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PERFORMANCE EVALUATION OF A DEVELOPED LOCAL SOD MOWER

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ABSTRACT

A sod mower machine was developed and constructed to used in garden and club. Experiments were carried out to evaluate its performance and estimate the operational cost .The performance of the sod mower machine in terms of field efficiency, cutting efficiency, fuel requirements and mowing cost were investigated departing on of change in kinematics parameter (ratio of rotary peripheral velocity to forward speed), cutting mechanisms (single or double drum) and knife types (straight or curved with two blades) during the mowing operation of sod.

The experimental results revealed that the use of the developed sod mower machine in order to maximized mower efficiency and minimized mower fuel consumption and operating cost under the following conditions:

The operating mower a kinematics parameter of 20 which corresponded to forward speed of 0.24 m/s, knife velocity of 5 m/s was the optimum. The best adjusting of the knife of the machine at cutting height of 4 cm with moisture content 50 % was used cutting mechanism of double drum with straight knife (two blades).

INTRODUCTION

Public and special gardens play a vital role in the population life. The green bed refines the atmosphere from the bad particles of pollution in the air. Green bed is used widely as a playground for most games in different clubs. This process is still operated depending on primitive methods using manual tools or imported machines of highly cost. So, sod cutting by means of up to date technology taking into consideration. Machine performance and improvement, field efficiency, fuel requirements and operating cost is an important.

Many researches were carried out on the rotary mechanisms of cutting

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machines and the design variables which affect the cutting efficiency. **Kepner et al. (1972)** stated that the common way of the cutting forces was by means of two opposed shearing elements. In the way of applying the cutting forces by single cutting elements, the material being cut may transmit the force required to oppose a single cutting element. An impact cutter having a single high speed cutting element relies primarily upon inertia of the material being cut to furnish the opposing required force for shear.

Prasad and Cupta (1973) found that the cross section area and moisture content of the cut material had significant influence over shearing energy and maximum shearing force. **Mored (1981**) found that the required force for cutting any material may be divided into two parts. The first part is the inertia force required to move the cutting mechanism, and the second is the shearing force required to shear the material. Inertia force is affected by the square of knife velocity resulting in a sharp increase of cutting energy. The force was found to be affected by knife velocity, machine forward speed, and material moisture content. **Awady et al. (1988)** reported that rotary disk with cutter blades gave better operation efficiencies (0.45-0.91). Appropriate tip speeds are determined according to forward speed, blade protrusion and other relevant factors. **Habib (2002)** Found that the cuttings force of the plant materials is the main parametric force affecting knife velocity. Whereas, the tension and bending forces that resulted in the plant stalk are of little effect on the cutting knife velocity. **El-Sahar (1988)** Indicated that the cuttings force is greatly affected by the diameter of the plant stem. For three types of plant stem of cotton, wheat and lawn, 625 N force was needed to cut of 9 mm cotton stalk diameter at 6.5 %, for 2.5 mm diameter lawn stems in bundles of four stems. Decreasing cutting forces at higher moisture contents were due to visibility of the stalk tissues of plant stems. **Imbabi (1992)** found that the energy requirements for cutting the sesame plants ranged from 4.32 – 27.03 Joule / stem according to the moisture content of stems, while the cutting force ranged from 432.14 – 1351.31 N/stem according to the moisture content of stems.

The objectives of the present research is :

1 . Performance evaluation of a developed local machine in sod mower to improve its performance and minimize the operational cost.

2 . Selecting the optimum conditions (kinematic parameter) and the optimum cutting mechanism for operating the machine.

MATERIALS AND METHODS

Experiments were carried out at Faculty of Agriculture, Al-Azhar University to evaluate of its performance under different operating parameters. The constructed of sod cutting machine was done in locally workshop .

The developed sod cutting machine:

Sod cutting machine (Fig.1) consists of the following main parts;

1 . **power unit**: The engine has a power of 3 kW and rotating speed of 900-2200 rpm, Two strok, Kawasaki kt-18, one cylinder and forced air cooling.

2 . **Cutting mechanisms**: Two type of cutting mechanisms were used in this study as follow:

Single cutting mechanism. The main parts of cutting unite consists of :

1. Bevel gear 4 and 8 teeth to transmission of power and change the direction of motion of rotary from horizontal to vertical.

2. A vertical shaft of 25 cm length ,4cm diameter and it is carried by two ball bearing which fixed on the fram as a link from bevel gear 8 ,16 and 24 teeth to cutting disc.

3. Cutting disc : Disc is make from spring steel, 50 cm diameter and the disc is connected to a knife has two blades; the knife connected to the disc by a bolt and nut to. The curved and straight knifes have of 7 cm length, 5 cm width and 2 mm thickens.

Double cutting mechanism: The double cutting unite consists of two single cutting unites but the diameter of disc was half diameter of single disc which gave the similar operating width as 58 cm, the motion of the discs was on opposite direction.

3. Power transmission system: The power transmission system mainly consists of pulleys, V belt and horizontal shaft. The drive pulley is mounted on the engine shaft and has a diameter of 6 cm . The driven pulley is mounted on a horizontal shaft it is multiple diameter of (20, 13.5 , 10 , and 8 cm). These variation of diameter of pulleys gave a lot of reduction ratio. The horizontal shaft; was of 40 cm length , 2. cm diameter and it is carried by ball bearing which fixed on the frame . Three bevel gears connected to the horizontal shaft to transmission the motion to the cutting unite.

4. Transporting wheels: The mower is provided by two sets of the front and rear wheel. The front wheel is 30 cm diameter and 5 cm width. Also it used in order to adjust the height of cut by means of an adjustment control .These wheels are fixed in the frame by means of ball bearing. The rear wheel is 40 cm diameter and 5cm width. These wheel are used for transport the mower during its operation. These wheels are fixed in the main body by means of ball-bearings

5. Frame The frame was constructed of steel plate (90 x 48 x 0.4 cm) to carry the engine and fixed it by means of four sets screw bolts and nuts, A rubber pad was put under the engine to reduce and dumb the vibrations. The frame also carried the cutting mechanism and the power transmission system. Handles were 85 cm long and made of 2.5 cm diameter steel pipes. A lever to control the tension of belt by jockey wheel and clutch was fixed on left handle. Engine accelerator lever was fixed also on the right hand.

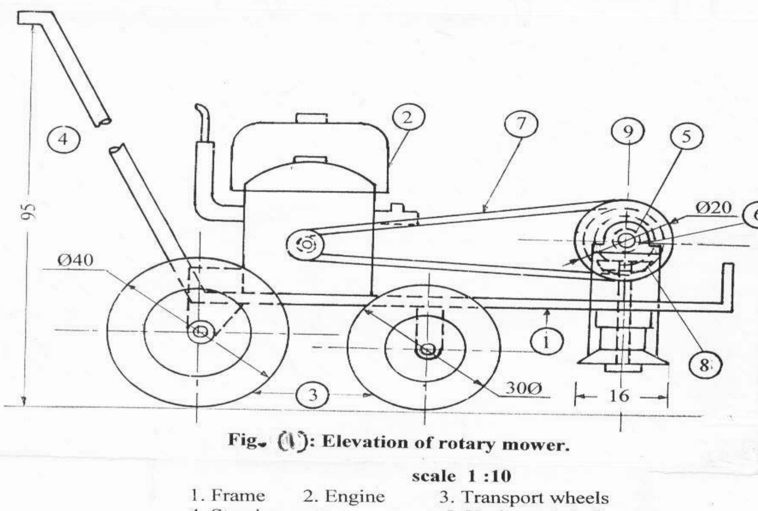

Fig. (1): Elevation of rotary mower.

scale 1 :10

1. Frame 2. Engine 3. Transport wheels
4. Steering system 5. Horizontal shaft
6. Ball bearing 7. power transmission 8. Bevel gears 9. Pulleys 10. Jockey clutch

Table (1) Knife velocity used in mower.

Cutting mechanism	Knife types	Knife velocity m/s	Kinematic parameter
Single drum	Straight blade	3	12
		4	16
		5	20
		6	24
	Curved blade	3	12
		4	16
		5	20
		6	24
Double drum	Straight blade	3	12
		4	16
		5	20
		6	24
	Curved blade	3	12
		4	16
		5	20
		6	24

The effective field capacity (C_{ef}) is the actual average working rate of area concerning the amount of time lost during the operation.

Cutting efficiency:

Cutting efficiency was calculated by using the following formula.

$$E_c = \frac{A - B}{A} \times 100 \qquad (3)$$

Where

A : height of sod stalks above the soil service before cutting, in cm.

B : height of sod stalks above the soil after cutting, cm.

Power requirements:

The power can be calculated by measuring fuel consumption and by using the following equation .

$$E_p = \{F_c\} \times LCV \times 427\ \eta_{th} \times \eta_m \qquad (4)$$

Where:

F_c : The fuel consumption, Kg / h

LCV:The lower calorific value of fuel (kJ / kg), average LCV of gasoline is 11000 kcal/kg.

η_m : mechanical efficiency of the about 80 % for gasoline engine

η_{th} : The thermal efficiency of the engine, (consider to be about 25 % for gasoline engine)

100: Thermal-mechanical equivalent, kg .m/kJ.

Kinematic parameter .

The Kinematic parameter was defined as the ratio of knife peripheral velocity to machine forward speed

$$\lambda = \frac{\omega\, r}{v}$$

Where:

λ : Kinematic parameter.

ω : Angular velocity of the knife, m/s

r : Rotor radius,

v : Machine forward speed, m/s

The proper adjustment of the kinematic parameter during sod cutting is great importance to decrease sod cutting losses and consequently increase cutting efficiency.

There were four ways in which the kinematic parameter can be varied: change the knife velocity, and machine forward speed 0.24 m/s.

In this investigation, the proper kinematic parameter was indicated experimentally. All experiments were run under a constant forward speed 0.24 m/s, and different knife velocity of 3, 4, 5, and 6 m/s, which corresponded to different kinematic parameter of 12, 16, 20, and 24 respectively (tables1).

The performance of the sod cutting machine was evaluated a change in kinematic parameter, cutting mechanism of single and double drum, and knife types of straight and curved (two blades) .

Evaluation of the sod cutting machine performance was carried out by taking into consideration the following indicators.

Field efficiency for the mower:

The field efficiency was calculated by using the following equation;

$$E_f = \frac{C_{ef}}{C_{th}} \times 100 \text{------------------------------------(1)}$$

Where:

E_f : The field efficiency.

C_{ef} ; effective field capacity in fed / h .

C_{th} : theoretical e field capacity in fed / h .

$$C_{th} = S \cdot W / 4200 \text{---(2)}$$

Where:

S = travel speed , in m / h .

W = operating width of the mower in m .

The effective field capacity (C_{ef}) is the actual average working rate of area concerning the amount of time lost during the operation.

Operation cost :

The operation costs of the mower were calculated according to (Awady 1978).

$$C = p / h (1/e + i/2 + t + r) + (1.2 \text{ kW} . F S) + W / 144 \text{---------------(5)}$$

Where:

C : is the hourly cost, LE / h

p : is the capital investment.

h : is the yearly operating hours, h

e : is life expectancy of equipment in year.

l : is the interest rate, %

t : is the taxes and overheads.

r : is the repairs ratio of the total investment.

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

F : is the specific fuel consumption in liter/kW.h.

S : is the price of fuel per liter .

w : is the labor wage rate per month (L.E).

144 : is the reasonable estimation of monthly working hours.

RESULTS AND DISCUSSION

The influences of some operating parameters on the performance of sod mower machine are discussed as follows:

Effect of kinematic parameter on field efficiency:

Representative values of field efficiency versus rotary mower kinemetic parameters with cutting mechanism (single and double) and knife straight or curved (two blade) are given in Fig. 2.

Results show that, field efficiency values were increased as the kinemetic parameters increased. Data obtained show that increased the rotary mower kinemetic parameters from 12 to 24, increased the field efficiency by 86.4 to 94.9 % with double cutting mechanism and straight knife, Through the curved knife there are some change as the field efficiency. Decreased at the lower values of kinemetic parameters,the field efficiency was 76.4 at 12 kinemetic parameters and 89.3 at the 24 kinemetic parameters for the single cutting mechanism and curved knife. Same trend was appended with the double drum bat with tight change.

The major reason for the increase in field efficiency by increasing the kinemetic parameters is due to the less theoretical time consumed in comparison with the other items of time losses.

Influence of some operating parameters on cutting efficiency:

Cutting efficiency is greatly affected by many operating parameters. Unadjustment of these parameters caused a serious sod damage that tends to increase losses, and in turn decreased sod quality, (Fig.3).

Representative values of cutting efficiency versus rotary mower kinemetic parameters with cutting mechanism (single and double) and knife straight, curved (two blade) are given in Fig.3.

Results show that cutting efficiency values were increased as the kinemetic parameters increased. Data obtained show that increased the rotary mower kinemetic parameters from 12 to 24, increased the cutting efficiency by 94.5 and 99.7 % with double cutting mechanism and knife straight. Through the curved knife there are some change as the cutting efficiency. Decreased at the lower values of kinemetic parameters. The cutting efficiency was 93.3 at 12 kinemetic parameters and 98.1 at the 24 kinemetic parameters for the single cutting mechanism. Same trend was appended with the double drum bat with tight change.

The major reason for the increase in cutting efficiency by increasing the kinemetic parameters.

The increase of cutting height with the decrease of kinematic parameter is due to bending of sod under the cutter disk of the rotary mower, added to that , a great number of plants were left without cutting, resulting in a remarkable drop in cutting efficiency.

Effect of kinematic parameter on fuel consumption:

Fuel consumption as related to the kinemetic parameters with cutting mechanism (single and double) and knife straight, curved (two blade). Fig. 4 shows that the fuel requirements increased as the kinemetic parameters increased. Increased the rotary mower kinemetic parameters from 12 to 24 ,in creased the fuel consumption by 262 and 272 cm^3 / h with double cutting mechanism and knife straight. Through the curved knife there are some change as the fuel consumption. Decreased at the lower values of kinemetic parameters. The fuel consumption was 249 cm^3 at 12 kinemetic parameters and 260 cm3 at the 24 kinemetic parameters for the single cutting mechanism. Same trend was appended with the double drum bat with tight change. The increase of fuel requirements by increasing the kinematic parameter is attributed to the increase of field capacity, results in low values of fuel per feddan.

Cost of using the machine:

The estimated costs:

- Capital investment for the mower were 2000 L.E.
- Yearly working hours of ٨٦٤ h / year.
- life expectancy of the machine of 10 years.
- interest rate / year 10 %.
- taxes overheads ratio 2 %.
- repairs and maintenance ratio 10%.
- power 4 Hp.
- specific fuel consumption o.3lit.
- fuel price 1.2 L.E/L.
- Labor wage rate per month of 200 L.E.

The operating cost was determined 37 L.E / fed.

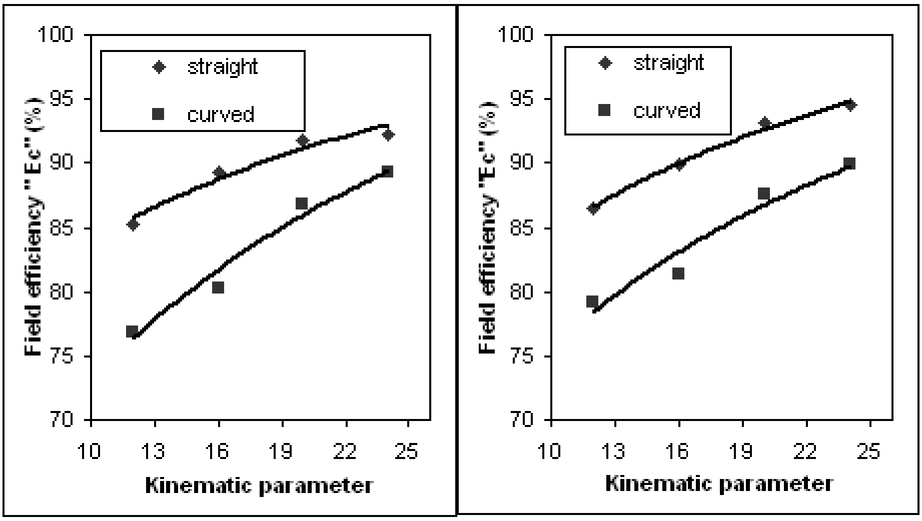

Fig.(2) Effect of the kinematic parameter"ג "on the field efficiency "Ec" (%) at different cutting mechanism and knife shape

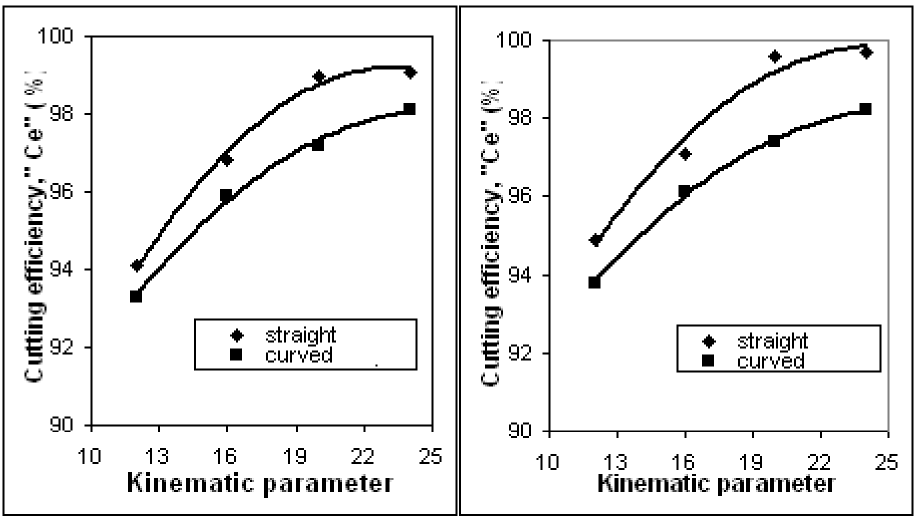

Fig. (3) Effect of kinematic parameter "ג " on the cutting efficiency "Ce" (%) at different cutting mechanism and knife shape

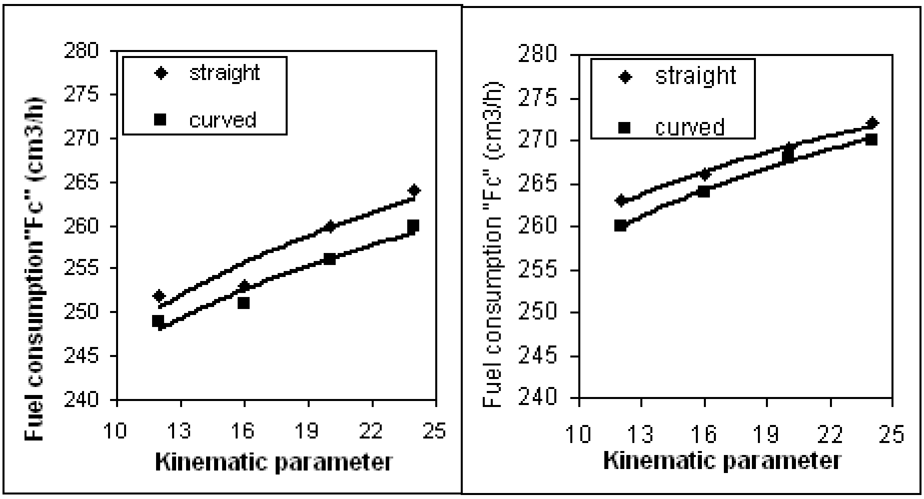

Fig.(4)Effect of kinematic parameter"λ"on the fuel consumption "Fc"(cm3 /h) at different cutting mechanism and knife shape

CONCLUSION

The proper adjustment of the rotary mower kinematic parameter during the mowing operation is of great importance to increase the field capacity and decrease cost requirements.

Increasing the rotary mower kinematic parameter from 12 to 24, increased the field efficiency by 86.4 to 94.9 % with double cutting mechanism and straight knife, increased the cutting efficiency by 94.5 and 99.7 % with double cutting mechanism and knife straight, and increased the fuel consumption by 262 and 272 cm^3 / h with double cutting mechanism and knife straight.

Rotary mower kinematic parameter of 20 minimized the mowing costs.

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الملخص العربي

تقيم أداء آلة مصنعة محليا في حش النجيل

***د / رأفت علي أحمد وربي   *د/ سمير حافظ محمد الدسوقي**

زادت الاحتياجات مؤخرا لزراعة وتجميل المدن والقرى والفنادق والنوادي والملاعب والطرق وملاعب الجولف والمنشات الحكومية وبناءا على هذا التوسع زادت المسطحات الخضراء التي تحتاج إلي قص علي فترات مختلفة والمستخدم حاليا أما الأدوات اليدوية أو الآلات المستوردة فواجهنا مشكلة زيادة أسعار الآلات المستوردة، مع عدم التوافر لقطع الغيار وزيادة أسعارها.

ولذلك يهدف البحث إلى تطوير محشة أسطوانية لقطع النجيل وتقييم أدائها من خلال المتغيرات الآتية:

علاقة السرعة الدورانية للسكاكين إلى السرعة الأمامية للآلة (المعامل الكينماتيكى - ٦)

واستخدام آلية قطع ذات اسطوانة واحدة، أو اسطوانتان مع استخدام نوعان من الأسلحة (سلاح

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مستقيم وسلاح منحنى مع شفرتان للقطع) ومحاولة دراسة تأثير ذلك على أداء المحشة.
وقد تم تقيم أداء المحشة من حيث:
- معدل الأداء والكفاءة الحقلية - ارتفاع القطع وكفاءة القطع
- استهلاك الوقود والقدرة المطلوبة - تكاليف التشغيل
وتم الحش عند نسبة رطوبة للنجيل ٥٠ % وارتفاع قطع ٤ سم من سطح الأرض.
وقد وجد من تحليل النتائج ما يلى:
- يقل معدل أداء الآلة بينما تزداد كفاءتها الحقلية كلما زاد المعامل الكينماتيكى مع آليات القطع ومع أشكال أسلحة القطع المختلفة. وكانت اعلي كفاءة حقلية ٨٦.٥ % عند معامل كينماتيكي ١٢ وكانت ٩٤.٤ % عند معامل كينماتيكي ٢٤ مع استخدام اسطوانتان قطع وسكينة مستقيمة. وكانت اقل كفاءة حقلية ٧٦.٩% عند معامل كينماتيكي ١٢ وكانت ٨٩.٣ % عند معامل كينماتيكي ٢٤ مع استخدام اسطوانة قطع واحدة وسكينة منحنية.
- يقل ارتفاع القطع وتزيد كفاءة القطع كلما زاد المعامل الكينماتيكى مع آليات القطع ومع كل أشكال أسلحة القطع. وكانت اعلي كفاءة القطع ٩٤.٩% عند معامل كينماتيكي ١٢ وكانت ٩٤.٤ % عند معامل كينماتيكي ٢٤ مع استخدام اسطوانتان قطع وسكينة مستقيمة. وكانت اقل كفاءة حقلية ٧٦.٩% عند معامل كينماتيكي ١٢ وكانت ٨٩.٣ % عند معامل كينماتيكي ٢٤ مع استخدام اسطوانة قطع واحدة وسكينة منحنية.
- يزيد استهلاك الوقود مع زيادة المعامل الكينماتيكي مع آليات القطع المختلفة ومع أسلحة القطع المستخدمة. وكانت اعلي استهلاك للوقود عند معامل كينماتيكي ١٢ هو ٢٦٣ سم ٣ / س وكانت ٢٧٢ سم ٣ / س عند معامل كينماتيكي ٢٤ مع استخدام اسطوانتان قطع وسكينة مستقيمة. وكانت اقل استهلاك الوقود عند معامل كينماتيكي ١٢ هو ٢٤٩ سم٣ / س وكانت ٢٦٠ سم٣ / س عند معامل كينماتيكي ٢٤ مع استخدام اسطوانة قطع واحدة وسكينة منحنية.
ونوصي باستخدام المحشة عند معامل كينماتيكي من ٢٠ إلي ٢٤ ليعطي اعلي كفاءة حقلية واعلي كفاءة قطع مع اقل التكاليف.