6 mm. The values of coefficient of determination are 0.9836, 0.9975 and 0.937 corresponding to 6, 8 and 10 mm thickness of spikes which indicate that tip diameter of round spiked threshing cylinder has positive correlation with threshing efficiency at maximum feed rate. It is observed from Figure 6. that increase in tip diameter of round spiked threshing cylinder decreased on wheat straw length at maximum feed rate.

There was decrease in wheat straw length from 23.06 to 21.66 mm with the increase in tip diameter from 500 to 600 mm for spike thickness of 6 mm. As the tip diameter increased from 500 to 600 mm, the length of wheat straw decreased from 24.3 to 22.66 mm and from 25.26 to 23.33 mm corresponding to spike thicknesses of 8 and 10 mm respectively. Minimum wheat straw length (21.66 mm) was observed for tip diameter of 600 mm and spike thickness of 6 mm due to higher impact of forces. Maximum wheat straw length (25.26 mm) was achieved at the tip diameter of 500 mm and spike thickness of 10 mm. The coefficient of determination values are 0.9951, 0.925 and 0.9869 which show that tip diameter is negatively correlated with wheat straw length at maximum feed rate. It can be seen from Figure 7. that increase in tip diameter of round spiked threshing cylinder increased percent split straw for wheat at maximum feed rate. There was increase in wheat straw split percent from 86.5 to 88.4% with the increase in tip diameter from 500 to 600 mm at the spike thickness of 6 mm. Maximum wheat straw split percent was 88.4% at the tip diameter of 600 mm and spike thickness of 6 mm due to higher impact of forces.

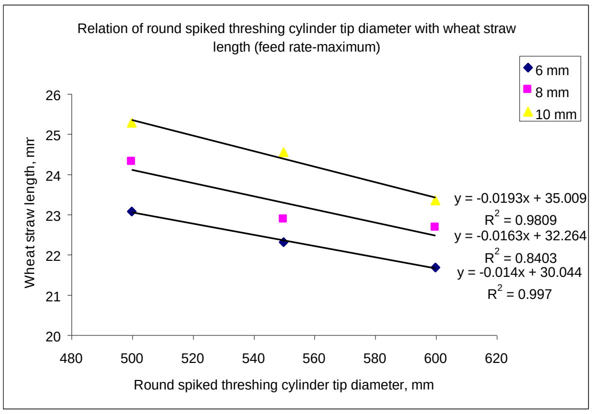


Figure 6. Relation of round spiked threshing cylinder tip diameter with straw length (maximum feed rate)

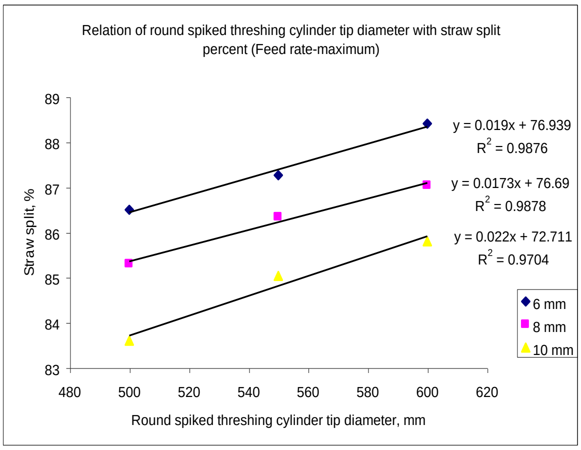
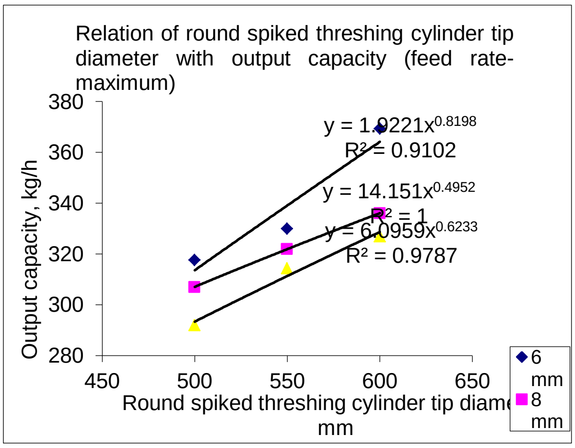


Figure 7. Relation of round spiked threshing cylinder tip diameter with straw split percent (maximum feed rate)

As the tip diameter increased from 500 to 600 mm, the wheat straw split percent increased from 85.3 to 87.03% and from 83.6 to 85.8% corresponding to spike thicknesses of 8 and 10 mm respectively. The coefficient of determination varied from 0.9902 to 0.9991 which show that tip diameter of round spiked threshing cylinder is positively correlated with wheat straw splitting at maximum feed rate. The increase in tip diameter of round spiked threshing cylinder increased output capacity at maximum feed rate as inferred from Figure 8. Threshing capacity was maximum (369.33 kg/h) at the tip diameter of 600 mm and spike thickness of 6 mm, which was due to larger crop volume handling at larger tip diameter inside threshing cylinder. There was increase in output capacity from 317.66 to 369.33 kg/h and from 307 to 336 kg/h with the increase in tip diameter from 500 to 600 mm at the spike thicknesses of 6 and 8 mm respectively. As the tip diameter increased from 500 to 600 mm, the output capacity increased from 292 to 327 kg/h corresponding to spike thickness of 10 mm. The coefficient of determination values are 0.9102,1 and 0.9787 which indicate that output capacity is positively correlated with the increase in tip diameter of round spiked threshing cylinder at maximum feed rate. The increase in tip diameter of round spiked threshing cylinder decreased specific power consumption at maximum feed rate as inferred from Figure 9. The specific power consumption reduced from 1.101 to 1.003 kWh/q and from 1.165 to 1.066 kWh/q with increase in tip diameter from 500 to 600 mm at the spike thicknesses of 6 and 8 mm respectively. Minimum specific power consumption was 1.003 kWh/q at 600 mm tip diameter and spike thickness of 6 mm due to handling of more crop volume. As the tip diameter increased from 500 to 600 mm the specific power consumption reduced from 1.24 to 1.144 kWh/q which corresponding to a spike thickness of 10 mm. It is also in conformity with the findings of statement of Majumdar et al. (1997).

Figure 8. Relation of round spiked threshing cylinder tip diameter with output capacity (maximum feed rate)



The coefficient of determination values are 0.853, 0.9443 and 0.8193 which show that tip diameter of round spiked threshing cylinder is negatively correlated with specific power consumption at maximum feed rate.

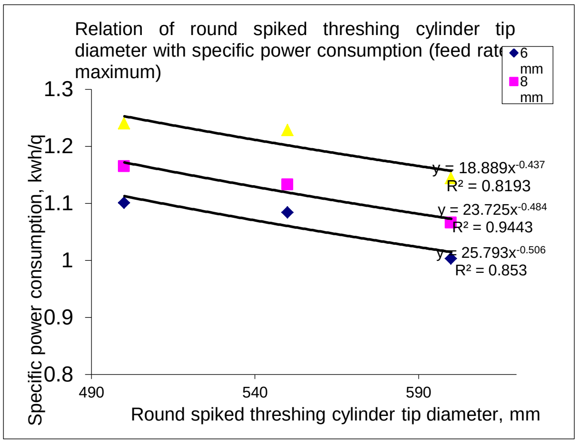


Figure 9. Relation of round spiked threshing cylinder tip diameter with specific power consumption (maximum feed rate)

Conclusions

The best results for round spiked threshing cylinder were corresponding to 780 kg/h feed rate at 600 mm tip diameter and spike thickness of 6 mm. The maximum threshing efficiency, maximum output capacity and minimum specific power consumption were 99.87%, 369.3 kg/h and 1.004 kWh/q, respectively. The minimum straw length, broken grain and total grain loss percent were 21.67 mm, 0.43% and 0.663%, respectively, corresponding to maximum threshing efficiency and output capacity. The maximum wheat straw split percent (88.40%) But from mass manufacturing point of view and to avoid fast wearing of round spikes, It has been recommended by Majumdar et al. (1997) to use minimum thickness of round spikes not greater than 8 mm. The recommended geometry of 600 mm tip diameter and round spikes of 8 mm thickness, the thresher produced fine straw (22.67 mm) and better straw split percent (87.03%). In addition to efficient threshing (threshing efficiency 99.84%), the output capacity (336 kg/h) at the maximum feed rate (780 kg/h) was acceptable. The broken grain and total grain loss percent were 0.533 % and 0.747% respectively corresponding to 8 mm spike thickness and 600 mm tip diameter. These values are within permissible limit. The round spiked threshing cylinder with the above geometry provided had a specific power consumption of 1.166 kWh/q which makes acceptable and justifies the selected geometry. Therefore it is also recommended that round spikes of 125 mm length having a thickness 8 mm fitted on 350 mm threshing cylinder is optimum geometries for efficient threshing and minimum specific power consumption.

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