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Testing and Evaluation of Rice Thresher

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ABSTRACT

The performance of a 4 feet rice thresher was evaluated at Kasetsart University under different drum speeds and feeding rates. The rice thresher was fixed on the steel rail in the laboratory after taking off the two rubber wheels used for transportation the thresher. The main axis of the rice thresher was connected by the v-belt to 19kw electrical dynamometer equipped with a torque transducer and rpm pick up. The variety of RD23 was prepared in which moisture content were 16.6% for grain and 11.3% for straw respectively. The test code of the rice thresher followed the IRRI test code. The result of the test, the capacity and power requirement were 949-1901 kg/hr and 3.69-5.75 kw respectively. The total losses due to breakage, unthreshed and blown was found to be 0.37-1.48%. The threshing and cleaning efficiency were 99.95% and 88.91% respectively. The aspect to be considered towards the machine development should be part modification in order to improve power requirement, capacity and cleaning efficiency.

INTRODUCTION

In Thailand, rice threshing practices have been recently changed for more mechanization. The mechanical threshers used are almost throw-in axial flow type and their capacities are generally determined in the term of threshing drum which always range between 4ft to 7ft. The threshing machines are powered by one cylinder diesel engines, "Etan" trucks or tractor engines depending upon the machine sizes.

In threshing, the farmer will install a thresher to a vehicle which is able to make a direct access to the harvesting field. The mode of action will be done by using pulleys and V-belts transmit power from the vehicle engine to the mechanical thresher. When threshing is finished the transmitted power is withdrawn and the engine is then reassembled to the vehicle before leaving the harvested field.

However, when operation with some relatively large machines, sole high-power engines are needed Frequently, an old engine from a used truck is applied to as the power source. Necessary modification while installing the engine to a thresher is encouraged and aided by thresher merchandizing agent.

The benefit of mechanization is apparently well-accepted the machinery regardless of the knowledge of a farmer who operates it, does not to same extent perform satisfactorily as far as power loss and grain loss are concerned. Rohani *et al.* (1984) reported an increase of 4.5% in grain breaking for machine harvested samples when compared to hand harvested samples.

To minimize such losses and to reduce operational problems, appropriate thresher with improved working parts should be developed and a power supply to the thresher should be properly managed to ensure an optimal level of the power supply.

National Agricultural Machinery Center and Department of Agricultural Engineering have undertaken a project concerning mechanical threshing improvement with the main objectives as follows

1. To study the performance and mechanism of existing domestic rice threshing machine.
2. To develop rice thresher with high efficiency

MATERIALS AND METHODS

Research Materials

1. Threshing machine An axial-flow thresher was used to test the performance at different drum speeds and feeding rates. The thresher was primarily consisted of 2 main working parts: the threshing and the separating sets (Figure 1).

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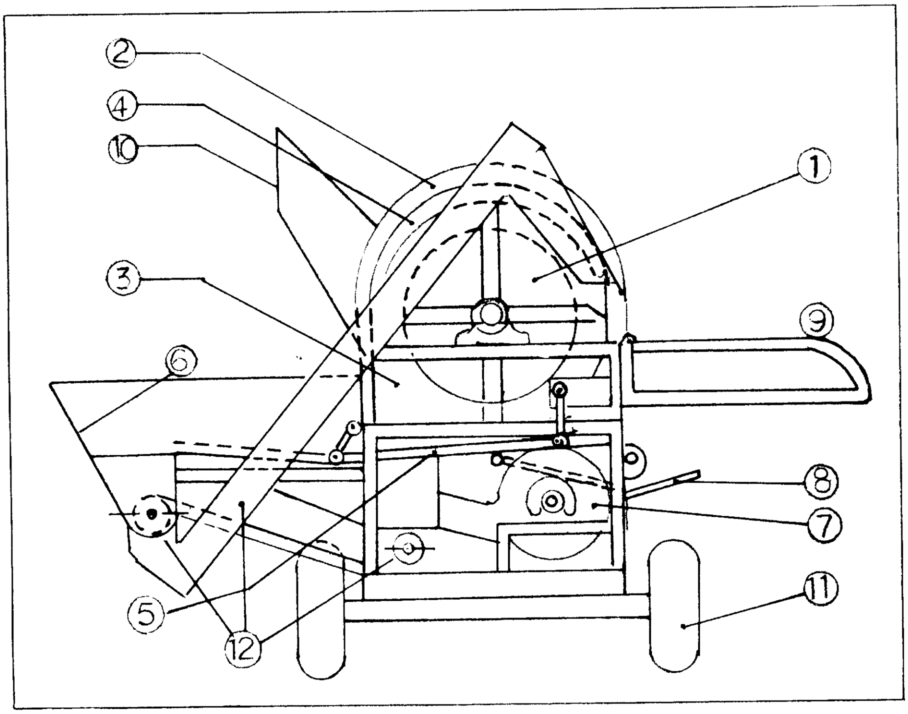

Fig. 1 Main component parts of axial flow rice thresher used in the experiment.

1. Threshing drum
2. Upper concave
3. Lower concave
4. Fins
5. Separating screen
6. Apron
7. Fans
8. Air inlet controls
9. Feeding tray
10. Straw outlet
11. Wheels
12. Screw conveyors

In the threshing section, a 4 ft length threshing drum together with lower and upper concaves were fixed alongside a semi-cylindrical casing. A feeding tray was located at the middle of the machine. Feeding vanes were welded on one side of the drum whereas outlet vanes were on the other. To convey the fed crop all the way down the line, a number of fins were attached beneath the upper concave and the drum was arranged with spike teeth.

The separating and also the cleaning set were located under the threshing chamber and consisted of separating screen, air and chaff outlet, apron, fans, feeding tray and screw conveyers.

In studying the thresher performance, rice bundles were fed into the threshing chamber through the feeding chute. The mode of action is done by impacting and rubbing the crop against the concave grates. Threshed grain was then dropped down through concave opening to the oscillating screen below whilst straw was forced along the axis of the threshing drum to be disposed from the straw outlet

On the screen, the fallen threshed grains, chaff, and foreign materials are exposed to an air stream provided through an outlet by two fans installed under the oscillating screen. Impurities and chaff were blown out whereas threshed grain dropped down on a screw conveyer to be carried through the grain outlet. Some threshed grains that were blown out altogether with impurities were trapped inside the apron and retrieved for recyling by another screw conveyer.

2. Rice bundles. The varicty of RD 23 was used throughout the performance test. The rice had 1.594:1 grain/straw ratio, 16.6% grain moisture content (wet basis), 11.3% straw moisture content (wet basis) and 47 centimeters cut length.

3. Instruments. The test set up for the experiment was shown in Figure 2. Electrical dynamometer was used to drive the thresher. Torque meter was installed to observe the torque requirement of the thresher. Speed of threshing drum was measured by lighting tachometer.

4. Sample collectors. Threshed grains were collected in bags whilst straw and chaff were collected by large nets.

The Variables

1. Drum speed. Three different drum speeds of

Fig. 2 Rice thresher set up and instrumentation.

600, 650 and 700 rpm were evaluated and compared. The measurement of the drum speeds was done at the start of the test when the machine was run with no loading. The drum speed of 700 rpm was best recommended by the manufacturer whereas the drum speeds of 600 and 650 rpm were anticipated to save energy at the relatively same output capacity.

To achieve the drum speed, a light-reflecting tape was attached to the drum pulley measured by lighting tachometer as the machine was being run.

A power transmission from a dynamometer to the threshing drum was done by means of a pulley and V-belts. The desired drum speeds were obtained by adjusting the dynamometer.

2. Feeding rate. The feeding rates of 2880, 3600 and 4800 kg/hr were investigated in this study.

As a matter of fact the feeding rate of 4,800 kg/hr was maximally designed for a thresher with drum length of 4ft. However, the feeding rates of 2880 and 3600 kg/hr were expected to contribute better threshing efficiency whereas reducing breakage as well.

Infeeding the machine, crop plants were thrown into the threshing chamber through the machine opening of 32 cm width and 22 cm height after the thresher had been run with no loading for 30 minutes.

To regulate the rate of feeding, rice bundles weighed 4 kg each were fed to the thresher at predetermined intervals. The feeding rate of 2880, 3600 and 4800 kg/hr required feeding intervals of the 4 kg rice bundle at 5,4 and 3 seconds respectively. Before feeding, the crops were spreaded on the feeding tray and evenly fed through the thresher opening.

Procedure

Prior to the test, rice variety, grain/straw ratio, grain and straw moisture content, cut length and machine details were recorded.

When the thresher was started all necessary speed measurements of dynamometer, threshing drum, separating screen, fan and screw conveyors were carried out.

Rice bundles were fed at predetermined intervals and by the time the machine was evenly operated samples were collected. A collecting time for each sample was 10 seconds, the data collecting was repeated twice. During the test, drum and dynamometer at-load torque, output at main grain, straw, and chaff outlets were measured.

After the test, collected samples from 3 outlets which were good grains, branches and brokens were subjected to calculation (Thai Standard Institute, 1987) for determining the following values:

$$\% \text{ Threshing efficiency} = \frac{(A1+A2+A3)+(B1+B2+B3)}{T} \times 100$$

$$= 100 - \frac{(C1+C2+C3)}{T} \times 100$$

$$\% \text{ Cleaning efficiency} = \frac{A1}{A1+B1+C1+E1} \times 100$$

% Total loss = % Broken loss + % Unthreshed loss + % Separation loss + % Blower loss

$$\% \text{ Broken loss} = \frac{B1+B2+B3}{T} \times 100$$

$$\% \text{ Unthreshed loss} = \frac{C1+C2+C3}{T} \times 100$$

$$\% \text{ Separation loss} = \frac{A2}{T} \times 100$$

$$\% \text{ Blower loss} = \frac{A3}{T} \times 100$$

$$\text{Capacity} = A1+A2+A3$$

$$\text{Power in Kw} = \frac{\text{torque in kg.m} \times \text{drum speed in rpm}}{973.4}$$

$$\text{Specific capacity} = \text{capacity/power}$$

where T = (A1+A2+A3)+(B1+B2+B3)+(C1+C2+C3)
A1 = weight of good grains at main grain outlet
A2 = weight of good grains at straw outlet
A3 = weight of good grains at chaff outlet
B1 = weight of brokens at main grain outlet
B2 = weight of brokens at straw outlet
B3 = weight of brokens at chaff outlet
C1 = weight our branches at main grain outlet
C2 = weight of branches at straw outlet
C3 = weight of branches at chaff outlet
E1 = weight of foreign matter at main grain outlet

Location

The test and all analyses were conducted at laboratories of National Agricultural Machinery Center and Department of Agricultural Engineering, Kasetsart University, Kampangsaen Campus during April 1988 to October 1988.

Research Design

Two factors factorial in Completely Randomized Design was used in this experiment. The two factors were drum speeds and feeding rates. The data point was replicate two times.

RESULTS AND DISCUSSIONS

The description of rice thresher used in experiment was shown in Table 1. The result of rice threshing by thresher with drum length of 4ft at drum speeds of 600-700 rpm and feeding rate of 2880-4800 kg/hr was found to contribute satisfactorily threshing efficiency (Table 2). However, when threshing was operated at the drum speed of 700 rpm which was in the recommended range of 700-750 rpm the machine was tremendously vibrated eventhough it was firmly held to the basement. According to the phenomenon it seemed to be absolutely impossible for the machine to run at the drum speed of 700 rpm or more than that in field condition where the machine had to be left freely stand.

Statistical analysis showed that the drum speeds and feeding rates used in this study were not significant for threshing and cleaning efficiency but significantly affected the total loss, capacity, power and specific capacity (Table 3).

The average threshing efficiency and cleaning efficiency were 99.9 and 88.9 % respectively

Total loss

Results of the performance indicated that at the drum speeds ranging from 600-700 rpm total loss was not affected (Table 4 and Figure 3). However, the total loss tended to increase with the increase in feeding rate (Figure 3) as found by Kradangnga (1982) and Ichigawa and Sugiyama (1986). The total loss of 0.37-1.48% from this test was just about the same as reported by Kradangnga (1982) and Yue (1988).

Table 1 Specifications of 4 feet rice thersher used in the experiment.

1. Type of machine: throw-in

2. i) Make: THAI SENG YON
   ii) Model:2531
   iii) Serial No:14
   iv) Manufacturer's address: Thai Seng Yon, 551 Mu 13 Soi Sudkhet,thonburi-Pakthor Road, Bangkok 10140.
   v) Market proce Baht 27,500 (US$ 1.058) Year 1987

3. Name of crops for which the machine is suitable: Rice

4. Overall dimension in cm.

	at operation	at transportation
Length:	332	332
Width:	254	194
Height:	266	266

5. Power source
   i) Name of engine: Yanmer
   ii) Model, rated output: TA 120L, 12 HP
   iii) Fuel used: Diesel

6. Power transmission system: V belts and pulleys

Table 1 Specifications of 4 feet rice thersher used in the experiment. (con't)

7. Threshing drum or cylinder
   i) Type: Axial flow
   ii) Constructional feature: Cage wheel threshing drum
   iii) Diameter of drum 37 cm
   iv) Length of drum 121.92 cm (4 feet)
   v) Rated revolution speed of drum 700-750rpm
   vi) Number and size of peg: 4 pairs of row as the follewing symbols

       xxooxxxxxxxxxxx

       xoxxoooxxxxxxxx

   x 8.4-cm length pegs

   o 10.4-cm length prgs

8. Concave
   i) Type and material: Round perforated screen at front end Slots formed by rods at back end
   ii) Size of opening of concave: 15 mm diameter opening of screen, 6 mm diameter of rod with 2 cm apart.

9. Sieve
   i) Type:Vibrating screen
   ii) Number:1
   iii) Screen slope range: 4 degrees

10. Cleaning fan
    i) Number: 2
    ii) Type: Straight blades centrifugal fan
    iii) Method for changing air volume: Shuttle valves at air inlet ports.

11. Elevator
    i) Type: Auger
    ii) Construction feature: Openable case
    iii) Height of grain spout: 61 cm

12. Crop feeding inlet
    i) Type: Tray
    ii) Length and width of feeding table: 150 x 70 cm
    iii) Height of feeding table from the ground: 138 cm
    iv) Recommmended optimum feed rate for each crop:-

13. Transport device
    i) Type: Trailer
    ii) Number, type and size of wheel: 3 Wheels, 2 back 77.50-15 and 1 front 155 SR 13

14. Labour requirement for feeding, supply of crop to feeder(s), collecting and bagging grain, disposal of other outlets: 8

15. Output capacity (announced) 1,500 kg/hr

Table 2 Performances of 4 feet rice thesher.

Drum Speed No-load rpm	Feeding Rate kg/hr	Threshing eff. %	Cleaning eff. %	Total loss %	Capacity kg/hr	Power kW	Specific capacity (kg/hr) kW
600	2880	99.97	89.14	0.48	1211	3.70	327
600	2880	99.97	89.09	0.62	1021	3.69	277
600	3600	99.99	88.29	0.41	1261	4.31	293
600	3600	99.98	89.83	0.37	1562	4.01	389
600	4800	99.93	85.13	1.48	949	4.52	210
600	4800	99.96	88.34	0.77	1203	5.14	234
650	2880	99.93	89.34	0.38	1312	4.05	324
650	2880	99.96	87.68	0.44	1161	4.34	268
650	3600	99.98	91.17	0.46	1224	4.41	278
650	3600	99.97	89.10	0.62	1230	3.94	312
650	4800	99.97	90.81	0.88	1663	5.05	329
650	4800	99.98	91.26	0.47	1901	5.10	373
700	2880	99.97	83.66	0.42	1176	5.13	229
700	2880	99.86	89.88	0.54	1419	4.87	291
700	3600	99.95	89.19	0.48	1212	5.32	228
700	3600	99.93	89.01	0.52	1317	5.31	248
700	4800	99.98	90.32	0.37	1843	5.18	356
700	4800	99.88	89.29	0.82	1431	5.75	249

Table 3 Analysis of variance.

Sources	Sum of squares	d.f.	Mean square	F ratio	Probability
		Threshing efficiency			
Drum speed	0.0053781	2	0.00268910	1.866	0.2100
Feeding rate	0.0018948	2	0.00094739	0.657	0.5415
Interaction	0.0016529	4	0.00041322	0.287	0.8794
Error	0.0130000	9	0.00144140		
Total	0.0220000	17			
		Clraning efficiency			
Drum speed	9.013	2	4.507	1.344	0.3085
Feeding rate	5.532	2	2.766	0.825	0.4689
Interaction	18.194	4	4.548	1.357	0.3222
Error	30.177	9	3.353		
Total	62.916	17			
		Total loss			
Drum speed	0.099	2	0.050	0.957	0.4200
Feeding rate	0.409	2	0.205	3.938	0.0591*
Interaction	0.274	4	0.068	1.316	0.3351
Error	0.468	9	0.052		
Total	1.250	17			

Table 3 Analysis of variance. (con't)

Sources	Sum of squares	d.f.	Mean square	F ratio	Probability
		Capacity			
Drum speed	173361.444	2	86680.722	3.156	0.0915*
Feeding rate	257208.444	2	128604.222	4.682	0.0404**
Interaction	460599.222	4	115149.806	4.192	0.0345**
Error	247218.000	9	27468.667		
Total	1138378.111	17			
		Power			
Drum speed	3.245	2	1.623	18.46	0.0006533***
Feeding rate	2.413	2	1.206	13.723	0.0018480***
Interaction	0.521	4	0.130	1.481	0.2863000
Error	0.791	9	0.088		
Total	6.90	17			
		Specific capacity			
Drum speed	6510.111	2	3255.056	1.708	0.2350
Feeding rate	131.444	2	65.722	0.034	0.9662
Interaction	232000.889	4	5800.222	3.044	0.0763*
Error	17148.500	9	1905.389		
Total	26990.944	17			

* Significance at probability < 0.10
** Significance at probability < 0.05
*** Significance at probability < 0.01

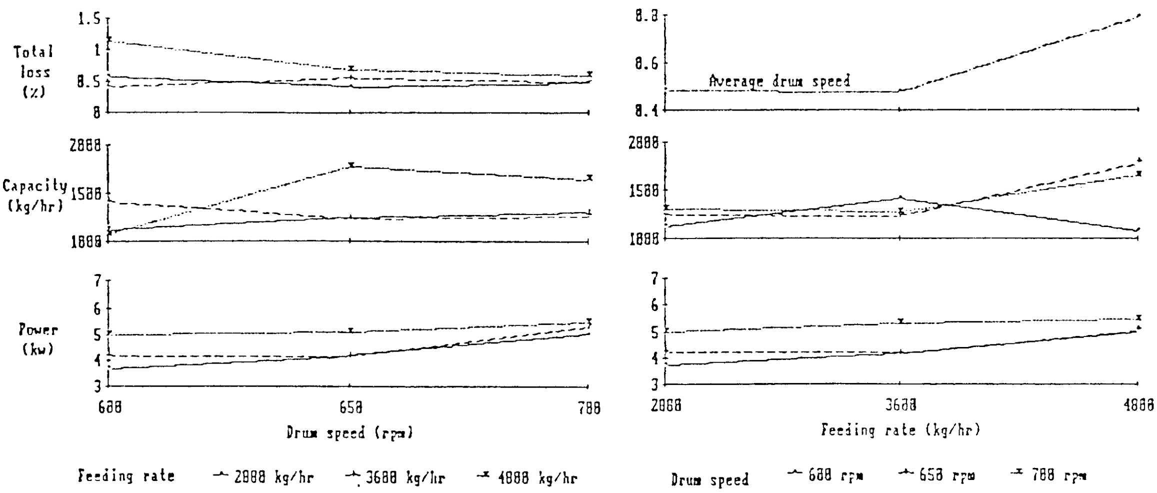

Fig. 3 Effect of drum speed and feeding rate on total loss, output capacity and power.

Capacity

The capacity increased as the drum speed and feeding rate increased and was found to be between 949-1901 kg/hr (Table 4 and Figure 3).

Power Requirement

Power requirement also varied according to the drum speed and feeding rate (Table 5 and Figure 3). As noted by Ramos (1987), the increase in power

Table 4 Determination of efficiency, losses and capacity.

Feeding rate	Drum Speed No-load	Main grain outlet				Straw outlet		Chaff outlet			Total output	Threshing eff.	Cleaning eff.	Broken loss	Unthreshed loss	Separation loss	Blower loss	Total loss	Capacity
		Total	Good	Branch	Broken	Good	Branch	Good	Branch	Broken									
kg/hr	rpm	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	%	%	%	%	%	%	%	kg/hr
4800	600	1104.12	939.943	0.163	8.915592	4.4280	0.5040	0.0720	0.0000	0.0036	954.029	99.930076	85.13047	0.934897	0.06992346	0.46413687	0.007546	1.476504	949.021
4800	600	1356.12	1197.932	0.105	4.923726	3.6432	0.2196	0.2988	0.1440	0.0000	1207.266	99.961204	88.33526	0.407840	0.03879509	0.30177269	0.024750	0.773158	1202.961
3600	600	1428.12	1258.029	0.107	3.316233	1.0548	0.0540	0.5904	0.0000	0.0252	1263.177	99.987256	88.08988	0.264526	0.01274368	0.08350374	0.046739	0.407512	1261.453
3600	600	1734.12	1557.731	0.169	3.819895	1.6488	0.0828	0.0612	0.0216	0.0000	1563.534	99.982544	89.82831	0.144311	0.01745564	0.10545344	0.003914	0.371134	1561.719
2880	600	1356.12	1208.783	0.156	2.282680	3.1140	0.2268	0.0828	0.0000	0.0072	1214.652	99.968514	89.13542	0.188521	0.03148533	0.25636963	0.006816	0.4113193	1211.222
2880	600	1140.12	1015.763	0.275	5.007283	0.9036	0.0648	0.0792	0.0072	0.0072	1022.108	99.966038	89.09266	0.490602	0.03396172	0.08840555	0.007748	0.620710	1021.046
4800	650	1824.12	1656.458	0.159	6.366910	7.8156	0.3744	0.0540	0.0000	0.0000	1671.288	99.968073	90.80860	0.380971	0.03192698	0.46765609	0.003231	0.083706	1662.984
4800	650	2076.12	1894.604	0.276	6.289600	2.1384	0.0540	0.1008	0.0000	0.0108	1903.474	99.982670	91.25697	0.330994	0.01732935	0.11234197	0.005295	0.465961	1901.170
3600	650	1338.12	1219.944	0.103	3.818776	1.1664	0.1008	0.3600	0.0252	0.0108	1225.530	99.981297	91.16853	0.312483	0.01870295	0.09517518	0.029375	0.455736	1223.866
3600	650	1374.12	1224.373	0.215	5.178861	1.8648	0.0725	0.2160	0.0180	0.0072	1232.045	99.975206	89.10231	0.429047	0.02579322	0.15135810	0.017531	0.622730	1229.867
2880	650	1464.12	1307.985	0.858	2.688031	0.8172	0.0504	0.5040	0.0648	0.0108	1312.978	99.925887	89.33593	0.205550	0.07411262	0.06224016	0.038386	0.380289	1311.531
2880	650	1320.12	1157.521	0.341	3.240604	0.5760	0.0396	0.7956	0.0720	0.0108	1162.597	99.961059	87.68303	0.279667	0.03094008	0.04954425	0.068433	0.436584	1161.103
4800	700	2036.52	1839.402	0.272	3.811668	1.1880	0.0612	1.4076	0.0216	0.0504	18.46.215	99.980768	90.32085	0.209188	0.01923188	0.06434786	0.076242	0.369010	1843.486
4800	700	1618.92	1445.464	0.505	5.276646	3.5172	0.83388	1.3428	0.3744	0.0396	1457.359	99.882087	89.20571	0.364786	0.11791266	0.24134068	0.092139	0.816170	1451.246
3600	700	1356.12	1209.455	0.425	2.603835	1.3788	0.0792	1.1916	0.0792	0.0252	1215.238	99.951983	89.18495	0.216339	0.04801660	0.11345926	0.098054	0.475869	1212.484
3600	700	1474.92	1312.783	0.471	3.765753	0.8428	0.4644	1.2276	0.0432	0.0252	1319.623	99.925863	89.00709	0.287275	0.07413627	0.06383642	0.093026	0.518274	1317.020
2880	700	1402.92	1173.643	0.107	2.511894	0.8964	0.1224	1.2636	0.0720	0.0252	1178.641	99.974437	83.65714	0.215255	0.02556241	0.07605360	0.107208	0.424080	1176.362
2880	700	1572.12	1413.058	1.902	3.593417	0.5076	0.0216	1.4688	0.0684	0.0324	1420.653	99.859754	89.88235	0.255221	0.14024517	0.03573004	0.103389	0.534586	1418.554

Table 5 Power requirement of 4 feet rice thresher.

Run no.	Feeding interval sec/bundl*	Feeding rate kg/hr	Drum speed		Outlet			Onload torque kg.m	On load power			Capacity kg/h	Specific capacity (kg/hr)/kW
			No-load rpm	On load rpm	Main grain gm/10sec	Straw gm/10sec	Chaff gm/10sec		ps	hp	kW		
1	3	4800	605	436	3767	2767	85.6	10.0	6.98	6.89	5.14	1202.961	234.192
2	3	4800	604	300	3067	2954	68.4	11.0	6014	6.06	4.52	949.021	209.949
3	4	3600	608	465	4017	2567	205.8	6.5	5.45	5.37	4.01	1561.719	389.456
4	4	3600	605	473	3967	2517	110.2	7.0	5.86	5.78	4.31	1261.453	292.856
5	5	2880	608	463	3167	2217	128.3	5.8	5.02	4.95	3.69	1021.046	276.706
6	5	2880	608	468	3767	3047	136.6	6.0	5.09	4.96	3.70	1211.222	327.500
7	3	4800	655	481	5767	3017	166.1	8.0	6.93	6.83	5.10	1901.190	373.104
8	3	4800	655	464	5067	9467	134.4	8.2	6.87	6.70	5.05	1662.984	329.013
9	4	3600	655	492	3817	2667	299.0	6.0	5.36	5.29	3.94	1229.867	311.758
10	4	3600	650	548	3717	2617	320.8	6.5	5.99	5.91	4.41	1223.866	277.695
11	5	2880	655	532	3667	2217	410.5	6.4	5.90	5.82	4.34	1161.103	267.570
12	5	2880	655	562	4067	2517	375.9	5.8	5.51	5.43	4.05	1311.531	323.692
13	3	4800	706	506	4497	3257	190.8	8.0	7.82	7.71	5.75	1431.246	248.912
14	3	4800	703	522	5657	3297	246.8	7.2	7.04	6.94	5.18	1843.486	356.041
15	4	3600	704	590	4097	2467	285.0	6.8	7.22	7.12	5.31	1317.020	248.062
16	4	3600	703	559	3767	2967	390.3	7.0	7.23	7.13	5.32	1212.484	227.850
17	5	2880	708	527	4367	2317	366.9	6.4	6.61	6.52	4.87	1418.555	291.558
18	5	2880	707	574	3897	2567	459.4	6.4	6.97	6.87	5.13	1176.262	229.361

* Rice bundle weighed 4 kg each.

requirement as a consequence of increase in feed rate may be attributed to the large amount of straw being threshed and crushed between the concave and threshing cylinder.

Specific capacity

Individually, drum speed and feeding rate had no significant effect on specific capacity. However the interaction of the two parameters significantly affected th specific capacity. According to the incidence, proper selection of drum speed together with the feeding rate seemed to be as important as to contribute a satisfactory specific capacity. From this study the drum speed of 650 rpm and feeding rate of 4800 kg/hr yielded the maximum specific capacity of 356 kg/hr per kw.

Recommendations

1. In interpreting the results of the performance test, as far as threshing efficiency and total loss were concerned it implied to some degree that the mechanism of the machine was quite effective and appropriate. The aspects to be considered towards the machine development should be partly modified in order to improve the power requirement, capacity and cleaning efficiency.

With cleaning efficiency, it was recently reported in a study of vertical axial flow thresher model 5TL-70 by Yue (1988) to be as high as 98%. The cleaning efficiency was remarkably higher than that observed in this experiment and seemed to be the highest ever been reported.

2. The thresher capacity could possibly be improved by increasing the size of feeding chute.

CONCLUSION

1. Thresher with threshing drum of 4 feet length in this test contributed a considerably high threshing efficiency of 99.9%.

2. Total loss due to breakage, unthreshed and blown was found to be 0.37-1.48% and varied according to the feeding rate.

3. Capacity and power requirement in this test were 949-1901 kg/hr and 3.69-5.75 kw respectively. The capacity and the power requirement increased with the increase in drum speed and feeding rate.

4. Drum speed over 700 rpm should not be practiced due to violent machine vibration. The favorable drum speed and feeding rate were 650 rpm and 4800 kg/hr since they provided the maximum specific capacity which was 356 kg/hr per kw.

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