Journal Crop and Weed, 11(1):75-79(2015)

Utilization of animal energy for post harvest operations in rotary mode

S. K. SWAIN, A. K. DASH, A. K. MOHAPATRA, D. BEHERA AND B. K. BEHERA

Department of Farm Machinery and Power
College of Agricultural Engineering and technology
OUAT, Bhubaneswar - 751003, Odisha

Received:16-08-2014, Revised: 05-02-2015, Accepted: 17-02-2015

ABSTRACT

The small and marginal farmers in many parts of the state of Odisha still depend upon the animal energy for accomplishment of agricultural operations because of small and fragmented land holding as well as poor socio-economic status. Of late, the maintenance cost of a pair of bullocks proves to be a burden on these farmers with increase in labour cost. A study on use of animal energy for two post harvest operations such as paddy threshing and chaff cutting with rotary gear system was made to increase the annual use of the bullocks so as to reduce the owning cost of bullocks.The results on operation of thresher indicated that the average output of the thresher was 143.23 q h^{-1} with mean threshing efficiency of 93.12%. The mean draft was 420 N which was 6.9 % of the bodyweight of the bullocks indicating that the bullocks were underutilized as far as power utilization is concerned. The results on operation of chaff cutter through bullock operated rotary unit indicated that the mean draft requirement was 250 N varying from 275 to 216 N which was 4.1 % equivalent to the bodyweight. The average output was found to be 69.43 kg h^{-1}. The power output was observed to be 0.207 kW. The cost of operation of the thresher and chaff cutter in rotary mode suggests that rotary unit is not economical compared to threshing and chaff cutting if operated by electrical power source but surely it will increase the utilization of animal which otherwise would have been sitting idle and can save time in threshing compared to traditional bullock treading.

Keywords : Bodyweight, draft requirement, output, rotary gear system, threshing efficiency

In Odisha, around 77 per cent of the farmers are under small and marginal categories and they posses about 43 per cent of the total cultivable land. The number of operational holdings is about 40.30 lakhs with a cropping intensity of 160 per cent. The average size of holding is 1.5 ha (Ghosal *et. al*., 2014). Thus, the small and marginal farmers in many parts of the state of Odisha still depend upon the animal energy for accomplishment of agricultural operations because of small and fragmented land holding as well as poor socio-economic status. Use of bullocks for agricultural work is limited to tillage, threshing and transportation in the state of Orissa (Kurup, 2003). The total annual use amounts to less than 300 hours. Cost of utilization is, therefore, very high as the bullocks are to be fed throughout the year whether they are in use or not (Anon., 2001). One way to reduce the economic burden of owning a pair of bullocks is to increase the utilization of bullocks which can be possible if the bullocks will be used to carry out post-harvest operations of different crops with rotary gear system (Kurchania and Mishra, 2003). This study aims at use of animal power in idle period so that the annual use will increase and ultimately the cost benefit ratio will improve besides providing useful information on the suitability of animals in rotary mode of operations.

Email: swainsangram@yahoo.co.in

MATERIALS AND METHODS

The rotary gear unit procured from UAE centre of Allahabad was installed in the premises of College of Agricultural Engineering and Technology, OUAT, Bhubaneswar. The rotary gear unit consists of few components such as a gear box, spur gears, bevel gears. Shafts, bearing, bearing cover, bushes and belt pulley transmission unit. In the rectangular shape gear box having dimensions of 660 x 579 x 274 mm different parts are assembled. It is made of 6 mm thick pressed mild steel plate. There is a set of spur gears which transmits the power between two parallel shafts. The spur gears are made of heat treated alloy steel having module 4.0 mm. The spur gear has 77 teeth while the spur pinion has 16 teeth. The speed ratio of 1: 4.8 is obtained. Further, there is a set of bevel gears (spiral tooth bevel gear having module 6.5 mm) which has 43 teeth and bevel pinion has 7 teeth. The material of the bevel gear is heat treated alloy steel. The speed ratio is 1: 6.14. Combination of bevel and spur gear can produce the speed ratio of 1:29.56. The first shaft of bevel gear is held in vertical position having diameter 50 mm and 63 mm at bottom side and top side respectively. The second shaft for bevel pinion and spur gear has diameter of 50 mm. The third shaft used for bevel pinion has diameter of 30 mm. One ball bearing 90x50x24 size is fitted on the 50 mm shaft and another ball bearing of 72x30x20 mm size is fitted on top of the same. One thrust bearing

60x38x20 mm size is fitted at the outer end of the pinion shaft with two ball bearings of 72x30x20 mm and 88x45x22 mm size. One bearing cover is used for thrust bearing 60x38x20 mm size. The cover is made of 45C8 steel. Two bushes are used for the input shaft. One is fixed at the bottom plate of the box and the other is fixed at the cover plate. Necessary lubrication arrangement has been provided. The two transmission shafts are mounted on two pillars each. The diameter of the shaft is 50 mm. The first drive shaft was connected to the output shaft of the gear box through universal joint coupling. One pulley of 60 cm was mounted on the first drive shaft and the counter shaft is having a pulley of 15 cm thereby stepping up the speed in the ratio 1: 4 when connected with flat belt. For threshing operation, a 35 cm pulley is also mounted on the counter shaft which is connected through belt with the thresher shaft having a 20 cm pulley stepping up the speed in the ratio 1: 1.75. So for thresher the final speed ratio is 1:210. Similarly for chaff cutting, the step up speed of speed ratio from main shaft to counter shaft is in the ratio of 1:1.7 and from counter shaft to chaff cutter is 1:1. Hence, a total speed ratio from the input to output is 1:50.25. A Ratchet assembly was developed to prevent the back flow of power to the bullocks when they stop during working. By this unit, the input shaft from the bullocks stops rotating when the bullocks stop moving; but the gear unit and the connected shafts keep on rotating due to their inertia (Anon.,2011).

Evaluation of thresher

A hold on type multi-crop thresher capable of threshing paddy as well as groundnut was used for the threshing operation. The thresher was tested for paddy only. The thresher can otherwise be operated with a one hp motor. The working width of the thresher drum was 800 mm. The detailed specifications of thresher are given in table 1.

Table 1: Salient specifications of the multi- crop thresher.

Sl No.	Components	Dimension
1	Over all dimension (LxBxH)	630x1200x760 mm
2	Length of the threshing drum	800 mm
3	Diameter of the threshing drum	33 mm
4	Height of the wire loop	50 mm
5	No of wire loops per slat	15
6	Arrangement of the wire loops	Staggered

Table2 : Specifications of the chaff cutter

Sl No.	Components	Dimension
1	Over all dimension (LxBxH)	1500x890x1350 mm
2	No. of blades	two
3	Diameter of the blades	600 mm
4	Safety device	Metallic cover
5	Feed	Automatic
6	Feed rollers (two no.) diameter	275 and 250 mm
7	Feeding unit (L x W)	850 x 175 mm

The thresher was run with the bullocks in rotary mode of operation and two persons were employed for threshing. The following parameters were studied during the experiment. Standard techniques were used for measurement of the different parameters. The experiment was conducted for three hours and the observations were taken at half an hour interval.

Rotary gear parameters

Power requirement at no load
Power requirement at load

Bullock parameters both at no load and load condition

Speed of bullocks
Average draft
Power output
Physiological responses
Fatigue score

Machine parameters (Thresher)

Peripheral speed of thresher
Threshing efficiency
Out put capacity
Cost of operation

Evaluation chaff cutter

A commercially available chaff cutter manufactured by M/s Akriti Engg. Works, Sundargarh was evaluated through rotary mode of operation by bullocks. The chaff cutter has two blades with diameter of 600 mm with a safety metallic cover on them. There was automatic feeding through a trough and two sets of rollers. The details of the chaff cutter were has been given in table 2. The chaff cutter was evaluated for the following parameters.

Rotary gear parameters

Power requirement at no load

Power requirement at load

Bullock parameters both at no load and load condition

Speed of bullocks

Average draft

Power output

Physiological responses

Fatigue score

Machine parameters (chaff cutter)

Size of cut straw

Out put capacity

Cost of operation

Cost economics

The cost of operation was calculated for both the thresher and chaff cutter in rotary mode of operation through bullocks and compared with traditional practices. The following assumptions were taken for calculating the cost (Table 3)

Variable cost:

Threshing: Two persons and one bullock operator

Chaff cutting: one person with one bullock operator

Local method of threshing (Bullock treading): 3 pairs of bullocks with three persons for 2 days (4 hours day^{-1}) for threshing of one acre of paddy (12 q). Labour charge Rs. 126 day^{-1}

RESULTS AND DISCUSSION

Paddy thresher

The thresher was operated in no-load condition with the thresher. The results are presented in table 4. It was observed that the draft requirement was between 199 N initially and reduced to 177 N after three hours of operation with a mean value of 185 N. which is 3 % of the bodyweight of the bullocks (bodyweight: 620 kg $pair^{-1}$). The speed of operation of the bullocks varied between 3.49 to 2.23 kmh^{-1} from 0.5 to 3 hours. The mean pulse rate, respiration rate and body temperature were 64 $beatsmin^{-1}$, 28 blows min^{-1} and 38.3 ^{o} C respectively. The average power output over three hours was 0.156 kW.

The data on evaluation of the thresher in rotary mode has been presented in table 7. The draft requirement varied 491 N in the beginning to 353 N at the end. The mean draft was 420 N which was 6.9 % of the bodyweight of the bullocks. The increase in pulse rate and respiration rate as usual decreased with duration and varied between 65 to 90 and 25 to 53 within three hours respectively. The corresponding mean values were 79 and 39. There was not much variation in the body temperature. Half hourly RPM of the bullocks were between 70 to 47 and gradually decreased with duration so also the linear speed. The mean linear speed of the bullocks was 2.8 km h^{-1} and the corresponding thresher drum peripheral velocity was 8.6 ms^{-1}. The mean RPM of the threshing drum was observed to be 380. Threshing efficiency varied between 92 to 95 % with a mean of 93.12 %. The output of the thresher gradually decreased with duration; may be due to decrease in the peripheral velocity of the threshing drum. The mean output was found to be 143.23 q h^{-1}. The power output was found to be 0.343 kW which indicated that the bullocks were underutilized as far as power utilization is concerned. The bullocks could sustain the duration of threshing without getting fatigue as the average fatigue score was only 10. It is proposed that a bigger size thresher will be tried during 2009.

The results of the experiment on chaff cutter have been presented in tables 6 and 7. no load test of the chaff cutter showed that the draft requirement was 160 N which was equivalent to 2.6 % of the bodyweight. The average power output was only 0.14 kW.

In load condition, the mean draft requirement was 250 N varying from 275 to 216 N which was 4.1 % equivalent to the bodyweight. The physiological responses increased with duration. Pulse rate varied between 56 beats min^{-1} after 1st half an hour to 77 beats min^{-1} after 3 hours and the mean pulse rate was 66 beats min^{-1}. Similarly respiration rate also increased with duration and the mean over a period of 3 hours was 29 blows min^{-1}. The corresponding mean body temperature was 38.37 ^{o} C. The bullock speed decreased with duration and the mean value was 2.87 km h^{-1} and the power output was 0.207 kW. The RPM of the chaff cutter shaft varied from 99 to 68 over three hours and the average value was 67. The straw size was in the range of 22.5 to 26 mm with an average size of 24.75 mm. It was observed that the straw size increased with duration, the reason may be reduction in the speed of the cutting blade which decreased as the speed of the bullocks decreased. The output capacity of the chaff cutter was 75 kgh^{-1} during the first hour and reduced as the duration increased and at the and of the 3rd hour it was 63.2 kgh^{-1}. The mean output was found to be 69.43 kgh^{-1}. The power output was observed to be 0.207 and the bullocks could sustain the draft comfortably as the fatigue score varied between 6 to 9. This shows that bullocks can operate the chaff cutter easily. The low power output indicates that the bullocks are underutilized. Hence, it is proposed to evaluate a bigger size chaff cutter in the year 2009.

Cost economics

The cost of operation of the thresher in rotary mode was Rs. 32.62 q^{-1} whereas it was Rs. 20.35 q^{-1} in case of thresher being operated by electric motor. The cost of threshing in rotary mode is Rs. 32.62 q^{-1} than that incurred in traditional method of bullock treading (Rs. 38.4 q^{-1}). It shows that threshing through rotary mode of operation is cheaper and economically viable than the traditional method of bullock treading. Chaff cutting cost per quintal with the rotary mode was also less (Rs. 53.52) compared to manual chaff cutting by the same

chaff cutter manually (Rs. 58.75q^{-1}). The above economics suggests that rotary unit is not economical compared to threshing by electric power but surely it will increase the utilization of animal which otherwise would have been sitting idle and can save time in threshing compared to traditional bullock treading. Both the thresher and cuff cutter require less power, so the bullock power is underutilized. Higher capacity thresher and chaff cutter should be used to increase capacity so that the unit cost of threshing will be reduced.

The following conclusions are made from the study:

i) The draft requirement of the thresher and chaff cutter were very low in term of percentage of body weight; 6.9 % for thresher and 4.1 % in case of chaff cutter. So the bullocks could sustain the draft for three hours.

ii) The operation of thresher through rotary mode was not economical compared to operated with electric motor but was slightly less (Rs. 2.88) compared to traditional method of threshing. However, chaff cutting in rotary mode was economical compared to operating the chaff cutter manually.

iii) Higher capacity thresher and chaff cutter should be utilized to enhance the output and reduce the unit cost of operation.

Table 3: Assumptions for computing cost of operation

Units	Cost (Rs.)	Life span	Repair & maintenance	Annual use (hrs)
Rotary unit	25000	10	5 % of the cost	960
Thresher		8000	10	-do-240
Thresher with motor	14000	10	-do-	240
Chaff cutter	15000	10	-do-	480
Bullocks	20000	5	Rs5 h^{-1}	1200

Table. 4: Physiological responses of bullocks in rotary mode of operation (Thresher) at no load

	Duration (hrs)							
Parameters	***In***	**0.5**	**1.0**	**1.5**	**2**	**2.5**	**3.0**	**Mean**
Pulse rate, bpm	50	52	55	60	66	76	76	64
Respiration rate, bpm	14	21	24	27	30	32	36	28
Body temp, ^{O}C	37.9	38	38	38.2	38.3	38.5	38.6	38.3
Amb. temp., ^{O}C	25.1	25.5	26	28	28.5	29.2	29.4	27.8
Rh, %	35	35	34	35	34	33	33	34
Draft, N	-	196	186	186	177	186	177	185
RPM of bullocks0.5h^{-1}	-	75	72	68	60	55	48	63
Speed, kmh^{-1}	-	3.49	3.35	3.16	2.88	2.56	2.23	2.95
Power output, kW	-	0.195	0.178	0.168	0.145	0.136	0.112	0.156

Table 5:Physiological responses of bullocks and performance of paddy thresher in rotary mode of operation

	Duration(hrs)							
Parameters	***In***	**0.5**	**1.0**	**1.5**	**2**	**2.5**	**3.0**	**Mean**
Pulse rate, bpm	50	65	72	78	83	86	90	79
Respiration rate, bpm	14	25	31	36	41	47	53	39
Body temp, ^{O}C	37.9	38	38.1	38.4	38.5	38.6	38.8	38.40
Amb. temp., ^{O}C	25.3	25.8	26.5	27.4	28.9	29.5	30	28.02
Rh, %	35	35	34	34	33	33	32	33.50
Draft, N	-	491	471	441	392	373	353	420
RPM of bullocks 0.5h^{-1}	-	70	69	64	60	53	47	61
Speed, km h^{-1}	-	3.26	3.21	2.98	2.79	2.46	2.19	2.81
RPM of thresher	-	440	435	392	375	340	300	380
Peripheral velocity, m s^{-1}	-	9.9	9.8	8.8	8.4	7.7	6.8	8.6
Threshing efficiency, %	-	95	93.2	93	93	92.5	92	93.12
Output, kg h^{-1}	-	155.6	152.3	150	145.2	130.6	125.7	143.23
Power output, kW	-	0.456	0.431	0.375	0.312	0.262	0.220	0.343
Fatigue score	-	7	7	10	10	12	13	10

Table 6: Physiological responses of bullocks in rotary mode of operation (Chaff cutter) at no load

	Duration (hrs)							
Parameters	***In***	**0.5**	**1.0**	**1.5**	**2**	**2.5**	**3.0**	**Mean**
Pulse rate, bpm	50	52	54	57	63	70	74	62
Respiration rate, bpm	14	19	21	26	28	32	36	27
Body temp, ^{O}C	37.9	38	38	38.2	38.3	38.5	38.5	38.3
Amb. temp., ^{O}C	25.1	25.6	26.2	27.5	28.5	29.1	29.3	27.7
Rh, %	35	35	34	35	34	33	33	34
Draft, N	-	167	167	167	157	157	147	160
RPM of bullocks 0.5h^{-1}	-	78	74	68	62	56	52	65
Speed, km h^{-1}	-	3.627	3.441	3.162	2.883	2.604	2.418	3.02
Power output, kW		0.173	0.164	0.150	0.129	0.117	0.102	0.14

Table 7: Physiological responses of bullocks and performance of chaff cutter in rotary mode of operation

	Duration(hrs)							
Parameters	**Initial**	**0.5**	**1.0**	**1.5**	**2**	**2.5**	**3.0**	**Mean**
Pulse rate, bpm	50	56	60	63	67	74	77	66
Respiration rate, bpm	14	20	24	27	30	33	38	29
Body temp, ^{O}C	37.9	38.1	38.2	38.2	38.4	38.6	38.7	38.37
Amb. Temp., ^{O}C	25.1	25.6	26.2	27.5	28.5	29.1	29.3	27.70
Rh, %	35	35	34	35	34	33	33	34
Draft, N	-	275	265	265	245	235	216	250
RPM of bullocks 0.5h^{-1}	-	76	70	64	60	52	48	61.67
Speed, kmh^{-1}	-	3.534	3.255	2.976	2.79	2.418	2.232	2.87
RPM of the shaft of chaff cutter	-	99	96	88	82	73	68	67
Size of cut straw, mm	-	22.5	23.8	24.45	25.2	26.55	26	24.75
Output, kgh^{-1}	-	75	73.5	70.3	69.2	65.4	63.2	69.43
Power output, kW	-	0.277	0.246	0.225	0.195	0.162	0.137	0.207
Fatigue score	-	6	7	7	8	8	9	7.50

Table 8: Cost economics of rotary mode of operation in threshing and chaff cutting

Machine	**Fixed cost, Rs hrs^{-1}**	**Variable cost Rs hrs^{-1}**	**Total cost Rs hrs^{-1}**	**Total cost, Rs q^{-1}**
Rotary unit	5.0	-	-	-
Thresher	6.5	-	-	-
Chaff cutter	6.0	-	-	-
Threshing in rotary mode	20.4	26.25	46.65	32.62
Thresher with electric motor	10.54	18.54	29.08	20.35
Bullock + plough man (when used)	8.90	8.75	17.65	-
Traditional method (bullock treading)		-	-	35.5
Chaff cutting in rotary mode	19.97	17.50	37.47	53.52
Chaff cutting manually with the chaff cutter	6.0	17.50	23.50	58.75*

Note: *The output was 40 kg h^{-1} when the chaff cutter was manually operated.*

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