Madras Agric. J., 102 (7-9): 277-280, September 2015
https://doi.org/10.29321/MAJ.10.001118

Influence of Blade Parameters on Cutting Force for Jowar Stalks

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The total harvesting of Jowar requires two stages of cutting, one at the top for separating cobs and another at the bottom for fodder. The study aimed to determine the cutting force required for three Jowar (*Sorghum officinarum*) varieties at different combinations of blade parameters. The minimum value of force was observed at the combination of bevel angle 45° and rake angle 0° for the varieties CSV-20 (2.04 N) and CSV-23 (2.10 N); whereas, for the variety CSH-9 the minimum force (1.26 N) was measured at blade bevel angle 35° and blade rake angle 0°. Similarly minimum force of 1.86, 1.59 and 1.06 N for cutting the stalks of Jowar varieties CSV-20, CSV-23 and CSH-9, respectively were recorded at the combination of blade rake angle 0° and blade velocity 350 rpm. At a combined effect, minimum force was recorded at blade bevel angle 45º and blade velocity 350 rpm for all the three varieties selected.

Key words: Blade parameters, Cutting force, Jowar stalks

India covers 34 % of the total area in the world and produces around 17 % of the Jowar grains per annum. It is cultivated in Maharashtra for both grain and fodder during *kharif* (area 13.84 lakh ha) and *rabi* (area 30.17 lakh ha). Cutting of stalks is an important process in Jowar harvesting, which is achieved by four different actions *viz.,* i)slicing action with a sharp smooth edge, ii)tearing action with a rough, serrated edge, iii) high velocity single element impact with sharp or dull edge and iv) a two element scissors type shearing action.

The total harvesting of Jowar requires two stages of cutting, one at the top for separating the cobs and another at the bottom for fodder. Hence, double labours are required for harvesting of this crop, which amounts to 25% of the total labour for grain production. Further, the present practice of harvesting is using a sickle, which involves slicing and tearing actions which may result in failure of plant structure due to compression, tension or shear. In hybrid Jowar when the crop attains maturity, the stand is erect and the cobs at the top of the plant are at uniform height. This genetic factor is favourable for introducing a mechanical harvesting device to reduce drudgery and time of operation. It will help to reduce labour requirement.

Mc Randal and McNulty (1978) conducted theoretical and experimental investigations of the impact cutting process under conditions chosen to simulate rotary mowing in the field. Ghahraei *et al.,* (2011) developed a new harvesting machine with a rotary impact cutting system for cutting kenaf stems.

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The design of the machine was based on the effective cutting knife angles and cutting speed. Dange *et al*., (2011) investigated the cutting energy and force required for the pigeon pea crop. Johnson *et al.,* (2012) investigated the effect of blade oblique angles and speeds on cutting energy. Cutting blade speed, before and after severing a single miscanthus stem was used to calculate the cutting energy. The present study aimed to undertake trials at various combinations of blade parameters and their effect on force for cutting Jowar stalks.

Materials and Methods

Three different varieties namely, CSV-20, CSV-23 and CSH-9 of Jowar planted on the experimental field at western block of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola were selected for the study. Stalks of physiologically matured plants were selected to determine cutting force of stalks at different combinations of blade parameters. The moisture content of the sorghum stalk was measured according to ASAE standard S.352 (ASAE ,1979). The stalk diameter was determined with the help of a slide calliper having a least count of 0.01mm. Three repeated measurements were taken for upper, middle and lower sections to get the average value.

The laboratory set up (Fig.1) of cutting mechanism was developed to measure the force for cutting Jowar stalks of three selected varieties at different combinations of blade parameters. Plane blade having dimensions 230 X 60 X 10 mm was used in the experiment.

Independent variables includes Varieties – 3(CSV-20, CSV-23 and CSH-9); Blade bevel angles –3 levels (25º, 35º, 45º); Blade rake angles – 3 levels (20º, 0º, -20º) and Blade velocity – 3 levels (350, 500, 650 rpm). Dependent variable include peak force. The experimental design was CRD with three replications.

The laboratory set up had different components *viz.,* central shaft, rotating disc, torque sensor and an electric motor with variable frequency drive (VFD). Rotating disc on which blades are fitted was mounted on central shaft at lower end for cutting stalks. The angle sims were used to vary rake angles of blade. Torque sensor mounted on the central shaft (Fig.2) was used to measure the cutting torque. The power for mechanism was supplied by electric motor and the speed of rotation was varied with the help of variable frequency drive (VFD).

The samples for investigations were collected at random. The stalks with an average diameter (2.5 cm) were selected for the experiment. The experiment was planned on the same day to avoid the fluctuation in the moisture content of the stalks. Before feeding the stalks to the machine, the disc was allowed to rotate at the pre determined speed for about five minutes to avoid all fluctuations in rpm. As per the experimental design, the samples of three varieties of Jowar stalks were fed to the machine with the help of a stalk holder. The torque observations were noted for each speed separately from the excel sheet data of torque sensor. The trials were repeated thrice for each treatment.

Results and Discussion

Effect of blade bevel angle and blade velocity

As an effect of blade bevel angle and blade velocity (Table 1), it was observed that the force for cutting stalk had increased with increase in blade velocity from 350 to 650 rpm for blade bevel angles 25°, as well as for 45° and decreased with increase

Table 1. Effect of blade bevel angle and blade velocity on force for cutting Jowar stalks

Bevel angle (degree)	Cutting Force, N											
	CSV-20				CSV-23				CSH-9			
	Velocity, rpm											
	350	500	650	Mean	350	500	650	Mean	350	500	650	Mean
25	3.32	3.75	4.77	3.94	2.26	3.74	3.81	3.27	1.55	1.96	2.00	1.84
35	10.02	8.10	4.95	7.69	4.72	5.78	3.20	4.57	3.69	3.41	2.23	3.11
45	2.12	3.19	4.10	3.14	1.85	2.54	4.27	2.89	1.34	1.60	2.32	1.75
Mean	5.15	5.01	4.61		2.94	4.02	3.76		2.20	2.33	2.19	
F-test		S				S				S		
SE(m)±		0.959				0.187				0.073		
CD (5%)		2.662				0.519				0.203		

in blade velocity for blade bevel angle 35°. When the variety CSV-23 was used, the cutting force increased with increase in blade velocity at blade bevel angles 25° and 45° whereas, at blade bevel angle 35°, the force increased non significantly with increase in blade velocity to 500 rpm. However, significant decrease with further increase in blade velocity from 500 to 650 rpm was observed. In case of variety CSH-9, the force increased with increase in blade velocity from 350 to 650 rpm at blade bevel angle 25° and 45° and decreased at blade bevel angle 35°. The combined effect of blade bevel angles and blade velocities showed significant differences in the mean values of forces at 5% level of significance. Fig.3 revealed that the mean value of force for cutting Jowar stalks increased with increase in blade bevel angle 25°to 35° and decreased with further increase in blade bevel angle from 35° to 45° for the three Jowar varieties. The combination of blade bevel angle 45° and blade velocity 350 rpm recorded the minimum force required for cutting stalks.

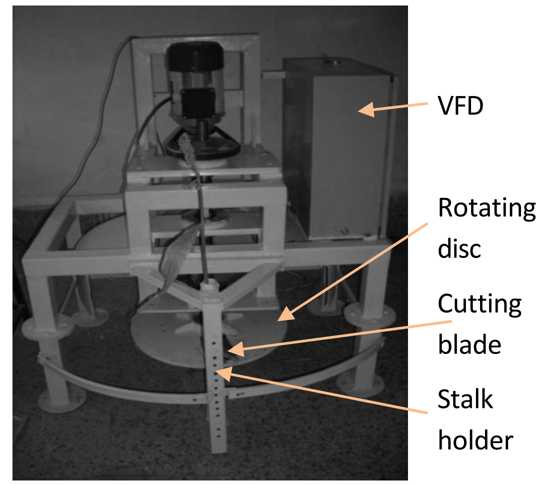

Fig.1 Laboratory set up for stalk cutting

Effect of blade bevel angle and blade rake angle

The data on effect of blade bevel angle in combination with blade rake angle on the force for cutting Jowar stalks (Fig.3) revealed that, for the variety CSV-20, the force for cutting stalk decreased with decrease in rake angle from 20° to 0° and then increased with further decrease in rake angle to -20° at all three blade bevel angles. For the variety CSV-23, the cutting force decreased with decrease in rake angles from 20° to 0°and then increased

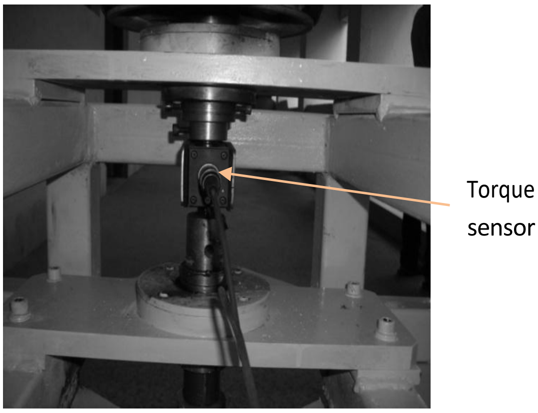

Fig.2 Mounting of torque sensor

with change in rake angles from 20° to -20° for all the three blade bevel angles. In case of variety CSH-9, at blade bevel angles 25° and 35°, the force decreased with decrease in blade rake angles 20° to 0° and then increased with decrease in rake angle 0° to -20°; whereas, at blade bevel angle of 45°, reverse trend was observed. The statistical analysis of data showed significant differences at 5% level in the mean values of forces for all the three selected

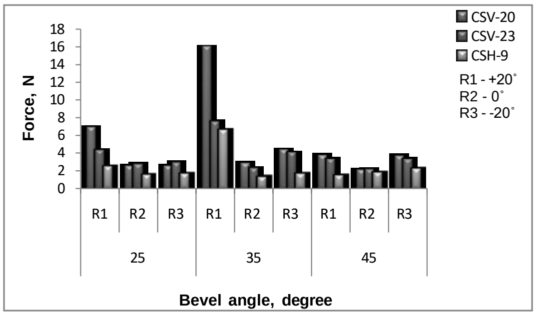

Fig. 3. Effect of blade bevel and rake angle on force for cutting Jowar stalks

Jowar varieties. It was also observed that the mean value of force increased with increase in blade bevel angle from 25°to 35° and decreased with increase in blade bevel angle to 45°. The mean value of force required for cutting the stalks was minimum for the variety CSH- 9 and it was maximum for the variety CSV-20.

Effect of blade rake angle and blade velocity

Fig.4 represents the effect of blade rake angles and blade velocity on force for cutting stalks of three Jowar varieties. The force for cutting stalk of variety CSV-20 increased with increase in blade velocity from 350 to 650 rpm at blade rake angles 0° and -20° and decreased with increase in blade velocity at blade rake angle 20°. When the variety CSV-23 was selected for testing, the force increased with increase in blade velocity for cutting stalks at blade rake angles -20° and 0°; whereas, at blade rake angle 20°, force increased non significantly with increase in blade velocity from 350 to 500 rpm and

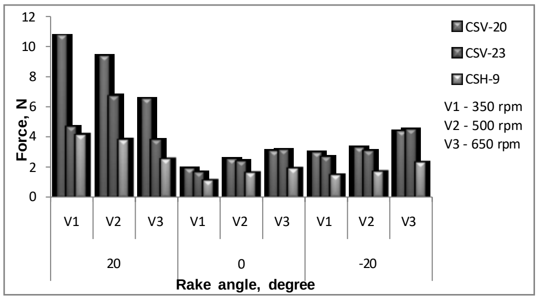

Fig. 4. Effect of blade rake angle and velocity on force for cutting Jowar stalks

significantly decreased with further increase in blade veloicty to 650 rpm. Similar trend of force values for cutting stalks was observed in case of CSV-20 and CSH-9. The statistical analysis of data revealed that combined effect of blade rake angles and blade velocities had showed significant difference at 5% level in the mean values of forces for cutting stalks. It was also observed that the mean value of force for cutting stalks of Jowar crop decreased with increase in blade velocity from 350 to 650 rpm for all the three varieties and the recorded cutting force was minimum for CSH-9 and maximum for CSV-20 for all the three blade rake angles selected.

When the combined effect of bevel angle and blade velocity was studied, the minimum force (2.12, 1.85 and 1.34 N) for varieties CSV-20, CSV-23, CSH-9, respectively was required for cutting the stalks at the combination of blade bevel angle 45°and blade velocity 350 rpm. The combination of blade bevel angle 45°and blade rake angle 0°recorded minimum value of force for cutting stalks of varieties CSV-20 (2.04 N) and CSV-23 (2.10 N) whereas, for the variety CSH-9 the minimum force (1.26 N) was observed at blade bevel angle 35° and blade rake angle 0°. When the combined effect of blade rake angle and blade velocity was studied, the minimum force (1.86, 1.59 and 1.06 N) for varieties CSV-20, CSV-23 and CSH-9, respectively was observed at the combination of blade rake angle 0°and blade velocity 350 rpm.

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Received after revision: September 25, 2015; Accepted: September 30, 2015