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Paddy Stems Cutting Energy and Suggested Blade Optimum Parameters

Tabatabaee Koloor Reza
Department of Agricultural Machinery, Complex of Agricultural Sciences and Natural Resources,
University of Mazandaran, P.O. Box 578, Sari, Iran

Abstract: A pendulum type impact shear test apparatus was designed and constructed to measure the energy required for cutting paddy stem. Experiments were carried out to determine the optimum values of blade bevel angle, oblique angle, tilt angle and blade cutting velocity for cutting paddy stem of Sepidrood variety. The results show that blade bevel angle of 28°, oblique angle of 30°, tilt angle of 35° and blade velocity of 2.24 m sec^{-1} are optimum.

Key words: Cutting energy, bevel angle, oblique angle, tilt angle, blade velocity

INTRODUCTION

Measurement of cutting energy is considered to be an important criterion for comparing the effectiveness of any cutting system. The principle of operation of the cutting element employed in any harvesting tool or equipment can be broadly classified under two categories, (1) cutting by impact and (2) cutting by a counter- edge.

Swinging type manually operated tools like long-bladed hoe, cradle, scythe and power-operated rotary harvesters are some such devices were crops are severed by impact.

Researchers, in general, agree that in impact cutting the energy consumed to overcome the shearing resistance of the stem is equal to the energy required for quasi-static cutting plus the energy expended in overcoming friction. Chattopadhyay and Pandey (1999) investigated the mechanical properties of sorghum stem. They found that the specific cutting energy increased from 34.1 to 101.1 mJ mm^{-2} at the forage stage and from 36.5 to 142.7 mJ mm^{-2} at the seed stage when bevel angle was increased from 30 to 70°. Ryvkin and Nuller (1994) developed a 3D model for the cutting of cellular elastic materials by a rigid triangular cutter. They modified the numerical model with the experimental data and suggested optimum values for blade different parameters. Rajput and Bhole (1973) reported that force and energy requirements in impact cutting of paddy were lowest with a 30° blade bevel angle. Visvanathan *et al*. (1996) suggested that the specific cutting energy of the tuber was a minimum for cutting velocities in the region of 2.5 m sec^{-1}, shear angles of 60 to 75° and bevel angles of 30 to 45°. Summers *et al*. (2002) found that cutting energy per stem decreased as the number of stems cut increased. Also results were compared against field measurements of operating sickle cutters used for on-combine stubble cutting. Theoretical power required for cutting the stems amounts to only 5-15% of total cutter power do to other factors relating to increased machine friction and cutting force.

The purpose of this study was to determine various optimum blade parameters which might be helpful in determining design parameters for a rice harvester.

MATERIALS AND METHODS

Apparatus: A pendulum impact shear test apparatus (Fig. 1) was used in this study. A cutting blade is attached to the end of the pendulum arm and this arm is dropped from various heights by releasing a spring loaded lock. The cutting is performed when the blade is in its lowest position. A pointer is connected to the end of the shaft and indicates the position of the swinging arm on a round scale divided into degrees. To obtain different cutting velocities of the blade, the pendulum arm was released from different angular positions. Stems positioned in the wooden stem holder directly beneath the lowest position of the blade.

Terminology: Blade bevel angle is the angle of the bevel edge of the blade. The blade may be beveled on one side or both sides.

Blade oblique angle is the angle the edge of the blade makes with the normal to the direction of the motion of the blade.

Blade tilt angle is the angle the plane of cut makes with the longitudinal axis of the stalk.

Energy required for cutting: When the pendulum arm is in the equilibrium position the potential energy is zero. But when it is raised to an angle, θ with the equilibrium position, the potential energy stored is given by;

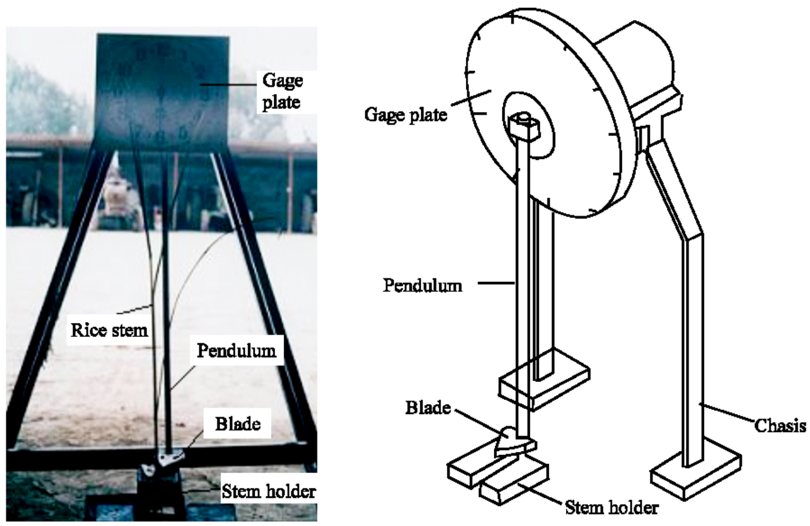

Fig. 1: Impact cutting tester

$$E_s = W_t R(1-\cos\theta) \quad (1)$$

If the pendulum arm is released from θ, in the absence of cutting, moves through an angle θ_o on the other side of the equilibrium position. Then the energy lost due to friction and air resistance by the pendulum will be:

$$E_f = W_t R[(1-\cos\theta)-(1-\cos\theta_o)]$$
$$E_f = W_t R(\cos\theta_o - \cos\theta) \quad (2)$$

When a blade is attached to the pendulum arm it will cut the stem and move through an angle, θ_c on the upswing after cutting. The energy utilized in cutting the stem E_c, is the difference between the initial potential energy, E_s and the potential energy available in the pendulum arm after cutting, E_o and the energy lost in friction and air resistance, E_f. This is expressed as:

$$E_c = E_s - (E_f + E_o)$$
$$E_c = W_t R(\cos\theta_c - \cos\theta_o) \quad (3)$$

The velocity of the blade at the equilibrium position was calculated by equating potential energy and rotational kinetic energy as given below:

$$W_t R(1-\cos\theta) = \frac{1}{2} I\omega^2 \quad (4)$$

If L is the distance between the center of the blade and axis of the rotation, the peripheral velocity of the cutting blade, V_c at its lowest position is given by:

$$V_c = \omega L = \sqrt{\frac{2W_t R(1-\cos\theta)}{I}}L \quad (5)$$

Experimental techniques: The experiments were conducted on Iranian local variety of Sepidrood grown in experimental field of Agricultural Faculty in August 2006 in Sari, Iran. Samples of the stem were cut from the ground level and brought to the laboratory in sealed plastic bags and were tested on the day of harvesting. Moisture content of the stem was determined by drying samples in an oven at 80°C for 24 h and was expressed on a wet basis. The blade bevel angles were 18, 23, 28, 33 and 38°. The various tilt angles selected for the study were 15, 25, 35, 45 and 55°. Five different oblique angles were 10, 20, 30, 40 and 50°. The cutting velocities used in the experiments were 1.6, 2.24, 2.67 and 3.2 m sec^{-1}. As the size of stem varies, the cutting energy was calculated per unit area of the cut stem measured over the cutting plane and express as specific cutting energy. In all cases the cross-sectional area of the cut stem was determined by a micrometer. All the experiments were replicated three times and the averages of the calculated specific cutting energy are reported.

RESULTS AND DISCUSSION

In this study, experiments were conducted on different blade parameters such as, blade velocity, blade bevel angle, blade oblique angle and tilt angle.

Figure 2 shows measurements for specific cutting energy at different blade velocity, blade bevel angle, blade oblique angle and blade tilt angle. The minimum value of specific cutting energy for each parameter is the optimum value that we can use in our harvester cutting mechanism design.

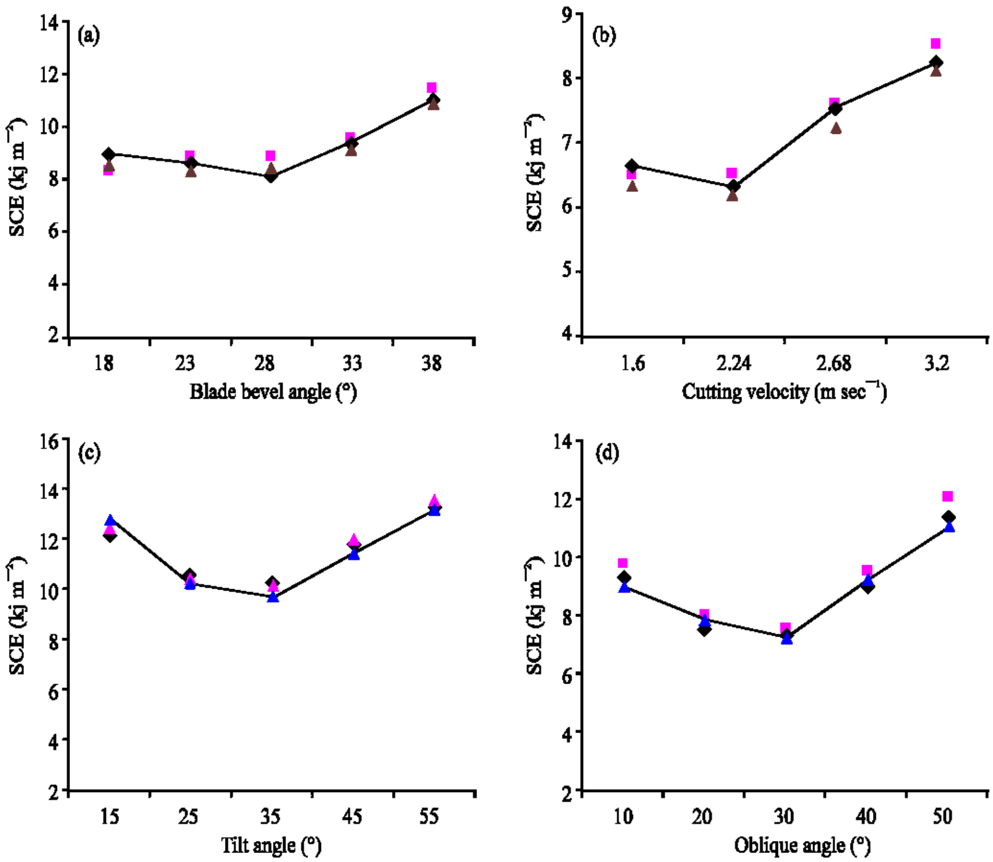

Fig. 2: Effects of blade velocity, bevel angle, tilt angle and oblique angle on Specific Cutting Energy (SCE). (a) Blade velocity of 2.24 m sec^{-1}; oblique angle of 30°; tilt angle of 35° (b) Bevel angle of 28°; oblique angle of 30°; tilt angle of 35° (c) Blade velocity of 2.24 m sec^{-1}; bevel angle of 28°; oblique angle of 30° and (d) Blade velocity of 2.24 m sec^{-1}; bevel angle of 28°; tilt angle of 35°. Figure signs indicate replications for each data

Effect of bevel angle: In Fig. 2a the extreme values encountered in the replications are shown by vertical points. The results show that cutting energy per unit area is a minimum for 28° bevel angle. It decreases from 18° to 28° and then increases only after the angle exceeds 28°. The energy requirements is a result of interaction among frictional, compression and shear forces. With less bevel angle, the frictional forces are more, as the sliding surface on the bevel edge is increased. The energy loss in friction is less when the slope of blade bevel angle approaches the static frictional angle. The static friction angle of rice stem and blade material is expected to vary from 25 to 30° and hence the energy requirement is a minimum at about 28°. For a bevel angle more than 28°, blade requires more force to penetrate through the hard outer layer of the stem and thereby increasing energy requirement. This is similar to results of Prasad and Gupta who found that an angle of 24° was the most efficient and small bevel angles resulted in rapid wear and dulling.

Effect of oblique angle: It is evident from the Fig. 2d that specific cutting energy decreased with increase in oblique angle and it is a minimum at 30°. The increase in cutting energy for small approach angles is explained by the greater wedging action of the blade edge. When the blade approach angle is higher, sliding occurs which in turn decreases the impact effect of the blade and hence energy requirement is increased.

Effect of tilt angle: Figure 2c shows that the specific cutting energy was a minimum for a tilt angle range of about 25 to 35°. As the tilt angle decreases from 55 to 35°, area of stem being cut increases, thereby decreasing the cutting energy per unit area. This effect is prevalent as long as the energy lost in overcoming friction between blade surface and stem material is not pronounced. According to Fig. 2c an angle of about 35° is optimum. This revealed that as the tilt angle was further decreased beyond 35°, the frictional forces became significant resulting in increased specific cutting energy.

Effect of cutting velocity: The specific cutting energy was a minimum at a velocity about 2.24 m sec^{-1}. It increased at a blade velocity less than 2.24 m sec^{-1} and increased sharply when the velocity was increased beyond it (Fig. 2b). This may happen due to the fact that at lower velocities, impact is too less to sufficiently fail the stem and hence energy requirement is increased. At the higher velocities, the increase in the specific cutting energy may be owing to the kinetic energy imparted by the pendulum to the separated parts of the stem after cutting.

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REFERENCES

Chattopadhyay, P.S. and K.P. Pandey, 1999. Mechanical properties of sorghum stalk in relation to deformation. J. Agric. Eng. Res., 73: 199-206.

Rajput, D.S. and N.G. Bhole, 1973. Static and dynamic shear properties of paddy stem. The Harvester, 4: 17-21.

Ryvkin, M. and B. Nuller, 1994. A model of cutting cellular elastic materials. Int. J. Fracture, 67: 325-342.

Summers, M.D., B.M. Jenkins and M.W. Yore, 2002. Cutting properties of rice straw. Paper No. 026154. An ASAE Meeting Presentation.

Visvanathan, R., V.V. Sreenarayanan and K.R. Swaminathan, 1996. Effect of knife bevel angle and velocity on the energy required to cut cassava tubers. J. Agric. Eng. Res., 64: 99-102.