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# IMPROVING THE PERFORMANCE OF CHOPPER MACHINE BY COATING STEEL KNIVES

***Khater, I. M. M. and Mona M. Abd El Aziz****

*Soil Conservation Dept., Desert Res. Center, Egypt

******Agric. Eng., Dept., Zagazig Univ., Egypt

**Key Words:** Chopper, Coating, knives, sharpness and straw.

## ABSTRACT

The aims of this research are to improve chopper machine performance and evaluate three steel types (AISI 304 ،Bohler K100 and Honing steel) coated by Nano chromium solution. Coating with Nano chromium solution was used to increase the sharpness of the rotating cutting knives .Results showed that the maximum machine productivity (338 kg/h) was obtained by using AISI 304 with speed of 1400 rpm (29.31 m/s) and moisture content 13.40% meanwhile, the minimum machine productivity (118 kg/h) was obtained by using honing steel knives with speed of 800 rpm (16.76 m/s) and moisture content 24.36%. The energy requirements of chromium coated honing steel knives were higher than AISI 304 and Bohler K100 steel knives. Whereas, the minimum production cost (70.80 EGP/Mg) at moisture content 13.40% and knives speed 1400 rpm (29.31 m/s).

## INTRODUCTION

Most of the systems and equipment used in agricultural machines are made of metals such as stainless steel, aluminum, nickel, Monel (**Khaledinia *et al.*, 2015**). **Erfan (2004)** studied that the abrasive wear behavior of two boron steels. AISI 15B35H and AISI 15B41H boron steel are compared by considering hardness and abrasive wear rate. The test carried out heat treated and untreated cubic steel specimens. The hardness of untreated boron steel specimens are increased with increasing carbon content of the test material and this positively effect the abrasive wear resistance. Each one as well as the principles for hygienic design of plants should at least have important features including good resistance to corrosion, proper polished rate and suitable mechanical behavior. Stainless steel has ideal characteristics for the production of equipment. AISI 304 is the most widely used type of stainless steel (**Shanaghi *et al.*, 2009**). The use of coating among the methods of controlling and preventing steel corrosion is considered as an effective method **(Zamanian, 2009)**. Currently, nano-coatings among all other types are highly regarded. Better appearance, high physical resistance, lower permeability than corrosive environments, convenience for cleaning the surface, proper adhesion of the coating, and scratch resistance are the main features of nano-coatings **(Shiravand, 2013).** Most agricultural operations are carried out on the field and are subjected to friction and wear of material that have accompanied man since his very beginning. Wear is defined as damage to a solid surface, generally involving progressive loss of material, because of relative motion between that surface and a contacting substances (**Gurrumoorthy *et al*., 2007).** Rice straw is one of the most residue problems in Egypt. Therefore, the rice-straw chopping process is very necessary as a pretreatment to reuse the rice straw in compost practice with appropriate cutting length should be within the range of about 1.27–7.62 cm. **Tiquia and Tam (2002).** The chopping process can be done by using variable type of chopping machines, but the productivity of these choppers is still little, not covering the farmer needs in addition to the high operation and production cost of the rice-straw chopping process **Mohamed (2016). EL-Eraqi and El-Khawaga (2003)** designed and evaluated a machine for cutting crop residues. It was found that the maximum percentage cutting-length of rice straw less than 5 cm about 87.80 % was investigated at using cutting speed 10.09 m/s. Also, the energy requirement was 6.36 kW.h/ton. The maximum operating and production costs were 5.10 L.E/h and 6.61 L.E/ton for cut rice straw residues. **El-Fatih *et al.* (2010)** modified and evaluated chopper for rice straw composting. It was found that by increasing the cutting drum speed from 56.6 m/s to 70.7 m/s the productivity increased from 489 kg/h to 1150 kg/h, from 430 kg/h to 976 kg/h and from 350 kg/h to 600 kg/h for 35 mm, 25 mm, and 9 mm concave-hole diameters respectively.

The objectives of this study are:

-Improve of the rice straw disc chopper machine.

-Testing of treated cutting knives by nano chromium for rice straw.

-Studying the effect of performance factors on cutting length, machine productivity, specific energy and costs.

## MATERIALS AND METHODS

The field experiment was conducted in Wadi El Molak ،Sharkia Governorate in July 2019 to improve chopper machine performance by increase the sharpness of the knife edge which were coated with Nano chromium solution. The coating and electrophoretic treatments were conducted in metallurgical development research center ،Al-Tibeen ، Cairo .

The studied parameters were as follows:

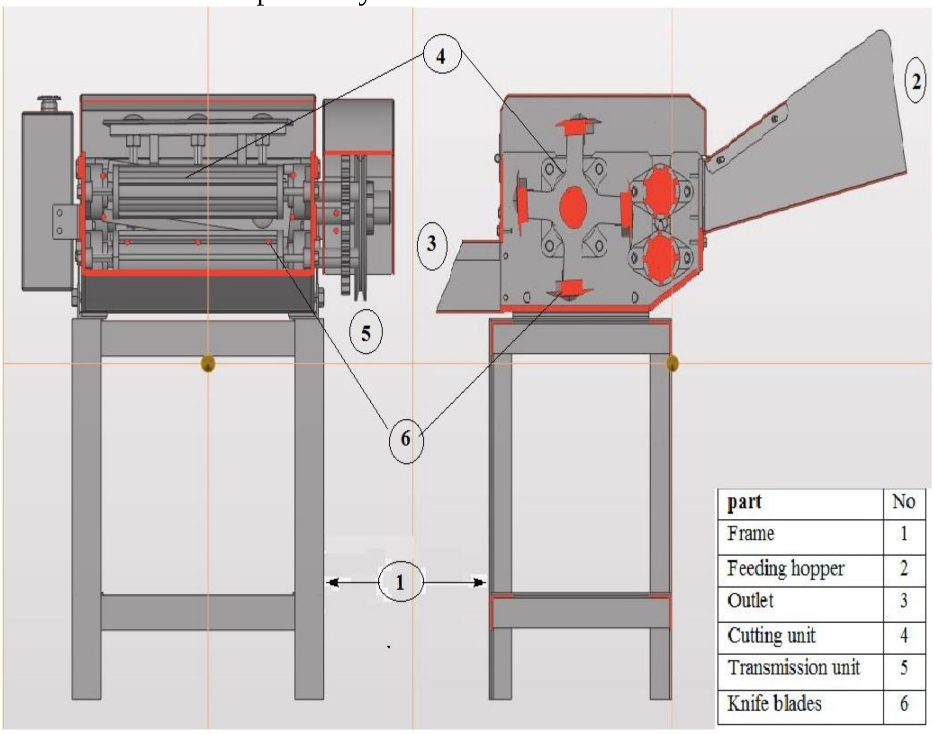
Three cutting knives AISI 304, Bohler K100 and Honing steel (coated with Nano chromium solution).

Four cutting-knives speed 800, 1000, 1200, and 1400 rpm (16.76, 20.94, 25.13 and 29.31 m/s).

Two levels of rice straw moisture contents 13.40 and 24.36 % (wet base).

**Rice Straw Chopper:** The rice straw chopper consists of frame, motor, feeding hopper, outlet, cutting unit, shaft, pulley, and fan housing as shown in Figure (1).

**-Frame**: The frame was made of U-angle steel with dimensions of 100 x 50 x 5 mm. The overall length, width and height of the frame are 800, 600 and 500 mm respectively.




| part | No |
|---|---|
| Frame | 1 |
| Feeding hopper | 2 |
| Outlet | 3 |
| Cutting unit | 4 |
| Transmission unit | 5 |
| Knife blades | 6 |

**Figure (1): Developed disc-chopper views**

**Feeding Hopper**: The feeding hopper of rectangular shape was made of iron sheet with thickness of 3 mm. Hopper dimensions are: upper face 260 × 240, lower face 70 × 50 mm and height 140 mm.

**Cutting Unit:** The cutting unit consists of the following parts:

Cutting unit housing, rotating cutting knives , outlet , electric motor of 5.6 kW (7.5 hp) and power transmission unite. Cutting knives were made of alloy steels with 5 mm thickness, 40 mm width and 150 mm length.

**Coating process:**

The steel plates were used as anode and cathode during the coating process having the distance of 12 mm between the electrodes. Due to its positive charge on the surface of chromium solution nanoparticles, the coating was done on the cathode as shown in figure (2).

Treated knives were left for 24 hours at room temperature after coating process to create a smooth coating with no cracks and pores. Then, heating at high temperature of 500°C by a Carbolite Furnaces S30 2AU under a flow of argon gas to create a coating with good adhesion to achieve high strength. **(Afshar and Amirnezhad, 2009).**

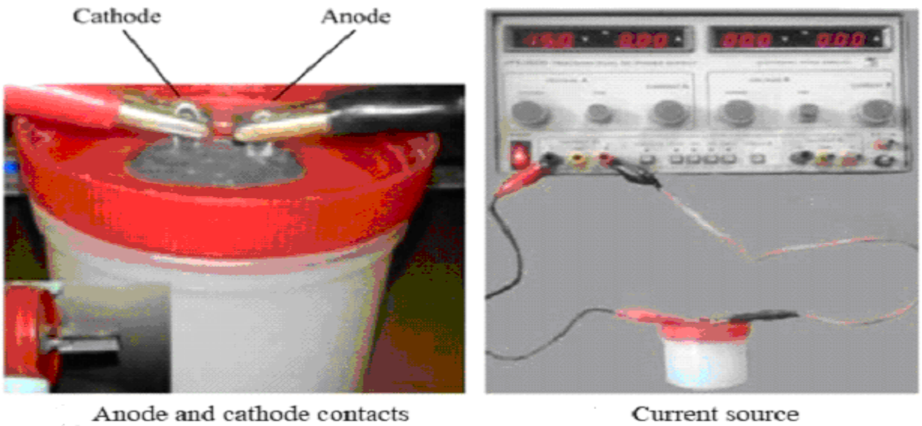



**Figure (2): Coating process with electrophoretic method**

**Steel chemical composition:**

Table (1) shows the chemical composition and weight of components in used samples.

**Table 1: The chemical composition of steel (average %):**

| Type of steel | Mn | Si | Cr | V | Fe | C |
|---|---|---|---|---|---|---|
| **AISI 304** | 2.00 | 0.75 | 19.5 | 0.37 | 66.99 | 0.08 |
| **Bohler K100** | 0.35 | 0.25 | 11.5 | 0.71 | 63.16 | 2.00 |
| **Honing steel** | 1.03 | 0.12 | 0.6 | 0.03 | 68.99 | 1.15 |

Where:

Mn: Manganese, Si: Silicon, Cr: Chromium, V: Vanadium, Fe: Iron and C: carbon

**Knives dimension:**

The knife dimensions (5 mm thickness*40 mm width*150 mm length) were used. Figure (3) shows a plate of uncoated (a) and coated plates with nano chromium solution (b) after the process of heating.

(a) Uncoated (b) Coated

**Figure (3):** Uncoated and coated knives

**Measurements:**

**Average and cutting length of rice straw:** Average cutting length for rice straw was measured from sample of 200 g for each treatment.

**Machine productivity:** Machine productivity was calculated by using the following equation:

$$p = W / t \quad , Mg/h$$

Where: P : Machine productivity, (Mg/h), W: Mass of the rice straw bale, (kg) and t : Time, (h).

**Specific energy:** The electrical power requirement (kW) was calculated by using the clamp meter to measure the line current intensity in Amperes (I) and potential difference values (v). The required power (P) was calculated according to **Kurt, (1979)** by using the following equation:

$$p = \sqrt{3} \times I \times V \times \eta \times \cos\theta / 1000 \quad , kW$$

Where: P: Power requirement for the cutting machine in kW, I : Line current intensity in amperes, V: Potential difference (Voltage) being equal to 380 V, Cos : Power factor (being equal to 0.85), 3 : Coefficient current three phase (being equal 1.73) and : Mechanical efficiency assumed (95 %). The specific energy was calculated by using the following equation:

$$\text{Specific energy} = \frac{\text{Power(kW)}}{\text{Productivity(Mg/h)}} \quad , kW.h/Mg$$

Production cost was calculated according to the following equation:

$$\text{Production cost} = \frac{\text{Operation cost (L.E/h)}}{\text{Machine productivity (Mg)}} \quad , \text{L.E/Mg}$$

## RESULTS AND DISCUSSION

### 1- Effect of Alloy types, cutting-knives speed and rice-straw moisture content on average of cutting-length.

Figure (4) shows the effect of steel alloy type, cutting-knives speed and rice-straw moisture content on average cutting length. The maximum average of cutting length of 42.3 mm was obtained by using honing steel, cutting-knives speed of 800 rpm (16.76 m/s) and moisture content of 24.36 %.

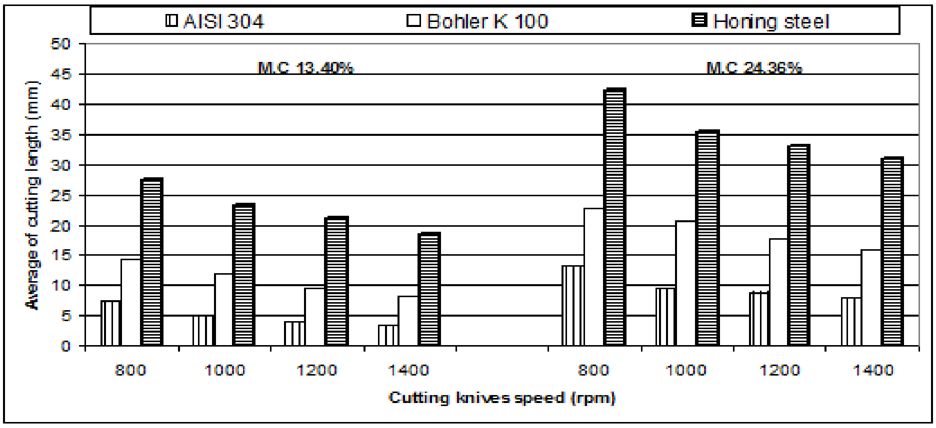



**Fig. (4). Effect of cutting-knives speed, rice-straw moisture content and alloy type on average of cutting length.**

Meanwhile, the minimum average of cutting length of 3.2 mm was obtained by using the AISI 304 steel, cutting-knives speed of 1400 rpm (29.31 m/s) and moisture content 13.40 %. The maximum of average cutting-length of 42.3 mm was obtained by using the honing steel and cutting knife speed of 800 rpm. Meanwhile, the minimum of average cutting-length of 3.2 mm was obtained with AISI 304 steel and cutting-knife speeds of 1400 rpm. The decreasing of average cutting-length of rice straw by using the AISI 304 is due to sharpness of knives on rice-straw stalks which assist the shear forces from knives. By increasing rice-straw moisture content from 13.40 to 24.36 % the average of cutting length increased at all tested cutting-knife speeds. The increasing of average cutting-length of rice straw by increasing rice-straw moisture content was due to causing bending of rice-straw stalks which faces the knives disc.

**2- Effect of alloy types, cutting-knives speed and rice-straw moisture content on machine productivity.**

Figure (5) shows the effect of alloy types, cutting-knives speed and rice-straw moisture content on the machine productivity. The maximum machine productivity of 338 kg/h was obtained by using AISI 304 steel with cutting-knives speed of 1400 rpm (29.31 m/s) and moisture content 13.40 %.

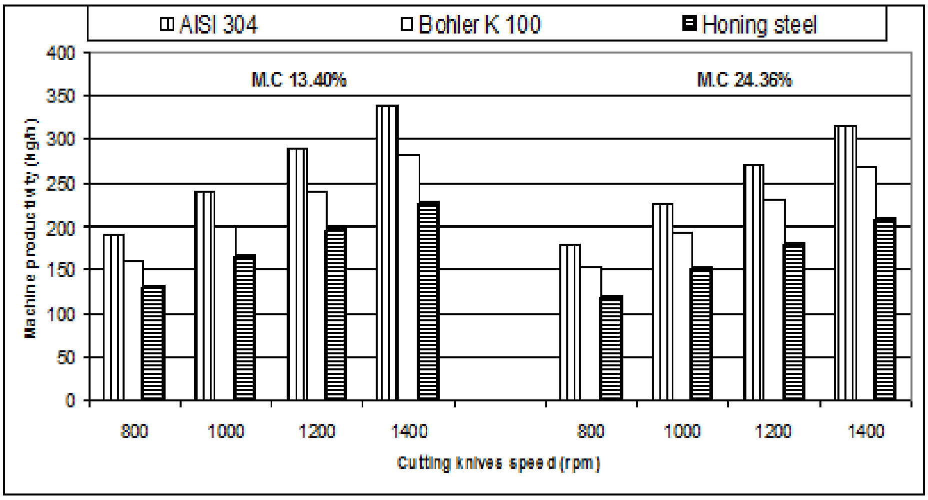



**Fig. (5). Effect of cutting-knives speed, rice-straw moisture content and alloy type on machine productivity.**

Meanwhile, the minimum machine productivity of 118 kg/h was obtained by using the honing steel with cutting knives speed of 800 rpm (16.76 m/s) and moisture content 24.36 %. The increasing of machine productivity by increasing cutting-knives speed was due to decreasing of cutting time. Meanwhile, the increasing of machine productivity by decreasing rice-straw moisture content was due to decreasing the cutting-straw mass.

**(3) Effect of cutting-knives speed, rice-straw moisture content and alloy type on specific energy.**

Figure (6) shows the effect of cutting knives speed, rice-straw moisture content and alloy type on specific energy. The maximum specific energy of 29.00 kW.h/Mg was obtained with honing steel, cutting-knives speed of 800 rpm (16.76 m/s) and moisture content 24.36 %. Meanwhile, the minimum specific energy of 9.00 kW.h/Mg was obtained by using the chopping machine with AISI 304 steel, cutting-knives speed of 1400 rpm (29.31 m/s) and moisture content 13.40 %.

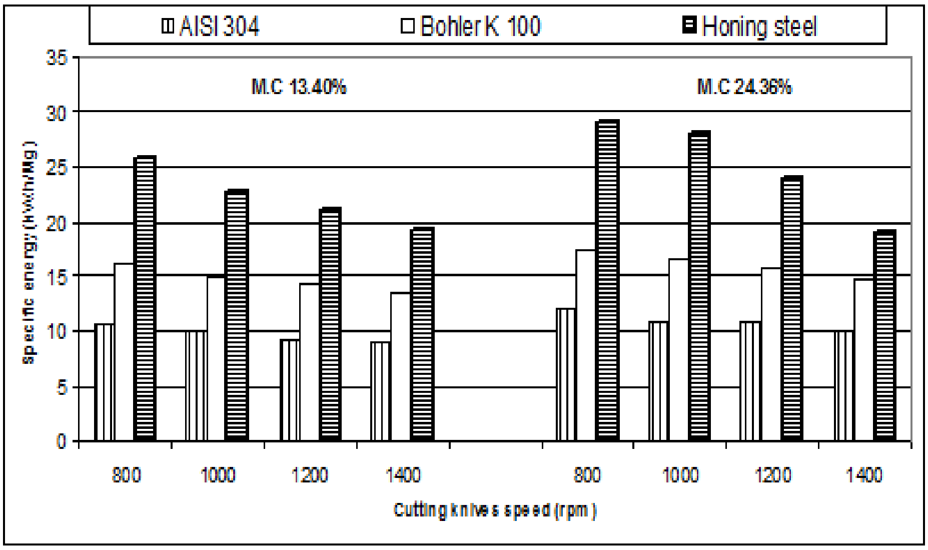



**Fig. (6). Effect of cutting-knives speed, rice-straw moisture content and alloy type on specific energy.**

**(4) Effect of cutting-knives speed, rice-straw moisture content and alloy type on operation and production costs.**

Production costs of using the disc chopper for at optimum cutting-knives speed of 1400 rpm (29.31 m/s) under rice straw moisture contents of 13.40 and 24.36 % were shown in table (2) . Generally, the production costs by using rice-straw moisture content of 24.36% was lower than moisture content 13.40%, at all tested steel alloys. The maximum production cost of 143.20 L.E./Mg was obtained by using moisture content 13.40 % and at optimum knives-speed of 1400 rpm (29.31 m/s) with honing steel. Meanwhile, the minimum production cost of 70.80 L.E./ Mg was obtained by using moisture content 24.36 % and at optimum knives-speed of 1400 rpm (29.31 m/s) with AISI 304 steel.

**Table 2: Effect of rice-straw moisture content and alloy type on production costs at optimum cutting-knives speed of 1400 rpm (29.31 m/s).**

| Moisture content (%) | Alloy type | Machine productivity (kg/h) | Production cost (L.E/ton) |
|---|---|---|---|
| 13.40 | AISI 304 | 338 | 70.80 |
| | Bohle K 100 | 281 | 81.20 |
| | Honing steel | 227 | 140.20 |
| 24.36 | AISI 304 | 317 | 80.60 |
| | Bohle K 100 | 269 | 102.80 |
| | Honing steel | 208 | 143.20 |

## CONCLUSIONS

The results showed that the energy requirements were lower and the cutting efficiency was higher for AISI 304 chrome-coated steel knives compared to Bohler K100 and hoening steel knives. Maximum machine productivity (338 Mg/h) was achieved with AISI 304 at speed 1400 rpm (29.31 m/s), with a moisture content 13.40%. The machine was less productive (118 Mg/hr) with hoening steel knives at 800 rpm (16.76 m/s) with moisture content 24.36%. Whereas, the minimum production cost (70.80 EGP/Mg) at moisture content 13.40% and knives speed 1400 rpm (29.31 m/s).

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## تحسين أداء الة التقطيع بواسطة طلاء سكاكين الصلب

***إسلام محمد منير خاطر– **منى محمود عبد العزيز**

*قسم صيانة الاراضى– مركز بحوث الصحراء– القاهرة– مصر

**قسم الهندسة الزراعية– جامعة الزقازيق – مصر

يهدف هذا البحث دراسة تأثير معالجة سكاكين ألة التقطيع بالطلاء الكهربى على كفاءة تقطيع قش الأرز حيث تم استخدام ثلاثة أنواع مختلفة من الفولاذ ، AISI 304 ، Bohler K100 ، والفولاذ المجلخ والذي يشيع استخدامه مع آلات التقطيع. وتمت عملية الطلاء باستخدام محلول نانو كروميوم مع معالجة كهربية لزيادة حدة سكاكين القطع.

عوامل الدراسة هى:

- ثلاثة أنواع مختلفة من الفولاذ
- اربع سرعات لسكاكين القطع ٨٠٠ ، ١٠٠٠ ، ١٢٠٠، ١٤٠٠ لفة/دقيقة (١٦.٧٦ ، ٢٠.٩٤ ، ٢٥.١٣ ، ٢٩.٣١ م/ث )
- رطوبة قش الارز المستخدم كانت عند مستويين (١٣.٤٠ و ٢٤.٣٦ % ).

أظهرت النتائج أن متطلبات الطاقة كانت أقل وكفاءة القطع كانت اعلى بالنسبة لسكاكين الصلب المطلية بالكروميوم من نوع AISI 304 مقارنة بالسكاكين من نوع K100 Bohler والسكين الفولاذية المجلخة. تم الحصول على أقصى إنتاجية للماكينة (٣٣٨ ميجاجرام/ساعة) باستخدام AISI 304 عند سرعة ١٤٠٠ لفة في الدقيقة (٢٩.٣١ م / ث) ، مع محتوى رطوبى لقش الأرز ١٣.٤٠٪. وكانت أقل إنتاجية للماكينة (١١٨ ميجاجرام/ساعة) مع استخدام سكاكين الفولاذ المجلخة عند سرعة ٨٠٠ لفة في الدقيقة (١٦.٧٦ م/ث) مع محتوى رطوبى لقش الأرز ٢٤.٣٦ ٪. فى حين كان الحد الأدنى لتكلفة الإنتاج (٧٠.٨٠ جنية/ميجاجرام) عند محتوى رطوبى لقش الأرز ١٣.٤٠ ٪ وبسرعة للسكاكين تبلغ ١٤٠٠ لفة في الدقيقة (٢٩.٣١ م / ث).