Zagazig Journal of Agricultural Engineering 1735-1750

Zagazig J. Agric. Res., Vol. 43 No. (5) 2016

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR CUTTING AND CHOPPING COTTON STALKS

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ABSTRACT

The aim of this study was to design, manufacture and evaluate the performance of a local machine for cutting and chopping cotton stalks. It consists of main frame, cutting and feeding unit, chopping unit and transmission system to transmit the rotating motion from power take off (pto) of tractor to the movable machine components. Field experiments were carried out under four different stalks moisture contents wet base (w.b.) of about 37.83, 33.54, 28.87 and 20.17%; four different clearances between cutting drums of 1, 2, 3 and 4 cm; four different peripheral shredder speeds of about 47.1, 54.95, 62.8 and 70.65 m/sec., and different numbers of plan blades on shredder of 2, 4, 6 and 8 blades. All experiments were carried out at four different kinematic parameters of about 7.83, 10.46, 13.48 and 17.21 between cutting rotating speed of 1000 rpm and different forward speeds. Machine performance was evaluated in terms of field capacity, cutting and shredding efficiency, energy requirements and cost. The experimental results revealed that 28.87%, 2 cm, 62.8 m/sec., 6 blades and 10.46 of stalks moisture content, cutting drums clearance, chopper peripheral speed, number of plan blades on shredder and kinematic parameter, respectively recorded minimum criterion cost of 135.35 LE.

Key words: Cotton stalks, choppers, machine design.

INTRODUCTION

Cotton is one of the major commercial crops grown in Egypt covering an area around of 375000 fad., and producing an output of 330300 Mg of seed cotton yield and the quantity of cotton residues were determined to be about of 500000 Mg/year according to Agricultural Economics Bulletin (2016). Chattopadhyay and Pandey (2001) stated that the range of cutting speed by flailing is very important while cutting principle is impact cut, which mean without counter shear. The velocity of the flail knife must be high enough to cut the stem. The common range of cutting speed at impact cut for most plant materials is between 20 and 60 m/sec. Gursoy (2002) found that most farmers are prepared to pay for the removal of the stalks from the field after harvesting. Where cotton stalks are mechanically chopped and integrated into the soil, 48% of nitrogen, 41% of phosphor and 74% of potassium taken from the soil by the cotton plant is returned to the soil. Younis *et al.* (2002) developed chopping machine for cutting residues of rice, cotton and maize. They found that the maximum required power and consumed energy were, 11.77 kW and 12.99 kW.hr./Mg, at rotor speeds of 2200 and 1600 rpm, respectively. The increase of rotor speed from 1600 to 2000 rpm caused a decrease of consumed energy by 17.11%. While the increase of rotor speed from 2000 to 2200 rpm caused an increase of consumed energy by 12.9%. Morad and Fouda (2009) investigated the performance of the reciprocating mower to clear soil from crop residues as a function of change in machine forward speed. The experimental results revealed that the operational cost as well as energy requirements were in the optimum region at forward speed between 4 to 5.5, 2.8 to 4.5 and 2.1 to3.2 km/hr., for removing rice straw, cotton stalks and sunflower stalks, respectively. Wangyuan *et al.* (2012) measured the bending force and shearing force by using a universal testing machine TMS-PRO with a specialized three-point fixture, and the bending resistance

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strength and shearing resistance strength were calculated. The experiments were conducted at different growth stage of cotton plants. The shearing force and bending force of cotton stem increases with age advance, but it is not obvious in the first five weeks. The results showed that the five weeks old cotton plants are still weak against external damage, the maximum bending force that a cotton plant stem can be suffered is 1.98 N and the maximum shearing force is 101.93 N. after five weeks, these values climb rapidly, and they reach to 68.27 and 622.77 N, respectively in the ninth week. El-Sharabasy (2013) manufactured a self-propelled machine with two saw discs constructed at front of the mower. The machine evaluated during cutting operation of cotton, maize and sunflower residues at different kinematic parameters and different stalks moisture contents. He found the most economical kinematic parameter is 81.98 and the optimum stalks moisture content which recorded minimum criterion costs were 31.20, 41.26 and 29.35% for cotton, maize and sunflower, respectively. A bad effect on economic, environment, public health and others, can be done by increasing this residues quantities if does not be treated in suitable ways. The mechanical treatment by cutting or grinding for residues is the most important and primary step should be done to make it great useful. In Egypt, there are many types of machines for cutting crop residues and others for shredding residues to use it in industrial processes but with some disadvantages, such as high cost. So, the aim of this present work is designing, manufacturing and evaluating cutting and chopping machine for cotton stalks residues.

MATERIALS AND METHODS

Field experiments were carried out at private farm in Sharkia Governorate during summer season of 2014-2015 to design and evaluate the performance of a local cutting and chopping machine.

Materials

Cotton Residues

Cotton variety (Giza 86) was taken under all test runs planting at 60 cm ridges spacing and about of 15 cm between hills.

Tractor

The tractor which was used to operate the local machine have the following: engine power of 75 hp and pto at rated speed of 540 and 1000 rpm.

Shaving machine

The overall specifications and photos of the designed shaving machine were given in Fig. 1. and Photo 1,

The equipment, Fig. 1 is mainly composed of the following units: cutting and feeding unit (1), shredder unit (2), transmission system (3) and main frame (4)

Cutting and feeding unit

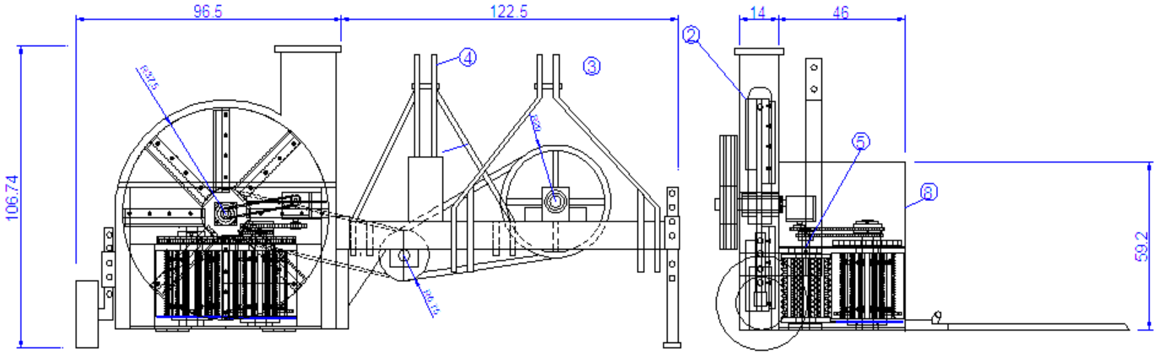
It is the subassembly of the equipment that perform the cutting operation of cotton stems from the field and transport the stem cuttings to the shredder for fragmentation into segments have length of 15 – 50 mm. This unit consists of frame**,** left cutting and drag reel**,** right cutting and drag reel**,** right compressing and feeding drum**,** left compressing and feeding drum

Frame

Two thick sheet-metal with dimensions of 60×45×0.6 cm between of them. Four supportive shafts at corners with length of 27 cm and thin sheet-metal welded, reinforced with them to close the two side having the supportive role of all sub-assemblies of cutting and chopping unit

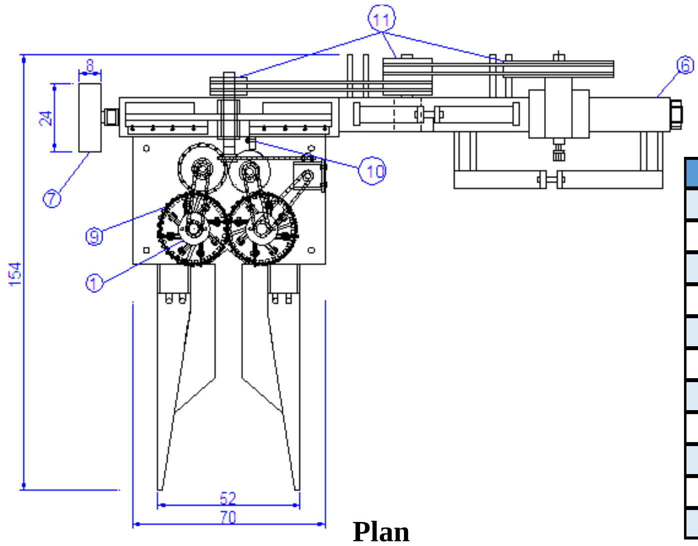
Right and left cutting-drag reel

This reel designed to achieve the cutting of cotton stalks and carrying the cut plants to the shredding drum in view of fragmentation. It consists of a vertical central shaft ended with a saw disk near the ground for cutting process with diameter of 25 cm, 0° rake angle, 30° clearance angle and 6 mm pitch was fixed whereas one of two saw disks of cutting- drag drums located above the other by vertical distance of 1 mm. Around of every two cutting-drag drums, the dragging roller body consisting of two hooks, and 8 sliding bushings. Four of them were made of iron and fixed on the drum.



Elevation

Side view



Plan

NO.	PART NAME	NO. OFF
1	Cutting and guidance drum	2
2	Shredder	1
3	Front three-point linkage hitch	1
4	Rear three-point linkage hitch	1
5	Fedding drum	2
6	Frame	1
7	Ground wheel	1
8	Driving box	1
9	Cutting saw disk	2
10	Fixed blade	1
11	Transmision system	1

Fig. 1. Elevation, Plan and side view of designed shaving machine

Photo 1. Cutting and chopping machine during field evaluation

1-Cutting and guidance unit 2- Shredder unit 3- Transmission system
4- Main frame 5- Front hitching 6- Rear hitching 7- Transporting wheel

Compressing and feeding drums

A pair of drums with 4mm gap between them, the compressing-feeding left drum had diameter of 18 cm and consists of an intermediate shaft fixed vertically by two axial bearing. A cylinder of 16 cm diameter was fixed around the intermediate shaft by two coupling and a 16 triangular toothed plates with width of 2cm welded at the extension of external circumference. The compressing-feeding right drum had diameter of 15 cm in order to avoid the fixed blade of the shredder and consists of an intermediate shaft fixed vertically by two axial bearing. A serrated cylinder of 15 cm diameter was fixed also, around the intermediate shaft by two coupling.

Chopping unit

Chopping unit is the subassembly executing the operation of fragmentation of cotton stalks and throwing of all fragments in a trailer or on the ground. It consists of housing, rotor chopper flywheel, and outlet tube.

Housing

Consists of two parts, each of them is a thick sheet welded construction with the role of supporting the chopping rotor, transport wheels, shredder flywheel, outlet tube of chopped materials and rotor driving group. On the wall of the housing, close to the feeding mouth a vertically counter-knives with rear clearance angel of 45^0, blade sharpened was 0.05-0.08mm and blade and rake angel of 25^0, 20^0, was mounted.

Rotor chopper flywheel

It consists of a disc with thickness of 60 cm and a diameter of 75 cm, at equally spaced radially around six plane knives mounted with dimension length of 20 cm and width of 5cm on one side with blade and rake angel of 25^0,20^0 respectively, blade sharpened was 0.05-0.08 mm as recommended and clearance between blades and counter blade arranged from 0.5 to 1mm. and six palettes, on the opposite side. the knives execute the fragmentation of the cotton stalks that enter into the supplying inlet and the palettes execute the throwing of the minced material through the deflector in the trailer.

Outlet tube

Is a welded construction that directs the fragments of cotton stalks in the mean of transportation. It consists of a body construction in welded sheet metal.

Transmission system

it consists of two groups, one of them is external (driving group) which transmits the movement from tractor to the rotor shaft of shredder. The other is internal (transmission system box) which receives the movement from the chopper rotor shaft output by chain and two sprocket wheels, one of them set on the shredder shaft and the other set on the shaft which considering input of a reduction bevel gear box (1:1.8) and the output shaft of this reduction bevel gear box carrying a sprocket wheel and the cutting-drag right drum carrying another one and chain transmitted the movement between them. The cutting-drag left drum received the movement from the cutting-drag right drum by two mesh spur gears each one had diameter of 25 cm. The cutting-drag right-left drums were considering of the input of movement to the compressing-feeding drums by chain and two sprockets wheels assembly for each of them.

Main frame

Main frame is made of laminated profiles welded together realizing the body of the frame, being provided at the front with a front three points hitching traction necessary for coupling at the tractor drawbar in working position. A supporting leg when it decoupled from the tractor, rear three points hitching traction necessary for coupling at the tractor drawbar in transporting position and ground wheel for controlling cutting height also.

Methods

The present study was conducted to investigate the optimum relation between operational factors and their effect on cutting and chopping efficiency, energy consumed and cutting cost for cotton stalks. The experimental area was about 5 faddans divided into four equal plots of (140 × 38.5m) per each and replicated 3 times. The machine was studied taking into consideration the following parameters:

- Stalks moisture content: 37.83, 33.54, 28.87 and 20.17%.
- Kinematic parameter (between cutting drums peripheral speed at 1000 rpm and machine forward speed of 2.75, 3.5, 4.5 and 6 km/hr.): 17.21, 13.48,10.46 and 7.83.
- Cutting drums clearance: 1, 2, 3 and 4 cm.

- chopper peripheral speeds: 47.1, 54.95, 62.8 and 70.65 m/sec .
- Numbers of plan blades on chopper: 2, 4, 6 and 8 blades.

Measurements and Determinations

Stem moisture content

The moisture content of cotton stalks was determined according to ASAE standard S.352 (ASAE, 1979).

$$MC = \frac{W_i - W_d}{W_i} \times 100 \quad \text{.........(1)}$$

Where:

MC: Stem moisture content (%)

W_i: Initial weight of sample (kg)

W_d: Dried weight of sample (kg)

Field capacity

The theoretical field capacity was determined according to forward speed and working width. The actual field capacity is the actual average rate of field coverage by the amount of actual time [lost + productive time] consumed in the operation. It can be determined by the following equation:

$$AFC = \frac{60}{Tu + Ti} \quad [fad./hr.]$$

Where:

AFC: Actual field capacity of the machine, fad./hr.

Tu: Utilized time per faddan in minutes.

Ti: Summation of lost time per faddan in minutes.

Field efficiency

The field efficiency is calculated by using the following formula:

$$\eta_f = \frac{AFC}{TFC} \times 100 \text{...........(3)}$$

Where:

TFC: Theoretical field capacity of the machine, fad./hr.

η_f= Field efficiency of the machine (%)

Cutting efficiency

The cutting efficiency was estimated by using the following equation.

$$\eta_{cut} = \frac{H_b - H_a}{H_b} \times 100 \text{..............(4)}$$

Where:

η_{cut}: Cutting efficiency (%)

H_b: Mean plant height before cutting (cm)

H_a: Mean stubble height after cutting (cm)

Chopping efficiency

The shredding efficiency can be calculated as following.

$$\eta_{shr} = \frac{S_a}{S_b} \times 100 \quad \text{..............(5)}$$

Where:

η_{shr}: Chopping efficiency (%)

S_a: The mass of the chopped production after segregation of shredding length 0< Lc <50 mm, g.

S_b: The mass of the shredded production before segregation, g (Habib, 2002).

Energy requirements

Engine power

The following formula was used to estimate the engine power :

Engine power (EP)= 3.16 FC, kW. (6) (Imbabi, 1985) ....(2)

Specific energy requirements

The energy requirements can be calculated by the following equation:

$$\text{Specific energy requirements} = \frac{\text{Power required (kW)}}{\text{Effective field capacity (fad./hr.)}}, \text{(kW.hr./fad.)} \text{..(7)}$$

Economical evaluation

The cost of mechanized process was based on the initial cost of machine, interest on capital, cost of fuel and oil consumed, cost of maintenance, and wage of operator according to the following formula:

$$C = \frac{p}{h}\left(\frac{1}{e} + \frac{i}{2} + t + r\right) + (1.2W \times s \times f) + \frac{m}{144} \quad \text{(Awady, 1978)}$$

Where:

C: Machine hourly cost, LE/hr.

P: price of machine, LE.

h: Yearly working hours, hr./year.

e: Life expectancy of the machine, year.

i: Annual interest rate (%).

t: Annual taxes, over heads rate (%)

r: Annual repairs and maintenance rate (%).

f: fuel price, LE.

1.2: A factor including reasonable estimation of the oil consumption in addition to fuel.

W=Engine power, hp.

s: Specific fuel consumption, L/hp. hr.

m= Monthly average wage, LE

144=Reasonable estimation of monthly working hours.

The operational cost can be determined using the following formula (Awady *et al.,* 1982):

$$\text{Operating cost} = \frac{\text{Machine cost/hr.}}{\text{Actual field capacity (fad./hr.)}}, \text{LE/fad.....(9)}$$

Criterion cost = (operating cost + product losses cost), LE/fad…………….(10)

Product losses cost=(stalk yield/fad.)(1-η_{cut} %) × (stalk price/kg), LE/fad……(11)

RESULTS AND DISCUSSION

Field Capacity and Field Efficiency

Effect of machine kinematic parameter and feeder drums clearance on actual field capacity and field efficiency

Fig. 2 show that decreasing kinematic parameter from 17.21 to 7.83 increase the actual field capacity from 0.390 to 0.618 fad./hr., and decrease the field efficiency from 99.26 to 72.15%, at the feeder drums clearance of 2cm, chopping unit speed of 1600 rpm and chopping unit blades number of 6 blades under stalks moisture content of 28.87%. The increase in field capacity and reduction in field efficiency by decreasing kinematic parameter are due to the less theoretical time consumed in comparison with the other items loss. On the other hand, the obtained data indicate the highest values of both actual field capacity and field efficiency were achieved by using the clearance of 2cm but the lowest values were recorded under the clearance of 1cm. This can be explained that, using clearance of 2cm will reduce the problem of blocking off caused by the populated plants and consequently the actual field capacity will increase.

Effect of cotton stalks moisture content on actual field capacity and field efficiency

Fig. 3 display that by decreasing cotton stalks moisture content from 37.83 to 28.87%, both actual field capacity and field efficiency increased slightly from 0.509 to 0.595 fad./hr., and from 79.19 to 92.54%, respectively but reducing the cotton stalks moisture content to 20.17%, the actual field capacity and field efficiency decreased to 0.502 fad./hr., and 78.01%, respectively at machine kinematic parameter of 10.46, feeder drums clearance of 2cm, chopping unit speed of 62.8 m/sec. and number of chopping blades of 6 blades. These results may be referred to that both cutting and chopping cotton stalks that have high and low moisture content by the designed machine may consume more time due to the high bending and shear strength, respectively which causes blocking out the designed machine parts.

Effect of chopper unit speed on actual field capacity and field efficiency

Fig. 4 display the effect of chopper unit speed on actual field capacity and field efficiency. It was a slight increase in actual field capacity which increased from 0.485 to 0.626 fad./hr., that represents about 29.07% when the chopper unit speed increased from 47.1 to 70.65 m/sec., at machine kinematic parameter of 10.46, feeder drums clearance of 2cm, chopping unit blades number of 6 blades and cotton stalks moisture content of 28.87%. Also, the same trend was occurred at the field efficiency under the same mentioned operating conditions where it increased from 75.37 to 97.32% when the chopper unit speed increased from 47.1 to 70.65 m/sec., at the same conditions. These results may be referred to consume more time at low speed due to blocking out the chopping chamber because of the insufficient energy which necessary to overcome resisting forces in it.

Effect of number of chopping blades on actual field capacity and field efficiency

Fig. 5 illustrate the effect of four different values of chopping unit blades number of 2, 4, 6

———Actual field capacity ……......Field efficiency

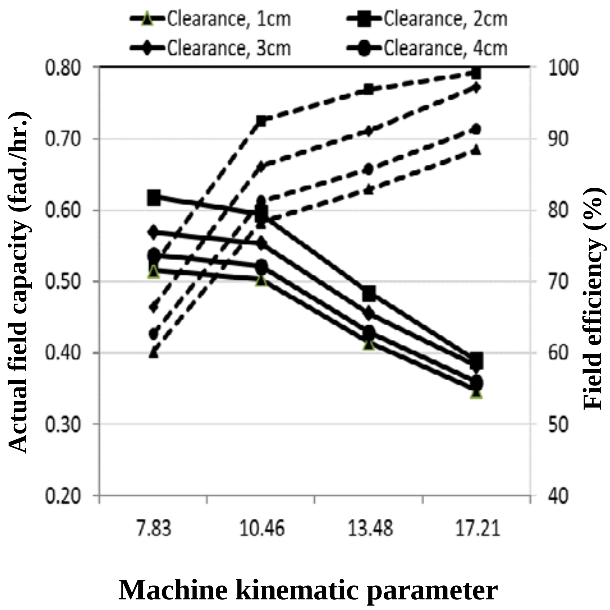


Fig. 2. Effect of machine kinematic parameter and feeder drums clearance on actual field capacity and field efficiency at optimum condition

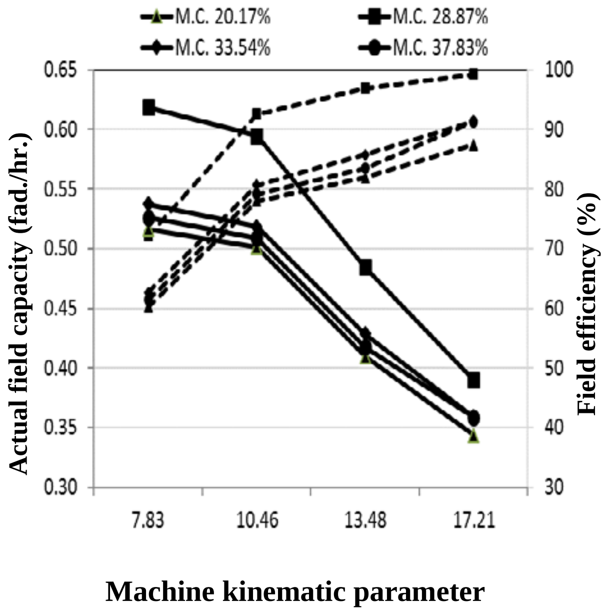


Fig. 3. Effect of cotton stalks moisture content on actual field capacity and field efficiency at optimum condition.

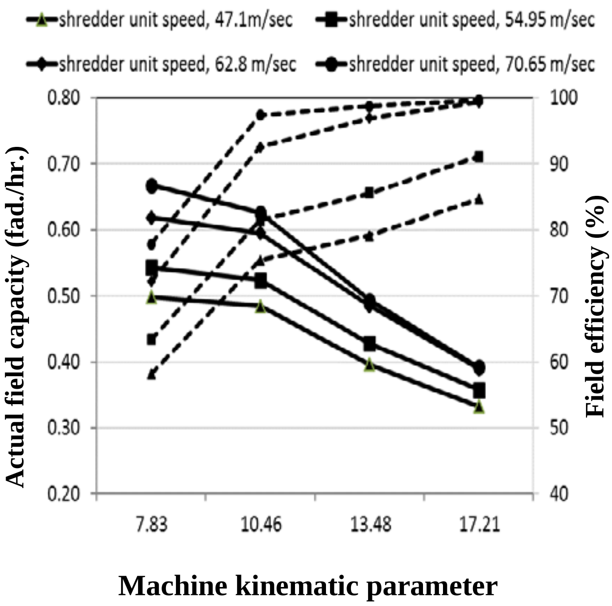


Fig. 4. Effect of chopper unit speed on actual field capacity and field efficiency at optimum condition

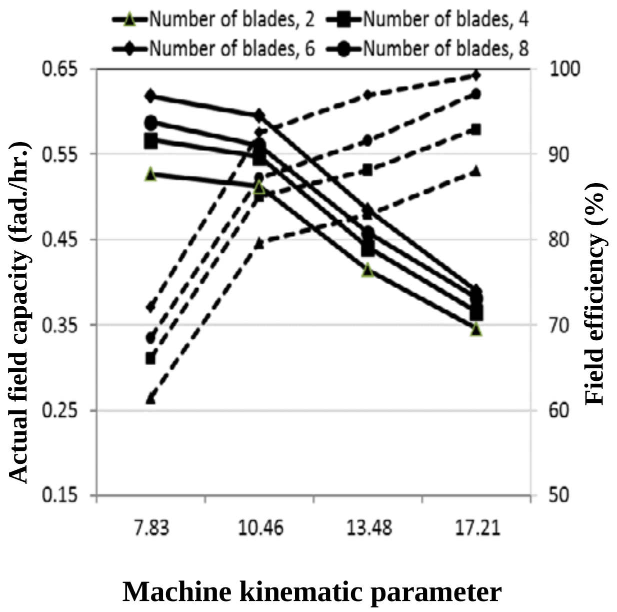


Fig. 5. Effect of number of chopping blades on actual field capacity and field efficiency at optimum condition

and 8. on actual field capacity and field efficiency. The results show that the actual field capacity increased slightly from 0.512 to 0.595 fad./hr., also, the field efficiency increases from 79.66 to 92.54% as the number of chopping blades increase from 2 to 6, however the increase of chopping unit blades number to 8, the actual field capacity will reduce to 0.561 fad./hr., that represents about 5.75% and the same trend was noticed with the field efficiency where it decreased to 87.13%, that represents about 5.86% at machine kinematic parameter of 10.46, feeder drums clearance of 2cm, chopping unit speed of 62.8 m/sec., and cotton stalk moisture content of 28.87%. These results could be attributed to the decrease in the number of chopping unit blades which decreased number of cuts per unit time and this increase the length of cuttings

Cutting Height and Cutting Efficiency

Effect of machine kinematic parameter and feeder drums clearance on cutting height and cutting efficiency

Fig. 6 presents that cutting height increased from 1.1 to 23.52 cm and cutting efficiency decreased from 99.33 to 85.57% as the machine kinematic parameter decreased from 17.21 to 7.83. at feeder drums clearance of 2 cm, chopping unit speed of 1600 rpm, chopping unit blades number of 6 blades and cotton stalks moisture content of 28.87%. This result attributed to, decreasing machine kinematic parameter which forces more quantity of direct into cutting and feeding drums and then cutting force was not sufficient to cut the stalks. Also, from obtained results it is clear that the highest cutting efficiency was 99.33% with cutting height of 1.1 cm under feeder drums clearance of 2 cm, machine kinematic parameter of 17.21, chopping unit speed of 1600 rpm, chopping unit blades number of 6 blades and cotton stalks moisture content of 28.87%. This increase can be referred to that the smoothly and consistently flow of the cutting stems from the feeder drums and pressure drums While, the lowest cutting efficiency was 60.62% with cutting height of 64.21 cm under feeder drums clearance of 1 cm, machine kinematic parameters of 7.83, chopping unit speed of 1200 rpm and chopping unit blades number of 2 blades and cotton stalks moisture content of 20.17%. This decrease can be referred to the jamming of the cutting stems in front of the machine causing the lodging and losing at the front of the moving machine.

Effect of cotton stalks moisture content on cutting height and cutting efficiency

Fig. 7 reveal that, decreasing cotton stalks moisture content from 37.83 to 28.87% decreased cutting height from 18.7 to 10 cm and increased the cutting efficiency from 88.51 to 93.87%, but reducing cotton stalks moisture content to 20.17%, increased cutting height to 21.9 cm and decreased cutting efficiency to 86.76% at feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, chopper unit speed of 62.8 m/sec and number of chopping unit blades of 6 blades. This can be attributed to the increase of plants deflection in front of the machine at higher or lower cotton stalks moisture content

Effect of chopper unit speed on cutting height and cutting efficiency

Fig. 8 show that increasing chopper unit speed from 47.1 to 62.8 m/sec., decreased the cutting height from 22.6 to 10 cm and increased the cutting efficiency from 86.16 to 93.87%, but increasing the chopper unit speed to 70.65 m/sec, increased the cutting height to about 19.2 cm and decreased the cutting efficiency to about 88.22% at feeder drums clearance of 2 cm, machine kinematic parameters of 10.46, chopping unit blades number of 6 blades and cotton stalks moisture content of 28.87%. This may be due to high vibration in cutting height.

Effect of number of chopping blades on cutting height and cutting efficiency

Fig. 9 indicate that increasing number of chopping unit blades from 2 to 6 blades decreased the cutting height from 15.7 to 10 cm and increased the cutting efficiency from 90.40 to 93.87%, the opposite trend was observed by increasing the number of chopping unit blades 8 blades, where the cutting height increased to about 15.6 cm and the cutting efficiency decreased to about 90.46% at feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, chopper unit speed of 1600 rpm and cotton stalks moisture content of 28.87%. This can be attributed to that the decrease in the number of chopping unit blades will decrease number of cuts per unit time and this increase the length of cuttings.

———Cutting efficiency ………Cutting height

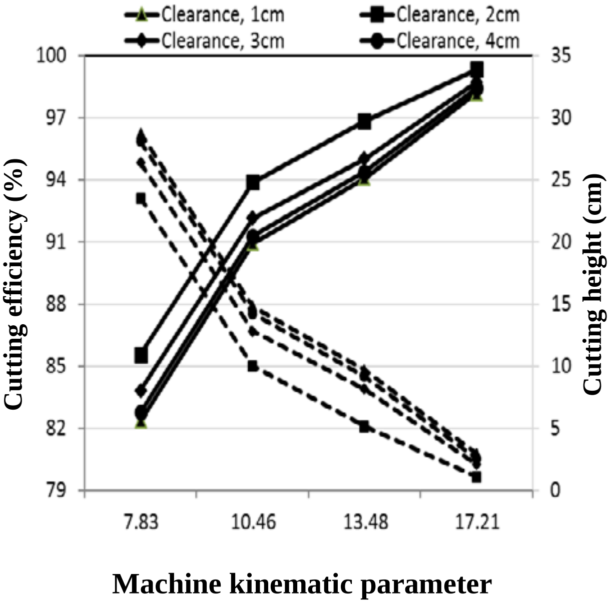


Fig. 6. Effect of machine kinematic parameter and feeder drums clearance on cutting height and cutting efficiency at optimum conditions

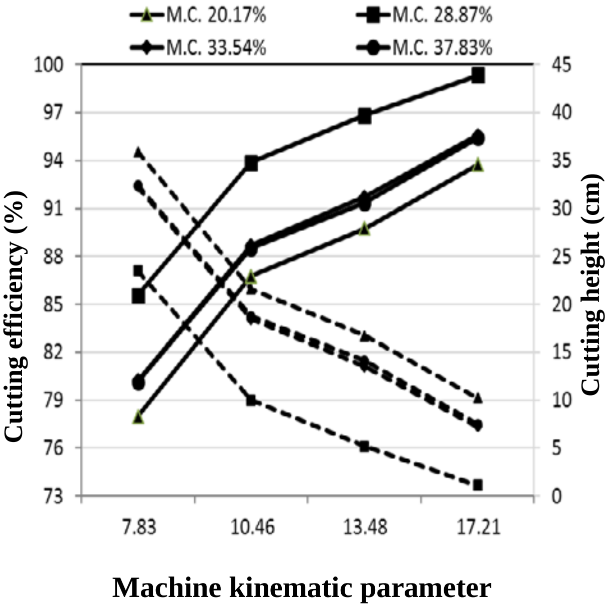


Fig. 7. Effect of cotton stalks moisture content on cutting height and cutting efficiency at optimum conditions

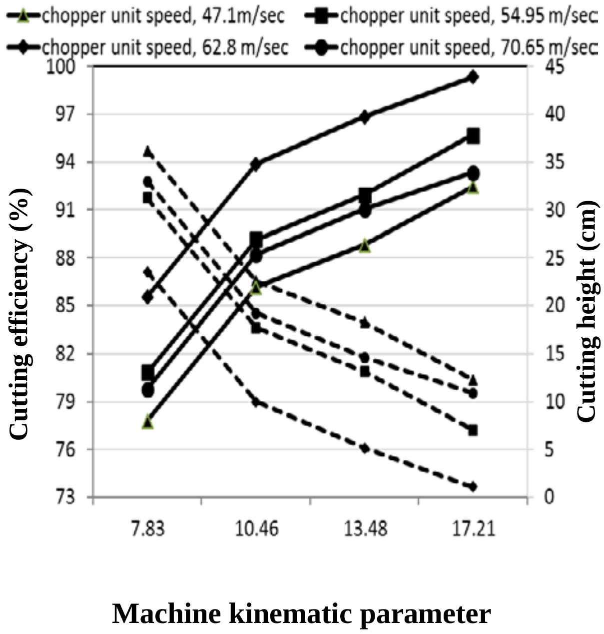


Fig. 8. Effect of chopper unit speed on cutting height and cutting efficiency at optimum conditions

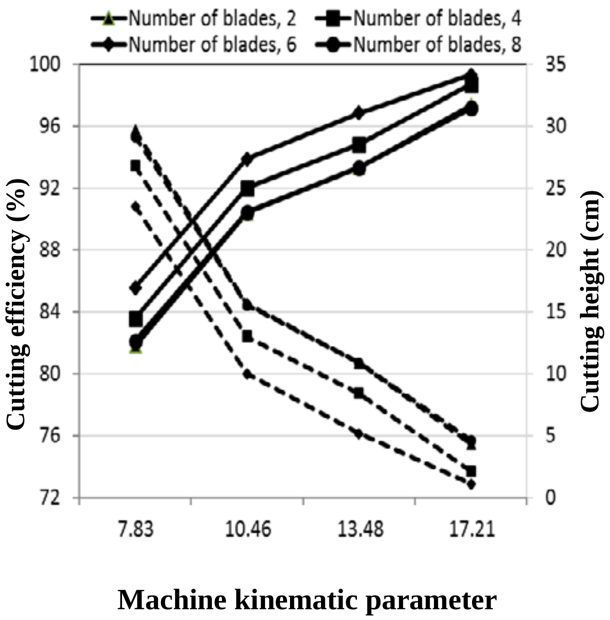


Fig. 9. Effect of number of chopping blades on cutting height and cutting efficiency at optimum conditions

Chopping Efficiency

Effect of machine kinematic parameter and feeder drums clearance on chopping efficiency

Fig. 10 show that, decreasing machine kinematic parameter from 17.21 to 7.83 decreased chopping efficiency from 59.50 to 56.85%. at feeder drums clearance of 2 cm, chopping unit speed of 62.8 m/sec., chopping blades number of 6 blades and cotton stalks moisture content of 28.87%. Also it is clear that the highest chopping efficiency was 64.52% under feeder drums clearance of 4 cm, machine kinematic parameter of 17.21, chopping unit speed of 70.65 m/sec., chopping blades number of 8 blades and cotton stalks moisture content of 28.87%. While, the lowest chopping efficiency was 29.58% under feeder drums clearance of 2 cm, machine kinematic parameter of 7.83, chopping unit speed of 47.1 m/sec., chopping blades number of 2 blades and cotton stalks moisture content of 37.83%.

Effect of cotton stalks moisture content on chopping efficiency

Fig. 11 indicate that decreasing cotton stalks moisture content from 37.83 to 28.87% increased the chopping efficiency from 50.90 to 57.26%, but decreasing cotton stalks moisture content to 20.17% decreased the chopping efficiency to 52.48% at feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, chopping unit speed of 62.8 m/sec., and chopping blades number of 6 blades. The decreasing of chopping efficiency at higher cotton stalk moisture content may be attributed to the plant stalk possesses the behavior of visco-elastic material and therefore, the maximum shear strength of the stem wall due to the gradual accumulation of lignin in the stem wall.

Effect of chopper unit speed on chopping efficiency

Fig. 12 show that increasing chopper unit speed from 47.1 to 70.65 m/sec., increased the cutting efficiency from 45.80 to 59.60% at feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, chopping unit blades number of 6 blades and cotton stalks moisture content of 28.87%. This may be due to the increase of chopper knocking number in time unit on the stems.

Effect of number of chopping blades on chopping efficiency

Fig. 13 reveal that, increasing number of chopping unit blades from 2 to 8 blades increased chopping efficiency from 48.12 to 58.64% at feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, chopper unit speed of 62.8 m/sec., and cotton stalks moisture content of 28.87%. This can be attributed to the increase in the number of chopping blades that will increase number of cuts per unit time and this decrease the length of cuttings.

Power and Specific Energy Requirements

Effect of machine kinematic parameter and feeder drums clearance on power and specific energy requirements

Fig. 14 show that the required power increased from 25.48 to 37.68 kW and the specific energy requirements decreased from 65.33 to 60.92 kW.hr./fad., when machine kinematic parameter decreased from 17.21 to 7.83, by using feeder drums clearance of 2cm, chopper unit speed of 62.8 m/sec., the chopping blades number of 6 blades and cotton stalks moisture content of 28.87%. On the other hand, the effect of feeder drums clearance on required power and specific energy requirements showed that the highest required power was 49.03 kW by using feeder drums clearance of 2cm, machine kinematic parameter of 7.83, chopper unit speed of 70.65 m/sec., the chopping blades number of 8 blades and cotton stalks moisture content of 20.17% and the maximum specific energy requirement was 105.41 kW.hr./fad., by using feeder drums clearance of 1cm, machine kinematic parameter of 17.21, chopper unit speed of 47.1 m/sec., the chopping unit blades number of 2 blades and cotton stalks moisture content of 20.17%. This could be attributed to the flow of the cutting stems from the feeder drums and pressure drums more difficult because the summation of stems diameter was more than the clearance of feeder drums resulting more stress on cutting and feeding unit and decreased actual field capacity, which reflect on required power then specific energy. By contrast, the lowest required power was 22.71 kW by using feeder drums clearance of 1 cm, machine kinematic parameter of 17.21, chopper unit speed of 47.1 m/sec., and number of chopping blades of 2 blades and cotton stalks moisture content of 28.87%. While, the lowest value of specific energy requirements of 56 kW.hr./fad., was achieved by using feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, chopper unit speed of 47.1 m/sec., number of chopping blades of 6 blades and cotton stalks moisture content of 28.87%, this could be due to the increasing in actual field capacity which was more than the increasing in required power.

Effect of cotton stalks moisture content on power and specific energy requirements

Fig. 15 show that decreasing of cotton stalks moisture content from 37.83 to 28.87% was

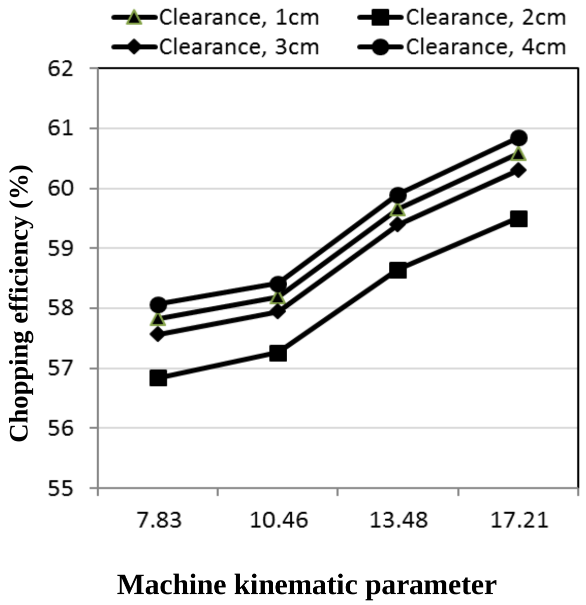


Fig. 10. Effect of machine kinematic parameter and feeder drums clearance on chopping efficiency at optimum condition

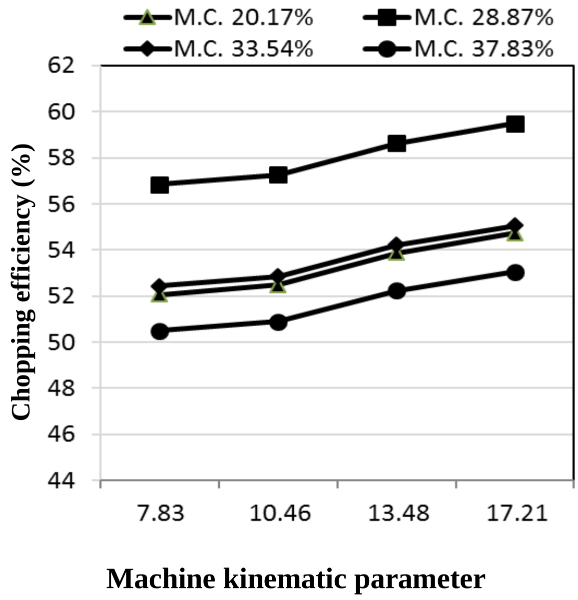


Fig. 11. Effect of cotton stalks moisture content on chopping efficiency at optimum condition

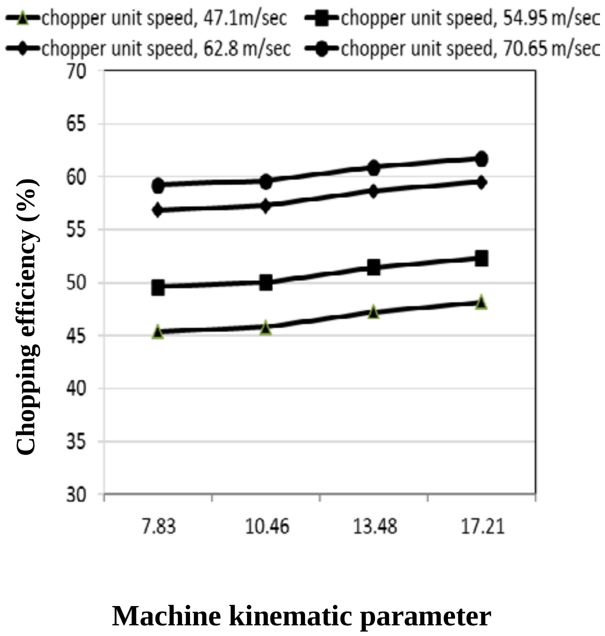


Fig. 12. Effect of chopper unit speed on chopping efficiency at optimum condition

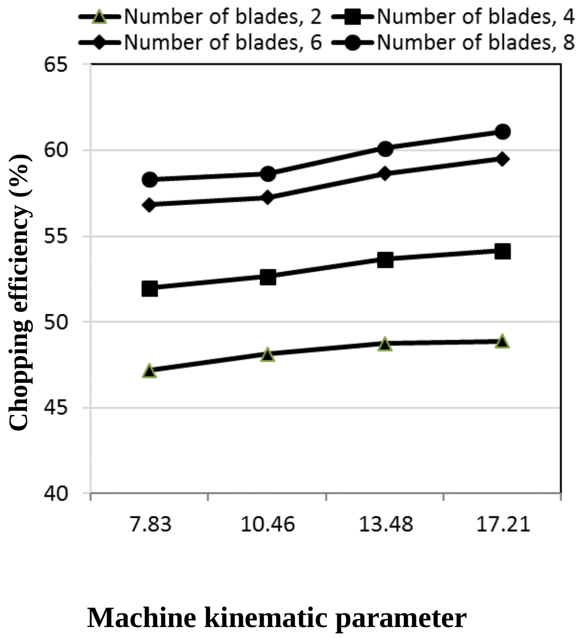


Fig. 13. Effect of number of chopping blades on chopping efficiency at optimum condition

———Specific energy requirement …………required power

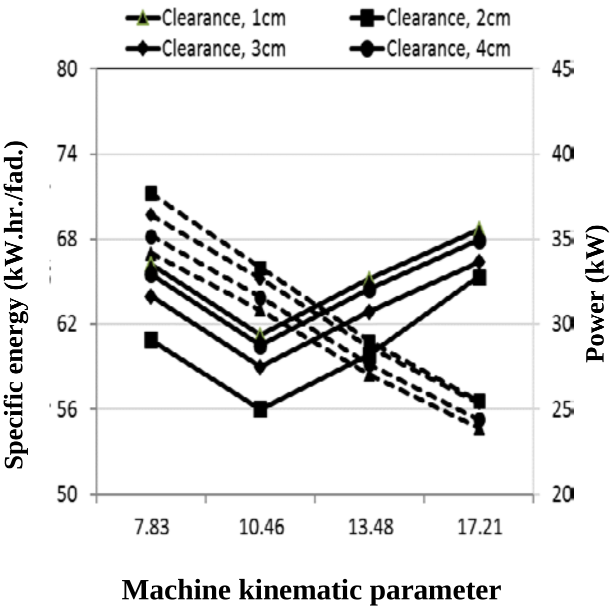


Fig. 14. Effect of machine kinematic parameter and feeder drums clearance on power and specific energy requirements at optimum condition

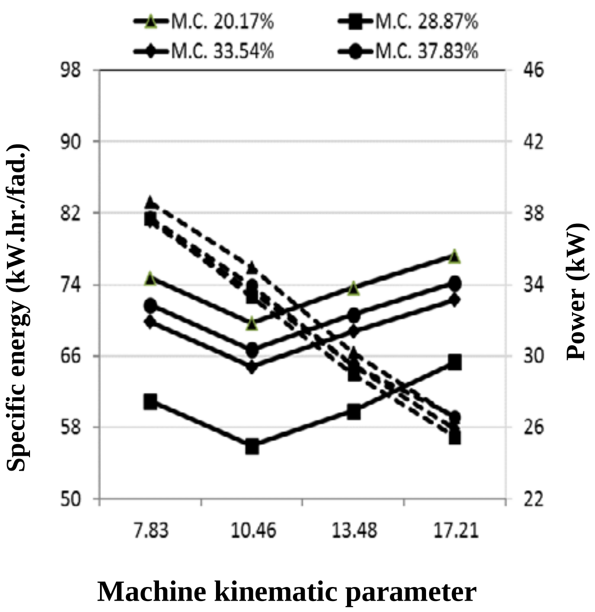


Fig. 15. Effect of cotton stalks moisture content on power and specific energy requirements at optimum condition

followed by decreasing in both of power and specific energy requirements but, the further decrease in cotton stalks moisture content to 20.17% will increase both of them. The obtained results indicate that, by decreasing the cotton stalks moisture content from 37.83 to 28.87%, the required power decreased from 33.95 to 33.31 kW and specific energy requirements decrease from 66.69 to 56 kW.hr./fad., then the required power increased to 34.95 kW and specific energy requirements increased to 69.70 kW.hr./ fad., as cotton stalks moisture content decreased to 20.17% at machine kinematic parameter of 10.46, feeder drums clearance of 2cm, chopping unit speed of 62.8 m/sec., and number of chopping blades of 6 blades. Finally, any further decrease or increase in cotton stalks moisture content less to or more than the optimum value mentioned above, both required power and consumed energy increased under all experimental conditions due to the increase in cutting resistance force at lower moisture contents and increase elastic plant conditions at higher moisture contents which consumed more fuel during cutting and chopping operation.

Effect of chopper unit speed on power and specific energy requirements

As shown in Fig. 16 it was observed that, the required power increased from 33.13 to 36.43 kW when the chopper unit speed increased from 47.1 to 70.65 m/sec., by using feeder drums clearance of 2cm, machine kinematic parameter of 10.46, number of chopping blades of 6 blades and cotton stalks moisture content of 28.87%. But, the specific energy requirement decreased from 68.39 to 56 kW.hr./fad., when chopper unit speed increased from 47.1 to 62.8 m/sec. at the same conditions but any increasing in chopper unit speed lead to increasing in specific energy requirements, this may be referred to the excessive stress on cutting knives at high speeds of cutting and feeding unit that may consume more power.

Effect of number of chopping blades on power and specific energy requirements

Fig. 17 depicts that, increasing number of chopping blades from 2 to 8 blades lead to increase in required power. The required power increased from 32.05 to 34.27 kW as the number

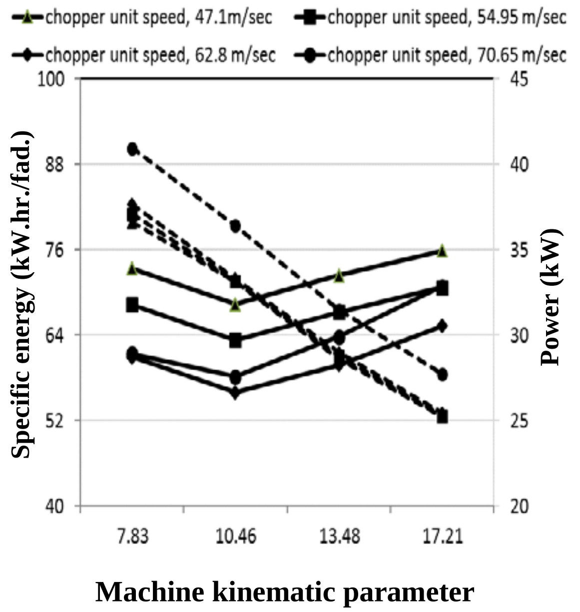


Fig. 16. Effect of chopper unit speed on power and specific energy requirements at optimum condition

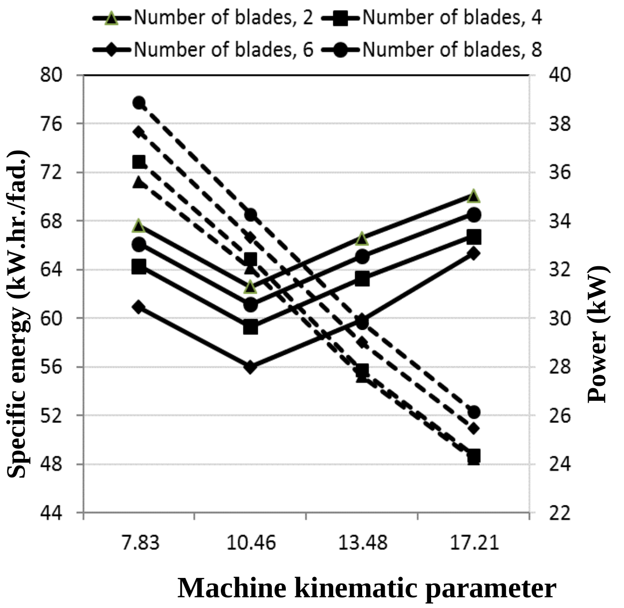


Fig. 17. Effect of number of chopping blades on power and specific energy requirements at optimum condition

of chopping blades increased from 2 to 8 blades by using feeder drums clearance of 2cm, machine kinematic parameter of 10.46, chopper unit speed of 62.8 m/sec. and cotton stalks moisture content of 28.87%. While, the specific energy requirement decreased from 62.59 to 56 kW.hr./fad., when the number of chopping blades increased from2 to 6 blades at the same conditions and any further increment in number of blades decreased the specific energy.

Criterion Cost

Effect of machine kinematic parameter and feeder drums clearance on criterion cost

Fig. 18 indicate that, the value of criterion cost decreased from 154.80 to 135.35 LE/fad., when machine kinematic parameter decreased from 17.21 to 10.46, then the value of the criterion cost increased to 172.36 LE/fad., as the machine kinematic parameter decreased to 7.83 by using feeder drums clearance of 2cm, chopper unit speed of 62.8 m/sec., the chopping blades number of 6 blades and cotton stalks moisture content of 28.87%. This was attributed to the increase of cutting height, which resulting in considerable increase of stalk losses. Also, it was noticed that, the highest value of criterion cost of 390.28 LE/ fad., was recorded under feeder drums clearance of 1 cm, machine kinematic parameter of 7.83, chopping unit speed of 47.1 m/sec., and chopping blades number of 2 blades and cotton stalks moisture content of 37.83%. This may be attributed to the increase in the product losses during mechanical removing of cotton stalks. On the other hand, the lowest value of criterion cost of 135.35 LE/fad., was achieved under feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, chopping unit speed of 62.8 m/sec., and chopping blades number of 6 blades and cotton stalks moisture content of 28.87%.

Effect of cotton stalks moisture content on criterion cost

By viewing the effect of cotton stalks moisture content on the value of criterion cost in Fig. 19, it was noticed that the value of criterion cost decreased from 177.98 to 135.35 LE/fad., when the cotton stalks moisture content decreased from 37.83 to 28.87%, then the value of criterion cost increased to 188.90 LE/fad., when the cotton stalks moisture content decreased to 20.17% at machine kinematic parameter of 10.46, feeder drums clearance of 2cm, chopper unit speed of 1600 rpm and number of chopping unit blades of 6 blades. It was observed that the higher values of criterion costs at lower or higher cotton stalks moisture contents were attributed to the lower values of cutting efficiencies resulting in more stalks stubble after removing operation.

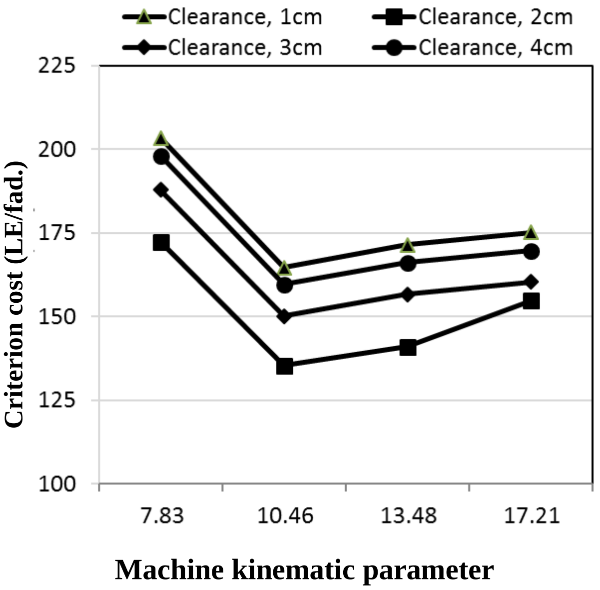


Fig. 18. Effect of machine kinematic parameter and feeder drums clearance on criterion costs at optimum condition

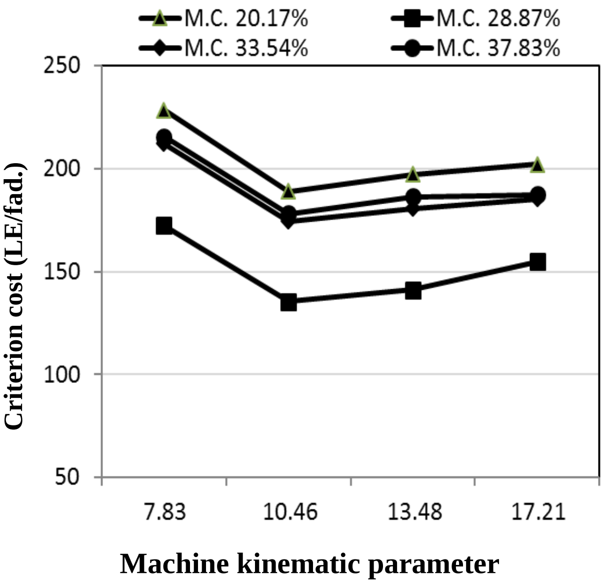


Fig. 19. Effect of cotton stalks moisture content on criterion costs at optimum condition

Effect of chopper unit speed on criterion cost

Fig. 20 illustrate that the value of criterion cost decreased as the chopper unit speed increased from 47.1 to 62.8 m/sec., then, it tends to increase when the cutting and feeding unit speed increased up to 70.65 m/sec. The recorded data showed that, increase of the chopper unit speed from 47.1 to 62.8 m/sec., followed by decreasing in the value of criterion cost from 193.58 to 135.35 LE/fad., then the value of criterion cost increased to 158.13 LE/fad., as the speed of the chopper unit speed increased up to 70.65 m/sec., by using feeder drums clearance of 2cm, machine kinematic parameter of 10.46, number of chopping blades of 6 blades and cotton stalks moisture content of 28.87%. This was attributed to the increase of cutting height due to high vibration, resulting in considerable increase of stalk losses.

Effect of number of chopping blades on criterion cost

Fig. 21 show that, the value of criterion cost decreased from 166.42 to 135.35 LE/fad., when the number of chopping blades increased from 2 to 6 blades, then the value of criterion cost increased to 158.11 LE/fad., when the number of chopping blades increased to 8 blades by using feeder drums clearance 2cm, machine kinematic parameters of 10.46, chopper unit speed of 62.8 m/sec., and cotton stalks moisture content of 28.17%. Generally, the increase of fuel consumption and product losses cause increasing in the value of criterion costs.

Conclusion

Amounted cutting and chopping machine for cotton stalks was evaluated from locally available materials and evaluated under field conditions. The main experiments were carried out at private farm in Sharkia Governorate through seasons of 2014 and 2015 in clay soil area of five faddans. Results showed that by using feeder drums clearance of 2 cm, machine kinematic parameter of 10.46, cotton stalks moisture content of 28.87% and chopper unit speed of 1600 rpm. (62.8 m/sec.) and number of chopping blades of 6 blades, the lowest values of criterion cost of 135.35 LE/fad., specific energy requirements of 56 kW.hr./fad., and highest values of cutting and chopping efficiency of 93.87%, 57.26%, respectively at actual field capacity of 0.6 fad./hr., and field efficiency of 92.54% were achieved.

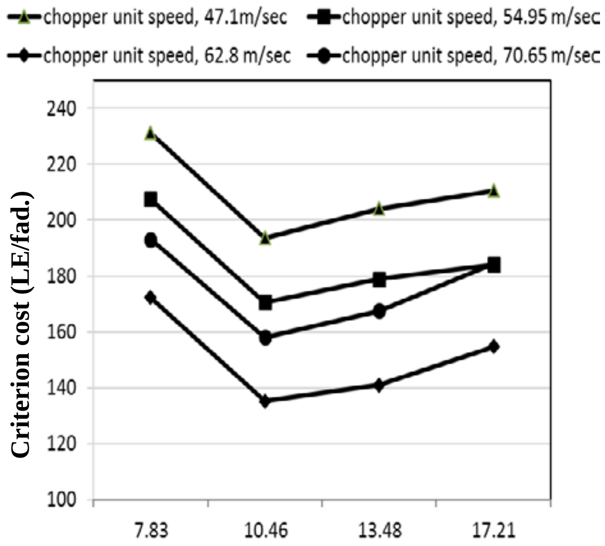


Fig. 20. Effect of chopper unit speed on criterion costs at optimum condition

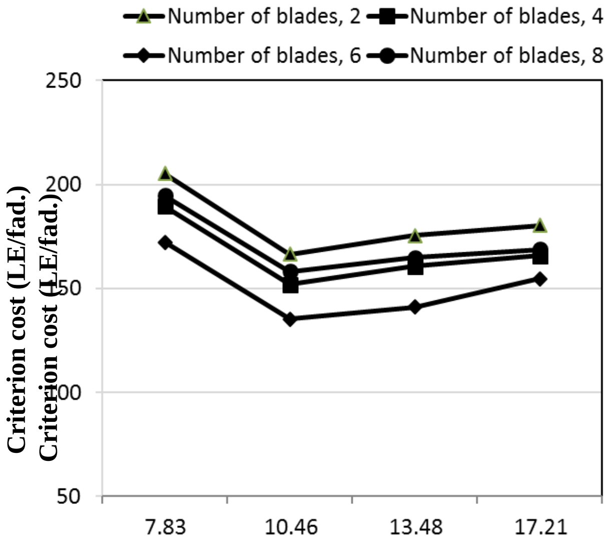


Fig. 21. Effect of number of chopping blades on criterion costs at optimum condition

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تقييـــــم أداء آلـــــة محليـــة لتقطيــــــع وفـــــــرم حطـــب القطـــــــن

عــلاء عوني أحمد عبد العاطي – محمود عبد العزيز حســـن

محمود خطـــــــاب عفيفــــي – حنان محمد سعد الدين الشال

قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

تهدف هذه الدراسة إلى تصميم وتقييم أداء آلة لقطع وفرم أحطاب القطن والوصول إلى أنسب الظروف اللازمة لتشغيل الآلة، تم تصميم وتصنيع الآلة في ورشة قسم الهندسة الزراعية - كلية الزراعة - جامعة الزقازيق وتم اختبارها في أحد المزارع الخاصة بمحافظة الشرقية، وتتركب الآلة من أربعة أجزاء رئيسية وهي الجزء الخاص بالقطع والتغذية، الجزء الخاص بالتقطيع والفرم، منظومة نقل الحركة والهيكل الرئيسي للآلة، تم دراسة عدد من المتغيرات لتقييم هذه الآلة بعد التصميم والتصنيع والتي تشمل ٤ محتويات رطوبة لإحطاب القطن وهي (٣٧.٨٣، ٣٣.٥٤، ٢٨.٨٧ و٢٠.١٧%)، ٤ معاملات كيناماتيكية ٧.٨٣، ١٠.٤٦، ١٣.٤٨ و١٧.٢١ بين السرعة المحيطية لدرفيلي القطع والتوجيه عند ١٠٠٠ لفة/دقيقة وبين السرعات الأمامية للالة ٢.٧٥، ٣.٥، ٤.٥ و٦ كم/س، ٤ خلوصات هي ١، ٢، ٣و ٤ سم بين درفيلي القطع والتوجيه، ٤ سرعات محيطية ٤٧.١، ٥٤.٩٥، ٦٢.٨ و٧٠.٦٥ م/ث لوحدة التقطيع والفرم و ٤ أعداد مختلفة للسكاكين المثبتة على وحدة التقطيع والفرم وهي ٢، ٤، ٦و ٨ سكينة وقد تم تقييم آداء هذه الالة من خلال قياسات السعة الحقلية والكفاءة الحقلية، كفاءة القطع، كفاءة التقطيع والفرم، القدرة اللازمة والطاقة المستهلكة، تكاليف التشغيل والتكاليف الكلية لعملية القطع والفرم، وكانت أهم النتائج المتحصل عليها هي أن أفضل كفاءة حقلية كانت ٩٢.٥٤%، أفضل سعة حقلية كانت ٠.٦ فدان/ساعة وكانت أفضل كفاءة للقطع ٩٣.٨٧% وأفضل كفاءة للتقطيع والفرم ٥٧.٢٦% بأقل طاقة مستهلكة مقدارها ٥٦ ك.وات.ساعة/فدان وكذلك أقل تكاليف حدية بلغت ١٣٥.٣٥ جنيه/فدان، وتمت التوصية بإستخدام الة القطع والفرم عند معامل كيناماتيكي ١٠.٤٦ ومتوسط نسبة رطوبة لإحطاب القطن٢٨.٨٧% وخلوص بين درفيلي القطع ٢سم وسرعة محيطية لقرص الفرم ٦٢.٨ م/ث وعدد ٦ سكاكين على وحدة التقطيع والفرم.

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