DEVELOPMENT OF CRUSHING MACHINE TO BE SUITABLE FOR CRUSHING PLASTIC RESIDUAL

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ABSTRACT

This research aims to achieve the best possible use of plastic waste through waste crushing plastic machine, to adapt these residues for the next operations of waste recycling, therefore reducing the pollution of the environment.

Testing of the machine after proper modifications has been deduced during actual experiments for crashing plastic residual under different feeding rates (800, 1000 and 1200 kg/h), crushing drum speeds (500, 750 and 1000 rpm) and clearance between fixed and moved knives (20 and 30 mm). Whereas, the modified machine performance was evaluated in terms of the cutting length percentage, the machine productivity and machinery operating cost.

The main results in this study can be summarized as follows: -

- *The proper performance was at feed rate of 1200 kg/h (1.2 ton/h) at a crushing drum speed of 1000 rpm (29.3 m/s) and clearance between fixed and moved knives of 30 mm (3 cm).*
- *Cut length percentage at these conditions was 97 % in cutting length of ≥15-20 mm.*
- *Productivity was 1200 kg/h.*
- *Operational cost was 16.81 L.E./ton.*

INTRODUCTION

Plastic recycling is a newly emerging industry and it has already been identified that there is a good potential to this sector. The recycled plastics can be shared with both small and large scale industries to produce new plastic items. Further, recycled plastics can replace pure material being imported from other countries and this will create many job opportunities amongst the people.

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Recycling of plastics therefore, is a resource that one could obtain maximum benefit out of it and helps minimize environmental degradation. Therefore, plastic material should not be disposed or buried without a proper disposal mechanism.

Plastic residues are considered the most critical problems facing the Egyptian society. Agricultural plastic residual are considered among the most problem in Egypt. The agricultural plastic residues in Egypt ranged between 850.000 to 950.000 ton yearly and it is estimated about 6 % from total residual of 16.5 million ton in Egypt **(The Al-Ahram newspaper 10/ 7/2008)**.

A number of attempts were made to advance the recycling technology of mixed plastic wastes. For example, Northwestern University has developed a polymer reclamation process in which the waste materials are converted into pastel-colored powder. The American Plastics Council has also succeeded in recycling the heterogeneous plastics into solid carbonaceous material **(Khan, 1996)**. However, these technologies were only implemented on a laboratory scale.

Although plastic recycling contributes to a significant reduction of the waste in need of final disposal, it results in the utilization of only about 80 percent of the total quantity of plastics. We refer to the remaining 20 percent as the rejects of the rejects. Those 20% accounts for 13,200 ton/year of non-recyclable mixed plastic waste in Cairo **(El Haggar and Sawiris 2001)** and they have traditionally been dumped in open dumpsites in the deserts, often burning up and producing noxious fumes. The residues that remain constitute an important source of soil and water contamination. To find a reasonable solution to the problem of the rejects of the rejects the Egyptian environmental authorities specifically have failed so far.

El-Khateeb, H. (2001) reported that, the quantities of crop residues in Egypt are estimated about 18.7 million ton/year, 53 % of which (9.91 million ton) are directly burned. This causes great losses of energy and air pollution. The burning of cotton residues (1.24million ton/year) causes a loss of 532.000 equivalent ton of hydrocarbon fuel (1.806 million LE). Corn fields provide 4.07 and 0.61 million ton of dry stalks and cubs respectively (based on mean yield of 0.43 ton/fed), **(as cited from Awady et al., 2001).**

Nasr, (2000) reported that the productivity of the chopper is proportional with drum speed, moisture content and feeding speed.

El-Berry et al. (2001) mentioned that the quantity of crop residues in Egypt reached about 25 million-ton per year and national income is expected to increase with 1.6 billion L.E/year if residues are recycled.

Helmy et al. (2003) mentioned that the quantity of different residues in Egypt equal 103.56 ton/year (agricultural, animal, sewage and rubbish residues). The agricultural residues were about 31.42 ton/year which may represent 30-50% of total agricultural production. The animal residues were about 55.37 ton/year. Meanwhile sewage residues were 3.99 ton/year and rubbish was 12.78 ton/year.

El-Ashry et al. (2004) mentioned that a developed combined unit that was recommended for harvesting corn crop and cutting stalks may reduce both energy and cost. The maximum percentage of cutting efficiency was 96.67 % and chopping efficiency 86.91 % obtained at forward speed of 0.9 km/h and knife revolving speed 920 rpm (72.25 m/s).

The objectives of the present study are:

1. Crushing plastic residual by using crashing unit, which is sharing in keeping of environment and improve the economic income of this machine.
2. Optimizing some different operating parameters affecting the performance of the used machine.

MATERIALS AND METHODS

A- Materials: -

In the present study, the crushing machine electric engine driven was developed to crash plastic residues, for maximizing profit, and increase its economic income. Plastic crushing machine was used to crush all kinds of plastics, defective plastic into granular form. This process increases the density of the plastic granules, and it can be recycled and remolded for use in manufacturing other products. All experimental tests were carried out at El-Karakra location, Zakizika district, Sharkia Governorate. The developed crushing machine consists of main frame, hopper, crashing drum and concave, as shown in fig.1. The frame was supported on four legs. Power transfer from the electric engine to the crashing drum was carried out through three V-belts.

1- Crushing machine specification:

Overall length, width and height are 1850, 1345 and 1940 mm respectively.

Frame: It is made of angle steel, sections 50 x 50 x 5 mm.

Hopper: It is made of steel sheet metal of 5 mm thickness and angle steel sections 30 x 30 x 3 mm. The hopper is located on the top of frame.

Crashing drum: It is mounted on two bearings and rotates in a semi-circular concave. Drum diameter 150 mm, length 600 mm. Total of 2 knives, 580 mm long, 120 mm wide and 30 mm thickness, were bolted to the central tube.

Concave: It is made of perforated steel sheet of 5 mm thickness. It has round holes, of 22 mm diameter.

2- Electric motor: An electric motor power of 50 hp (37.5 kW) was used at 50000 r.p.m.

3- Modification recommendation:

Such development had been introduced to overcome the problems noticed during crushing plastic residues using the ordinary crushing machine. The crushing machine is not suitable for crushing plastic residues successfully.

The problem here is the difficulty of changing the clearance between the fixed knives and concave, and this is because the knives was fixed on crushing drum. causing break down of plastic residues into very small pieces. Therefore, two-rooms were olrs played in the crushing chamber in two different directions and the work of two moved knives were placed in front of each other and installed by screws so that the worker can mobilize these knives by dismantling and moving those knives to the desired conclusion as shown in fig. 2.

4- Instruments:

Speedometer:

Speedometer was used to measure the rotational speed (range 40-5000 rpm.), with accuracy of 1 %.

Spring balance.

A spring balance was used for weighing the crashed materials of plastic residual as a component of machine productivity. It had a range up to 75 kg max. and 0.5 kg accuracy.

Test procedures for the experimental crushing machine unit.

The experiments were carried out to study the effect of the following factors on the cutting length weight percentage.

1. Feed rate: Three different feed rates were used namely: 800, 1000, and 1200 kg/h.,
2. Drum speed: Three different drum speeds were used namely: 500, 750 and 1000 rpm and.
3. Clearance between fixed and moved knives: Two different clearances were used namely: 20 and 30 mm.

B) Methods:

Experiments and measurements.

The plastic residual were collected in bundles before starting the crashing process. The speed of crash drum was measured by speedometer. The residual were dropped to the spout after cutting in crashing room through concave. Samples of crashing pieces were weighted and taken from each experiment to laboratory separated and classified into four categories using hand sieves as follows: -

$\geq$ 15 to 20 mm

$\geq$ 10 to 15 mm

$\geq$ 0.3 to 10 mm

$<$ 0.3 mm

To establish that classification, a sample of 100 g. was placed in a stack of sieves arranged from largest to the smallest opening sizes. The sieve series selected were based on the range of particles in sample. Sieve analysis was repeated three times for each ground sample.

Each evaluated length category in the sample was weighed and its percentage from the total weight of the sample was determined as follows.

$$\text{Cutting length percentage, \%} = \frac{\textit{mass of cut length category}}{\textit{total mass of sample}} \times 100 \quad \text{--(1)}$$

<u>Cost analysis:</u> The hourly cost of plastic crushing was calculated according to the following equation given by **Awady, 1978** modified for electrical motor drive:

C=P/h(1/a+I/2+t+r)+(w.e)+m/144---------------------(2)

Where:

C = hourly cost, P = price of machine, h = yearly working-hour, a = life expected of machine, I = interest rate/year, t = taxes and overhead ratio, w = power of motor in kW, e = hourly cost/kW.h, and m/144 = monthly wage ratio.

Notice that all units have to be consistent to result in " C = L.E./h".

While the operational cost was determined using the following equation:-

$$\text{Operational cost (L.E./ ton)} = \frac{Hourly\ \cos t\ (L.E./h)}{Machine\ productivity\ (ton/h)} \text{-(3)}$$

RESULTS AND DISCUSSION

1-1 Effect of Feeding rates on cutting length percentage:

Data in figs. 3 and 4 shows the effect of different feeding rates on cutting length percentage at different crushing drum speeds and different clearance between fixed and moved knives.

By increasing feeding rates from 800 to 1000 and to 1200 kg/h, increased the percentage of cutting length of ≥15-20 mm (first category). But decreased the other three categories from ≥10 to 15 mm, from ≥0.3 to 10, and less than 0.3 mm for plastic residues. It is refered to increased friction between the chopped materials and knives by increasing feed rates.

By increasing feed rates from 800 to 1000 and to 1200 kg/h. the cutting length percentage of ≥15-20 mm increased from 61 to 85.51 and to 97 % respectively at crushing drum speed of 1000 rpm and clearance between fixed and moved knives of 30 mm.

In experiments, by increasing the feeding rates more than 1200 kg/h. the crushed materials accumulated inside crushing room and crushing machine drum was choked and stopped. The best feed rate was 1200 kg/h.

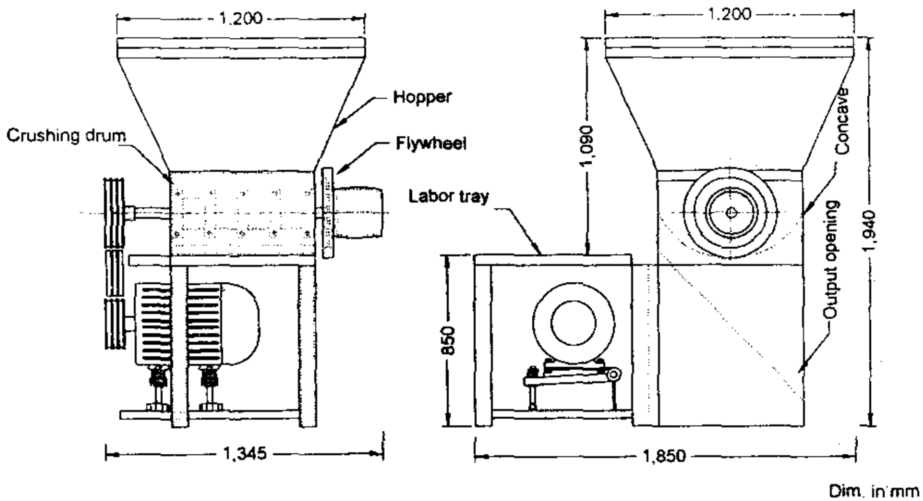

Fig. 1: Crushing machine before modification.

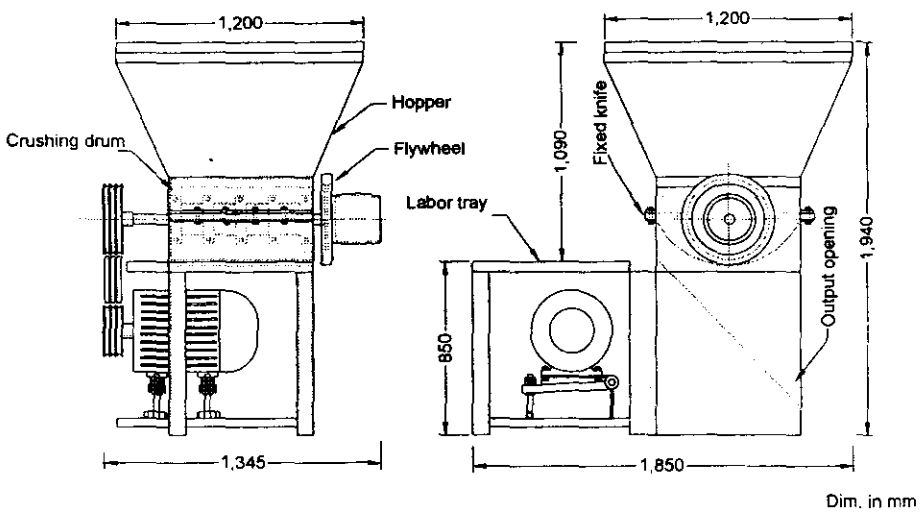

Fig. 2: Crushing machine after modification.

1-2 Effect of crushing drum speeds on cutting length percentage.

Figs. 5 and 6 shows the effect of different crushing drum speeds on cutting length percentage at different feeding rates and clearance between fixed and moved knives. There is high effect of crushing drum speed on cutting length percentage of plastic residues.

By increasing crushing drum speed from 500 to 750 and to 1000 rpm., the cutting length percentage of ≥15-20 mm (first category) increased, and decreased the other three categories from ≥10 to 15 mm, from ≥0.3 to 10 mm, and less than 0.3 mm for plastic residues. It is due to increased impact between the crushed materials and knives by increasing the drum speed.

By increasing crushing drum speed from 500 to 750 and to 1000 rpm., the cutting length percentage of ≥15-20 mm increased from 70 to 77 and to 85.5 % respectively at feed rate of 1000 kg/h. and clearance between fixed and moved knives of 30 mm.

1-3 Effect of clearance between fixed and moved knives on cutting length percentage.

Figs. 3, 4, 5 and 6 show the effect of clearance between fixed and moved knives on cutting length percentage at different feeding rates and different crushing drum speeds. There is high effect of clearance between fixed and moved knives on cutting length percentage of plastic residues.

By changing the clearance between fixed and moved knives, the cutting length percentage changed.

At clearance between fixed and moved knives of 20 mm the cutting length percentage of ≥15-20 mm was smaller than 30mm.

By changing the clearance between fixed and moved knives from 20 to 30 mm the cutting length percentage was 9 and 50 % respectively at drum speed of 750 rpm, feed rate of 800 kg/h. and cutting category of ≥15-20 mm.

It is due to at small 20 mm distance (clearance) between the fixed and moved knives, it is making it very small pieces up to the powder, and this not good for factory, because the next step in the process of recycling plots need certain sizes (like ≥15-20 mm), because when used in the form of small pieces that could be lead to increased costs for the next step in the process of recycling.

The best clearance was 30 mm which give certain size of ≥15-20 mm.

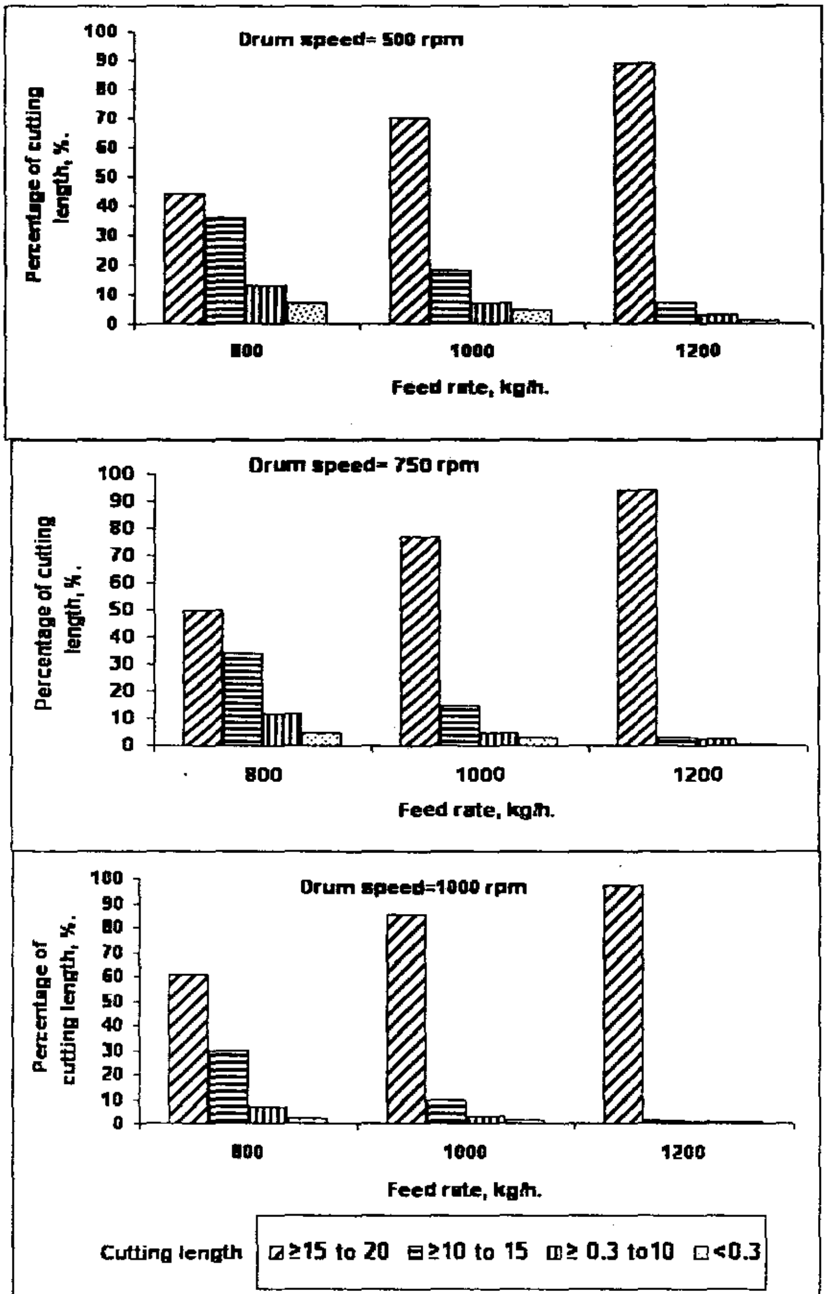

Fig.3: Effect of different feeding rates and crushing drum on cutting

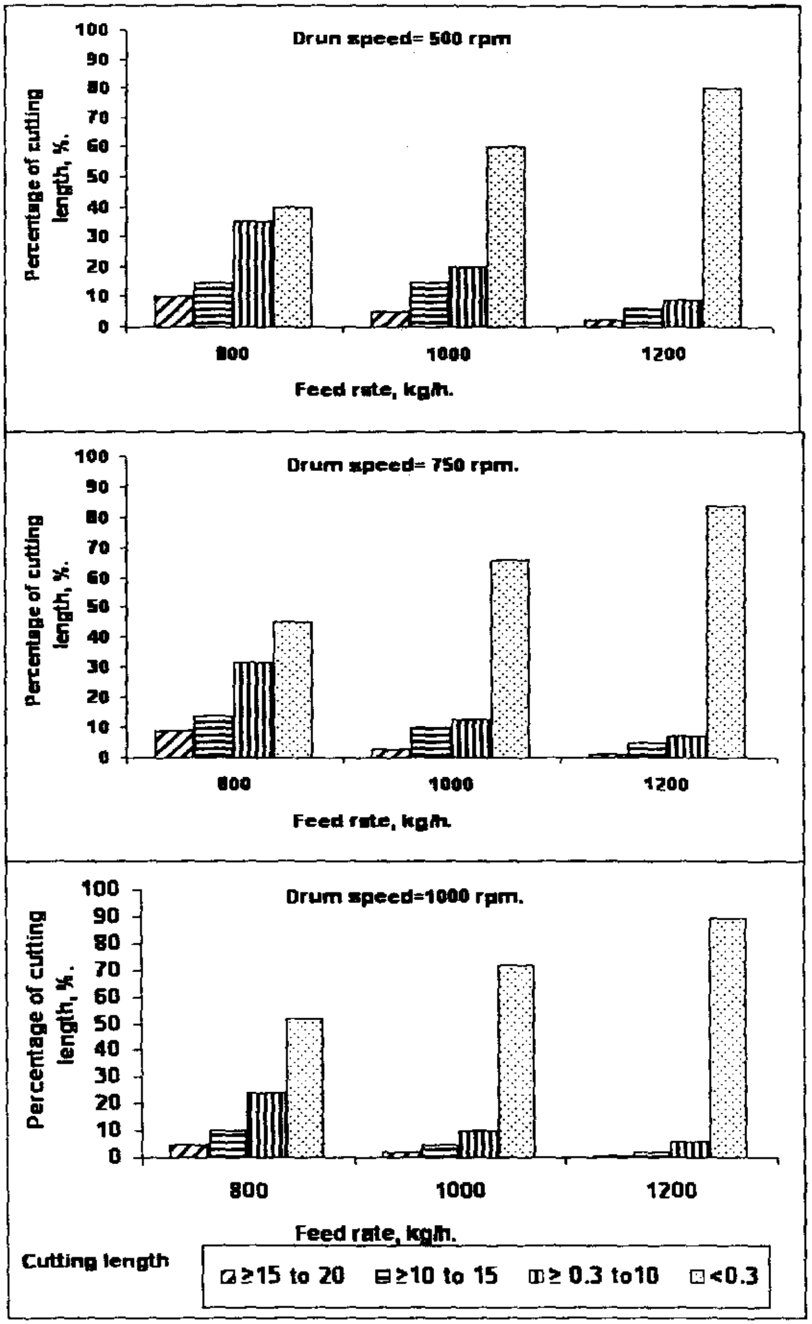

Fig.4: : Effect of different feeding rates and crushing drum speeds on cutting length at clearance of 20 mm.

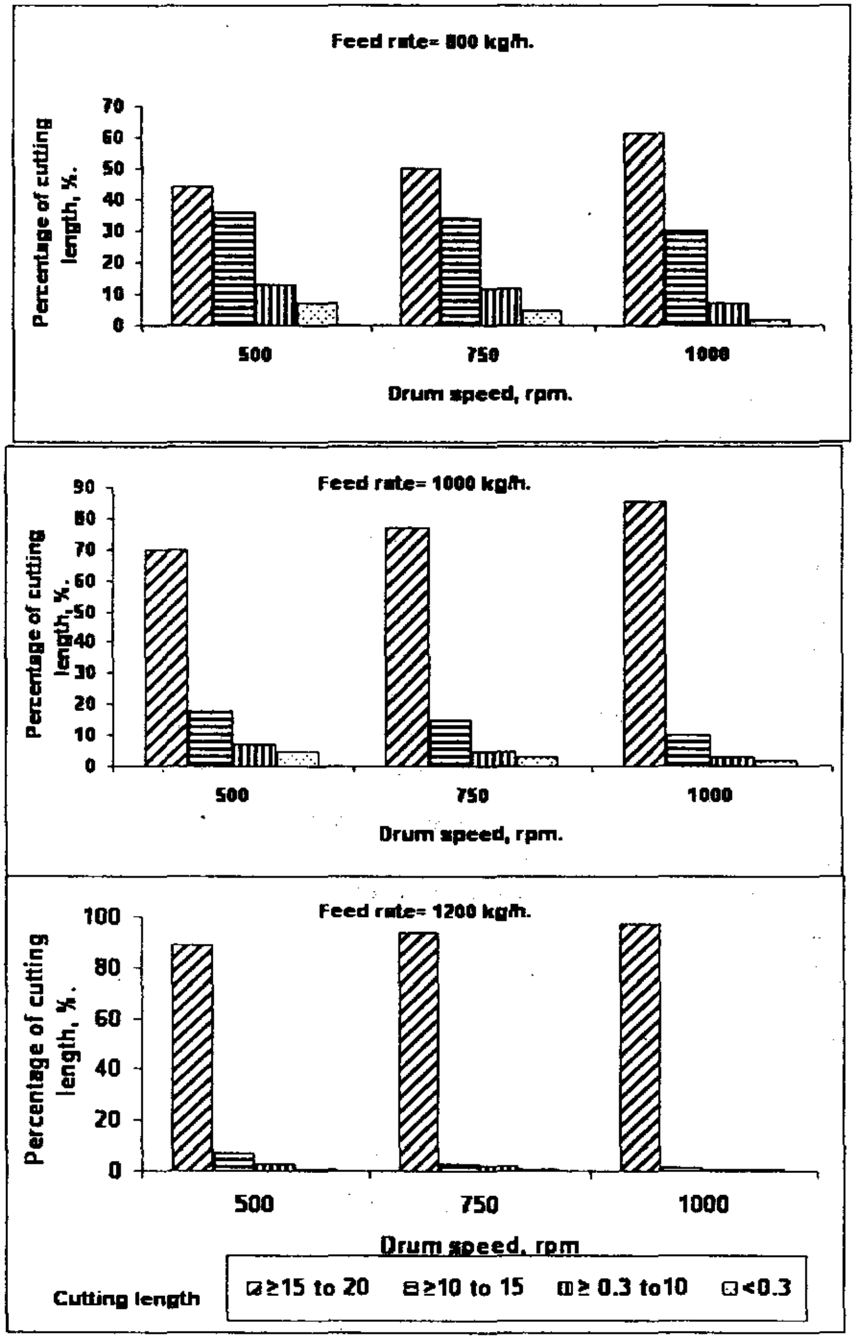

Fig.5: Effect of different drum speeds and feeding rates on cutting length at clearance of 30 mm.

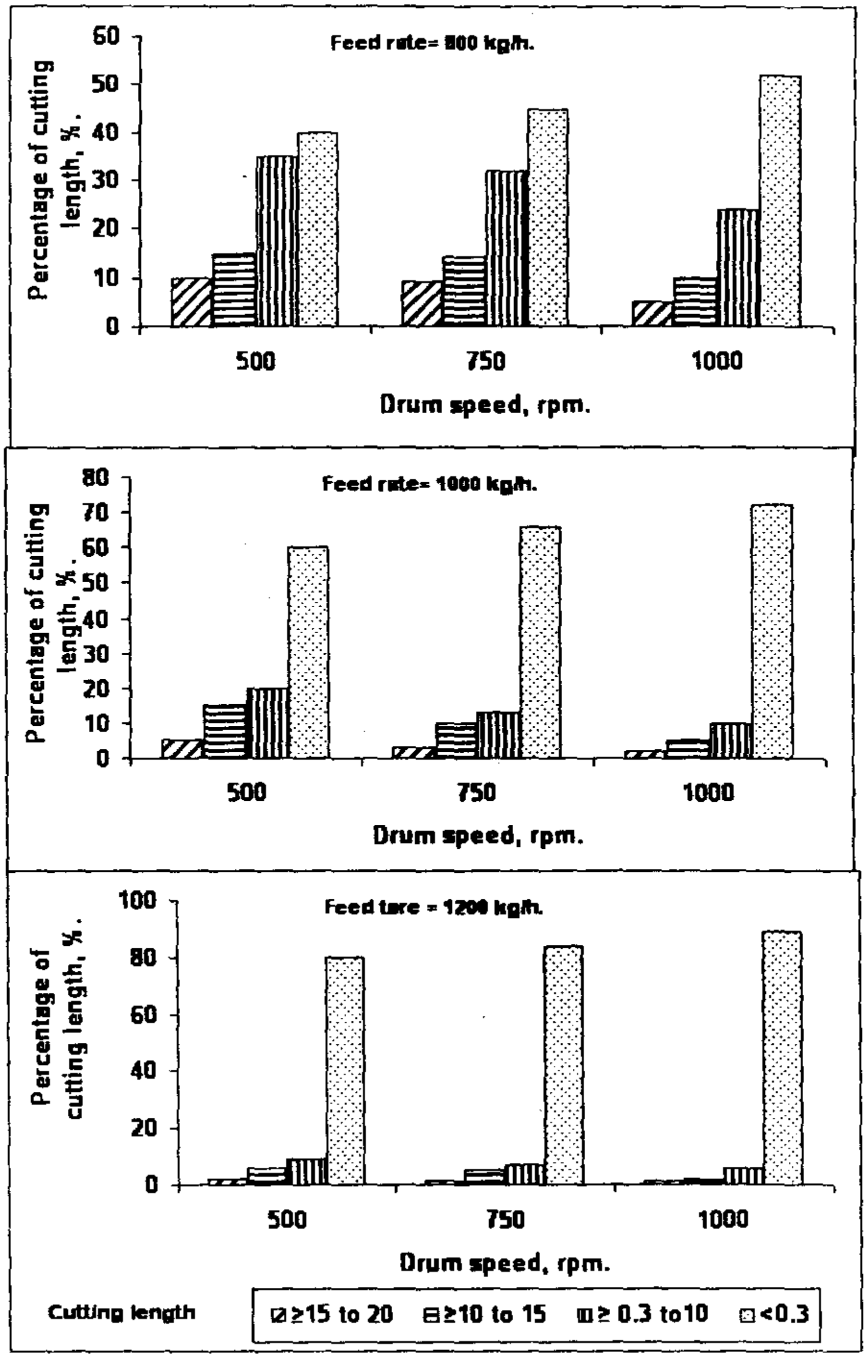

Fig.6: Effect of different drum speeds and feeding rate on cutting length at clearance of 20 mm.

2- Productivity.

Fig. 7 shows the effect of crushing drum speeds on productivity. By increasing crushing drum speeds, the productivity increased.

By increasing crushing drum speeds from 500 to 1000 rpm the productivity increased from 892.75 to 1200 kg/h. respectively.

Increasing chopping drum speed, increased the power able to crush material of plastic. Machine productivity was 1200 kg/h at drum speed of 1000 rpm.

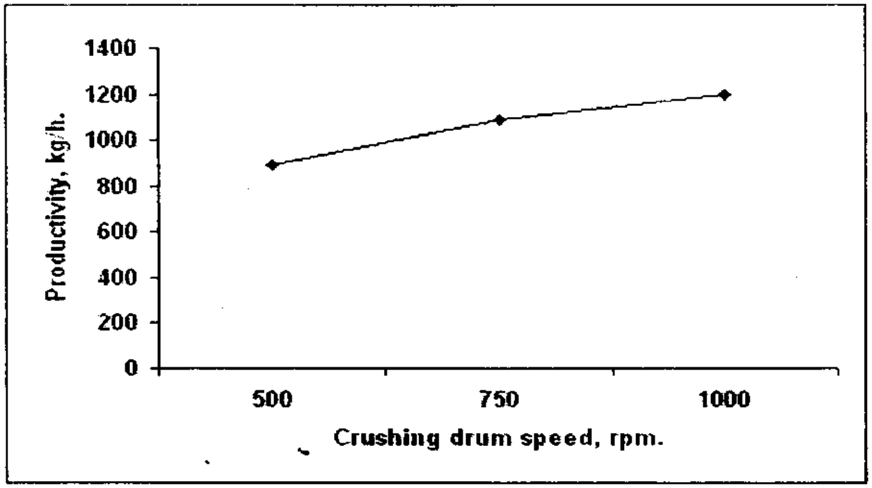

Fig.7: Effect of crushing drum speed on machine productivity.

3- Estimating the productive cost of using the machine.

It was found that the operation cost of the machine is 20.17 L.E./h (16.81 L.E./ton).

CONCLUSION

The main results in this study can be summarized as follows:-

- The proper performance was at feed rate of 1200 kg/h (1.2 ton/h) at a crushing drum speed of 1000 rpm (29.3 m/s) and clearance between fixed and moved knives of 30 mm (3 cm).
- Cut length percentage at these conditions was 97 % in cutting length of $\geq$15-20 mm.
- Productivity was 1200 kg/h.
- Operational cost was 16.81 L.E./ton.

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الملخص العربى

تطوير الة السحق لتناسب تكسير مخلفات البلاستيك

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لقد تطورت وتقدمت اساليب الزراعة بفضل انتشار المواد البلاستيكية، وذلك لان نظم الرى الحديثة تعتمد على المواسير والخراطيم والوصلات المصنعة من المواد البلاستيكية مثل البولى ايثلين. وكذلك تستعمل المنتجات البلاستيكية فى انبات البذور وتكوين الشتلات وذلك لقوة خواصها الميكانيكية ومدى مقاومتها للعوامل الجوية وخفة وزنها ورخص ثمنها. وفى اطار حصر كمية المخلفات البلاستيكية السنوية فى مصر والتى تقدر كميتها بمايتراوح بين ٨٥٠، ٩٥٠ الف طن سنويا وتقدر هذة الكمية بحوالى ٦ % من اجمالى المخلفات فى مصر والتى يصل اجماليها سنويا الى ١٦.٥ مليون طن (تحقيقات الاهرام ٢٠٠٨/٧/١٠)

لذا يهدف هذا البحث إلى تحقيق افضل استفادة ممكنة من مخلفات البلاستيك من خلال ماكينة تكسير المخلفات البلاستيكة وبذلك يمكن تقليل تلوث البيئة، حيث تم إجراء بعض التعديلات على الماكينة كى تلائم عملية تكسير المخلفات البلاستيكية.

وقد تم تقييم أداء الآلة المعدلة بتشغيلها بمتغيرت دراسية هى:-

- ٣ معدلات تغذية : ٨٠٠، ١٠٠٠، ١٢٠٠ كج/ساعة (٠.٠٨، ١.٠، ١.٢ طن/ساعة).
- ٣ سرعات لدرفيل التكسير: ٢٠.٩، ٢٥.١١، ٢٩.٣ م/ث (٥٠٠، ٧٥٠، ١٠٠٠ ل/د).
- الخلوص بين السكاكين الثانتة والمتحركة: ٢٠ ، ٣٠ مم.
- ولقد أوضحت النتائج إمكانية استخدام ألة التكسير (محل الدراسة) فى تكسير المخلفات البلاستيكية بكفاءة عالية. حيث أعطت أعلى نسبة من أطوال القطع تصل إلى ٩٧ % من أطوال القطع ١٥-٢٠مم.
- بلغت إنتاجية الآلة ١٢٠٠ كج/ساعة.
- وجد أن انسب ظروف تشغيل للآلة عند معدل تغذية ١٢٠٠ كج/ساعة وسرعة الدرفيل الفرم ١٠٠٠ لفة/د والخلوص بين السكاكين الثابتة والمتحركة ٣٠ مم.
- وجد أن تكاليف طن واحد ١٦.٨١ جنية.
- يوصى البحث بعودة المرشدين الزراعيين ولفت نظر المزراعين الى كيفية الاستفادة من الألات المتاحة لديهم، لتغظيم الاستفادة منها بدلا من الدخول فى عمليات التصنيع والاستيراد والتي تمثل عبئا اقتصاديا ومشاكل فنية.
- عند الخلوص الصغير ٢٠ مم المسافة بين السكاكين الثابتة والمتحركة اقل مايمكن ولذلك سوف يحدث سحق للمادة المدروسة مما يجعلها فى صورة قطع صغيرة جدا قد تصل للبودرة، وهذا لايرضى المصنع لان الخطوة التالية فى عملية اعادة التصنيع تحتاج قطع بمقاسات معينة لان عند استعمالها فى صورة قطع صغيرة يؤدى ذلك الى زيادة تكاليف الخطوة التالية فى عملية اعادة التصنيع.

***باحث أول بمعهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الدقى -الجيزة – مصر.**