International Journal of Agricultural
Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 7, Issue 5, Oct 2017, 227-242

PERFORMANCE EVALUATION AND MODIFICATION OF SHREDDER CUTTING MECHANISM

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ABSTRACT

In order to aid in engineering design and modification of cutting mechanism in shredders, and to investigate the effect of parameter on cutting energy, an impact type pendulum test rig was used to measure the energy required for cutting the plant stems. A total number of 324 experiments were carried out on KC$_1$ cotton variety, in different thickness viz., 6 (T_1), 8 (T_2) and 10 (T_3) mm, approach angle viz., 0 (φ_1), 15 (φ_2), and 30 (φ_3) deg, shear angle viz., 0 (θ_1), 15 (θ_2) and 20 (θ_3) deg and bevel angle of cutter blade viz., 23 (α_1), 25 (α_2), 28 (α_3) and 30 deg (α_4). The results show that the optimum value of Specific Cutting Energy (SCE) 178.04 J was obtained, at treatment combination level of $\alpha_2 \times T_3 \times \theta_1 \times \varphi_2$, respectively. The optimized treatment combination has been selected, for modifying the cutting mechanism of selected shredder. The modified shredder, evaluated in actual field condition resulted in saving 37.5 and 82 percent cost and time, when compared with conventional method of crop residue removal, from agricultural field.

***KEYWORDS:** Angle of Cutting, Pendulum Test Rig, Field Efficiency & Shredding Efficiency*

Received: Jul 24, 2017; **Accepted**: Aug 12, 2017; **Published**: Sep 19, 2017; **Paper Id**.: IJASROCT201728

Original Article

INTRODUCTION

Govt. Of India estimates, approximately 500 Mt of crop residues are generated every year (MNRE, 2009). According to different estimates, 72 Mt–127 Mt of crop residues are burnt on-farm (Mehta, 2004; Pathak *et al.*, 2006; Pathak *et al.*, 2010). Burning residues leads to a plethora of problems, such as the release of soot particles and smoke causing human health problems, emission of greenhouse gases, such as carbon dioxide, methane and nitrous oxide adding to global warming and loss of plant nutrients, such as N, P, K and S. Niveta Jain *et al (*2014) reported burning of 98.4 Mt crop residues emitted 8.57 Mt of CO, 141.15 Mt of CO2, 0.037 Mt of SOx, 0.23 Mt of NOx, 0.12 Mt of NH3 and 1.46 Mt NMVOC, 0.65 Mt of NMHC, 1.21 Mt of particulate matter, during the year 2008–09. Instated of burning, retention on of crop residues on field surface, which help to conserve moisture, nutrients and controlling weeds in addition to moderating soil temperature. Rajendra Reddy *et al.* (2002) conducted a study, to find out the effect of crop residues and tillage operations, on the physico- chemical and microbial properties of soil and the crop performance. It was found that, the incorporation of crop residue like wheat straw about 5 t ha^{-1} resulted in improved soil physical characteristics (bulk density decreased from 1.29 to 1.26 mg m^{-3}, infiltration rate and hydraulic conductivity increased from 2.42 to 2.86 cm hr^{-1}), along with increased nutrient status (available nitrogen increased from 160.9 to 221.2 kg ha^{-1}, phosphorous increased from 16.2 to 21.2 kg ha^{-1}and potassium increased from 320.8 to 429.8 kg ha^{-1}).In India, mostly the plants are removed by manual pulling or cutting by sickle, up to the height of 50 to 75 mm above the ground surface and burnt later. Non-availability of labor, troubles of mechanization and high cost of residue removal from the field crops, are some of main reasons behind burning of crop residues. Shredders are most commonly used, for removing the crop residues from agricultural field. Shredding of crop can be performed in a short span of time, which is of great advantage, especially in the early decomposition of the crop residue in field, to increase soil nutrient content. The performance of each shredder differs depending on many factors *viz,.* thickness of cutter blade, bevel angle, shear angle, approach angle of cutter blade, peripheral velocity of cutter blade and forward speed of operation. Design a new shredder, or modification of the cutting mechanisms of shredder needs new engineering data, on the cutting properties of crop stem. Determination of specific cutting energy, is considered to be an important criterion for comparing the effectiveness of any cutting system. Prasad and Gupta (1975), investigated the mechanical properties of maize stalk, as related to harvesting in a pendulum impact test apparatus. They reported that, the specific cutting force for maize stalk was 6.3 N mm^{-1}, while studying the rheological properties of maize stalk under transverse loading, they found that, the optimal value of 23 deg for the bevel angle and 55 deg for shear angle and 2.65 m s^{-1} for cutting velocity. The minimum cutting energy was 17 MJ $mm^{-2,}$ for maize stalk, at 73.6 percent moisture content on a wet basis. Persson (1987) reported that, impact on cutting the energy consumed to overcome the shearing resistance of the stem, is equal to the energy required for quasi-statics cutting, plus the energy expended in overcoming friction. Imbabi (1992) found that, the energy requirements for cutting the sesame plants ranged from 4.32 to 27.03 Joule $stem^{-1}$, according to the moisture content of stems, while the cutting force ranged from 432.14 to 1351.31 N $stem^{-1}$, according to the moisture content of stems. The energy required for the cutting unit of stalk cutter, may be categorized as: friction in the moving parts of the machine and air friction; kinetic energy required to accelerate the chopped material; energy required to overcome friction of the chopped material, against the stationary parts of machine; and energy required to cut the stalk (O'Dogherty *et al.,* 1995; Chattopadhyay and Pandey, 1999).The cutting strength of the plant stem, and effective parameters on cutting energy have been reported by many researchers, such as rice (Lee and and Huh 1984), wheat (Hoseinzadeh et al., 2009; Esehaghbeygi et al., 2009; Muller, 1988), barely (Tavakoli et al., 2009), potato vines (Godesa, 2004), soya bean (Mesquita and Hanna, 1995) and alfalfa (Nazari Galedar et al., 2008). Reza (2007) designed and constructed a pendulum type impact shear test apparatus, for measuring the energy required for cutting paddy stem, and optimized the blade optimum parameters. The optimized blade parameters were 28 deg blade bevel angle, 30 deg oblique angle (approach angle), 35 deg tilt angle (shear angle) and 2.24 ms^{-1} peripheral velocity of blade. Yumnam Jekendra and Pratap Singh (1991) concluded that, the rake angle (approach angle) of 10 to 20 deg and operating speed between 25 to 35 ms^{-1}, gives an optimum cutting energy requirement for forage chopping. O 'Dogherty and Gale (1986), investigated the effect of blade parameters on the dynamics of cutting grass. They have used blade thickness of 1 to 3 mm, in blunt condition. The results showed that, below the critical speed (35 ms^{-1}) both cutting time and distance were significantly less, for the 1 mm blade than for the 2 and 3 mm blades. Vagadia *et al.* (2004) developed an agricultural waste shredder, with the size of blade of 362×80×11 mm. One side of the blade was sharpened and the edge was made 30 deg beveled, for smooth cutting. Senthilkumar (2004) developed a cotton stalk shredder, cum in situ applicator, with the combination of 2 number of blades, 28.60 ms^{-1} peripheral velocity, 6 mm blade thickness (model) and 0 deg rake angle was selected, for experimental cotton stalk shredder for prototype 2 number of blades, 0 deg rake angle and 12 mm blade thickness was selected. Morad and Fouda (2009) reported that, the forward speeds between 4 to 5.5 km h^{-1}, 2.8 to 4.8 km h^{-1} and 2.1 to 3.2 km h^{-1} were recommended for removing rice straw, cotton stalks and sunflower stalks, respectively. Maughan *et al.* (2012) investigated the impact of cutting speed, blade type, and blade angle on miscanthus harvesting energy requirement. The cutting energy was determined at three cutting speeds (31.5, 47.3 and 63.0 m s^{-1}), three oblique angles (approach angle) (0, 30 and 40 deg) and two blade fixtures (fixed, flexible). The differences between the blade fixtures were found to be negligible. A 40 deg oblique angle, operating at 31.5 ms^{-1} had the lowest energy consumption, averaging 9.1MJ ha^{-1}.

Information on physical and mechanical characteristics of plant, and the power or energy requirement of equipment, has been very valuable for selecting a design and operational parameters of the equipment Persson, (1987). Such information is needed, for the design of shredding and other agricultural machineries, assuring appropriate machine functions and an efficient use of energy.

The specific objectives of the present study were,

- To study the effect of blade parameters and to determine their optimum values for modification of the cutting mechanism.
- To investigate the shredding efficiency of modified shredder based on optimized values.

MATERIALS AND METHODS

The efficiency of shredder is the ability to cut the crop stalk into very small pieces. The impact type rotary cutter performance, mainly depends on the design of cutting mechanism of rotating blades. Many factors were involved in the design of rotary cutter blades. The most significant features of the rotating blades are, thickness of cutter blade, bevel angle, shear angle, approach angle of cutter blade, peripheral velocity of cutter blade and forward speed of operation. For achieving maximum shredding efficiency of crop stalks, the following variables were selected for the investigation.

- Bevel angle of cutter blade
- Shear angle of cutter blade
- Approach angle of cutter blade
- Thickness of cutter blade

A total number of 324 experiments were conducted, in Department of farm power and machinery, AEC&RI, Tamil Nadu agricultural University, Coimbatore, by using the impact type pendulum test rig, as shown in Plate 1. The KC_1 (H) variety cotton stem was selected, for the entire laboratory experiment. The investigation was carried out, with four levels of bevel angle viz., 23, 25, 28 and 30 deg, three levels of approach angle 0, 15, and 30 deg, three levels of shear angle 0, 15, and 20 deg, and three levels of thickness of the cutter blade 6 mm, 8 mm and 10 mm, respectively. The moisture content of cotton stalk was maintained constant (42 to 53.23 per cent in dry basis) throughout all experiments. The specific cutting energy for selected cotton stem was recorded, during the lab investigation. The effect of selected levels of variables, for the evaluation parameters was analyzed using a completely randomized design.

Principle of Operation of Pendulum Test Rig

The working principle of impact, type pendulum test rig, where a long swing arm suspended at its top end and has a blade fixed at the lower end is made to oscillate, in a vertical plane. It is normally displaced to one side of the equilibrium position, by an angular deflection ‘θ’. By the principle of conservation of energy, the swing arm, when released is expected to oscillate to the other side of equilibrium line, and deflection through an angle ‘θ’. There is a continuous exchange of energy of the swing arm, from maximum potential energy (when the arm is at its extreme upswing position before it is released to swing down) to maximum kinetic energy (when the swing arm is at the equilibrium line). The material to be cut is normally placed at the point of maximum kinetic energy, of the swinging arm and held by a material holder. When the swing arm is released, it gains speed till it contacts, and cuts the material placed in the path of the blade (koloor and Kiani, 2007; Johnson *et al.*, 2012; Yiljep and Mohammed, 200).

Cutting Energy Calculation

The cutting energy of the stem was determined, by the difference between θ and θ_0. Expressions for determining cutting energy requirement and peripheral knife speed, were given as stated by Prasad and Gupta (1975). The following formula has been used, for calculating specific cutting energy during the experiment.

$$E = M\,g\,R\,(\cos\theta_0 - \cos\theta) \qquad (1)$$

Where,

E = Energy utilized for cutting the pendulum, Joules

M = Mass of the pendulum, (kg)

R = Distance between the center of rotation and the center of gravity of the pendulum arm, m

θ_0 = Maximum angle of deflection on the pendulum frame from vertical after cutting the specimen, (deg)

θ = Maximum angle of deflection of the pendulum from vertical at the end of free swing, (deg)

Optimization of Variables

The selected levels of a variable have optimized, with respect to minimum specific cutting energy, for modification of the cutting mechanisms of selected shredder. The quality of cut was done by selecting treatment combination, as shown in Plate 1.

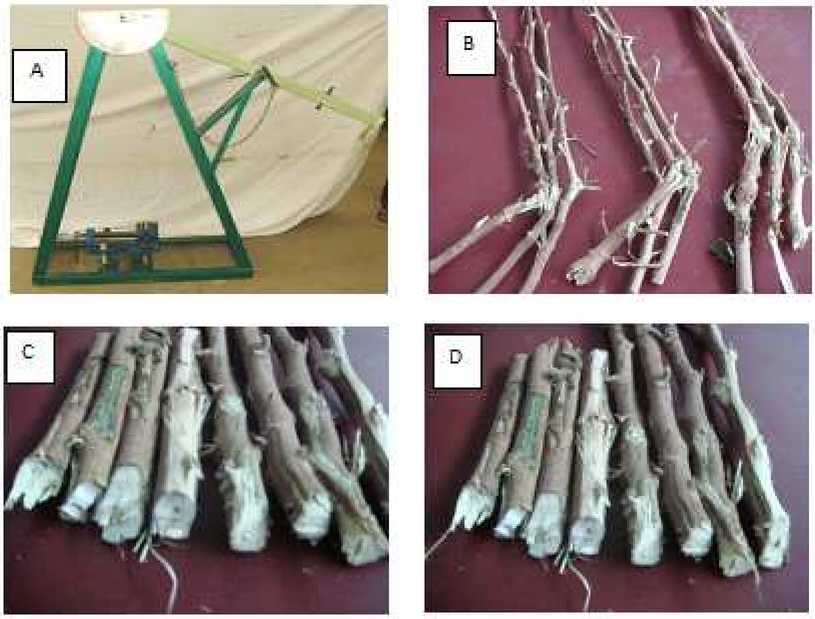
Modification of Cutting Mechanism of Shredder

The optimized value has been used, for modification of the cutting mechanisms of selected shredder. Hence, the tractor had been chosen, as the prime mover for work and the modified Shredder. It has been proposed to mount on the rear of the tractor, to complete the shredding operation. The schematic drawing of the tractor operated, modified Shredder and internal components of shredder, as shown in Figure 1 and Plate 2. The technical specifications of tractor operated modified shredder, as furnished in Table 1.

Table 1: Technical Specifications of Modified Shredder

SI. No	Item	Values
A	Prime mover	45 hp tractor
B	Over all dimensions (L×B×H), mm	1400 × 1340× 840
C	**Cutter blade**	
i.	Type of cutter	Rotary impact type
Ii	Number of cutter blades	6
Iii	Bevel angle of cutter blade, deg	25
Iv	Shear angle of cutter blade, deg	0
v.	Approach angle of cutter blade, deg	15
Vi	Thickness of cutter blade, mm	10
Vii	Rotary speed of cutter blade m s^{-1}	27.8
viii	Forward speed of operation km h^{-1}	2
D	Type of power drive	PTO

E	Power transmission for cuter blade	Through gear box



Plated 1: A = Impact Type Pendulum Test Rig, B Indicates Improper Cut and Indicates Proper Cut by Selected Treatment Combination

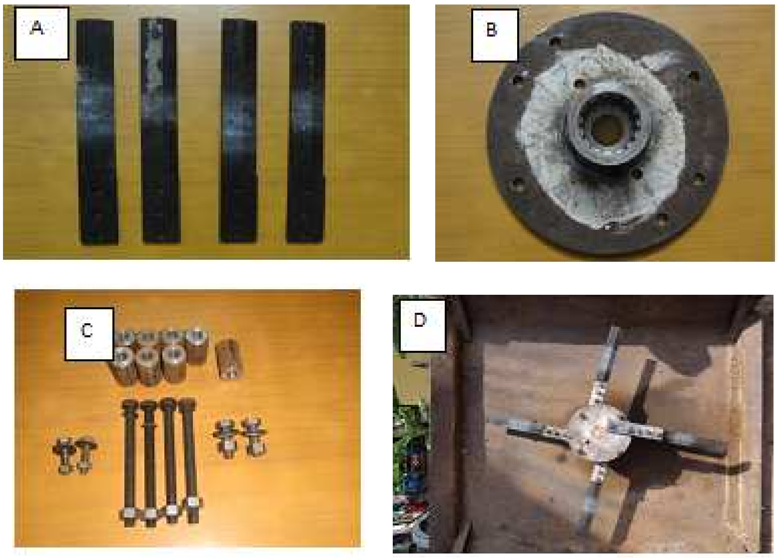


Plate 2: Internal Components of Modified Shredder (A= Cutting Knife, B= Circular Disc C= Bush, Nut and Bolt D= Cutting Knife Assembly

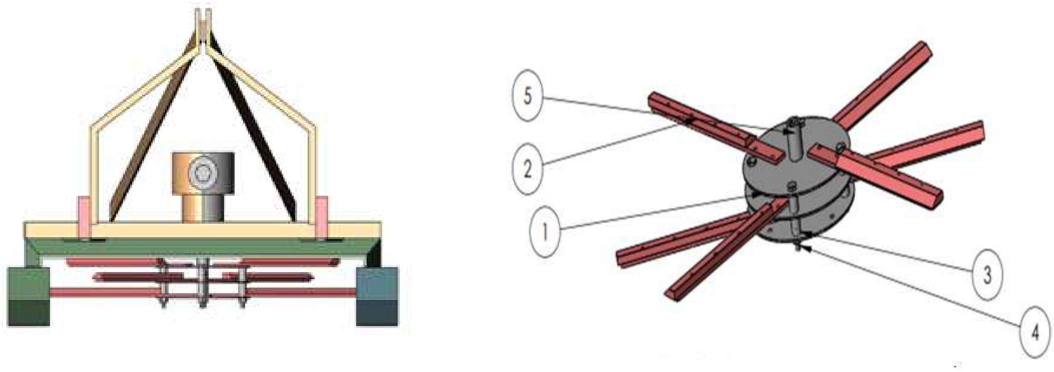


Figure 1: Modified Shredder Based on Optimized Values

Components of Shredding Assembly

ITEM NO.	DESCRIPTION	QTY.
1	Circular Disc - Made up of MS Plates	3
2	Cutter Blade - Made up of Soring Steel	6
3	Bush - Made up of MS	8
4	Bolt and Nuts - Made up of MS	4
5	Input Shaft - Made up of EN8	1

Figure 2: Blade Assembly of prototype

Performance Evaluation of Modified Tractor Operated Shredder

The **modified tractor operated shredder** was evaluated in actual field condition, in terms of shredding efficiency, field capacity and cost of operation. After the completion of shredding, the sample had been collected randomly, in shredded field. The collected samples have been measured by different scale level (referred to Luis et.al, 1993; Church 1991) , according to their length *viz.,* 0 -5 cm, 5-10 cm, 10-15 cm, 15- 20 cm, >20 cm, respectively.

RESULTS AND DISCUSSIONS

The three replications were taken from a different cross sectional area of cotton stem. The dial showed the indicated angle, for cutting cotton stem and corresponding cutting energy were calculated, using a formula.

Effect of Approach Angle of Cutter Blade (φ) on Specific Cutting Energy

The effect of approach angle (φ) of cutter blade, on specific cutting energy at 0 deg (θ_1), 15 deg (θ_1) and 30 deg (θ_1) shear angle, with bevel angle and thickness (T) of cutter blade are shown in Figure 2.

In general, increase in approach angle from 0 (φ_1) to 15 (φ_2) deg, reduced the specific cutting energy, as well as increase in approach angle up to 30 deg ($\varphi_{3),}$ increased the specific cutting energy of cuter blade, respectively. When the cutter blade approach angle was higher at 30 deg (φ_3), sliding of cutter blade occurred, which in turn reduced the impact effect of the blade and hence, higher specific cutting energy is required. The cutter blade with 15 deg (φ_2) approach angle, yielded minimum specific cutting energy for selected levels of shear angle, bevel angle with 6 (T_1),8 (T_2) and 10 mm (T_3) thickness of the cutter blades. This is in close agreement with the results, reported by El-Sahar 1988 and Sumner *et.al* 1984a.

Effect of Shear Angle of Cutter Blade (θ) on Specific Cutting Energy

The effect of shear angle (θ) deg, bevel angle (α) deg and thickness (T) mm, of cutter blade on specific cutting energy at 0 (φ_1) deg, 15 (φ_2) deg and 30 (φ_3) deg, approach angle is shown in Figure 3.

It is inferred that, there was a reduction of specific cutting energy, with increase in shear angle from 0 deg (θ_1) to 15 deg (θ_2). Increase in shear angle from 0 (θ_1) to 15 (θ_2) deg of cutter blade, has led to a reduction of frictional force of crop stem under impact and hence, reduced specific cutting energy (impact energy). Further increase of shear angle to 20 (θ_3) deg, resulted in an increasing of specific cutting energy, for bevel angle 23 (α_1), 25 (α_2), 28 (α_3) and 30 (α_4), with 6 (T_1), 8 (T_2) and 10 (T_3) mm thickness of cutter blade, respectively. This might be due to the fact that, the plane of least resistance coincides with optimal value of shear angle of 20 deg (θ_3).

Effect of Blade Thickness on Specific Cutting Energy

The thickness of blade affects the specific cutting energy and shredding efficiency of the shredder (Bosoi *et al.*, 1990). The effect of shear angle (θ) deg, bevel angle (α) deg and approach angle (φ) deg of cutter blade, on specific cutting energy, with respect to the thickness of cutter blade (T) mm is shown in Figure 4.

It is observed that, the cutting energy increases with increase in bevel angle (α) deg, approach angle (φ) deg and shear angle (θ) deg but decreases with increase of the thickness of cutter blade (T) mm. Hence, the bevel angle, shear angle and approach angle should be kept at minimum, with maximum thickness 10 mm (T_3) of cutter blade resulted in minimum specific cutting energy required for cutting the crop stem.

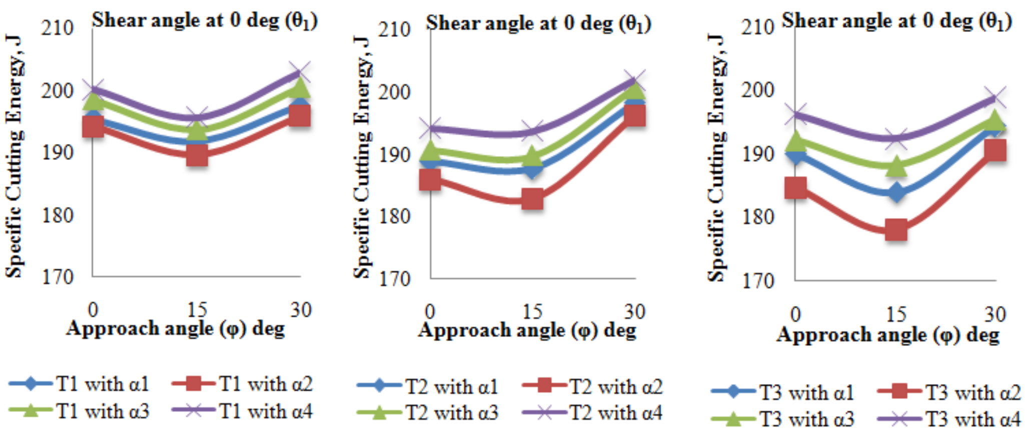


Figure 3(1): Effect of Approach Angle (φ) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 0 Deg (θ_1) Shear Angle with Respect to Bevel Angle (α) and Thickness of Cutter Blade (T)

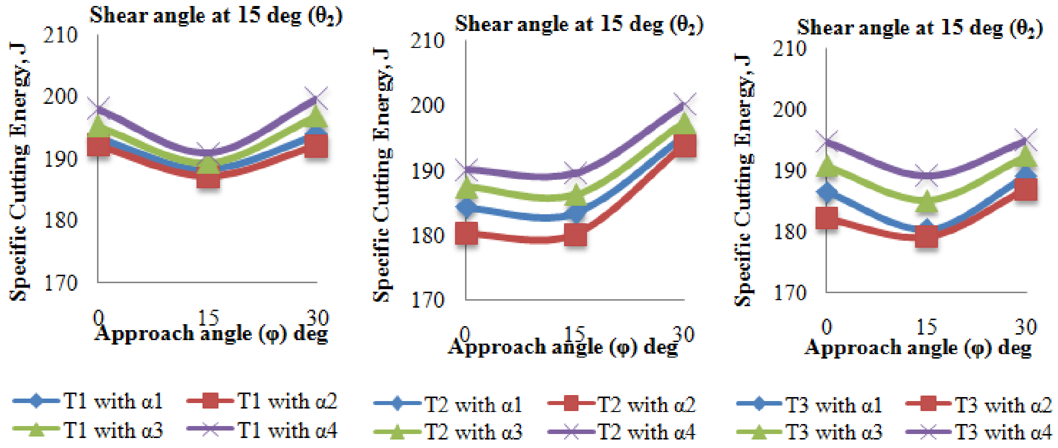


Figure 3(2): Effect of Approach Angle (φ) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 15 Deg (θ_2) Shear Angle, with Respect to Bevel Angle (α) and Thickness of Cutter Blade (T)

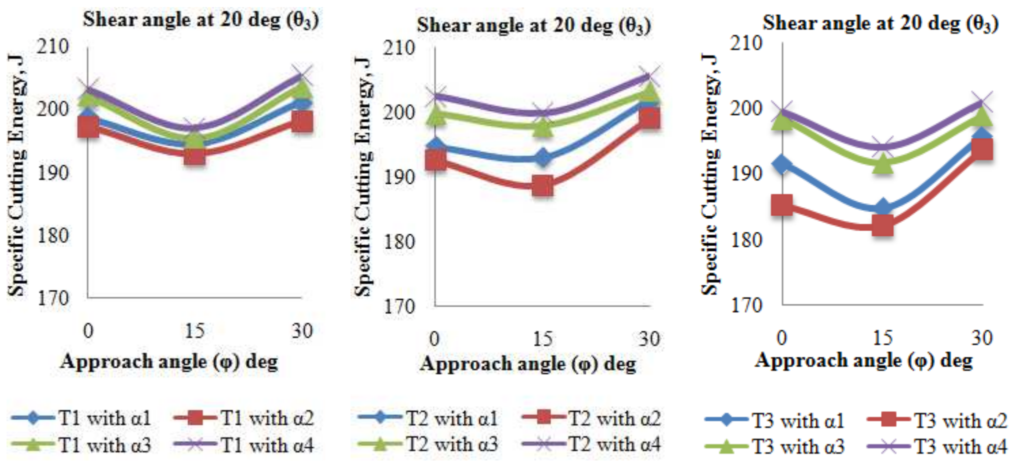


Figure 3(3): Effect of Approach angle (φ) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 20 Deg (θ_3) Shear Angle with Respect to Bevel Angle (α) and Thickness of Cutter Blade (T)

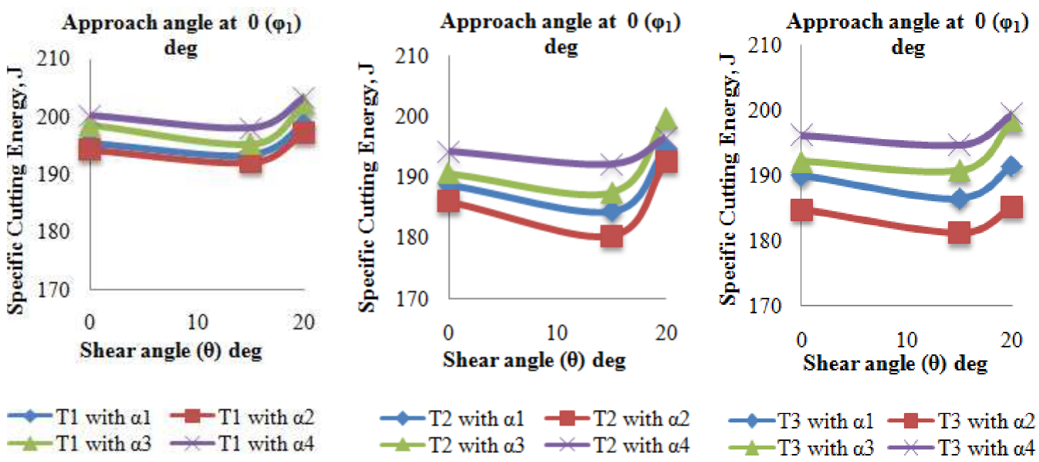


Figure 4(1): Effect of Shear Angle (θ) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 0 Deg (φ_1) Approach Angle with Respect to Bevel Angle (α) and Thickness of Cutter Blade from (T)

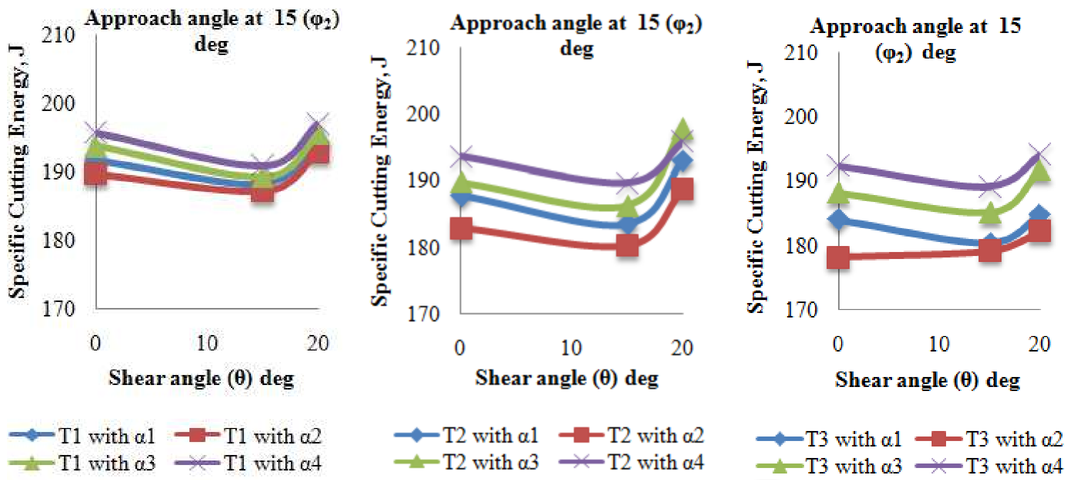


Figure 4(2): Effect of Shear Angle (θ) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 15 Deg (φ_2) Approach Angle with Respect to Bevel Angle (α) and Thickness of Cutter Blade from (T)

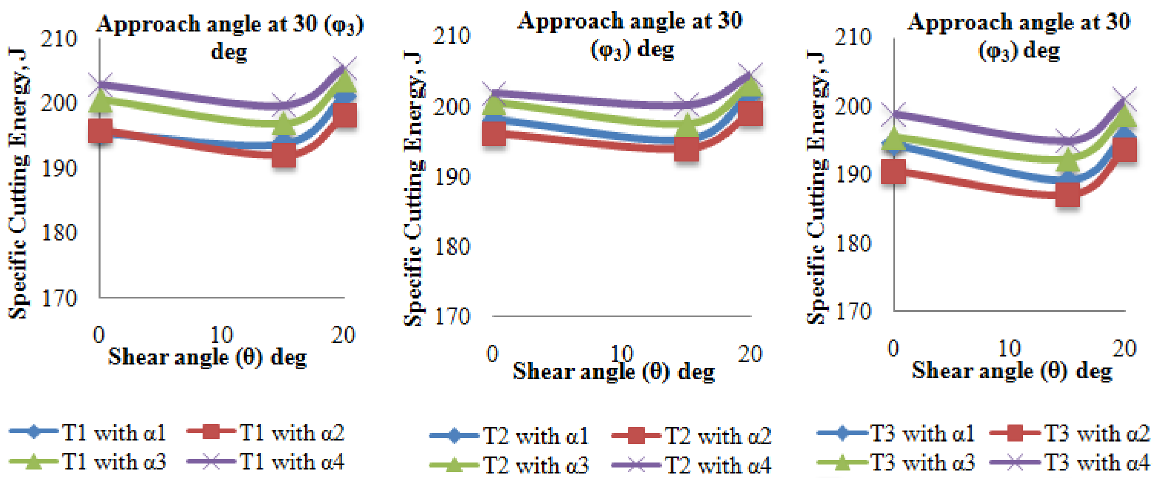


Figure 4(3): Effect of Shear Angle (θ) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 30 Deg (φ_2) Approach Angle, with Respect to Bevel Angle (α) and Thickness of Cutter Blade from (T)

Effect of Bevel Angle of Cutter Blade (α) on Specific Cutting Energy

Bevel angle significantly affects the specific reaction force and energy (Jelani *et.al, 1999*). The effect of shear angle (θ), approach angle (φ) and thickness (T) of cutter blade on specific cutting energy, with respect to a bevel angle (α) is shown in Figure 5.

In general, the force and energy required for cutting only increases, when the fineness exceeds a bevel angle of 30 deg. The most efficient fineness is at bevel angle of 24 deg, if any angle smaller than 24 deg resulted in rapid wear and dulling of the blade (Chacellor, 1958). From the above observation, it shows that, there is no more variation of specific cutting energy reduced, when the bevel angle increased from 23 (α_1) to 25 deg (α_2), but further increase of bevel angle from 25 (α_2) to 30 deg (α_3) of cutter blade, resulted in increase of specific cutting energy with all selected levels of shear angle, approach angle and thickness of cutter blade, respectively. The specific cutting energy was lower for bevel angle at 25 deg (α_2) with 10 (T_3) mm thicknesses of cutter blade, at all selected levels of shear angle (θ) and approach angle (φ).

Statistical Analysis of Specific Cutting Energy (SEC)

The statistical analysis of the data was performed, to assess the significance of the variables viz., thickness (T), bevel angle (α), shear angle (θ) and approach angle (φ) on specific cutting energy (SEC). The analysis of variance on SEC is furnished in Table 2.

The result of ANOVA indicates that, there was a significant difference among the treatments. The individual effect of the variables *viz.,* thickness (T), approach angle (φ) shear angle (θ) deg and bevel angle (α) deg of cutter blade on specific cutting energy (SEC) was significant, at 1 percent level of probability.

Table 2: ANOVA on Specific Cutting Energy

Sl. No	SV	DF	SS	MS	F
1	Treatment	107	12134.81	113.40	6.45**
	Bevel angle of cutting blade (α)	3	281.97	93.99	5.35 **
2	Thickness of blade (T)	2	1342.09	671.04	38.19**
3	Shear angle of cutting blade (θ)	2	2362.53	1181.27	67.24**
4	Approach angle of cutting blade (φ)	2	2986.14	1493.07	84.99**
5	$\alpha \times T$	6	856.59	142.76	8.13 **
6	$\alpha \times \theta$	6	377.70	62.95	3.58 **
7	$\alpha \times \varphi$	6	153.03	25.50	1.45**
8	$T \times \theta$	4	365.62	91.40	5.2032 **
9	$T \times \varphi$	4	53.69	13.42	0.76**
10	$\theta \times \varphi$	4	892.77	223.19	12.70 **
11	$\alpha \times T \times \theta$	12	266.91	22.24	1.26**
12	$\alpha \times T \times \varphi$	12	396.19	33.01	1.87**
13	$\alpha \times \theta \times \varphi$	12	470.81	39.23	2.23**
14	$T \times \theta \times \varphi$	8	330.83	41.35	2.35**
15	$\alpha \times T \times \theta \times \varphi$	24	997.89	41.58	2.36 **
16	Err	214	3759.34	17.56	
	Total	**428**	**28028.97**		

Cv = 1.82 per cent ** = Significant at 1 % level

Optimization of Levels of Variables with Impact Type Pendulum Test Rig

The selected levels of variables were optimized, for achieving the best performance of cutter blade, in terms of minimum specific cutting energy with impact type pendulum test rig. The lowest mean value of specific cutting energy with different combination of the selected levels of variable, is furnished in Table 3.

Table 3: Optimized Values of Variables for Different Treatment Combination

Parameter	Treatment Combination Levels of Selected Variables	Values
Specific cutting energy	$\alpha_2 \times T_3 \times \theta_1 \times \varphi_2$	178.04 J

Hence, the treatment combination of $\alpha_2 \times T_3 \times \theta_1 \times \varphi_2$ can be selected, as the optimized combination of selected variable (specific cutting energy was 178.04 J) for designing a new shredder, or modification of the cutting mechanisms of shredder.

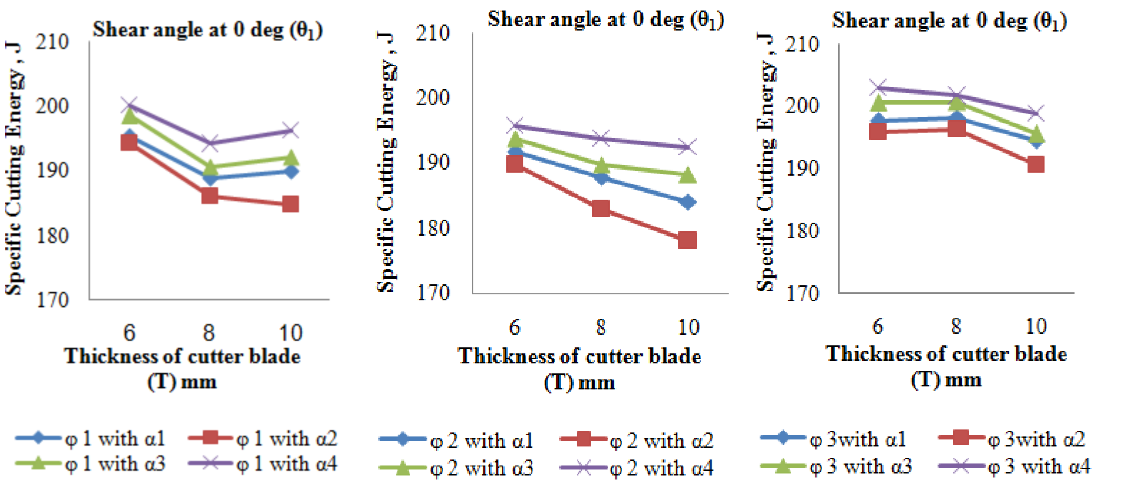


Figure 5(1): Effect of Thickness of Cutter Blade on Specific Cutting Energy for Cotton Stem at 0 Deg (θ_1) Shear Angle with Respect to Bevel Angle (α) and Approach Angle 0 (φ)

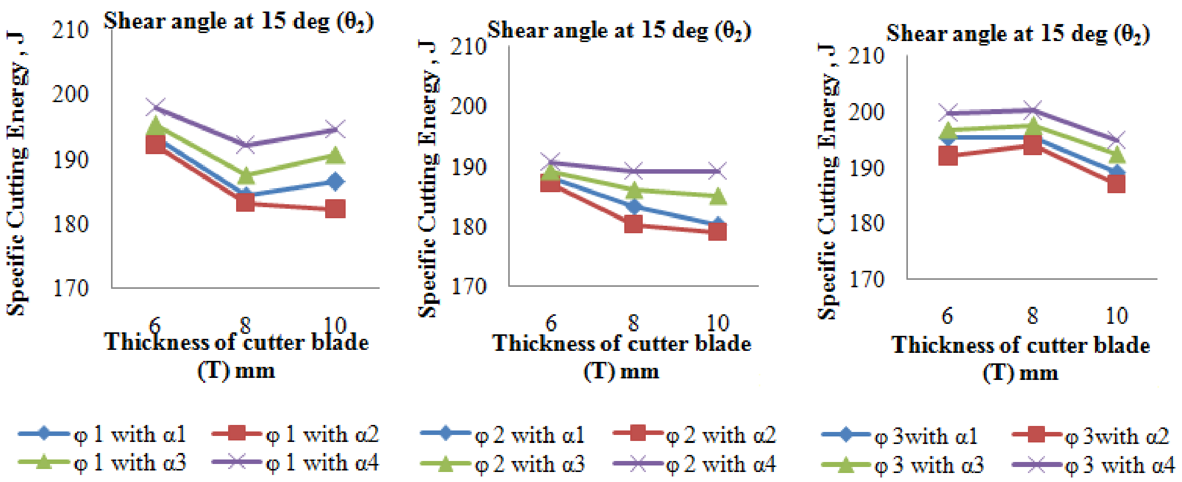


Figure 5(2): Effect of Thickness of Cutter Blade on Specific Cutting Energy for Cotton Stem at 15 Deg (θ_2) Shear Angle with Respect to Bevel Angle (α) and Approach Angle 0 (φ)

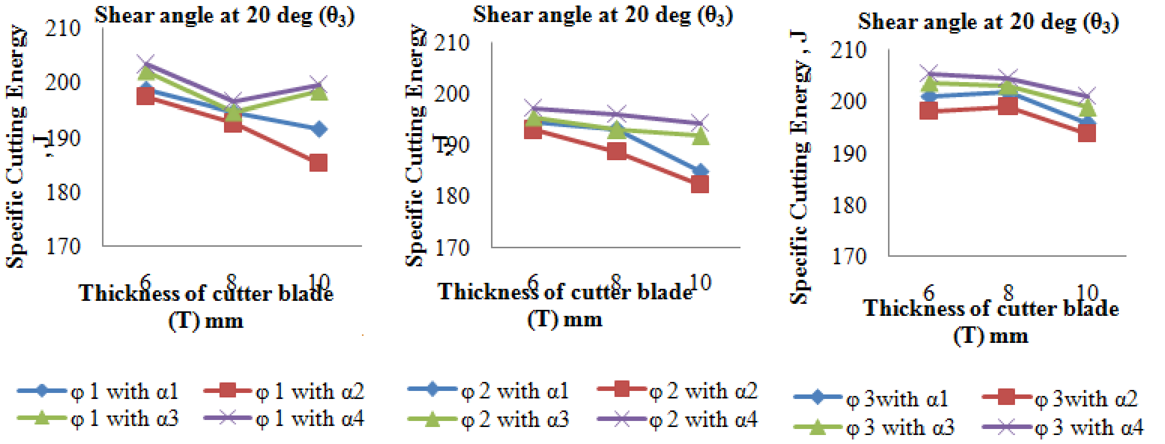


Figure 5(3): Effect of Thickness of Cutter Blade on Specific Cutting Energy for Cotton Stem at 20 Deg (θ_3) Shear Angle with Respect to Bevel Angle (α) and Approach Angle 0 (φ)

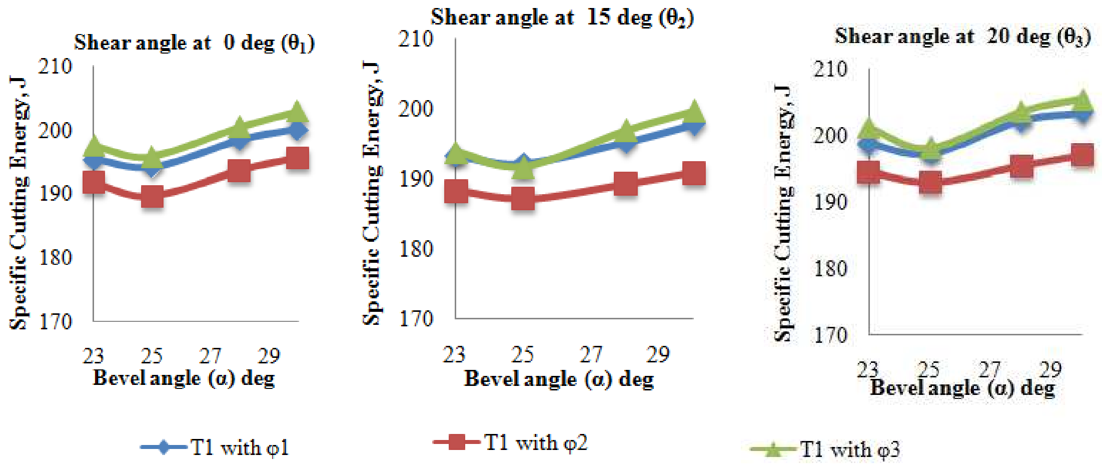


Figure 6(1): Effect of Bevel Angle (A) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem At 6 mm (T_1) Thickness of Cutter Blade with Respect to Shear Angle (Θ) and Approach Angle 0 (Φ)

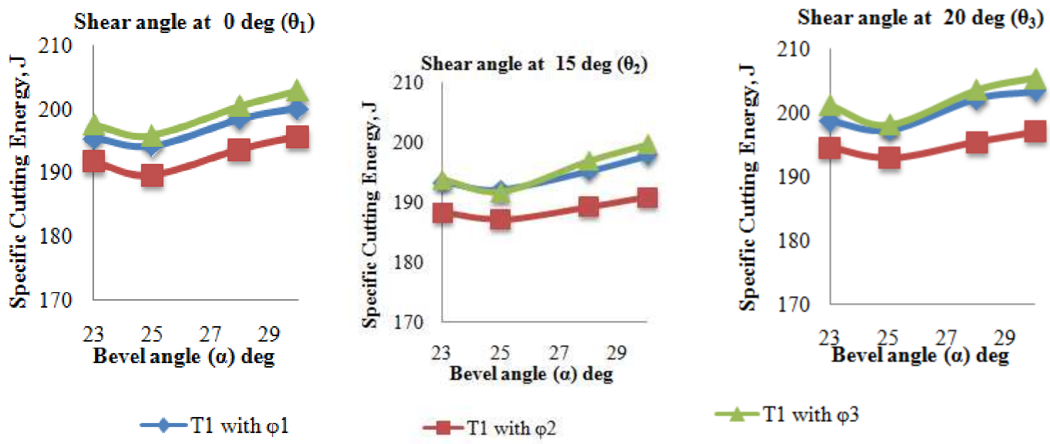


Figure 6(2): Effect of Bevel Angle (A) Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 8 mm (T2) Thickness of Cutter Blade with Respect to Shear Angle (Θ) and Approach Angle 0 (Φ)

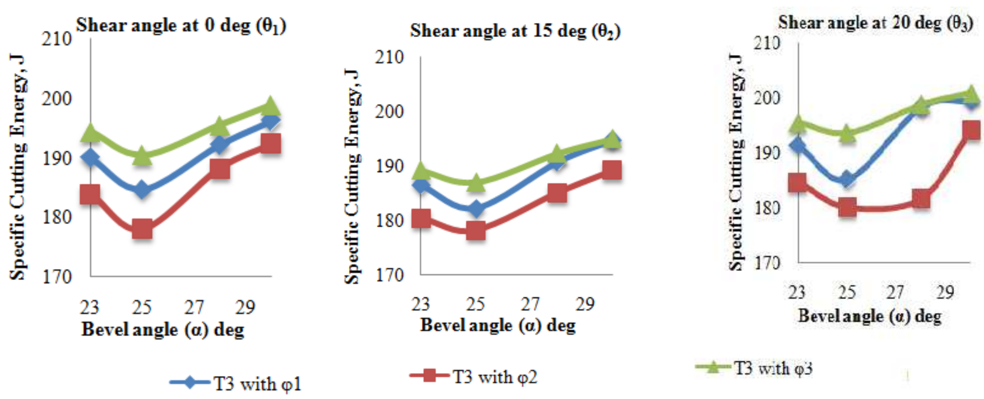


Figure 6(3): Effect of Bevel Angle Deg of Cutter Blade on Specific Cutting Energy for Cotton Stem at 10 mm (T_3) Thickness of Cutter Blade with Respect to Shear Angle (Θ) and Approach Angle 0 (Φ)

Performance Evaluation of Modified Shredder

Modified shredder was evaluated in cotton fields, with a forward speed of operation 2 to 5 km h^{-1} and the peripheral velocity of cutter blade 28 m s^{-1}, respectively. The observation on shredding efficiency, in terms of length of cut of crop residues at different scale level (L_1 to L_5), was recorded during field evaluation. The view of the trial field, during and after shredding operation are done, as shown in Plate 3

Plate 3: Field Experiments of Shredder with Selected Levels of Variables

The observation on shredding efficiency, field capacity and time consumed were observed during the evaluation. The result of field evaluation of prototype tractor operated modified Shredder is furnished in Table 4.

Table 4: Result of Performance Evaluation of Modified Shredder

Sl. No	Items	Prototype
1	Location	Farmer field, Coimbatore
2	Variety of cotton	KC_1
3	Diameter of cotton stem, mm	12 to 17
4	Moister content of cotton at the time of shredding d.b %	44.21
5	Operation cost Rs ha^{-1}	2654.65
6	Time required to cover ha h^{-1}	5.29
7	Width of operation, m	1.10
8	Number of un cut cotton stem in row 100 m length	2
9	Theoretical field capacity, ha h^{-1}	0.24
10	Actual field capacity ha h^{-1}	0.196
11	Field efficiency, %	81.66
12	Shredding efficiency, %	92

The length of cut of crop stem at different forward speed of operation from 2 to 5 km h^{-1} with a constant peripheral velocity of cutter blade 28 m s^{-1} as shown in Figure 5.

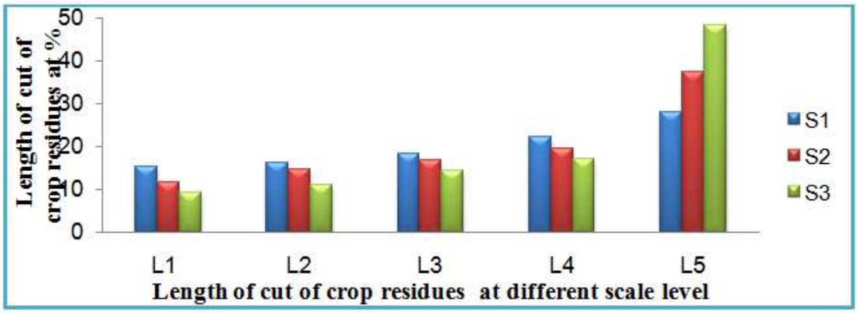


Figure 7: Length of Cut of Crop Stem at Different Forward Sped of Operation

The modified shredders resulted in 37.55 and 82 percent savings, in cost and time of operation, respectively, when compared to conventional method of crop residue removing in agricultural field.

CONCLUSIONS

The following conclusions were obtained from the experiments:

- The lowest specific cutting energy 178.04 J was observed in treatment combination of 15 deg (φ_2) approach angle, 0 deg (θ_1) shear angle, 25 deg bevel angle (α_2) with 10 mm (T_3) thickness of cutter blade. This combination has been selected, for modifying the cutting mechanism of shredder.
- The actual field capacity, theoretical field capacity, field efficiency and shredding efficiency of the modified shredder were 0.24, 0.196 ha h^{-1}, 81.66 and 92 percent observed, during the field evaluation.
- The modified shredder saves in 37.55 and 82 percent cost and time, when compared with conventional method of crop residue removal.

REFERENCES

1. *Chancellor, W.J. (1958). Energy requirement for cutting forage. Journal of Agri. Eng. 30(10):633-636.*
2. *Chattopadhyay, P.S. and Pandey, K.P. (1999). Effect of knife and operational parameters on energy requirement in fail forage harvesting. J. agric. Engg. Res., 23(1):3-12.*
3. *Church, M., J.F. Wolcott and W.K. Fletcher. 1991. A test of equal mobility in fluvial sediment transport: Behaviour of the sand fraction. Water Res. Res. 27(11): 2941-2951*
4. *EL-Sahar, E.A., 1988. Design of harvester appropriate for Egyptian. MSe. Thesis. Fac. of Ag. Ain Shams Univ. Egypt.*
5. *Eshaghbeygi A, Hoseinzadeh B, Khazaei M, Masoumi AA (2009) Bending and shearing properties of wheat stem of Alvand variety. World Appl Sci J 6(8): 1028-1032.*
6. *Godesa T (2004) Determination of minimal cutting speed by flailing potato vines. Act Agr Scand 83 -1.*
7. *Hoseinzadeh B, Eshaghbeygi A, Raghami N (2009) Effect of moisture content, bevel angle and cutting speed on shearing energy of three wheat varieties. World Appl Sci J 7(9):1120-1123.*
8. *Imababi, A.T. 1992. Design and development of rotary harvester for harvesting sesame crop. Ph. D. Thesis Ag. Eng. Dept., Fac. of Ag. Cairo Univ. Eygpt.*
9. *Jelani, A.R., D. Ahmad, A. Hitam, A. Yahya, and J. Jamak. 1999. Reaction force and energy requirement for cutting oil palm fronds by spring powered sickle cutter. Journal of Oil Palm Research. 11(2), 114-122.*

10. Johnson, P.C., C.L. Clementson, S. K. Mathanker, T.E. Grift and A.C. Hansen. 2012. Cutting energy characteristics of Miscanthus X giganteus stems with varying oblique angle and cutting speed. Biosystems engineering. 112(1): 42-48.
11. Koloor, R.T, and G. Kiani. 2007. Soybean stems cutting energy and the effects of blade parameters on it. Pakistan Journal of Biological sciences.10(9):1532-1535.
12. Lee SW, Huh YK (1984) Threshing and cutting forces Korean rice. Trans ASAE 27: 1954-1957
13. Luis, F.C.; G. M. Savage; L. L. Eggerth and G. G. Clarence 1993.Composting and Recycling Municipal Solid Waste. Lewis Pub.London. P: 453-468.
14. Maughan, J.D., M. Brian Fehrenbacher., S. K. Mathanker., T. E. Grift and A.C. Hansen. 2012. Impact of Cutting Speed, Blade Type, and Blade Angle on Miscanthus harvesting Energy Requirement. An ASABE Meeting Presentation.12-1338182.
15. Mehta, H. (2004). Bioconversion of Different Wastes for Energy Options, Sardar Patel Renewable Energy Research Institute Vallabh Vidyanagar, ppt.
16. Mesquita CM, Hanna MA (1995) physical and mechanical properties of soybean crops. Trans ASABE 38(6): 16551658.
17. Morad and Fouda 2009. Energy and cost required for removing residues of some field crops using different implements Egypt.J. og Appl. Sci., 24(3).
18. Muller Z (1988) An investigation of mechanical and geometrical properties influencing the stability of wheatstalk. Physical Properties of Agricultural Materials and Products, Edited by R Reznicek. Washington: Hemisphere Publishing Corporation.
19. Nazari Galedar M, Tabatabaeefar A, Jafari A, Sharifi A, Rafiee S (2008) Bending and shearing characteristics of alfalfa stems. CIGR Ejournal, Manuscript FP 08 001. Vol.X.
20. Niveta Jain, Arti Bhatia, Himanshu Pathak (2014) Emission of Air Pollutants from Crop Residue Burning in India - Centre for Environment Science and Climate Resilient Agriculture, Indian Agricultural Research Institute, New Delhi- 110012, India
21. O'Dogherty, M.J. and Gale, G. E. (1986). Laboratory studies of the cutting of grass stems. J. agric. Engg. Res., 35(3):115-129.
22. Pathak, B.S. (2006). Crop Residue to Energy, In Environment and Agriculture, Chadha, K.L. and Swaminathan, M.S. (Eds.), Malhotra Publishing House, New Delhi, p. 854– 869.
23. Pathak, H., Bhatia, A., Jain, N. and Aggarwal, P.K. (2010). Greenhouse Gas Emission and Mitigation in Indian Agriculture – A Review, In ING Bulletins on Regional Assessment of Reactive Nitrogen, Bulletin No. 19, (Ed. Bijay-Singh), SCON-ING, New Delhi, p. i–iv, 1–34.
24. Pathak, H., Singh, R., Bhatia, A. and Jain, N. (2006). Recycling of Rice Straw to Improve Wheat Yield and Soil Fertility and Reduce Atmospheric Pollution. Paddy Water Environ. 4: 111–117.
25. Persson, S.1987.Mechanics of cutting Plant Materials 62, 102,105.St. Joseph, Mich. ASAE.
26. Prasad, J. and Gupata, C.P. (1975). Mechanical properties of maize stalk in relation to harvesting. J. agric. Engg. Res., 20 (2): 79-87.
27. Prasad,J. and C.P. Gupta. 1975. Mechanical properties of maize stalk as related to harvesting. J.of Agric. Eng. Res.
28. Rajendra Reddy, G., G.U. Male war and B.G. Karle. 2002. Effect of crop residue incorporation and tillage operations on soil properties of vertisol under rainfed agriculture. Indian J. Dryland Agric. Res. & Dev., 17(1): 5-58.
29. Reza, T.K.2007.Paddy stems cutting energy and suggested blade as related to harvesting. J. of Agric. Eng. Res.20:79-87.

30. *Senthilkumar, T. 2004. Investigation on development of a tractor operated cotton stalk shredder cum insitu applicator as influenced by crop, machine and operational parameters PhD Thesis. Department of farm Machinery, Tamil Nadu Agricultural University, Coimbatore, India.*

31. *Tavakoli H, Mohtasebi SS, Jafari A (2009) Effects of moisture content inter node position and loading rate on the bending characteristics of barely straw. Res Agr Eng 55(2): 45-51.*

32. *Vagadia, V.R., R.K.Kathiria and J.B.Savani,2004. Design and development of agricultural wastes shredder a new concept.Paper presented at the XXXVIII Annual convention of ISAE, held at College of agricultural Engineering and Technology, Dr. BSKKV, Dapoli, January, 16-18.*

33. *Yiliep, Y.D. and U.S. Mohammed, 2005.Effect of knife velocity on cutting energy and efficiency during impact cutting of sorghum stalk. The E-Journal of CIGR, Vol. VII: Manuscript PM 05004.*

34. *Yumnam Jekendra and Pratap Singh, 1991. Energetic of forge chopping. Agricultural Mechanization in Asia, Africa and Latin America.22 (1):59-63.*