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Effect of Blade and Operational Parameters on Shredding Efficiency of an Experimental Cotton Stalk Shredder

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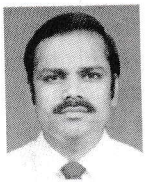

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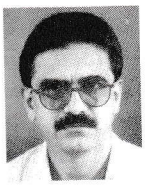

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Abstract

The influence of the selected level of variables of three levels of blades (viz. 2, 3 and 4), four levels of peripheral velocity (viz. 21.52, 23.80, 26.58 and 28.60 ms^{-1}), three levels of blade thickness (viz. 2, 4 and 6 mm) and four levels of blade rake angle (viz. 0, 15, 30 and 45 deg) on shredding efficiency of an experimental cotton stalk shredder, in terms of length of cut of cotton stalk, was investigated. Increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The lowest value of length of cut was 113.83 mm with 2 blades, 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity. At 0 deg blade rake angle, the length of cut of shredded cotton stalk was much lower than other blade rake angles at 6 mm blade thickness. Increase in number of blades from 2 to 4 resulted in increased length of cut for all the levels of blade rake angle. Increase in blade rake angle from 0 to 45 deg resulted in increased length of cut for all levels of peripheral velocity and number of blades. Two blades with 0° blade rake angle, 6 mm blade thickness and 28.60 ms^{-1} peripheral velocity recorded the lowest value of length of cut.

Introduction

One of the difficulties in cotton production is the need to clear the ground from old cotton plants after harvesting. Only manual uprooting or cutting the stalks are followed, which is highly labour intensive. Some farmers used repeated heavy disking to cut the cotton stalk and cover it with soil. Incorporation of cotton stalks into the soil ensures rapid decomposition. The most rapid decomposition occurs when residue is placed 10 cm deep. Shredding stalks as finely as possible also allows for rapid decomposition. Hence, the type of shredding mechanism should be selected based on the efficiency in terms of finished dimensions of the stalk required for incorporation in the soil to facilitate quick decomposition. A rotary cutter is an implement in the mechanization chain of crop production. After harvesting the crop, these machines cut the stalk and distribute them on the field surface. The rotary cutter consists of blades pivoted horizontally on a vertical shaft and moves forward on the field. Rotary

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cutters are generally used in shredding crop stalks. They are simple and sturdy in construction, with less wearing parts and, therefore, the frictional power loss is minimum (Guzel and Zeren, 1990). Hence, an impact type rotary blade shredder was selected for investigation.

Review of Literature

Guzel and Zeren (1990) suggested that a rotary cutter is an implement in the mechanization chain of cotton production. After harvesting the cotton, these machines cut the cotton stalk and distribute them on the field surface. Rider and Barr (1976) reported that the uniformity of cut and cutting efficiency depended upon the shape of the rotating knives. Specially shaped knives were used in forage harvesters. The number of knives, for a given cutter head diameter, determined the amount of space between knives for material to flow in and out during the operation. The cutting angle was an important design factor in the knife shape. The cutting angle was defined as the angle between the beveled edge of the knife, which needed the crop entering the cutter head, and inside the surface of the knife. A smaller cutting angle provided a more uniform cut, but a larger angle increased knife strength. A compromise angle of 30 to 45 deg is commonly used.

Chattopadhyay and Pandey (1999) suggested that the minimum cutting speed increased from 12.9 to 18.0 ms^{-1} for a knife rake angle of 20 to 60 deg. O'Dogherty (1982) stated that the specific energy was inversely proportional to the mean chop length; or the power required to cut forage material was inversely proportional to chop length for a given machine throughput. High energy consumption will result in short crop lengths.

Materials and Methods

The efficiency of a shredder is the ability to cut the crops/straw/stalk into very small pieces. The impact type rotary cutter performance depends mainly on the design of rotating blades. Many factors are involved in rotary cutter design. The most significant features of the rotating blades are number of blades, peripheral velocity, thickness and rake angle. It is evident that the variables (viz. number of blades, velocity of blade, blade thickness and rake angle) have a profound effect on the shredding efficiency in terms of finished dimensions of shredded pieces. For achieving maximum shredding efficiency of cotton stalks the following variables were selected for the investigation.

1. Number of blades
2. Peripheral velocity
3. Blade thickness
4. Rake angle

The performance of the shredder is assumed to be optimum when the cutting and shredding of the stalks results in small pieces.

Effect of Selected Levels of Variables on Length of Cut

A total number of 432 experiments were conducted using the experimental set up. The investigation was carried out with three levels of number of blades (viz. 2, 3 and 4), four levels of peripheral velocity (viz. 21.52, 23.80, 26.58 and 28.60 ms^{-1}), three levels of blade thickness (viz. 2, 4 and 6 mm) and four levels of blade rake angle (viz. 0, 15, 30 and 45 deg). The moisture content of the cotton stalks was maintained constant (95.30 percent dry basis) throughout all experiments. The values of finished dimensions of cotton stalks in terms of length of cut were recorded for all treatments. The effect of selected levels of variables on finished dimensions of the cotton stalk in terms of length of cut was analyzed.

Results and Discussion

Effect of Selected Variables on Length of Cut

Effect of Peripheral Velocity on Length of Cut for 2 Mm Thickness (T_1)

The relationship between the length of cut and the peripheral velocity for the 2 mm blade thickness for different levels of blade rake angle and number of blades is depicted in **Fig. 1**.

An increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The above result was in conformity with the findings of Manjeet Singh *et al.* (1998). The lowest value of length of cut was observed at the shredder with 2 (N_1) blades and 28.60 ms^{-1} (S_4) peripheral velocity.

Effect of Peripheral Velocity on Length of Cut at 4 Mm Thickness (T_2)

An increase in peripheral velocity from S_1 to S_4 resulted in decreased length of cut for 2, 3 and 4 blades (**Fig. 2**).

Effect of Peripheral Velocity on Length of Cut at 6 Mm Blade Thickness (T_3)

An increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The above result was in conformity with the findings of Manjeet Singh *et al.* (1998). The lowest value of length of cut of 113.83 mm was at the shredder with 2 blades, 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity (**Fig. 3**).

A 0 deg blade rake angle and S_4 level of peripheral velocity combination recorded lowest value of length of cut when compared with other combinations. In the case of number of blades, 2 blades with 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity recorded lowest value of length of cut. Increase in blade rake angle from 0 to 45 deg resulted in increased length of cut for all the levels of peripheral velocity and number of blades.

Statistical Analysis and Mathematical Modeling

The analysis of variance for the torque requirement to shred the cotton stalk is furnished in **Table 1**. All the interaction effects were significant at the one percent level.

Regression Equation for Length of Cut

The multiple linear regression equation fitted for the length of cut in shredding cotton stalk is given below.

$$Y = 252.070 + 8.341^{**} X_1 - 0.1^{**} X_2 - 3.6^{**} X_3 + 1.507^{**} X_4$$

$$R^2 = 0.71^{**}$$

$$R^2 \text{ (adjusted for DF)} = 0.70^{**}$$

** Significant at 1 percent level

The R-square value of 0.71 was significant at the one percent level of probability, which showed that a unit increase in X_1 (number of blades) ceteris paribus would result in an increase of 8.341 units of Y, a unit increase in X_2 (peripheral velocity) ceteris paribus would result in decrease of 0.1 units of Y, a unit increase in X_3 (blade thickness) ceteris paribus would result in decrease of 3.6 units of Y, where as a unit

Fig. 1 Effect of peripheral velocity on Length of cut at 2 mm blade thickness (T_1)

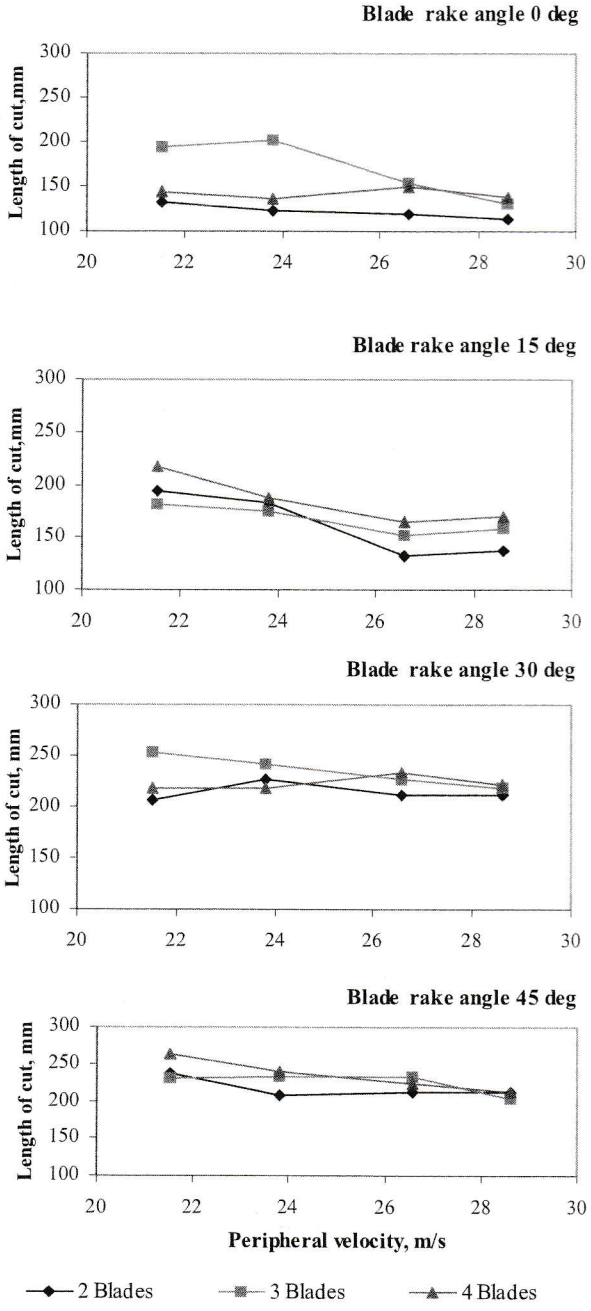
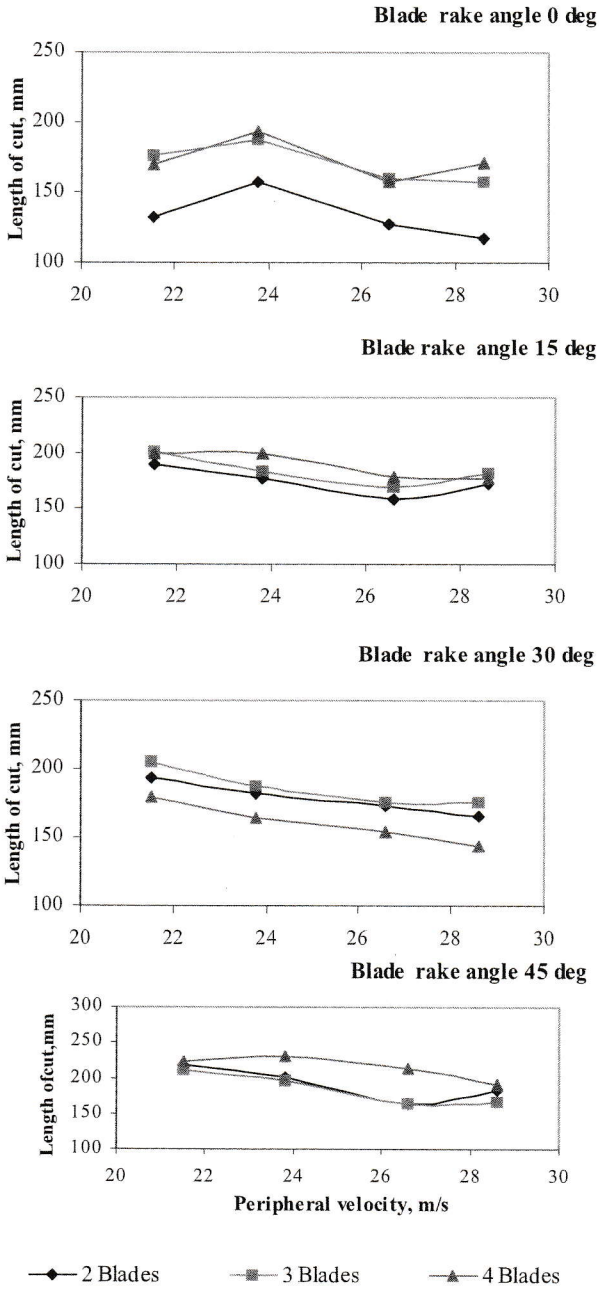


Fig. 2 Effect of peripheral velocity on length of cut at 4 mm blade thickness (T_2)



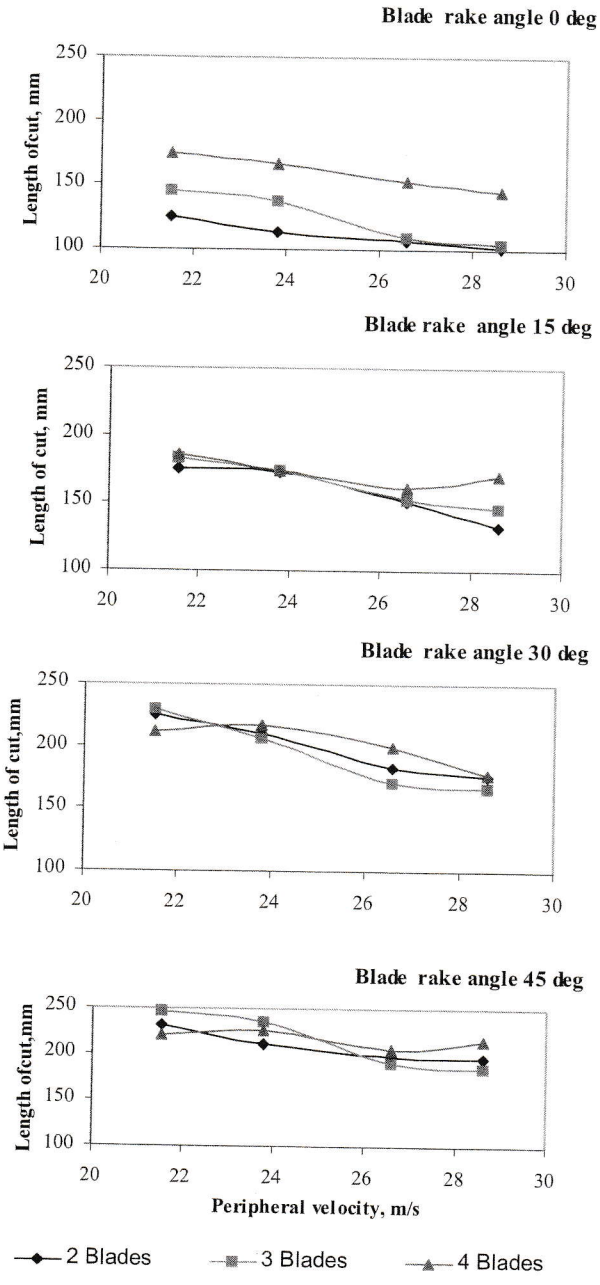
increase in X_4 (blade rake angle) ceteris paribus would result in an increase of 1.507 units of Y.

Optimization of Variables for Cotton Stalk Shredder

The selected level of variables have to be optimized for achieving the maximum shredding efficiency reflected in terms of minimum length of cut of shredded cotton stalk. The lowest mean values of torque, energy required to shred cotton stalk and length of cut for different interaction of the selected level of variables are analyzed.

It was observed that the combination of $N_1S_4T_3\theta_1$ resulted in the lowest length of cut of shredded cotton stalk of 101.00 mm.

Fig. 3 Effect of peripheral velocity on Length of cut at 6 mm blade thickness (T_3)



Conclusions

Influence of the selected level of variables on shredding efficiency in terms of length of cut of shredded cotton stalk was investigated. Increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The lowest value of length of cut of 113.83 mm was observed at the shredder with 2 blades, 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity. At 0 deg blade rake angle, the length of cut of shredded cotton stalk was much lower than other blade rake angles at 6 mm blade thickness. Increase in number of blades from 2 to 4 resulted in increased length of cut for all the levels of blade rake angle. Increase in blade rake angle from 0 to 45 deg resulted in increased length of cut for all the levels of peripheral velocity and number of blades. For achieving maximum shredding efficiency, the combination of 2 blades, 28.60 ms peripheral velocity, 6 mm blade thickness and 0 deg blade rake angle was selected.

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