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Research Paper

Effect of Operational Parameters on Dehusking Cum-Shelling Efficiency and Broken Grain Percentage of Maize Dehusker-Cum-Sheller

Agriculture

KEYWORDS : Broken grain percentage, Dehusking, Feed rate, Maize, Shelling

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ABSTRACT

Maize (Zea mays L.) is one of the most important cereal crop in the global agricultural economy. In India, maize is grown across all the states and it is one of the important staple foods. The conventional method of dehusking and shelling operations are time consuming and involves drudgery and exposure of crop over a times to natural hazards and animals, birds and insects damage leading to losses in quantity and quality of grains. In order to overcome these problems, the maize dehusker cum sheller of 600 kg h-1 capacity suitable for marginal, small and medium size farming community was developed by considering engineering properties of maize. The length of axial flow sheller cylinder was designed as one meter along with 8 row beaters. The solid lugs were provided as threshing element. The blade type blower with converging casing section were developed to separate grains from non-grain material. The V-belt power transmission system was used with an electric motor as prime mover. The numerical optimization technique was fallowed to optimize the operational parameters viz., cylinder peripheral speed (4 levels), concave clearance (4 levels) and feed rate (3 levels). The 7.1 m s-1 of peripheral speed with 25 mm of concave clearance of cylinder at 600 kg h-1 feed rate was found to be optimum and which were having dehusking efficiency, shelling efficiency and broken grain percentage were achieved 98.88, 99.12 and 1.23 per cent, respectively.

INTRODUCTION

In India, maize is grown across all the states and it is one of the important staple food. Among the cereal crops, maize ranks third in production (21.57 mt) and fifth in area (8.5 m ha) (Anon., 2012). The rise in area was driven by widened usage of maize in different sectors like starch, confectionaries, *etc.*, for consumption (28%), industrial (12%) apart from poultry feed (48%). However, the country lags far behind in productivity (24.7 q ha^{-1}) against world average of 51.4 q ha^{-1} (Anon., 2013a). The area has increased from 6.6 m ha in 2000-2001 to 8.66 m ha in 2011-2012 (Anon., 2013b). In India maize is grown in all the seasons, of which nearly 90% during *Kharif*, 7-8% during *Rabi* and 1-2% during *Summer*. Andhra Pradesh and Karnataka are leading producers of maize in India. Karnataka is the second largest producing state contributing to 17% of total production.

Farm mechanization is viewed as package of technologies to ensure timely field operations to increase productivity, reduce crop losses and improve quality of agro produce. Besides cost effective, it increases the land and other input productivity using labour saving and drudgery reducing devices. It is reported that tillage, sowing/planting and weeding operations for maize cultivation have been mechanized by 80-90% whereas, level of mechanization in harvesting and threshing is below 20% (Singh, 2010). The farm operations like harvesting, threshing and post harvest operations require mechanization and demand the use of suitable and appropriate equipment to obtain higher operational efficiencies.

Threshing or shelling is one of the most important crop processing operations to separate the grains from ear heads or the plants and prepare it for market. Traditionally, dehusking and shelling of maize are carried out by manually which involves a lot of drudgery. The grains were detached from dried dehusked cobs by manual or mechanical device, which is known as shelling. The output of manual separation reported to be 30 kg h^{-1} with shelling efficiency of 80% and grain damage of 8.3% (Mudgal *et al.*, 1998). It was also reported that the per cent recovery of grain from maize cob in manual shelling was 78.4% (Anon., 2005). Thus, this operation is highly labour intensive and more drudgery in addition to losses of grain in terms of quantity and quality. The available equipment are suitable for certain group of farmers (medium and large farmers), while in the country, about 80.3% of farmers are marginal and small group cultivating 36% of the area.

The capacity of manually operated equipment varied from 27 to 150 kg h^{-1} which is suitable for marginal farmers, whereas 1000 to 1800 kg h^{-1} for engine operated and more than 2000 kg h^{-1} for tractor operated equipment are suitable for large farmers. So there is a pressing need for developing a power operated maize dehusker cum sheller of capacity ranging from 400 to 800 kg h^{-1} suitable for small and medium farmers with higher level of dehusking and shelling efficiency. Keeping the above factors in view, present study was undertaken on development and evaluation of maize dehusker cum sheller.

MATERIALS AND METHODS

The methodology used for development of power operated maize dehusker cum sheller based on engineering properties of maize and the procedures adopted for performance evaluation of the developed machine in College of Agricultural Engineering, Raichur are explained below.

ENGINEERING PROPERTIES OF MAIZE

Engineering properties are useful and necessary in the design and operation of various equipment are necessary for agricultural operations (Sahay and Singh, 1994). The engineering properties such as physical, aerodynamic and frictional properties of maize were determined. The physical properties including dimensions of the maize cobs were measured/ determined using standard procedure (Tarighi *et al*., 2011). The aerodynamic and frictional properties were determined using the methodology stated by El Fawal *et al.* (2009).

THE DEVELOPMENT OF POWER OPERATED MAIZE DEHUSKER CUM SHELLER

The length of cylinder of axial flow maize dehusker cum sheller was decided (Singh, 2010 and Klenin *et al*., 1985) by using following equation.

$Q = Q_0 \, L \, M$

Where,

Q = Feed rate, kg/s

Q_0 = Permissible feed rate kg/s

L = Length of cylinder

The feed rate (Q) was taken as 0.167 kg s^{-1} for feeding cobs continuously to machine. Permissible feed rate (Q_0) was taken as 0.0216 kg s^{-1} m^{-1} length of the cylinder. Number of beaters (M) for making cylinder was taken as eight, as the recommended values for the cereals threshers were 4 to 8 (Klenin et al., 1985). The length of cylinder selected as one meter with 8 row beaters.

The solid lugs were adopted as threshing element on cylinder and kept as 44 numbers. The lugs of 6 or 5 numbers were provided on alternative rows of beater on the cylinder. The lug centre to centre distance in an each row was 190 mm, with a diagonal pitch of 95 mm for dehusking and shelling of cobs having minimum length of 95 mm.

Concave consists of three bend (half circular) MS flats support, square rods and two MS flat at both top surface as a reinforcement to increase the strength of frame. The three half circular bend (25.4 mm width and 6.35 mm thick) of three MS flats of 1020 mm length spaced at 500 mm were provided. The square rods were provided in order to increase sufficient friction to cobs which also helped in removing the grain and husk from cob. In order to detach the grains and husk over the cob, the size of the square rod size was selected based on the arithmetic and geometric mean diameter of the maize grains *i. e.,* 8.15 mm and 7.69 mm.

In order to enhance the easy flow of the plant mass and create more abrasion, the top cylinder cover was made cylindrical in shape using MS sheet of 1080 mm length x 160 mm diameter x 1.5 mm thick.

The 'throw-in' type feeding hopper was selected to feed cobs by gravity flow. The hopper height form the ground level was 1400 mm. The hopper had rectangular opening of 250 mm in length and 350 mm wide was provided. The studies revealed that, the maximum power consumption of 1160 W was observed for a feed rate 600 kg h^{-1} at 7.1 m s^{-1} cylinder peripheral speed. Considering the losses in the power transmission system, a three phase 2.23 kW electric motor was selected as prime mover for operating maize.

The diameter of rotating blades was taken as 220 mm as outer diameter of impeller. At the centre of inner diameter, the blower shaft of 25 mm diameter was placed to hold blades. The four straight blades of 75 mm in width and 300 mm in length with converging casing section at outside were developed.

The power transmission system of the power operated maize dehusker cum sheller was designed by considering an electric motor as prime mover having 2.23 kW power and rated speed of 950 rpm. The system was developed for a cylinder peripheral speed of 8 m s^{-1}. The power from the electric motor is transmitted to shelling cylinder shaft and blower shaft by using the V-belt of B cross section. The suitable diameter of pulley were selected and mounted on shelling cylinder shaft and blower shaft. A double grooved pulley of 101.8 mm diameter was provided on electric motor to transmit the power.

PERFORMANCE EVALUATION OF MAIZE DEHUSKER CUM SHELLER

Performance evaluation of designed power operated maize dehusker cum sheller was carried out at College of Agricultural Engineering, UAS Raichur with commonly grown maize variety (CP-818) in accordance with procedure and guidelines prescribed by the BIS code IS: 7051-1973 and IS: 6284-1985 cereals. The experiments were conducted at different levels of independent parameters *viz.,* four cylinder peripheral speeds (6.2, 66, 7.1 and 7.6 m s^{-1}), four concave clearances (20, 25, 30 and 35 mm) and three feed rates (400, 600 and 800 kg h^{-1}) with a 4 x 4 x 3 asymmetric factorial completely randomized design.

The performance evaluation of maize dehusker cum sheller was carried out one hour duration at specified cylinder speeds, concave clearances and feed rates. During the evaluation, a sample was collected from main grain outlet, cob and husk outlet and chaff outlet for further analysis. The various performance evaluation parameters were calculated by observations made on each treatment. A view of the evaluation setup of maize dehusker-cum-sheller is shown in Fig. 1.

The total grain input per unit time is the sum of the quantity of clean grain, broken grain and unthreshed grain from all outlets per unit time. This was calculated by following formula.

$A = B + C + D$

Where,

A = Total grain input per unit time

B = Quantity of clean grain from all outlets per unit time

C = Quantity of broken grain from all outlets per unit time

D = Quantity of unthreshed grain from all outlets per unit time

The dehusking efficiency was calculated as the ratio of number of dehusked cobs to the total number of cobs used in test run. The shelling efficiency is the ratio of shelled grains collected in all the outlets per unit time to the total grain input per unit time. The broken grain percentage was determined as the ratio of the quantity of broken grain from all outlets per unit time to the total grain input per unit time.

Numerical optimization technology was adopted in the design of experimental combinations for optimization of operational parameters (Montgomery, 2001). The data was statistically analysed using Design Expert (Version 7.0.0) statistical package.

RESULTS AND DISCUSSION

The results pertaining to engineering properties of maize, development and performance evaluation of the maize dehusker cum sheller are presented and discussed below.

ENGINEERING PROPERTIES OF MAIZE

The different engineering properties of most commonly grown maize variety (CP-818) are presented in the Table 1. The moisture content of the maize grains during the study was found to be 13% (w. b.) The mean length and diameter of un-dehusked cob was of 183.25 and 54.21 mm respectively. The sphericity of the grain was found to be 0.71 with a deviation of 0.69. The minimum diameter of cob without grains was found to be 23.11 mm whereas the maximum diameter of cob without grains was 29.53 mm. The average length of the shelled maize cob of 159.62 mm was noticed with a deviation of 15.43 mm. The test weight of the maize grain was noticed as 249.77 g with deviation of 46.96 g. The grain to dry matter ratio was recorded as 3.29 with deviation of 0.41. The mean terminal velocity of maize husk was found to be 1.22 m s^{-1} where as it was 15.6 m s^{-1} for maize grains. The maximum angle of repose (23.7°) for maize grains was found in CP 818.

DEVELOPMENT OF MAIZE DEHUSKER CUM SHELLER

The length and diameter of cylinder was designed as 1000 and 250 mm, respectively. The blade type blower of 220 mm diameter and 300 mm length was designed which runs at a 950 rpm. The electric motor of 2.23 kW power was selected as prime mover.

PERFORMANCE EVALUATION OF MAIZE DEHUSKER CUM SHELLER

The effect of feed rate, cylinder peripheral speed and concave clearance on dehusking efficiency of maize dehusker cum sheller is presented in Table 2. It was observed that the mean dehusking efficiency with respect to F1, F2 and F3 feed rate were 95.40, 94.89 and 94.01%, respectively. Among all the different treatments, the dehusking efficiency was maximum (99.71%) with respect to F1C1S4 treatment combination whereas it was minimum (84.65%) in F3C4S1 treatment. The dehusking efficiency increased with the increase in cylinder peripheral speed for all the concave clearances tested with respect to 400, 600 and 800 kg h^{-1}. The maximum dehusking efficiency (99.71%) was observed for the 400 kg h^{-1} while it was minimum ((84.65%) for 800 kg h^{-1}. Further, the maximum dehusking efficiency obtained at 20 mm concave clearance for all the cylinder peripheral speeds, while minimum for 35 mm concave clearance. The dehusking efficiency was found to increase at higher rate up to cylinder speed of 7.1 m s^{-1} thereafter it was nearly constant at 7.6 m s^{-1} peripheral speed. From Table 3, it was observed that all the first level factors and interaction effect of SC were significant at 1%. The interaction effect of SF, CF and SCF were non-significant for dehusking efficiency.

The shelling efficiency with respect to the cylinder peripheral speeds and concave clearances for 400 kg h^{-1} feed rate is shown in the Fig. 2a. The shelling efficiency, for all the concave clearances, increased with the increase in peripheral speeds. The shelling efficiency increased drastically from peripheral speed of 6.2 to 6.6 m s^{-1}, thereafter it increased gradually and remains nearly constant up to 7.6 m s^{-1} peripheral speed. The effect of cylinder peripheral speed and concave clearances on shelling efficiency at feed rate of 600 kg h^{-1} is shown in the Fig. 2b. The shelling efficiency increased with increase in the cylinder peripheral speed, and decreased with increase in concave clearances. The increase in the shelling efficiency was more as the cylinder peripheral speeds increased from 6.2 to 6.6 m s^{-1}. It increased gradually for 30 and 35 mm concave clearances and it was nearly constant at 20 and 25 mm concave clearances. The variations in shelling efficiency at different cylinder peripheral speeds and concave clearances for 800 kg h^{-1} feed rate are shown in the Fig. 2c. The concave clearance of 35 mm resulted in a minimum shelling efficiency at all the cylinder peripheral speeds while maximum at 20 mm concave clearance.

The percentage of broken grains during dehusking and shelling operation is presented in the Table 4. From the table, it was found that mean percentage of broken grains at F1, F2 and F3 feed rates were 1.35, 1.18 and 0.95 %, respectively. Among all the treatments, the percentage of broken grains was maximum (2.46 %) in F1C1S4 treatment combination and minimum of 0.40% was recorded in F3C4S2 treatment combination. It was observed that the grain broken percentage increased with increase in the cylinder peripheral speed for all the concave clearances tested. Further, the maximum percentage of broken grains were obtained at 20 mm concave clearances for all the cylinder peripheral speeds while minimum for 35 mm concave clearance. The percentage of the broken grains were decreased significantly as the concave clearance increased from 20 to 30 mm concave clearance, thereafter it is not varied much from 30 to 35 mm concave clearance. The decreased broken grain percentage with increase in feed rate was observed in the study. The effect of different factors on broken grain percentage was analysed statically and is shown in Table 5. It was observed that all the first level factors were significant at 1% level. Among all the interaction effects, the SF, CF and SCF treatment combination found as non-significant for grain broken percentage. The F1 and F2 feed rate effects had significant difference over the F3 feed rate.

The solutions were found for all the treatment combinations with a desirability ranging from 0.618 to 0.759. The maximum desirability value of 0.759 was obtained for 7.1 m s^{-1} of peripheral speed, 25 mm of concave clearance and 600 kg h^{-1} feed rate, thus selected as optimum treatment combination. The dehusking efficiency of the developed machine was obtained as 98.88 % with a shelling efficiency of 99.12 %. The findings of the Sandhar and Panwar (1975) were in agreement with the present results. The broken grain per cent in the machine were 1.23 %.

Fig. 1 The view of the evaluation setup of maize dehusker cum sheller

Table 1 Parameters and properties of maize variety selected for the study

Particulars	Mean	SD
Physical properties		
Length of un-dehusked cob, mm	183.25	29.56
Diameter of un-dehusked cob	54.21	4.37
Sphericity	0.71	0.04
Min. diameter of cob without grains, mm	23.11	2.17

Max. diameter of cob without grains, mm		29.53	2.86
Avg. length of shelled cob, mm		159.62	15.43
Test weight, g		249.77	46.96
Grain to dry matter ratio		3.29	0.41
Moisture content, %		13	1.9
Aerodynamic property			
Terminal velocity, m s^{-1}	Husk	1.22	0.06
	Grain	15.60	0.43
Frictional property			
Angle of repose, degree		23.73	1.12

Table 2 Percentage of dehusking efficiency at different feed rate for various cylinder peripheral speed and concave clearance

Concave clearance (C), mm	Feed rate (F)s																	
	F1 = 400 kg h-1						F2 = 600 kg h-1						F3 = 800 kg h-1					
	Cylinder speed (S), m s-1						Cylinder speed (S), m s-1						Cylinder speed (S), m s-1					
	S1	S2	S3	S4	Mean	SD	S1	S2	S3	S4	Mean	SD	S1	S2	S3	S4	Mean	SD
C1	95.35	98.05	99.55	99.71	98.17	2.02	94.88	98.02	99.27	99.54	97.93	2.14	94.52	97.05	99.21	99.52	97.58	2.32
C2	93.10	95.88	98.55	99.66	96.80	2.93	92.45	96.78	98.88	99.27	96.85	3.13	91.88	95.55	98.20	99.05	96.17	3.23
C3	90.92	94.32	97.05	98.55	95.21	3.36	90.02	93.89	96.57	98.08	94.64	3.53	88.22	92.22	95.43	97.08	93.24	3.91
C4	87.58	90.55	93.02	94.57	91.43	3.05	85.78	89.55	91.88	93.43	90.16	3.33	84.65	88.08	91.08	92.47	89.07	3.47
Mean	91.74	94.70	97.04	98.12	95.40		90.78	94.56	96.65	97.58	94.89		89.82	93.22	95.98	97.03	94.01	
SD	3.31	3.16	2.87	2.43			3.88	3.76	3.40	2.84			4.31	3.98	3.64	3.22		

Note: CD for SC, SF and CF interaction is 0.80, 0.90 and 0.64; CD for SCF interaction is 1.13

Table 3 ANOVA table for dehusking efficiency at different feed rate for various cylinder peripheral speed and concave clearance

Source	Sum of squares	Degree of freedom	Mean square	F value	p-value Prob. > F	
S-Peripheral speed	1112.29	3	370.76	238.52	< 0.0001	Significant
C-Concave Clearance	1200.60	3	400.20	257.46	< 0.0001	Significant
F-Feed rate	129.87	2	64.94	41.78	< 0.0001	Significant
SC	79.04	9	8.78	5.65	< 0.0001	Significant
SF	27.80	6	4.63	2.98	0.0103	Non-significant
CF	17.97	6	2.99	1.93	0.0842	Non-significant
SCF	27.53	18	1.53	0.98	0.4844	Non-significant
Pure Error	149.22	96	1.55			
Total	2744.31	143				

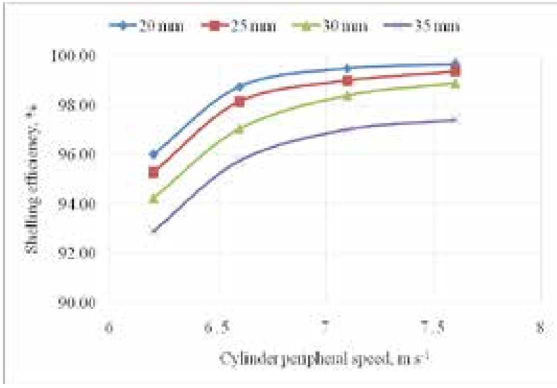
Table 4 Percentage of broken grains at different feed rate for various cylinder peripheral speed and concave clearance

Concave clearance (C), mm	Feed rate (F)s																	
	F1 = 400 kg h^{-1}						F2 = 600 kg h^{-1}						F3 = 800 kg h^{-1}					
	Cylinder speed (S), m s^{-1}						Cylinder speed (S), m s^{-1}						Cylinder speed (S), m s^{-1}					
	S1	S2	S3	S4	Mean	SD	S1	S2	S3	S4	Mean	SD	S1	S2	S3	S4	Mean	SD
C1	1.50	1.64	1.98	2.46	1.90	0.43	1.30	1.42	1.64	2.35	1.68	0.47	1.02	1.11	1.45	2.04	1.40	0.46
C2	0.83	1.08	1.38	1.99	1.32	0.50	0.85	0.95	1.23	1.85	1.22	0.45	0.53	0.70	1.00	1.59	0.96	0.47
C3	0.62	0.92	1.22	1.85	1.15	0.53	0.59	0.75	1.01	1.52	0.97	0.41	0.40	0.55	0.83	1.38	0.79	0.43
C4	0.59	0.84	1.10	1.66	1.05	0.46	0.52	0.67	0.85	1.33	0.84	0.35	0.40	0.45	0.65	1.10	0.65	0.32
Mean	0.88	1.12	1.42	1.99	1.35		0.82	0.95	1.18	1.76	1.18		0.59	0.70	0.98	1.53	0.95	
SD	0.42	0.36	0.39	0.34			0.35	0.34	0.34	0.45			0.29	0.29	0.34	0.40		

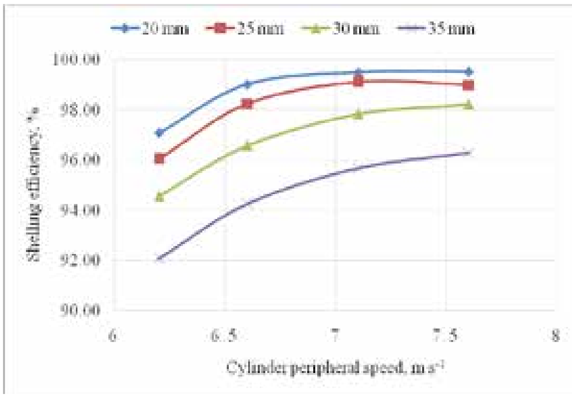
Note: CD for SC, SF and CF interaction is 0.09, 0.07 and 0.07; CD for SCF interaction is 0.12

Table 5 ANOVA table for broken grains at different feed rate for various cylinder peripheral speed and concave clearance

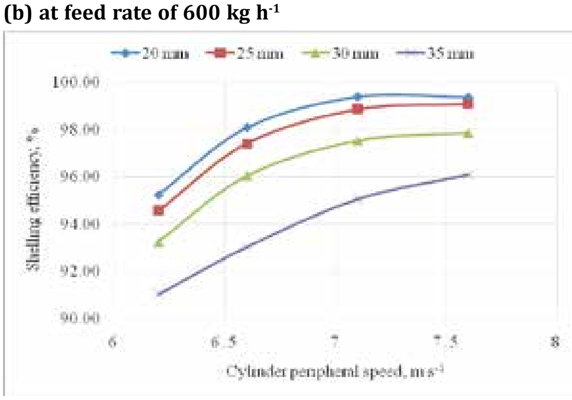
Source	Sum of squares	Degree of freedom	Mean square	F value	p-value Prob. > F	
S-Peripheral speed	23.79	3	7.93	446.80	< 0.0001	Significant
C-Concave Clearance	9.85	3	3.28	185.05	< 0.0001	Significant
F-Feed rate	2.47	2	1.23	69.55	< 0.0001	Significant
SC	1.49	9	0.17	9.30	< 0.0001	Significant
SF	0.11	6	0.018	1.00	0.4329	Non-significant
CF	0.36	6	0.059	3.34	0.0050	Non-significant
SCF	0.53	18	0.029	1.66	0.0603	Non-significant
Pure Error	1.70	96	0.018			
Total	40.30	143				



(a) at feed rate of 400 kg h^{-1}



(b) at feed rate of 600 kg h^{-1}



(c) at feed rate of 800 kg h^{-1}

Fig. 2 Effect of cylinder peripheral speed and concave clearance on shelling efficiency

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