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FORCE REQUIRED FOR CUTTING SORGHUM STALKS INFLUENCED BY BLADE PARAMETERS

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Abstract: The total harvesting of Sorghum requires two stages 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 Sorghum (*Sorghum officinarum*) varieties at different combinations of blade parameters. When the interactive effect of blade rake angle and blade velocity was considered, the combination of 0˚ rake angle and velocity of 350 rpm required minimum force for all three varieties. The combination of 25˚bevel angle and 25˚ shear angle required minimum force for all three varieties with the combine effect of blade bevel angle and blade shear angle. For the interactive effect of blade rake angle and blade shear angle, the combinations of 20˚ rake angle and 35˚ shear angle, 0˚ rake angle and 25˚ shear angle and -20˚ rake angle and 25˚ shear angle required minimum force for varieties CSV-20, CSV-23 and CSH-9 respectively.

Keywords: Blade parameters, cutting force, Sorghum stalks

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INTRODUCTION

India covers 34 % of the total Sorghum area as that of the world and produces around 17 % of the world production of Sorghum grains per annum. It is being 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 Sorghum harvesting, which is achieved by four different actions, 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 Sorghum requires two stages cutting of plant, one at the top for separating cobs and another at the bottom for fodder. Hence, double labours are required for harvesting of this crop which amounts 25% of the total labour for grain production. In hybrid Sorghum 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 which is a need of a day to reduce the drudgery and time of operation. It also avoids the dependency on labour.

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

Materials and Methods

Three different varieties CSV-20, CSV-23 and CSH-9 of Sorghum planted on the experimental field at western block of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola was selected for the study. Stalks of physiologically matured plants were selected and the experiments were conducted 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 Year Book 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 average value.

The laboratory set up (Plate 1) of cutting mechanism was developed to measure force for cutting Sorghum stalks of three selected varieties at different combinations of various blade parameters. The blade selected for the experiment was plane blade having dimensions 230 X 60 X 10 mm.

Independent variables:

Varieties – 3(CSV-20, CSV-23 & CSH-9)

Blade bevel angles –3 levels (25º, 35º, 45º)

Blade rake angles – 3 levels (20º, 0º, -20º)

Blade velocity – 3 levels (350, 500, 650 rpm)

Dependent variables : Peak force

Replications : 3

Design : CRD

The laboratory set up has different components such as central shaft, rotating disc, torque sensor, 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 (Plate 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 were selected for the experiment. The experiment was planned on the same day to avoid the fluctuation in the moisture content of the stalk. Before feeding the stalks to the mechanism, the rotating 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 Sorghum stalks were fed to the machine with the help of 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.

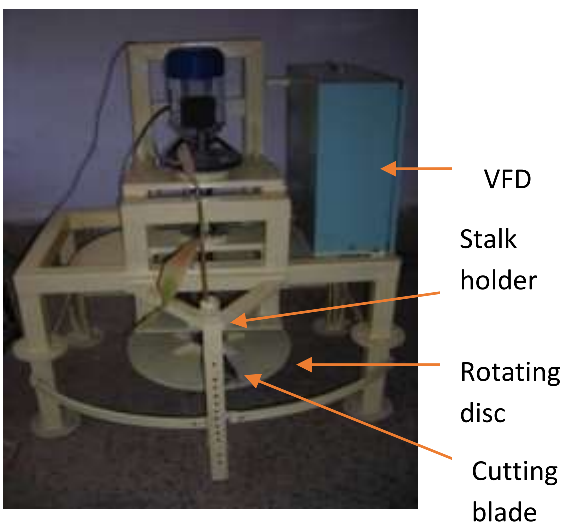

Plate 1 Laboratory set up

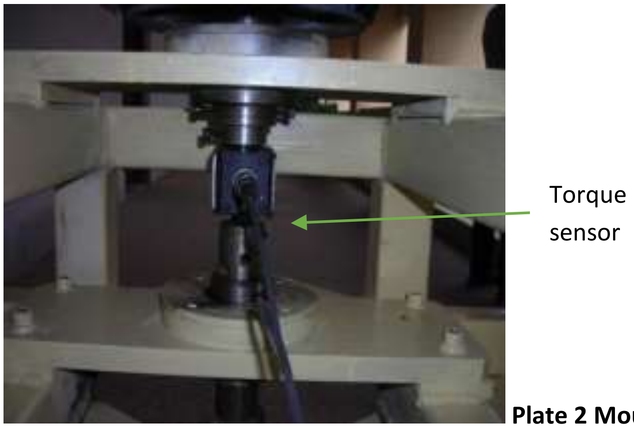

Plate 2 Mounting of Torque sensor

Results and Discussion

Effect of blade rake angle and blade velocity

As an effect of blade rake angle and blade velocity (Fig. 1) for the variety CSV-20, it was observed that the force for cutting stalk increases with increase in blade velocity from 350 to 650 rpm for 0˚ and -20˚ blade rake angles and decreases with increase in blade velocity for blade rake angle 20˚. However no significant difference was observed in mean values of force as an effect of velocity. When the variety CSV-23 was selected for experiment, the force increases with increase in blade velocity for cutting stalks with blade rake angles 0˚ and -20˚ whereas with blade rake angle 20˚, force increases slightly with increase in blade velocity from 350 to 500 rpm and significantly decreases with further increase in blade velocity from 500 to 650rpm. The significant difference was observed amongst the mean values of force as an effect of rake angles.

Similar trend of force as in case of variety CSV-20 was observed for hybrid variety CSH-9 for cutting the stalks. It was also observed that the force for cutting stalk increases with increase in blade velocity from 350 to 650 rpm for 0˚ and -20˚ blade rake angles and decreases with increase in blade velocity for blade rake angle 20˚. The mean value of force for cutting stalks of sorghum crop increases with increase in blade rake angle from 0˚to 20˚ and decreases with increase in blade rake angle from 20˚ to -20˚for all three varieties. The combination of 0˚ rake angle and velocity of 350 rpm required minimum force for all three varieties.

Effect of blade bevel angle and blade shear angle

The Table 1 revealed that the mean value of force 3.94N was observed for cutting the stalks of variety CSV-20 using plane blade with 25˚ bevel angle in combination of three shear angles 25˚, 30˚ and 35˚. It was also observed that the force for cutting stalk increases with increase in shear angles from 25˚ to 30˚ and then decreases with increase in shear angle from 30˚ to 35˚ for 25˚blade bevel angle whereas continuous decreasing trend was observed for the bevel angles of 35˚ and 45˚ as shear angle was increased from 25˚ to 35˚. However significant difference was observed in mean values of force as an effect of shear angles.

When the variety CSV-23 was considered, the mean value of forces 3.27, 4.57 and 2.89 N were recorded for cutting the stalks using plane blade of with 25˚, 35˚ and 45˚bevel angle in combination of three shear angles 25˚, 30˚ and

35˚ respectively. It was also observed that the force for cutting stalk increases with increase in shear angles from 25˚ to 30˚ and then decreases with increase in shear angle from 30˚ to 35˚ for 25˚ and 45˚ blade bevel angle whereas reverse trend was observed for the bevel angles of 35˚as shear angle was increased from 25˚ to 35˚. The table also shows the effect of blade bevel angle and rake angle for cutting the stalks of hybrid variety CSH-9. The mean value of force 1.84N was recorded with 25˚ bevel angle in combination of 25˚, 30˚ and 35˚ shear angles of blade. It was also observed that the force for cutting stalk increases with increase in shear angles from 25˚ to 30˚ and then decreases with increase in shear angle from 30˚ to 35˚ for 25˚ blade bevel angle whereas reverse trend was observed for the bevel angles of 35˚ and 45˚ as shear angle was increased from 25˚ to 35˚ However significant difference was observed in the value of force as an effect of shear angles for cutting stalks of sorghum variety CSH-9. The combination of 25˚bevel angle and 25˚ shear angle required minimum force for all three varieties.

Effect of blade rake angle and blade shear angle

The Table 5.20 revealed that the mean value of force 2.45N was observed for cutting the stalks of variety CSV-20 using plane blade with 0˚ rake angle in combination of three shear angles 25˚, 30˚ and 35˚.Howerver the mean value of forces 8.82 and 3.50N were recorded at the same shear angles with blade rake angles 20˚ and -20˚respectively. It was also observed that the force for cutting stalk increases continuously as the shear angle was increased from 25˚ to 35˚ for rake angle of 0˚ while the reverse trend was observed for the rake angle of 20˚. The value of force increased with increase in shear angles from 25˚ to 30˚ and then decreased with increase in shear angle from 30˚ to 35˚ for -20˚blade rake angle. When the variety CSV-23 was considered, the mean value of forces 2.34, 5.02 and 3.37N were recorded for cutting the stalks using plane blade of with 0˚, 20˚ and -20˚rake angle in combination of three shear angles 25˚, 30˚ and 35˚ respectively. It was also observed that the force for cutting stalk increases with increase in shear angles from 25˚ to 30˚ and then decreases with increase in shear angle from 30˚ to 35˚ for 0˚ rake angle. For 20˚rake angle the cutting force continuously decreased with increase in shear angles from 25˚ to 35 whereas reverse trend was observed for the rake angle of -20˚.

The table also shows the effect of blade rake angle and shear angle for cutting the stalks of hybrid variety CSH-9. The mean value of force 1.49N was recorded with 0˚ rake angle in combination of 25˚, 30˚ and 35˚ shear angles of blade. The mean value of force 3.44 and 1.78N were observed when blade rake angle was changed to 20˚ and -20˚ respectively. It was also observed that the force for cutting stalk decreases with increase in shear angles from 25˚ to 30˚ and then increases with increase in shear angle from 30˚ to 35˚ for 0˚ rake angle. For 20˚rake angle the cutting force continuously decreased with increase in shear angles from 25˚ to 35 whereas reverse trend was observed for the rake angle of -20˚.

The combination of 20˚ rake angle and 35˚ shear angle, 0˚ rake angle and 25˚ shear angle and -20˚ rake angle and 25˚ shear angle required minimum force for varieties CSV-20, CSV-23 and CSH-9 respectively.

Conclusions

1) The combination of 0˚ rake angle and velocity of 350 rpm required minimum force for all three varieties.

2) The combination of 25˚bevel angle and 25˚ shear angle required minimum force for all three varieties.

3) The combination of 20˚ rake angle and 35˚ shear angle, 0˚ rake angle and 25˚ shear angle and -20˚ rake angle and 25˚ shear angle required minimum force for varieties CSV-20, CSV-23 and CSH-9 respectively.

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