

**DEVELOPMENT AND EVALUATION OF AXIAL FLOW PADDY
THRESHER EQUIPPED WITH FEEDER CHAIN TYPE
MECHANICAL FEEDING SYSTEM**

Abstract

The threshing of paddy which was usually done by manual feeding in threshers led to the reduction of threshing capacity due to half filling of threshing drum. This drawback had given rise to mechanical feeding system for wheat threshers which increased their threshing capacity. In this study, in order that the threshing capacity should increase, a feeder chain type feeding system for axial flow paddy thresher was developed. The type of feeder housing used in this thresher was of trapezoidal shape. The length of chain was 2830 mm and two sprockets having diameter 320 mm each. After preliminary testing, its performance evaluation was studied on PR-124 to ascertain the effect of cylinder speed (12.27, 14.44 and 16.61 m/s), conveyor speed (2.52, 2.96 and 3.4 m/s) and feed rate (4.08, 4.8 and 5.52 t/h). The threshing efficiency, non-collectable loss, broken grain, cleaning efficiency, sieve overflow and torque were 98.90%, 0.55%, 0.23%, 98.44%, 0.38% and 336.3 Nm respectively at the best combination of cylinder speed, feed rate and conveyor speed of 16.61 m/s, 5.52 t/h and 2.52 m/s respectively

Keywords: Axial flow, paddy, Mechanical feeding, Conveyor system, torque etc.

1. Introduction

India is one of the main rice producing and consuming countries of the world. The productions of rice has increased many folds after the green revolution in the 1970s. The total production of rice in India during 2013-14 was 106.64 million tonnes of which the contribution from Punjab was 11.26 million tonnes (Anon., 2014). In most of rice farms in India, harvesting is carried out by sickle or mechanical reapers. After harvesting, the harvested crop is left on the field to reduce crop moisture content and then bundled together and shifted for threshing operations. Threshing is the process of detaching the edible part of cereal/grain or other part from the inedible chaff that surrounds it. These days it is mostly carried out through machines known as threshers. Straw bruising and threshing are the integral functions of threshing systems in India. Delay in threshing operation results in delayed sowing of next crop and hence reduction in yield.

Low capacity and higher grain losses in conventional threshers led to the development of axial flow threshing mechanism (Khan 1986). The axial flow concept was a major departure from threshing mechanisms used up to that time in threshers and combine harvesters worldwide. In axial flow machine, the crop moves spirally between the threshing drum and concave for several turns. Crop is thus threshed for longer duration by repeated impact of threshing pegs (Sessiz and Ulger 2003). This principle permits multi-stage

39 threshing and grain straw separation, resulting in a high output and cleaning efficiency
40 (Harrison 1992).The retention time of crop inside the threshing unit was varied from 3.0 to
41 7.5 sec (Waman 2012).

42 In India, a large number of axial flow threshers are manufactured and most of these
43 are based on the designs of IIRRI axial flow threshers. These have been exhaustively evaluated
44 and improvised to suitable local conditions by the state agricultural universities researchers
45 and local manufacturers. There is an opinion regarding the performance of the axial flow
46 machines that the breakage of grain is less than that of cross flow machine (Majumdar 1985).
47 The losses in existing axial threshers were up to 4.49% (Anon 2011) whereas acceptable loss
48 level for threshing cereals is of 1% (Anon 2001). So, locally manufactured threshers failed to
49 achieve the internationally acceptable loss level.

50 It has been observed that the threshing cylinder on which the crop were fed directly
51 by hand were only receiving material for about half of the time (Harrington 1970). The
52 capacity of wheat threshers increased multifold when equipped with mechanical feeding
53 system. In order to increase the capacity of paddy threshers, a feeder chain type axial flow
54 paddy thresher was developed.

55 2. Materials and Methodology

56 2.1 Design considerations for developed feeder chain type axial flow paddy thresher:

57 The capacity of feeder chain housing was calculated as

58
$$\text{Capacity (t/h)} = \frac{1}{2} ((\text{Length} + \text{Width}) \times \text{Height of feeder housing}) \text{ per unit time}$$

59 which come out to be 13.01 t/h and speed of feeder chain was calculated as

60
$$\text{Speed of feeder chain (m/s)} = \frac{(\text{Pitch (mm)} \times \text{speed (rpm)} \times \text{teeth})}{60 \times 1000} \text{ of chain}$$

61 Which comes out to be 4.2 m/s respectively. The peripheral speed of crop inside the threshing
62 unit was calculated as

63
$$\text{Peripheral speed of crop (m/s)} = \frac{\pi \times \text{Diameter of cylinder (mm)} \times \text{Speed of cylinder (rpm)}}{60 \times 1000}$$

64 Which is found to be 1.01 m/s. Based on these findings, a feeder chain type feeding system
65 for axial flow paddy thresher was developed.

66 2.2 Constructional details of feeder chain type axial flow paddy thresher:

67 The thresher consisted of main frame, threshing cylinder, concave, cylinder casing,
68 blower, aspirator I & II and a reciprocating sieve system. The threshing cylinder was of spike
69 tooth type with cylinder length of 1240 mm and diameter of 460 mm. A view of feeder chain
70 type axial flow paddy thresher has been shown in figure 1 and 2.



Fig 1: Feeder chain type axial flow paddy thresher

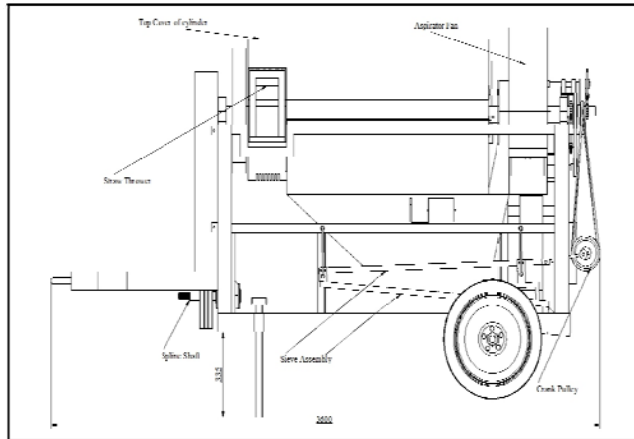


Fig 2: Cross-sectional view of Feeder chain type axial flow paddy thresher

The overall dimensions of thresher were $3810 \times 1480 \times 1900$ mm. The threshing cylinder has two portions namely threshing and straw throwing. In the first portion, the threshing spikes were mounted and these were staggered in the paired rows. In the second portion (straw ejecting section), the throwing members comprising of fins were fitted on the cylinder to throw away the straw. The cylinder had hexagonal shaped cover with louvers attached in it, which make the crop to flow axially. The thresher also consisted of a hopper and a feeder chain assembly. The feeder chain assembly consisted of box type structure, encompassing two sets feeder chain sprockets and feeder chain. Some technical specifications of the thresher are given in table A:

84 **Table A:** Specifications of feeder chain type feeding system of axial flow paddy thresher

85

S.No.	Particulars	Dimensions (mm)/ Details	
1.	Power source	Tractor	
2.	Type of thresher	Axial flow	
3.	Overall dimension: a) Length, mm b) Width, mm c) Height, mm	3810 1480 1900	
4.	Concave clearance, mm	20	
5.	Diameter of cylinder, mm	460	
6.	Length of cylinder, mm	1240	
7.	Description of threshing elements on cylinder a) No. of rows b) No. of spike in a row c) Total spikes d) Type of spike	7 4 28 5 mm thick flat studs	
8.	Aspirator I & II a) Type of aspirator b) No of blades	Centrifugal 4	
9.	Blower, No of blade	4	
10.	Sieving system Total length & width Diameter of opening	Upper sieve 1750 x 700 9	Lower sieve 2290 x 700 1.5
11.	Feeding system Type of feeder Type of feeder housing Upper base, (Lx W) Lower base, (Lx W) Height Chain pitch Length of chain Sprocket No. of teeth Diameter Feeding Hopper Length Width	Chain type Trapezoidal 310 x 340 700 x 850 1240 90 2830 18 320 620 1100	

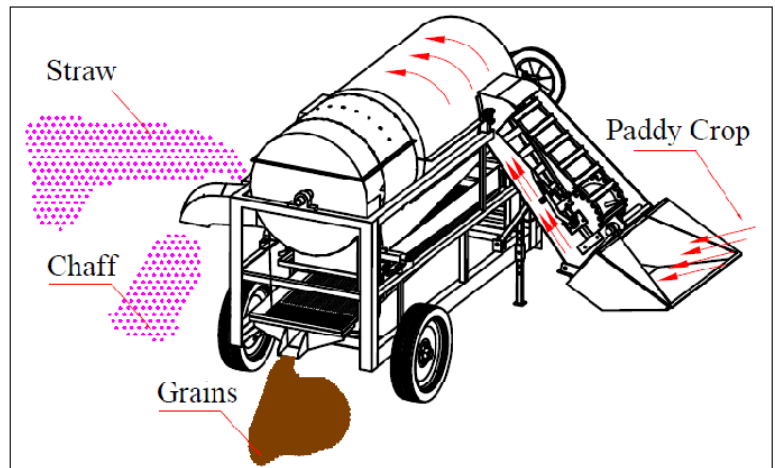


Fig 3: Schematic diagram of feeder chain type axial flow paddy thresher

The lower end of feeder chain sprockets were attached to metallic cylinder encompassing retractable finger for gathering the crop fed in the hopper. The crop was fed in the trapezoidal hopper (figure 4) and



a) Top view

b) Front view

Fig 4: Trapezoidal feeding hopper

retractable finger attached to lower end of feeder chain gathered the crop and feeder chain transmits it to the threshing unit where it is threshed. The speed of feeder chain unit was maintained by different sets of pulleys. The feeder chain type feeding unit is shown in figure 5:



a) Front view

b) Side view

Fig 5: Feeder chain type feeding unit

2.3 Materials and Methodology

a. Layout of experimental plan

Different independent parameters selected for the experimental purpose have been discussed as below:

2.3.1 Feed rate

2.3.2 Cylinder peripheral speed

2.3.3 Conveyor speed

Table 1 Independent parameters used for performance study of feeder chain typethresher

S No.	Parameters	Levels	Range
1	Feed Rate	3 (F1, F2 and F3)	4.08, 4.8 and 5.52 t/h
2	Cylinder Speed	3 (CS1, CS2 and CS3)	12.27, 14.44 & 16.61 m/s (510, 600 and 690 rpm)
3	Conveyor Speed	3 (V1, V2 and V3)	2.52, 2.96 and 3.40 m/s

2.4 Dependent parameters

The various dependent parameters determined under following ways:

2.4.1 Threshing efficiency

2.4.2 Cleaning efficiency

2.4.3 Broken grains

2.4.4 Non-collectable loss

2.4.5 Sieve overflow

2.4.6 Torque

117 2.5 Experimental layout and procedure

118 The paddy crop of variety PR-124 was harvested manually and by reaper binder
119 during Oct, 2015. After the crop harvesting, the bundles were placed in stalk to maintain
120 moisture content in one range during threshing operation. The straw grain ratio was varied in
121 the range of 1.13-1.3. The moisture content of straw and grain varied in the range of 16 to
122 19% and 12 to 14% respectively.

123 The thresher was operated by the tractor PTO and tachometer was used to set up the
124 rpm level of threshing cylinder. In the initial attempt preliminary evaluation of the thresher
125 was carried out to locate the feasible points for threshing viz. conveyor speed, suitable rpm of
126 threshing cylinder and feed rate etc. The bundles were made and weighed according to the
127 crop required per minute to set up the feed rate for thresher. After that, the bundles were fed
128 to the thresher within specified time.

129 To achieve the different levels or speeds of conveyor various pulleys had been used.
130 Each pulley had different diameter which alter the motion of conveyor. The pulleys were
131 changed during each replication according to the required level of conveyor speed. The grains
132 collected for determining losses were also weighed on electronic balance. The output of test
133 was recorded and expressed in kg/h.

134 2.6 Statistical Analysis

135 Factorial design in CRD had been used to analyze the experimental data statistically.
136 For statistical analysis CPCS1 software was used. The difference between the various
137 treatments was also calculated at 5% level of significance in this study.

138 3. Results and Discussion

139 3.1 Initial testing of machine

140 Initial testing of thresher was carried out at the departmental farm on paddy (crop
141 variety PR-124). To achieve different levels of conveyor speed, pulleys and belts were used
142 for maintaining the speed ratio throughout the experiment. The different settings were made
143 in aspirator section for controlling the air inlet. The threshers were operated at cylinder speed
144 of 14.44 m/s. The feed rate and conveyor speed were varied. The levels of feed rate and
145 conveyor speed was reckoned at which the thresher could be operated uninterrupted just prior
146 to chocking of threshing cylinder. The feed rate and conveyor speed were observed to be 4.80
147 t/h and 2.96 m/s respectively.

148 3.2 Evaluation of feeder chain type axial flow paddy thresher

149 3.2.1 Effect of study variables on threshing efficiency

150 The statistical analysis (Table 2) showed that the effect of cylinder speed, feed rate
151 and conveyor speed on threshing efficiency was significant at 5% level of confidence.
152 Minimum threshing efficiency of 97.14% was found at cylinder speed CS1, feed rate F1 and
153 at conveyor speed V1. Similarly, maximum threshing efficiency of 99.10% was found at

cylinder speed CS3, feed rate F3 and at conveyor speed V3. In the graph 1, it was observed that the threshing efficiency increased with increase in the cylinder speed, conveyor speed and feed rate.

3.2.2 Effect of study variables on non-collectable loss

Statistical analysis (Table 2) showed that the effect of cylinder speed, feed rate and conveyor speed were significant on non-collectable losses at 5% level of confidence. The minimum non-collectable loss of 0.12% was observed at cylinder speed CS1, feed rate F3 and conveyor speed V1. The maximum loss of 0.74% was observed at cylinder speed CS3, feed rate F1 and conveyor speed V3. The non-collectable loss increased with an increase in cylinder speed and conveyor speed. The non-collectable loss was found to be in decreasing order with increased in feed rates. This might be due to the fact that with increased in feed rate the broken losses and unthreshed grain percentage decreased which lead to decrease in non-collectable loss.

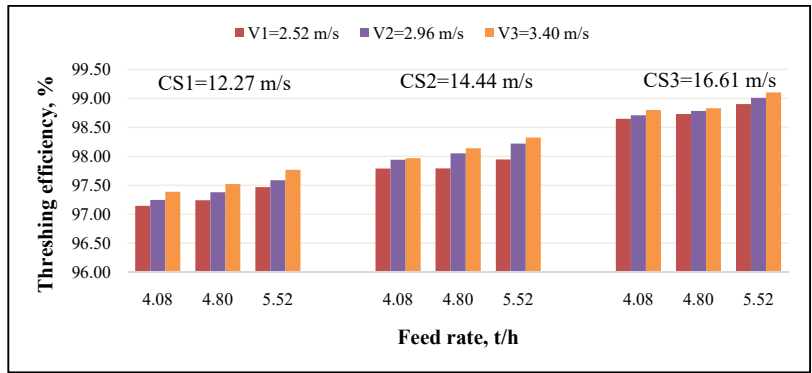
3.2.3 Effect of study variables on broken percentage

The statistical analysis (Table 2) showed that the effect of cylinder speed, feed rate and conveyor speed on broken percentage was significant at 5% level of confidence. The minimum broken grain damage of 0.089% was observed at cylinder speed CS1, feed rate F3 and conveyor speed V1. The maximum broken grain damage of 0.46% was observed at cylinder speed CS3, feed rate F1 and conveyor speed V3. It was observed from the graph 3 that the broken percentage increased with increase in cylinder speed and conveyor speed. The graph 3 also depicts that the broken percentage decreased with increase in feed rate. This might be due to the fact that when there was increase in feed rate, the cushioning effect increased in the threshing drum, which lowered the impact forces which act on the crop mat.

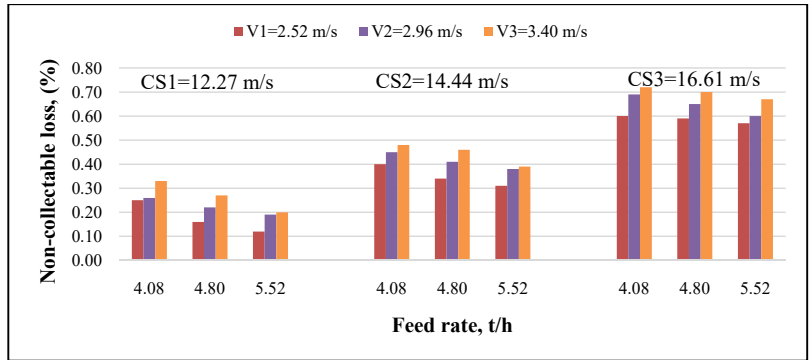
Table 2: ANOVA for the paddy threshing unit performances

Source of variation	df	CD (5%)					
		Threshing efficiency	Non collectable loss	Broken grains	Cleaning efficiency	Sieve overflow loss	Torque
A (Cylinder speed)	2	0.135	0.036	0.080	0.13	0.0192	1.31
B (Feed rate)	2	0.135	0.036	0.080	0.13	0.0192	1.31
C (Conveyor speed)	2	0.135	0.036	0.080	NS	0.0192	NS
A * B	4	NS	NS	NS	NS	NS	2.27
A * C	4	NS	NS	NS	NS	NS	NS
B * C	4	NS	NS	NS	NS	NS	2.27
A * B * C	8	NS	NS	NS	NS	NS	NS
Error	54						
Total	80						

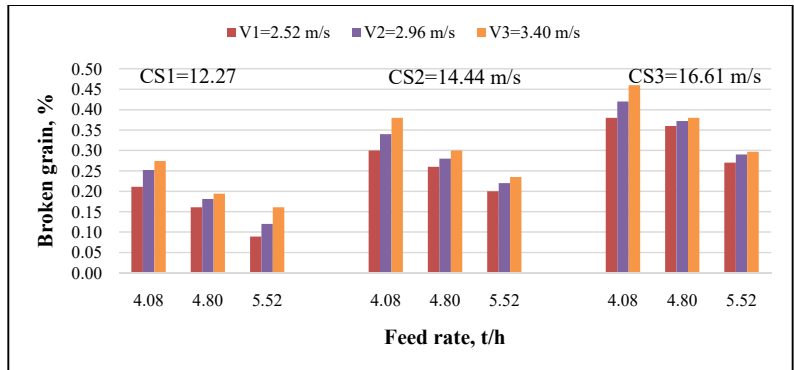
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Graph 1 Effect of cylinder speed, feed rate and conveyor speed on threshing



Graph 2 Effect of cylinder speed, feed rate and conveyor speed on non-collectable



Graph 3 Effect of cylinder speed, feed rate and conveyor speed on broken grain

188 3.2.4 Effect of study variables on cleaning efficiency

189 The statistical analysis (Table 2) showed that the effect of cylinder speed and feed
190 rate on cleaning efficiency were significant at 5% level of confidence. The conveyor speed
191 had non-significant effect on cleaning efficiency at 5% confidence level. The maximum
192 cleaning efficiency of 98.71% was obtained at cylinder speed of CS3, feed rate of F1 and
193 conveyor speed of V1. The minimum cleaning efficiency of 97.21% was obtained at cylinder
194 speed of CS1, feed rate of F3 and conveyor speed of V3. The graph 4 depict that the cleaning
195 efficiency increased with increase in cylinder speed. Similarly, it was observed that cleaning
196 efficiency decreased with increase in feed rate. This might be due to with increase in feed
197 rate, the amount of material also increased on sieves which reduced the separation of clean
198 grains from material other than grains (MOG).

199 3.2.5 Effect of study variables on sieve overflow

200 The statistical analysis (Table 2) showed that the effect of cylinder speed, feed rate
201 and conveyor speed on sieve overflow was significant at 5% confidence level. The minimum
202 sieve overflow of 0.20% was observed at cylinder speed CS1, feed rate F1 and at conveyor
203 speed V1. The maximum value of sieve overflow 0.40% was observed at cylinder speed CS3,
204 feed rate F3 and at conveyor speed V3. The graph 5 showed that the sieve overflow increased
205 with increase in cylinder speed, conveyor speed and feed rate.

206 3.2.6 Effect of study variables on torque

207 The statistical analysis (Table 2) revealed that the effect of cylinder speed and crop
208 feed rate was significant on torque requirement at 5% confidence level. The interaction
209 between cylinder speed and feed rate, cylinder speed and conveyor speed was significant at
210 5% level of confidence. The conveyor speed had non-significant effect on torque requirement
211 at 5% confidence level. The maximum torque requirement of 336.3 Nm was observed at
212 cylinder speed CS3, feed rate F3 and conveyor speed V1. The minimum torque requirement
213 of 148.3 Nm was observed at cylinder speed CS1, feed rate F1 and conveyor speed V3. The
214 graph 6 depict that the torque requirement increased with increase in cylinder speed and feed
215 rate.

216 3.2.7 Optimization of independent variables for feeder chain type axial flow paddy 217 thresher:

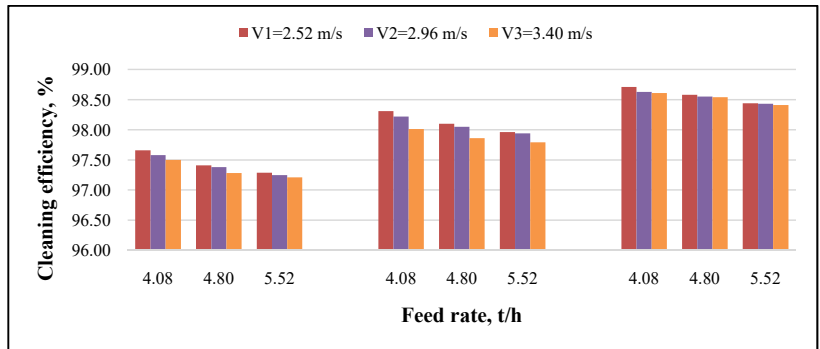
218 To suggest the optimum values for operational parameters based on evaluation of
219 experimental setup, the treatment combinations with maximum efficiencies and minimum
220 grain loss were chosen.

221 4.2.7.1 Threshing efficiency should be maximum

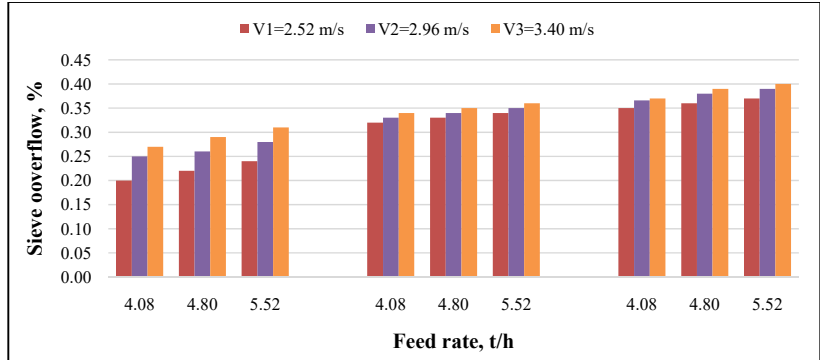
222 4.2.7.2 Non-collectable losses should be minimum

223 4.2.7.3 Grain breakage should be zero or minimum

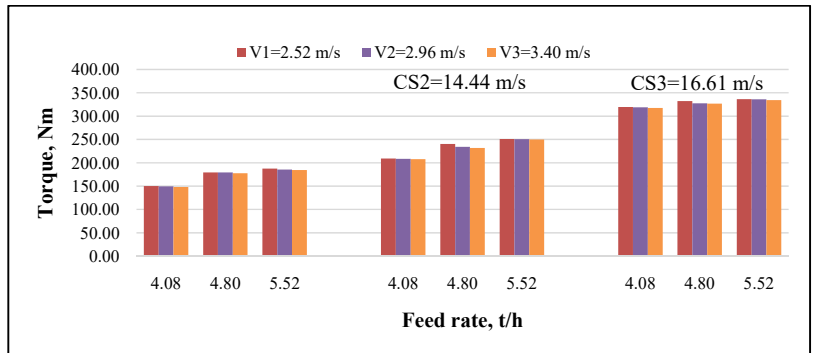
224 4.2.7.4 Cleaning efficiency should be optimum



Graph 4 Effect of cylinder speed, feed rate and conveyor speed on cleaning efficiency



Graph 5 Effect of cylinder speed, feed rate and conveyor speed on sieve overflow loss



Graph 6 Effect of cylinder speed, feed rate and conveyor speed on torque

235 4.2.7.5 Sieve overflow should be minimum
 236 4.2.7.6 Torque requirement should be minimum
 237 Based on the above objectives, the combination CS3F3V1 was best combination because for
 238 this combination threshing efficiency, non-collectable loss, broken grain percentage, cleaning
 239 efficiency, sieve overflow percentage and torque requirement were 98.90%, 0.55%, 0.23%,
 240 98.44%, 0.38% and 336.3 Nm respectively.

241 4. Conclusions

- 242 a) The maximum threshing efficiency of 99.10% was found at cylinder speed of 16.61
- 243 m/s, conveyor speed of 3.40 m/s and feed rate of 5.52 t/h.
- 244 b) The non-collectable loss was found to be in the range of 0.12 to 0.739%.
- 245 c) The non-collectable loss was minimum at cylinder speed of 12.27 m/s, conveyor
- 246 speed of 2.52 m/s and feed rate of 5.52 m/s.
- 247 d) The broken grains were observed in the range of 0.089-0.46%.
- 248 e) The minimum broken grains value were found at cylinder speed of 12.27 m/s,
- 249 conveyor speed of 2.52 m/s and feed rate of 5.52 t/h.
- 250 f) The cleaning efficiency was found to be in the range of 97.21-98.71%.
- 251 g) Maximum cleaning efficiency was observed at cylinder speed of 16.61 m/s and feed
- 252 rate of 4.08 t/h.
- 253 h) The sieve overflow was observed in the range of 0.20-0.40%.
- 254 i) The minimum sieve overflow was observed at cylinder speed of 12.27 m/s, conveyor
- 255 speed of 2.52 m/s and feed rate of 4.08 t/h.
- 256 j) The torque requirement was observed to be in the range of 148.26-336.3 Nm.
- 257 k) The minimum torque requirement was observed at cylinder speed of 12.27 m/s and
- 258 feed rate of 4.08 t/h.
- 259 l) The best combination of operational variables for threshing operation was CS3F3V1.
- 260 The cylinder speed, feed rate and conveyor speed was 16.61 m/s, 5.52 t/h and 2.52
- 261 m/s.
- 262 m) At this combination threshing efficiency, non-collectable loss, broken grains, cleaning
- 263 efficiency, sieve overflow and torque were 98.90%, 0.548%, 0.26%, 98.44%, 0.377%
- 264 and 336.3 Nm, respectively.

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