EFFECT OF CUTTING KNIVES SPEED AND FEEDING SPEED ON SOME TECHNICAL INDICATORS FOR THE PERFORMANCE OF A LOCALLY MANUFACTURED MACHINE

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ABSTRACT

The experiment was carried out to study some engineering factors for a locally manufactured machine, It cuts agricultural residues to make animal feed , in the workshops of the Agricultural Engineering Department/Faculty of Agriculture/Ain Shams University for the academic year 2021-2022. The effect of three-speed knives cutting speed (1000,1200,1400 rpm) and three-speed feeding speed (0.75,1,1.25 m/s) and the knife cutting angle with two angles (15°.30°) was studied at a knife clearance of 2.5 mm and a moisture content of 5.3%. With an electronic system with sensors to operate the machine and without. Among the technical indicators that have been studied are productivity, cutting power consumption, specific energy, machine operating costs and the thrust power, The results showed that the performance of machine with an electronic system(senser) to a maize chopping machine is better than a maize chopping machine without In terms of specific energy consumption, machine operating costs, at constant clearance of 2.5mm and moisture content 5.3% and an optimum knife speed of 1400 with cutting angle (30°), The maize chopping machine with an electronic system (sensor) of specific energy consumption (0.0027 kw.h/kg), machine operating costs (0.2159 LE/kg) and highest productivity (105,170 kg/hr) at cutting angle (30°).

Keywords:- cutting speed, productivity, operating cost, cutting angle, sensitive, forage.

تأثير سرعة سكاكين القطع وسرعة التغذية على بعض المؤشرات الفنية لأداء آلة محلية الصنع لقطع الأعلاف

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المستخلص

نفذت التجربة لدراسة بعض العوامل الهندسية لآلة مصنعة محلياً تعمل على تقطيع المخلفات الزراعية لعمل الاعلاف للحيوانات في ورش قسم الهندسة الزراعية / كلية الزراعة / جامعة عين شمس للعام الدراسي 2021–2022. تمت دراسة تأثير سرعة القطع للسكاكين بواقع ثلاث سرعات (1000،1200،1400 دورة في الدقيقة) وسرعة التغذية بواقع بثلاث سرعات (0.75،1،1.25 م \ ث) وزاوية قطع السكين بواقع بزاويتين (15 درجة .30 درجة) عند خلوص سكين 2.5 مم ومحتوى رطوبة 5.3٪. مع وجود نظام الكتروني مع حساسات يعمل على تشغيل الماكينة وبدونه. من بين المؤشرات الفنية التي تم دراستها الإنتاجية ، استهلاك الطاقة ، والطاقة النوعية ، وتكاليف تشغيل الماكينة، وقدرة الدفع للاعلاف ، وأظهرت النتائج أن أداء الآلة بنظام إلكتروني (حساس) لآلة تقطيع الذرة أفضل من أداء آلة تقطيع الذرة بدون حساس من حيث استهلاك الطاقة النوعية، وتكاليف تشغيل الماكينة، عند خلوص ثابت 2.5 مم ومحتوى رطوبة 5.3٪ وسرعة قصوى للسكين 1400 بزاوية تقطيع (30 درجة)، أظهرت النتائج لآلة تقطيع الذرة مع نظام إلكتروني (حساس) استهلاك الطاقة النوعية كان (0.0027 كيلوواط ساعة /كغم)، اقل تكاليف تشغيل للماكينة (0.2159 جنيه / كغم) وأعلى إنتاجية (105.170 كغم / ساعة) بزاوية القطع (30 درجة).

كلمات مفتاحية: سرعة القطع، الانتاجية، تكاليف التشغيل، زاوية القطع، الحساسات، العلف

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INTRODUCTION

Agriculture is fundamental to human society, supporting food security, economic development, and environmental sustainability (3, 17, 23). Studying agriculture to improve productivity involves understanding and applying scientific principles, new technologies, and sustainable practices to increase yields, enhance crop quality, and use resources efficiently (1,7,8,18). Agricultural waste in general is anything that is produced secondary or accidentally during the production of field crops, whether during harvesting or preparing for marketing or manufacturing of these crops. Where there are a lot of these wastes, which is one of the most important problems facing farmers. These wastes can be used to make feeding for livestock as an alternative or auxiliary sources for traditional feed, which contributes to finding cheap and efficient feed sources. Corn is an important source of human nutrition animals, and in the production of biofuels, (21) is considered the third most important crop after wheat and rice (6, 10). Animal production is characterized by a clear deficiency in the diet, especially herbs, good quality pastures and green fodder, and the availability of these feeds is essential for feeding livestock animals (22). Important problems facing Egyptian farmers, especially after the harvest process, as there are approximately 18.7 million tons annually of this waste, which can increase the national income by 1.6 billion Egyptian pounds annually through recycling. That the cutting itself is most important operation in very technology of forest chips harvesting. During the cutting processes of agricultural plant, a cutting knife penetrated in to the material over coming its strength an separating it. Throughout this process, various deformations Occur in the material, depending on the form of the cutting edge and the kinematics of cutting process (12). It was investigated the function behavior of the base-cutter blades with different designs, edge geometries and impact angles (19). The cutting energy requirement of forage crop is mainly affected by two factors, namely physical and mechanical properties of plant stem and the cutter head parameter, However, for the machine working performance the parameter is the cutting rotation speed (25). The rate of energy consumption was decreased with the increase of feed rate of rice and barley straw At 1.5 to 0.18 kg\s the rate of energy consumption was decreased from 9.84 to 8.36 kw.h\t for rice and from 8.36 to 7.1 kw.h\t for barley (13) . The chopping energy increased with increasing the rotational speed of knives at each feeding quantity except when increasing from 1800 to 2000 rpm with 0.67kg of feeding quantity at 73.45% and from 1800 to 2000 rpm with 1.12 kg of feeding quantity at 73.45% of crop moisture content for modified,(Add conveyor belt) and non-modified chopping machine, respectively (2). Increasing drum speed energy requirement of wheat and rice straw decreased. By increasing drum speed from 560 to 1040 rpm energy requirement of wheat straw decreased from 39 to 26 kw.h/ton at using knives without hammers (5). The energy used for chipping represents only about 3% of the energy return (24). the total power requirement increased with increasing the feeding drum speed for example the total power requirement increased from 1.23 kw to 1.9 kw with increasing feeding drum speed from 0.35m/s to 1.41 m/s knives clearance, for example the total power requirement increased from 1.23 kw to 1.48 kw with increasing the knives clearance from 2mm to 5mm. The maximum power requirement for chipping is not strongly affected by the chip length, but is mostly related to the diameter of logs butted. One explanation for this is that butted of a log causes the maximum absorption of power during the chipping process the peak chipping power was 24-125% higher than the average absorbed when chipping the rest of the log (9). The rate of feeding material and drum peripheral speed are two main factors affecting machine productivity, the relationship between each of drum peripheral speed and feeding rate on machine productivity. Generally, there are a direct relationship between machine productivity and each of drum peripherals speed and rate of feeding (m/s) for example, if required production of 10kg/h, the chipper machine must be controlled at drum peripheral speeds of 218RPM with feeding material rate at 0.68 m/s,(16). The machine productivity increases with increasing each of drum speed, Feed rate and moisture content of onion resides and the maximum value of machine productivity was 18.8kg/min at drum speed of 650 RPM, 20kg/min feeding rate and 17.6% moisture content of onion residues (26). The cutting efficiency increased with increasing cutting drum speed for cotton stalks, which is due to an increase in the number of cuts per time unit and an increase in suitable cutting length. Increasing the cutting drum speed from 1200 to 2000 rpm increased the cutting efficiency from 85.72, 83.5 and 81.85 % to 97.77, 95.43 and 93.87 % at 8, 10 and 12 % moisture content, respectively (15). Increasing chopping speed from 1650 to 2400 rpm, operating cost decreased from 75.73 to 49.23, from 55.67 to 39.13, and from 47.18 to 32.74 LE /ton at moisture contents of 60,70 and 77 % respectively. Meanwhile with the use of chopping machine with sharpener results showed that by increasing chopping speed from 1650 to 2400 rpm, operating cost decreased from 53.31 to 36.75, from 49.36 to 32.90, and from 45.25 to 29.43 LE /ton, at moisture contents of 60,70 and 77 %, respectively (14). The result revealed that the criterion function cost was decreased from129.75 to 32.438 LE/t when the feed rate increased from 2 to 8 kg/min (11).

MATERIAIS AND METHODS

This study was aimed to study the effect of some engineering and control factors for the locally manufactured machine, this study was conducted at the Agricultural Engineering Department / College of Agriculture / Ain Shams University, where the machine was developed by placing a feeding belt for the safety of the worker and operating the machine with an electronic system (electronic control device with sensors) that works To operate the machine automatically for cutting or chopping of crop residues.

Machine and devices used

Machine description

The machine used in this study shows in Figs (1), and photographed in Fig,(2), The machine has a narrow chopping cylinder mounted on two flanges ball bearings which rotates in the end of the feeding tray that has a cutting edge. The assembly is bolted to the chopper frame for easy removal and repair. the machine has a feed in take opening at one end and a straw thrower out let at the other end. small beater rotates in the end section of feeding tray to feed the material against the chopping cylinder.

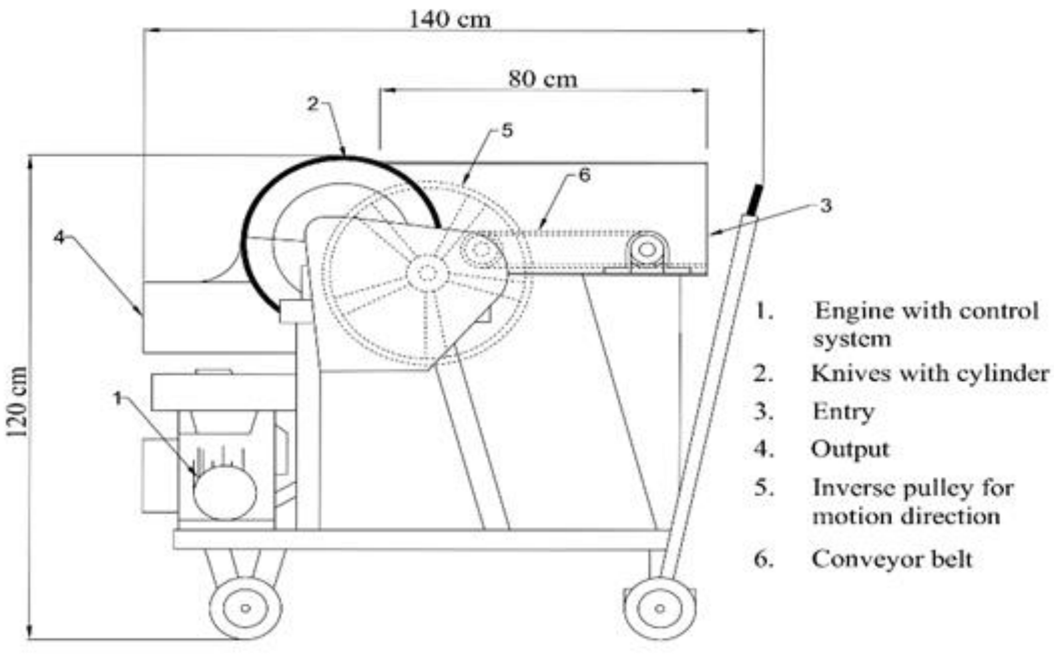


Fig 1. sketched for machine

Fig 2. photographed for machine

Machine specification

A – General :- Ain shams machine shop for agriculture – Egypt shredder, used engine powered chopping (1) Hp.

B – Power transmission type :- used all belts sections ((V)) shape belts

C_ Tacho meter :- Tachometer was used to measure the rotation speed , (**Fig**. 3).

Fig 3. Tacho meter

D-Clamp meter :- A clamp meter-300k Japan case made was used to measure the line current strength (I) and the potential difference value (V)

E-Stop watch: A stop watch with an accuracy of 0.01s was used to record the time spend during cutting operations.

F- Electronic system:- It is an electronic device that operates the machine automatically by connecting and disconnecting the electric current from the motor. It consists of Arduino, sensors, relay and a small electrical transformer to operate the Arduino. (**Fig**. 4).

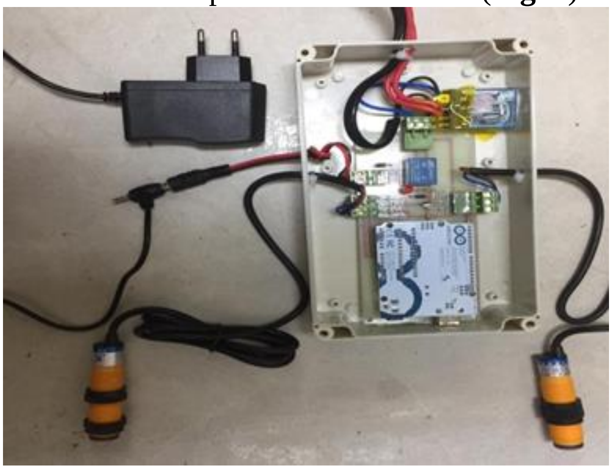


Fig 4. Electronic system

Experimental conditions

Experiment was carried out to cognition the performance of the developed machine was experimentally measured under the following parameters:

A – Chopping cylinder peripheral velocity (1000 , 1200, 1400 rpm)

B – Feeding rate peripheral velocity (0.75, 1 and 1.25 m/s)

C – Cutting angle (15° and 30°)

D- Clearance chopping cylinder – fixed knife clearance was at 2.5 mm.

E-- Maize (dry):- Samples of ten maize dry plants . were taken to determine the mentioned specification, (Table 1).

Table 1. maize dry plants specifications

no	Plant Length cm	Minimum stem Diameter cm	Maximum stem Diameter cm
1	140	1.3	2.5
2	150	1.4	2.5
3	110	1.5	2.9
4	110	1.6	3.1
5	108	1.4	2.8
6	107	1.5	2.6
7	107	1.6	2.5
8	103	1.9	3.2
9	100	2.0	3.1
10	100	1.9	2.7
Mean	130	1.61	2.79

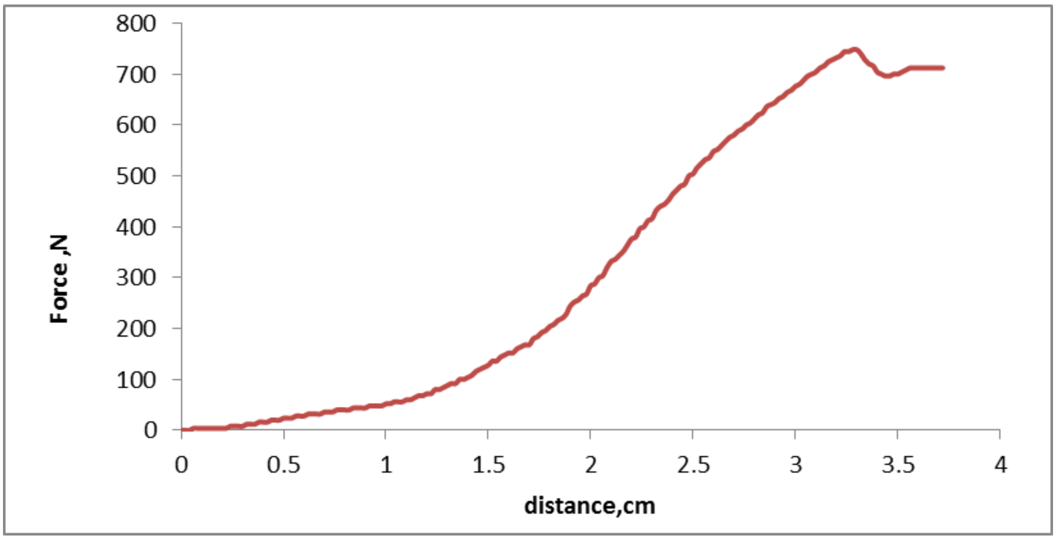


Fig 5. Diagram of mean theoretical cutting force of Maize stalks

Calculation of the affected variables

A- Determination of moisture content of the agricultural residues

The moisture content of the agricultural materials was determined using the standard oven method, samples of agriculture residues were weighted, (using an electrical balance, 0.1 g accuracy) and dried in an oven, at 70c° for 48 hr. the moisture content was calculated, using the following equation:

$$M= \frac{M_b - Ma}{M_b} x\ 100$$

Where:

M : moisture content

M_b : mass of the sample(g)before drying

Ma mass of the sample (g)after

B- Determination of thrust power

This relationship is used to estimate the thrust power (kw) which corresponds to the feed rate and peripheral velocity of the cutter:

$$Paccel = \frac{mf\ vp^2}{2000}$$

Where :

mf = Feed rate (kg/s) Vp = peripheral velocity of the cutter (m/s)

C- Determination of machine productivity

Machine productivity was estimated by using the following equation,(5)

$$P= {}^{w}/_{t}$$

Where :

P= Machine productivity, (kg/h)

W= mass of plant, (Kg), and t = Time, (h)

E- Determination of the power requirement for cutting

Clamp meter were used for measuring potential difference value and current strength, respectively before and during experiment been read of volt (V) and ampere (I) were taken before and during each treatment. The power consumption (P) was calculated from the values of volt (V) and ampere (I) by using the follow equation, (20).

Total consumed power (P) = Load

$$Ep = \frac{I * V * \eta * \cos\theta}{1000}$$

Where; Ep = Required power for cutting, (KW)

I = Line current strength in Amperes, (A)

V= Potential strength (Voltage) equal to 220V

= Power Factor (being equal 0.84)

ɳ = mechanical efficiency assumed (90%)

E- Determination of the specific energy consumption

Estimation of the consumed specific energy was carried out using the following equation, (1).

$$EC = \frac{EP}{P}$$

Where:

EC = Specific energy consumption (kw.h/ton)

Ep = Required power for cutting (KW), and

P= machine productivity, (ton/h)

J-Operation Cost: The operation cost (L.E/Kg) was calculated according to the price of materials, in year 2020 by the following formula:

$$Operation\ Cost = \frac{Machine\ Cost\ (LE/h)}{Machine\ productivity, Kg/h}\ , LE/Kg$$

The Machine cost was determined by using the following formula according to(3,8).

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W\ x\ e) + \frac{m}{288}$$

Where:

C: machine hourly cost, L.E/h; P: price of machine, h: yearly working hours, a: life expectancy of the machine, 10 years; i: interest rate / year, 10%; t: taxes and over heads ratio, 10%; r: repairs and maintenance ratio, 10%; W: required power, kW; e: electricity cost, LE /kW.h; m: the monthly average operators wage, and 288: the monthly average operators working hours.

RESULTS AND DISCUSSION

Machine productivity

Fig. (6)[A,B] shows that machine productivity at 1000 r.p.m , increased with increasing feeding rate , it increased from71.174 to79.086 and from 71.104 to 79.120 kg/hr , increased rate 10.13 % ,with sensor and without respectively. with increasing feeding rate from 0.75 to 1.25 m/s ,at cutting angle 15° and 2.5 mm clearance this agrees with (23) . they ,also shows that machine productivity increased with increasing cutting angle from 15°to 30°, it increased from 71.371 to 81.319 kg/hr , increased rate 12.23 % . of the same Fig (6)[C,D,E.and F] shows that machine productivity at 1200 and 1400 r.p.m , same machine productivity at 1000 r.p.m , it creased with increasing feeding rate and cutting angle , with sensor and without ,like wise.

[A] productivity ,kg/hr , at 1000 r.p.m without sensor

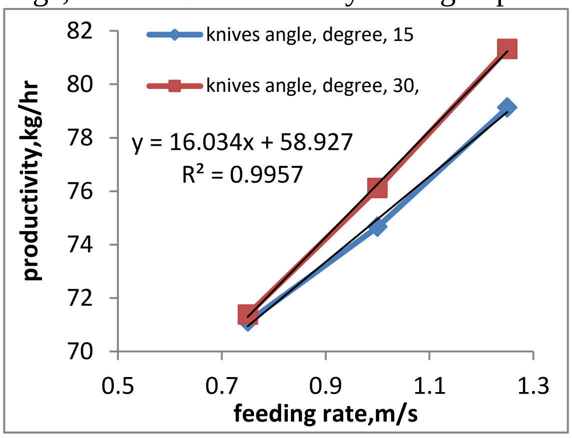
[B] productivity ,kg/hr, at 1000 r.p.m with sensor

[c] productivity ,kg/hr , at 1200 r.p.m without sensor

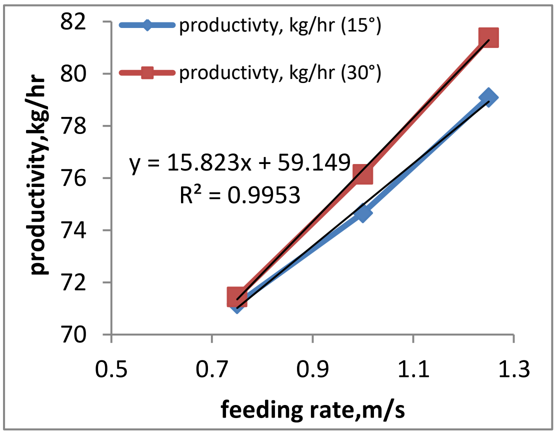
[D] productivity ,kg/hr , at 1200 r.p.m with sensor

[E] productivity ,kg/hr , at 1400 r.p.m without sensor

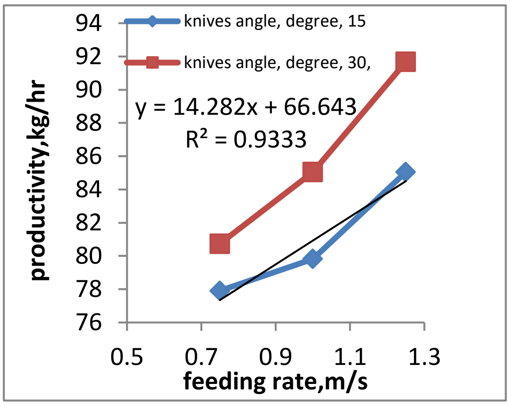
[F] productivity ,kg/hr , at 1400 r.p.m with sensor



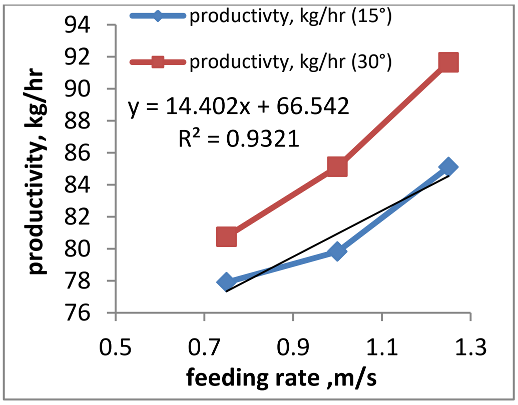
[A] productivity ,kg/hr , at 1000 r.p.m without sensor



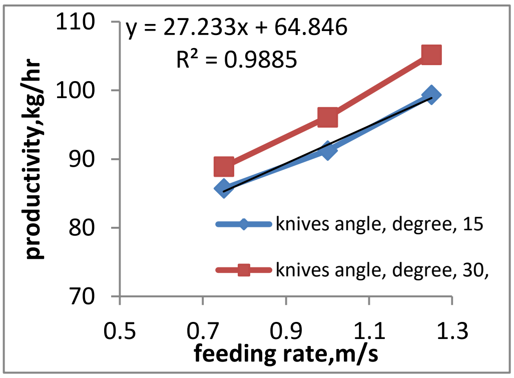
[B] productivity ,kg/hr, at 1000 r.p.m with sensor



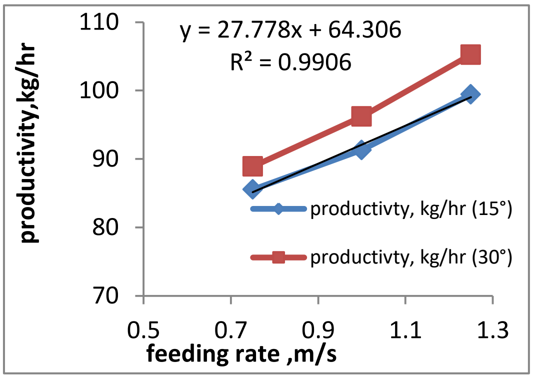
[c] productivity ,kg/hr , at 1200 r.p.m without sensor



[D] productivity ,kg/hr , at 1200 r.p.m with sensor



[E] productivity ,kg/hr , at 1400 r.p.m without sensor



[F] productivity ,kg/hr , at 1400 r.p.m with sensor

Fig 6. A.B.C.D.E.F] machine productivity

Thrust power

Fig(7)[A.B] shows that thrust power at 1000 r.p.m , increased with increasing feeding rate , it increased from0.0188 to 0.0210 and from 0.0173 to 0.0192 kw , increased rate 9.89 % , with sensor and without respectively. with increasing feeding rate from 0.75 to 1.25 m/s , at cutting angle 15° and 2.5 mm clearance . These results also show that thrust power increased with increasing cutting angle from 15°to 30°, it increased from 0.0173 to 0.0197 kw, increased rate 12.18 % . of the same Fig (7)[C.D.E. and F] shows that thrust power at 1200 and 1400 r.p.m, same thrust power at 1000 r.p.m , it increased with increasing feeding rate and cutting angle , with sensor and without,like wise.

[A] thrust power ,kw , at 1000 r.p.m without sensor

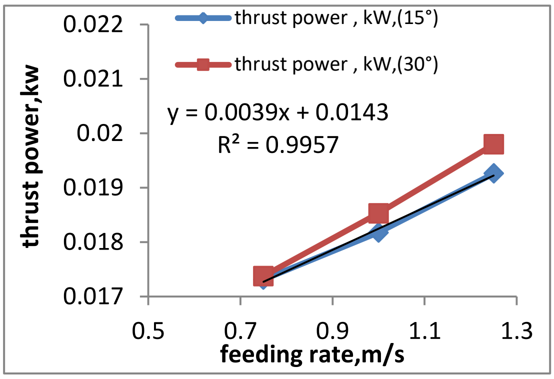
[B] thrust power,kw, at 1000 r.p.m with sensor

[C] thrust power ,kw , at 1200 r.p.m without sensor

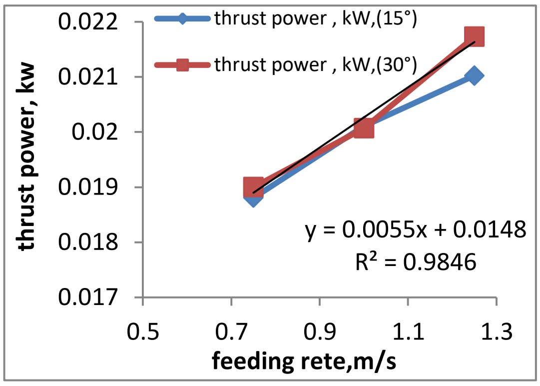
[D] thrust power,kw , at 1200 r.p.m with sensor

[E] thrust power ,kw , at 1400 r.p.m without sensor

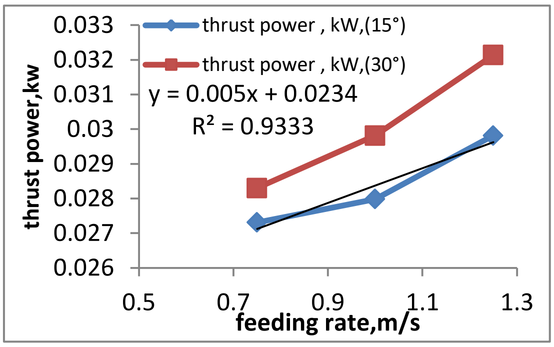
[F] thrust power,kw , at 1400 r.p.m with sensor



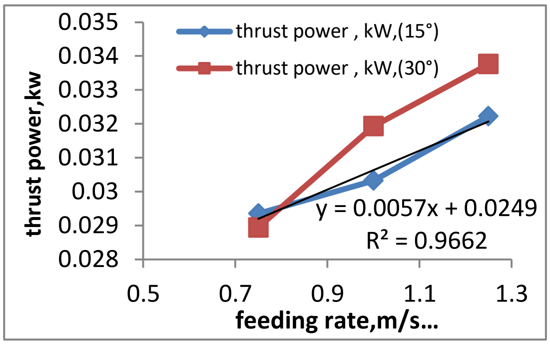
[A] thrust power ,kw , at 1000 r.p.m without sensor



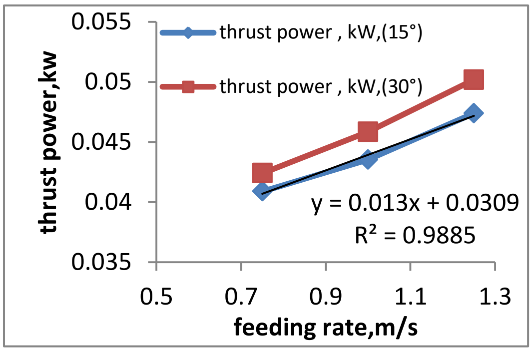
[B] thrust power,kw , at 1000 r.p.m with sensor



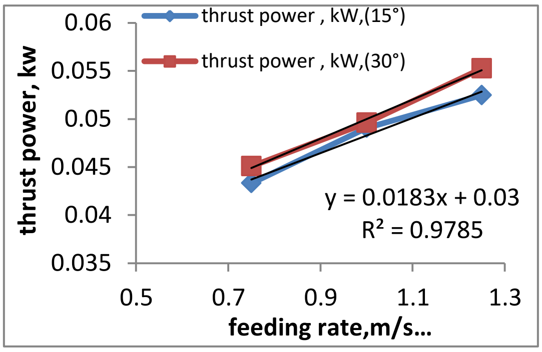
[C] thrust power ,kw , at 1200 r.p.m without sensor



[D] thrust power,kw , at 1200 r.p.m with sensor



[E] thrust power ,kw , at 1400 r.p.m without sensor



[F] thrust power,kw , at 1400 r.p.m with sensor

Fig 7 [.A.B.C.D.E.F] thrust power

Power requirement for cutting

Fig(8)[A.B] shows that the power requirement at 1000 r.p.m , increased with increasing feeding rate , it increased from 0.201 to 0.214 kw and from 0.2 to 0.214 kw , increased rate 6.074 % with sensor and without respectively , with increasing feeding rate from 0.75 to 1.25 m/s ,at cutting angle 15° and 2.5 mm clearance this agrees with (12) . They ,also shows that the power requirement decreased with increasing cutting angle from 15°to 30°, it decreased from 0.201 to.0.184 kw, decreased rate 8.45 % .of the same Fig (8)[C.D.E.and F] shows that the power requirement at 1200 and 1400 r.p.m, same the power requirement at 1000 r.p.m , it creased with increasing feeding rate and decreased with increasing cutting angle from 15° to 30° , with sensor and without,like wise.

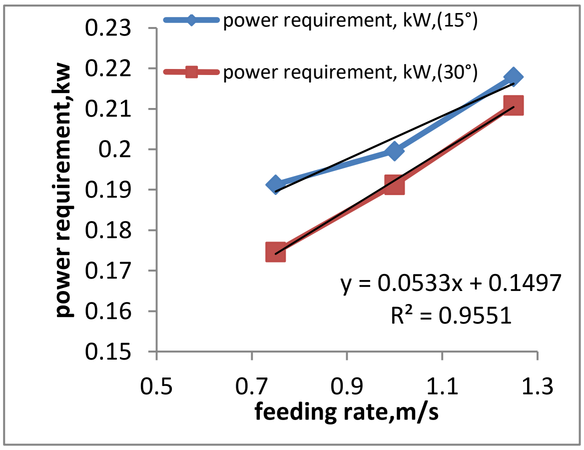
[A] power requirement ,kw , at 1000 r.p.m without sensor

[B] power requirement ,kw , at 1000 r.p.m with sensor

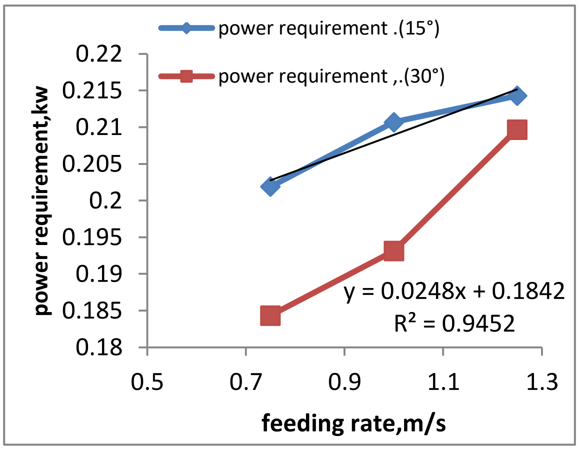
[C] power requirement ,kw , at 1200 r.p.m without sensor

[D] power requirement ,kw , at 1200 r.p.m with sensor

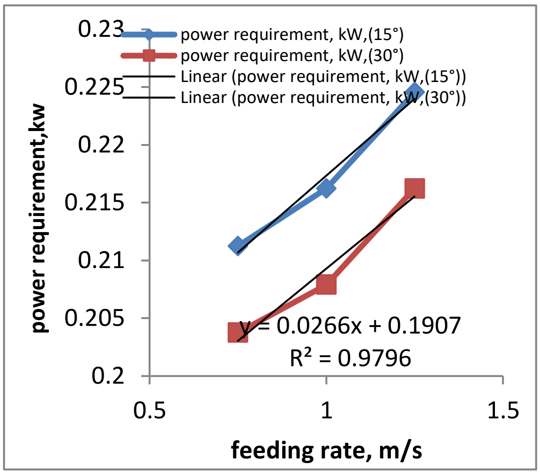
[E] power requirement,kw , at 1400 r.p.m without sensor [F] power requirement,kw , at 1400 r.p.m with sensor



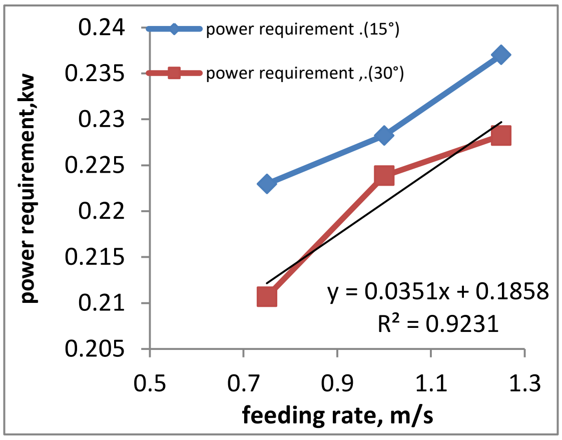
[A] power requirement ,kw , at 1000 r.p.m without sensor



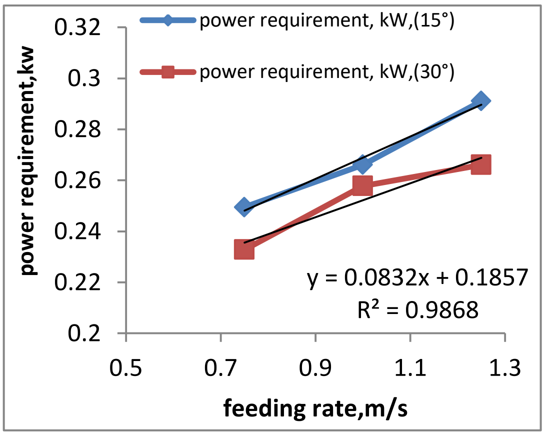
[B] power requirement ,kw , at 1000 r.p.m with sensor



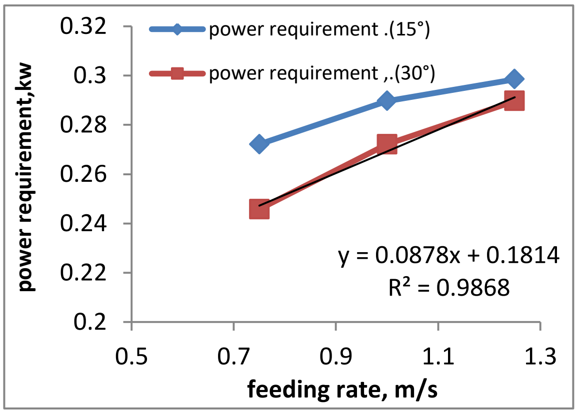
[C] power requirement ,kw , at 1200 r.p.m without sensor



[D] power requirement ,kw , at 1200 r.p.m with sensor



[E] power requirement,kw , at 1400 r.p.m without sensor



[F] power requirement,kw , at 1400 r.p.m with sensor

Fig 8. [A.B.C.D.E.F] power requirement

the specific energy consumption

Fig(9)[A.B] shows that the specific energy consumption at 1000 r.p.m , decreased with increasing feeding rate , it decreased from 2.8366 to 2.7082 w, and from 2.452839 to 2.452707 w , decreased rate 0.053 % with sensor and without respectively , with increasing feeding rate from 0.75 to 1.25 m/s ,at cutting angle 15° and 2.5 mm clearance this agrees with this agrees with (5) . they ,also shows that the specific energy consumption decreased with increasing cutting angle from 15°to 30°, it decreased from 2.452583 to 2.452483, decreased rate 0.01% . of the same Fig. (9) [C.D.E. and F] shows that the specific energy consumption at 1200 and 1400 r.p.m, same the specific energy consumption at 1000 r.p.m , it decreased with increasing feeding rate and cutting angle from 15° to 30° , with sensor and without , like wise. Also, from Fig. (9) shows that that the specific energy consumption to cutting the residues with the sensor was less than with out it, and the reason for this is the lack of time lost when operating the machine with the sensor .

[A] Special energy consumption ,kw.h/kg , at 1000 r.p.m without sensor

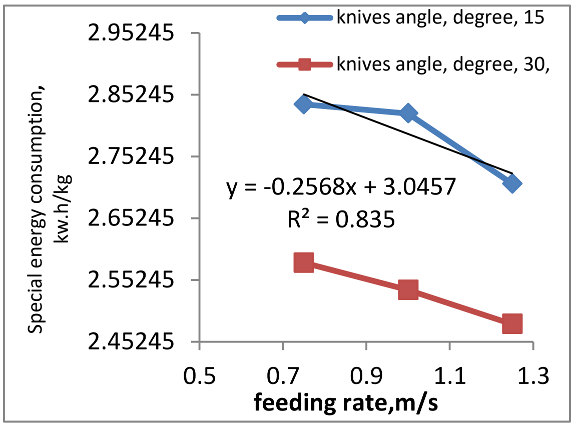
[B] Special energy consumption ,kw.h/kg , at 1000 r.p.m with sensor

[C] Special energy consumption ,kw.h/kg , at 1200 r.p.m without sensor

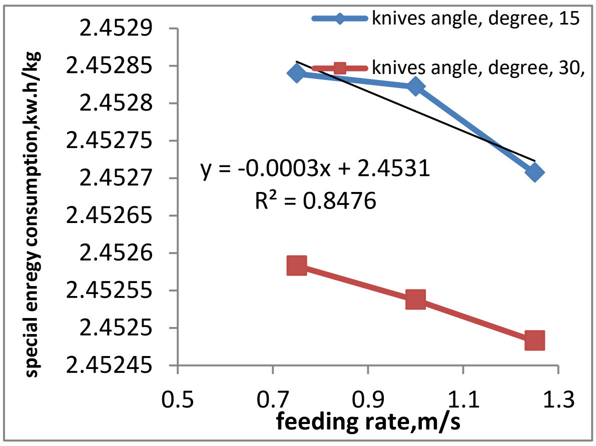
[D] Special energy consumption ,kw.h/kg , at 1200 r.p.m with sensor

[E] Special energy consumption ,kw , at 1400 r.p.m without sensor

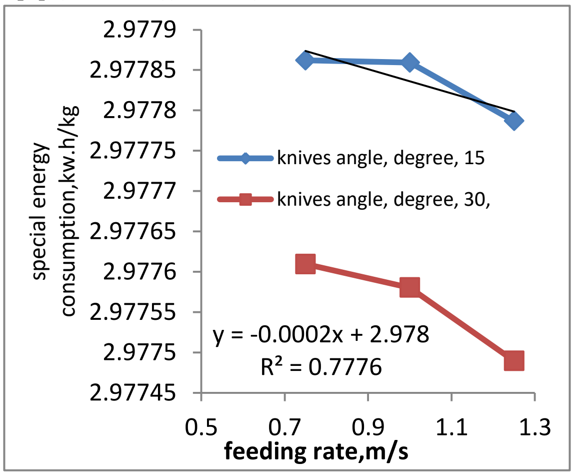
[F] Special energy consumption ,kw.h/kg , at 1400 r.p.m with sensor



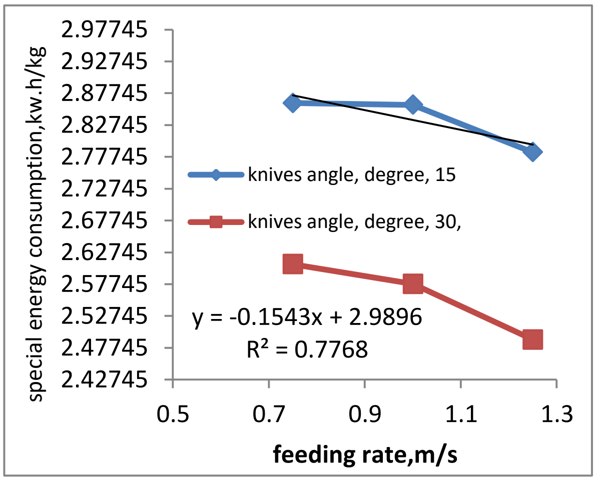
[A] special energy consumption ,kw.h/kg , at 1000 r.p.m without sensor



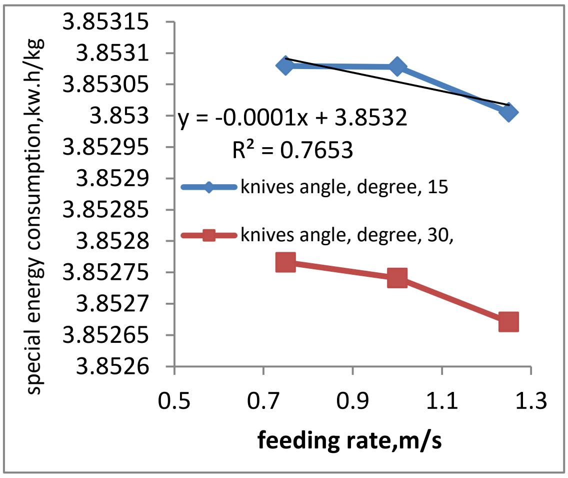
B] special energy consumption ,kw.h/kg , at 1000 r.p.m with sensor



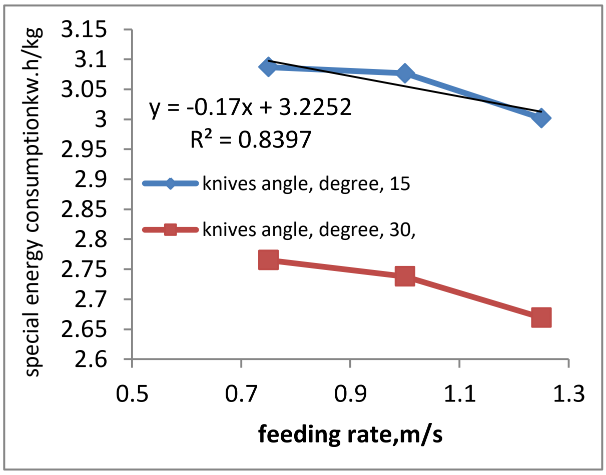
[C] special energy consumption ,kw.h/kg , at 1200 r.p.m without sensor



[D] special energy consumption ,kw.h/kg , at 1200 r.p.m with sensor



[E] special energy consumption ,kw , at 1400 r.p.m without sensor



[F] with special energy consumption ,kw.h/kg , at 1400 r.p.m with sensor

Fig 9. [A.B.C.D.E.F] special energy consumption

Operation cost

Fig(10)[A.B] shows that the operating cost at 1000 r.p.m , decreased with increasing feeding rate , it decreased from 0.2342 to0.2100 LE/kg, and from 0.2540 to 0.2290 LE/kg , decreased rate 9.84 % with sensor and without respectively , with increasing feeding rate from 0.75 to 1.25 m/s ,at cutting angle 15° and 2.5 mm clearance this agrees with (11, 20). they ,also shows that the operating cost decreased with increasing cutting angle from 15°to 30°, it decreased from 0.2526 to 0.2225 LE/kg, decreased rate 11.91 % . of the same Fig (10)[C, D, E, and F] shows that the operating cost at 1200 and 1400 r.p.m, same the operating cost at 1000 r.p.m , it decreased with increasing feeding rate and cutting angle from 15° to 30 , like wise. Also, from Fig (10) shows that that the operating cost to cutting the residues with the sensor was less than with out it, and the reason for this is the lack of time lost and power consumption when operating the machine with the sensor

[A] Operating cost ,LE/kg, at 1000 r.p.m without sensor

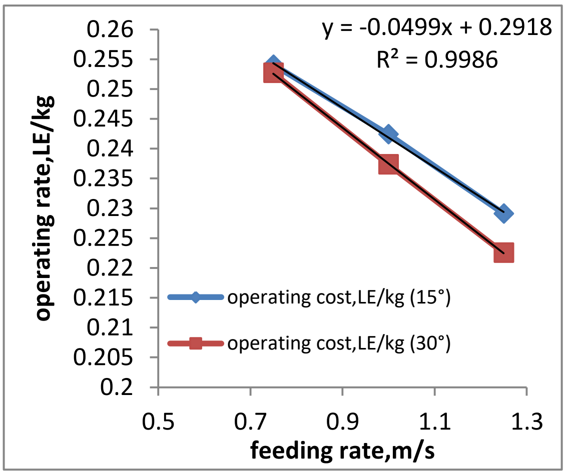
[B] Operating cost ,LE/kg, at 1000 r.p.m with sensor

[C] Operating cost ,LE/kg, at 1200 r.p.m without sensor

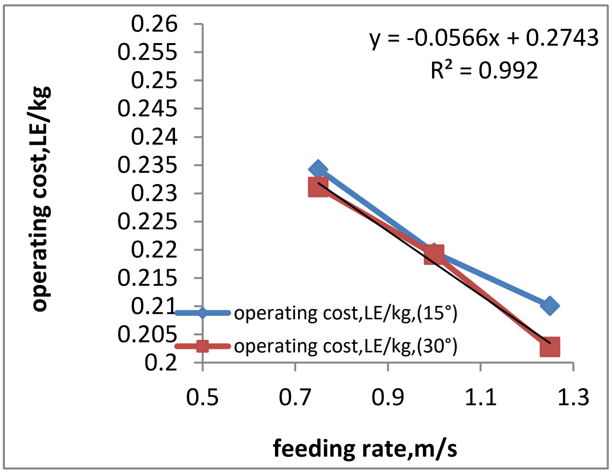
[D] Operating cost ,LE/kg, at 1200 r.p.m with sensor

[E] Operating cost ,LE/kg, at 1400 r.p.m withoutsensor

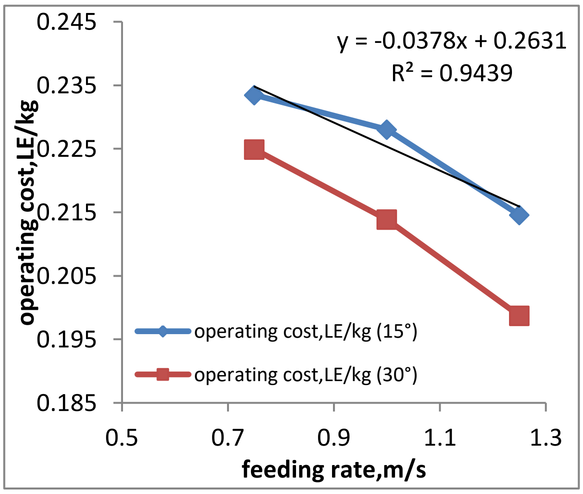
[F] Operating cost ,LE/kg , at 1400 r.p.m with sensor



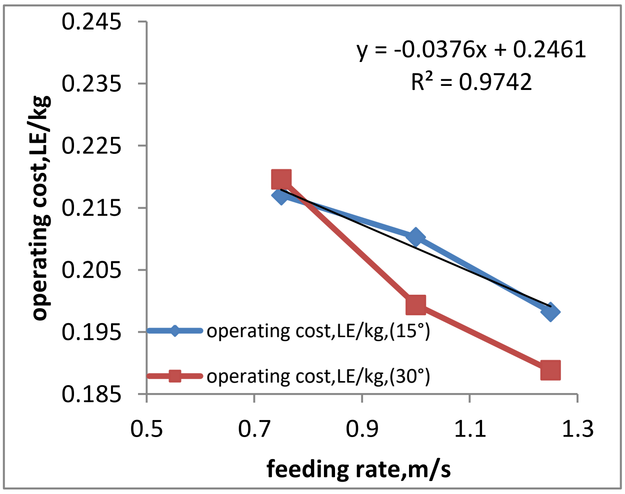
[A] operating cost ,LE/kg, at 1000 r.p.m without sensor



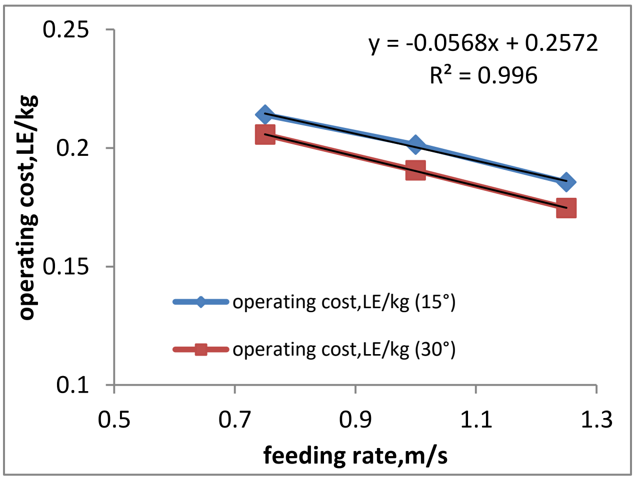
[B] operating cost ,LE/kg, at 1000 r.p.m with sensor



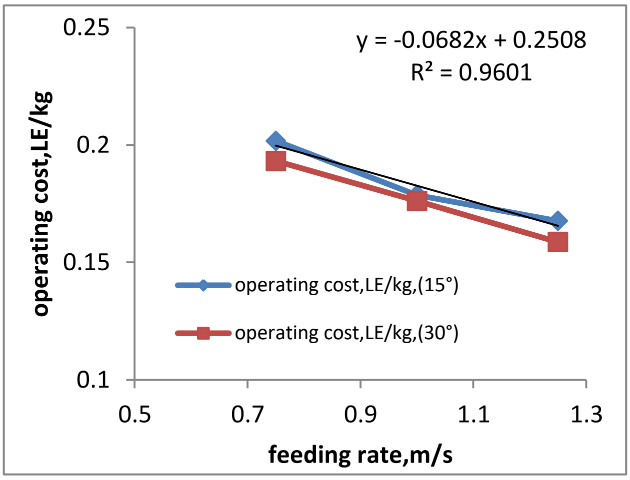
[C] operating cost ,LE/kg, at 1200 r.p.m without sensor



[D] operating cost ,LE/kg, at 1200 r.p.m with sensor



[E] operating cost ,LE/kg, at 1400 r.p.m without sensor



[F] operating cost ,LE/kg , at 1400 r.p.m with sensor

Fig 10. [A.B.C.D.E.F] operating cost

Conclusion

1- The machine has been modified to use a conveyor belt for the materials being cut to increase the safety level for the worker and reduce the risks.

2-Consumed energy was reduced by 19.8 % and operating costs by 7.8 % through the use of sensors that operat the machine automatically.

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