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DEVELOP AND TEST ATACHMENTS TO THE AXIAL-FLOW COMBINE HARVESTER FOR STRAW BREAKAGE INTO CHAFF

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ABSTRACT

The aim of this work is to develop and construct attachments to the combine harvester to directly obtain fine chaff suitable for animal feeding. The auxiliary parts attached o the combine for chaff may maximize combine exploitation. The combine with attachments was tested at different operating conditions, at rotor speed (16.8, 20.4 and 24 m/s), cylinder concave clearance ratio between front and rear holes (0.4, 0.52, 0.64 and 0.76). Suction fan speeds (1000, 1250 and 1450 rpm) were also tested. The result show that optimum rotor speed was 24 m/s, concave clearance ratio 0.4 and suction fan speed 37.94 m/s respectively. At these variable levels, the straw fineness was maximized. The development of obtaining chaff directly from combine saves time, effort and minimizes combine operation cost.

INTRODUCTION

Combine harvester throw straw of wheat on the ground where more labors for collecting and re-threshing are required. Under Egyptian conditions wheat chaff is considered valuable byproduct for animal feeding. So this study aimed to break straw into chaff directly while threshing operation in order to save the time, effort and cost.

Hanna and Suliman (1982) mentioned that Egypt has a unique agricultural feature. It has a very strong livestock program but with meager green fodders during the summer season. This situation makes the cattle feeding almost entirely dependant on the wheat straw after it has been cut and properly bruised by stationary threshers. Using a combine that usually throws back the wheat into the fields does not provide the exact requirements of the Egyptian farmers.

Morad (1997) investigated threshing machine performance in terms of grain losses, energy requirements and threshing cost as a function of change in feed rate, cylinder speed and grain moisture content during threshing wheat. He found that threshing losses as well as threshing cost can be minimized when the feed rate was one ton/h, the drum speed was 25 m/s and moisture content was 20%.

El-Danasory and Imbabi (1998). Show that yield of straw about 3752 kg/fed, the labor required for manual picking and packing per wheat straw of one feddan after harvesting with combine was 6 labors with 9 working hour per day then the time required per one feddan was 54 hours. Also, they added that the average losses of straw were 13.7% and high cost of picking and packing of straw after harvesting (165 L.E/fed).

Kamel and El-Khateeb (2002) reported that two types of Japanese combine harvesting machines were studied. The experiments were tested at three different forward speeds approximately (2.3, 3.2 and 4.5 km/h), three cylinder speeds (22.7, 28 1 and 32.1 m/s and two moisture contents (13.3 and

10.9%) for wheat crop. The minimum values of total losses were 0.84 and 0.79% respectively obtained at forward speed of 2.3 km/h, cylinder speed of 28.1m/s and grain moisture content of 13..6% were recommended for optimum harvesting of wheat.

Johnson (2003) revealed that the effect of combine setting and grain damage-sample purity: damage comes from impact, crushing and shearing of grain that takes place not only in the thresher but in grain handling equipment as well. Augers are not the best way to move grain if damage is to be kept small. The dominant machine setting affecting grain damage is cylinder or rotor speed, but other settings are relevant. Grain damage tends to increase with thresher speed, so try to operate at the lowest cylinder or rotor speed that will shell the most grain with acceptable levels damage to grain (with acceptable loss levels). Damage to grain can start right at the head it self. Corn is more susceptible to damage at higher moisture content therefore, harvesting at 15% to 22% kernel moisture level is advantageous.

Metwalli *et al.*, (2003) in their research carried out at Nobaria area using the following: 1) Traditional method (manual harvesting, collecting and transfer + mechanical threshing). 2) Tractor rear, mounted mower + manual collect and transfer + mechanical threshing). 3) Combine harvesting machine +pillar. In addition they added that the results reveal that combine reduced energy by 39.84%, time by 99.7%, losses by 86.91%. About 42.96% grain losses was saved compared manual harvesting, mower reduced energy by 0.64% time by 35.25% losses by 8.05% and cost by 9.26% compared with the first system. In general the third system was recorded the best results compared with the other two systems.

Ellinbank (2005) mentioned that chaff is hay cut into small pieces for feeding to livestock. It is a good fodder, and at its best is cleanly and evenly cut, free of dust, of good colures and with a fresh aroma. Chaff is usually cut into 6 – 10 mm long pieces. Cereal chaff can be up to 20 mm for cheep and horses, or even slightly longer for cows. Nutritional value is not changed by the cutting from hay to chaff but utilization by the animal may be better. An unevenly cut chaff lacks appeal to the eye and so may be downgraded in value. An excess of fines or dust particles is detrimental to animal health.

MATERIALS AND METHODS

This study was conduct to develop CICOREA combine harvester (T) type, longitudinal axial – flow cereal crops combine, to be suitable for break straw to be chaff. The following parts were fabricated and assembled for the proposed development. 1) A cover to close the straw outlet. 2) Replacing the rasp bars by spikes. 3) Use one part only for concave. 4) Use an auger under the threshing chamber for chaff discharge through a suction fan. This modification aimed to increase the efficiency, maximizing the benefiting of the developed combine, saving the time and effort, decreasing power requirements and minimizing the high direct cost. The performance of the modified combine will be influenced by rotor speed, concave clearance ratio and suction fan speed. The experiments were carried out on wheat crop at the farms of Gemmiza Research Station a harvesting seasons of 2005 and 2006.

Materials:

The utilized combine machine:

The CICOREA combine harvester (T) type, model longitudinal axial-flow consists of group of parts as shown in Fig. 1. It has gross dimensions 2.4 m. wide, 2.50 m high and 4.6 m long. Engine has of 32.25 kW (43 Hp) and gross weight of 3000 kg. The axial flow threshing drum provided with six spikes instead of rasp bars and knifes for straw cutting. Diameter and length of threshing drum 53 cm and 160 cm respectively. The type of straw racks is fans, vibrators, and sieves.

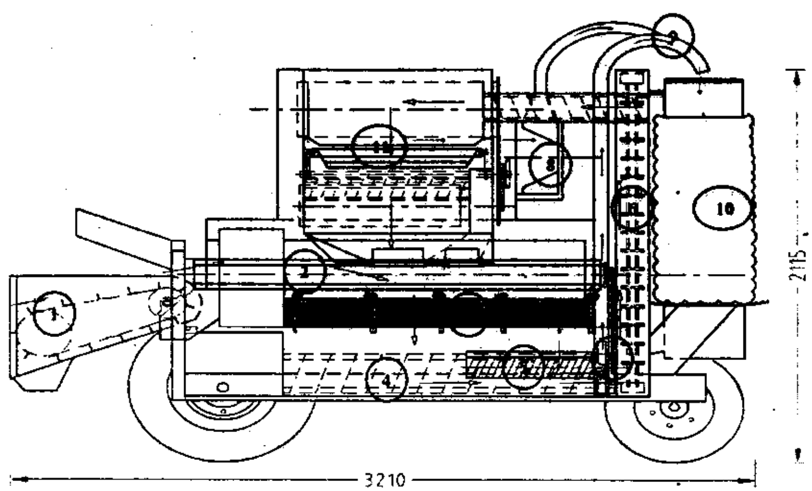

Fig. (1)Schematic diagram for modified CICOREA combine (T) type
1. Elevator (beads + necks) 2. Threshing rotor 3.Concave (seed + Coarse chaff) 4. Main auger (seed + coarse chaff) 5.Manufactured auger 6.Elevator (seed +coarse chaff) 7. Fabricated suction fan 8.Cleaning fan 9. Chaff transporting tube 10. Chaff tank 11. Cleaning shoe 3, 5, 7,9,10 (modified parts).

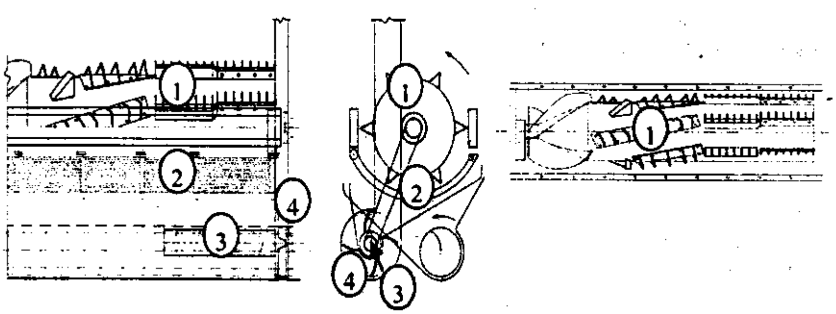

Fig. (2) Schematic diagram of modified components (rotor (1), concave(2), fabricated augur (3), and fabricated suction fan (4).

Field experiments

The machine was tested at combine forward speed 2.8 km/h (1.78 m/s). Mean moisture content of straw at the time of test 14.35 % and mean moisture content of grain 16.85 % on wet bases, Concave hole diameter 14 mm, of cleaning sieves holes of 8 mm and tilt angle of threshing forks 20^{-0} on longitudinal axis for drum in threshing zone.

Variable parameters

1- Rotor speed 700, 800 and 1000 rpm (16.8, 20.4 and 24 m/s) named R_1, R_2 and R_3 respectively,

2- The cylinder concave clearance was adjusted to obtain four clearances ratios front to rear holes 0.4, 0.52, 0.64 and 0.76 named C_1, C_2, C_3 and C_4 respectively.

3- Suction fan speed was adjusted to attained three levels 1000, 1250 and 1450 rpm named F_1, F_2, F_3 and F_4 respectively.

Experimental measurements:

To study influence of the variable parameters on the grain losses, shoe losses, chaff lengths and power requirement, the following measurements were carried. The tests were repeated three times for more accurate average data.

1. Grain losses in chaff (separating losses %):

$$\text{grain losses percentage} = \frac{\text{weight of grain losses in chaff}}{\text{weight of total grain}} x100 ----3.1$$

2. Shoe losses:

$$\text{Shoe losses percentage} = \frac{\text{weight of grain losses in chaff under sieves}}{\text{weight of total grain}} x100 --3.2$$

3. Separating efficiency:

Separating efficiency = (100 – grain losses percentage) ----3.3

4. Shoe efficiency:

Shoe efficiency = (100 - shoe losses percentage) - - - - - - - 3.4

5. Determination of fuel consumption:

Fuel consumption was determined by measuring the volume consumed fuel during harvesting.

6. Power consumed = 3.163 * fuel cons.(L/h). kW) (Empapy 1985)

7. Chaff fineness: among (>2, 2 to 3.5 and > 3 cm) calculated as weighed ratio (dimensionless).

RESULTS AND DISCUSSION

1- Effect of different tested factors on grain losses:

Data plotted in Fig. (3) Show the effect of rotor speed on the separating grain losses. Increasing rotor speed tends to decrease the separating grain losses. At suction fan speed (1000 rpm) and concave clearance ratio (0.4), increasing rotor speed from 16.8 to 24.0 m/s decreased the separation losses from 0.82 to 0.61 %. Optimum rotor speed that decrease separation losses 24 m/s. Higher rotor speed tend to increase wispy chaff. Separating losses had an inverse relationship with the rotor speed and had direct effect with fan speed. This may because of increasing suction fan speed ratio led to dragging more grain in chaff.

The following equation was obtained through a multiple regression analysis to illustrate the dependency of independent variables on the separation losses.

Separation losses (%) = 0.945 +0.000507 Fan speed (rpm) - 0.00109 Rotor speed (rpm) + 0.409 Clearance (%)

R-Sq = 93.9%

2- Effect of different tested factors on shoe losses:

Data in Fig. (4) show the effect of rotor speed on the shoe losses. At fan speed 1000 rpm, and concave clearance ratio 0.4 rotor speed range from 16.8 to 24.0 m/s; shoe losses decreased from 0.46 to 0.35 %, which is inverse relationship between rotor speed and shoe losses. This indicates that optimum rotor speed was the (24.0 m/s). The high shoe losses may be attributed to the excessive load of the threshed material (straw and grains) on the shoe sieves. Excessive load occurred by decreasing rotor speed which cause slow motion of the threshed material. Due slow motion some grains which did not have the chance to go penetrate the threshed material layers and holes of the shoe sieves.

A multiple regression analysis was carried out taking shoe losses, as dependent variable and fan speed, concave clearance and rotor speed as independent variables.

Shoe losses (%) = 0.863 -0.000533 Fan speed (rpm) -0.000301 Rotor speed (rpm) + 0.786 Clearance (%)

3. Effect of tested factors on the chaff losses:

Total chaff losses decrement linearly with increasing combine rotor speed as shown Fig. (5). Increasing rotor speed from 16.8 to 24.0 m/s decreased the chaff losses from 4.21 to 2.51 % at fan speed of 1000 rpm and concave clearance ratio 0.4 . This may be due to higher threshing rate. The same data clarify that chaff losses decreased with increasing fan speed. While the same data indicated that decreasing of fan speed from 1000 to 1450 rpm decreased the chaff losses from 4.21 to 0.75 % at concave clearance ratio 0.4 and rotor speed 16.8 m/s. This may be due to increasing suction fan speed that led to increasing dragging of chaff because of increment discharge of fan air. So the rotor speed 16.8 m/s, concave clearance ratio 0.4 and fan speed 1450 rpm are recommended for decreasing the chaff losses.

The following equation was obtained through a multiple regression analysis to illustrate the dependency of independent variables on separation losses.

Chaff Losses (%) = 9.53 - 0.00638 Fan speed (rpm) - 0.00310 Rotor speed (rpm) + 6.37 Clearance (%)

R-Sq = 95.5%

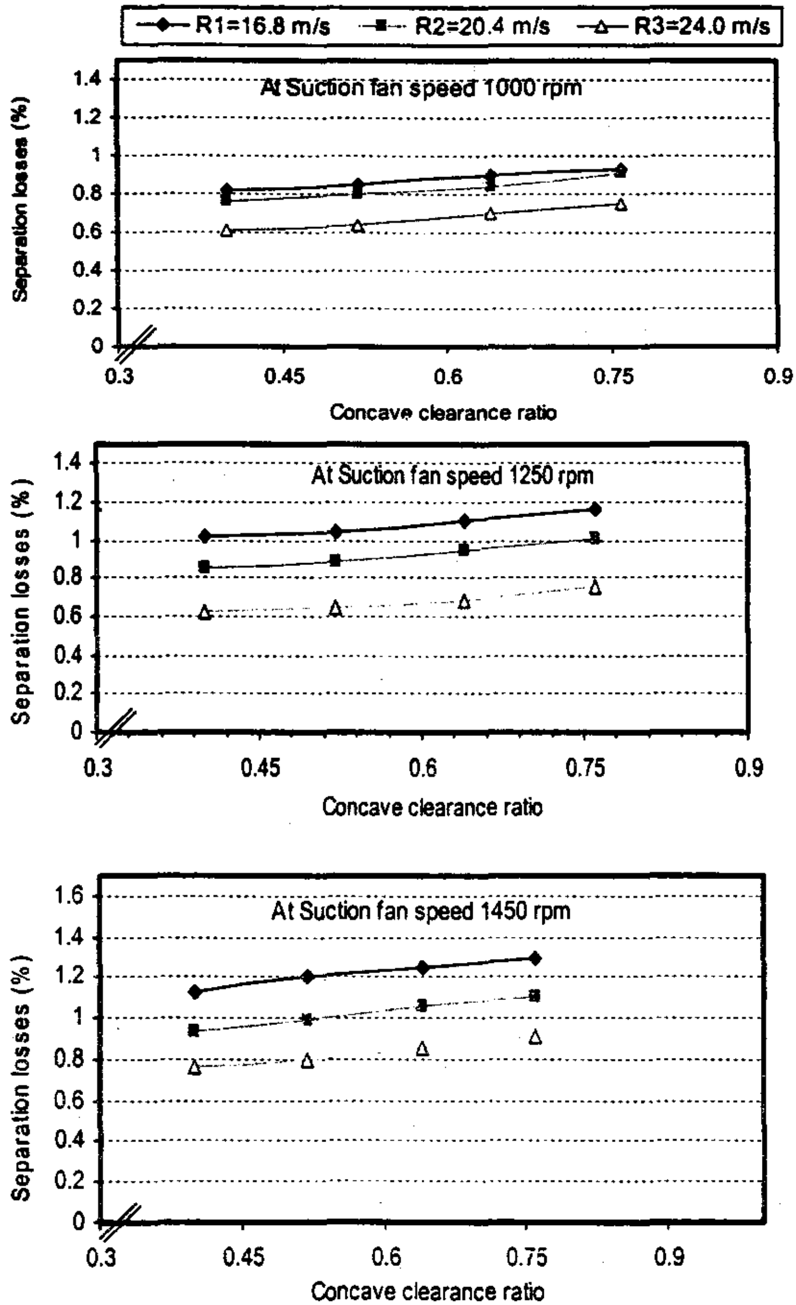

Fig.3. Effect of fan speed, Concave clearance and rotor speed on the separation losses

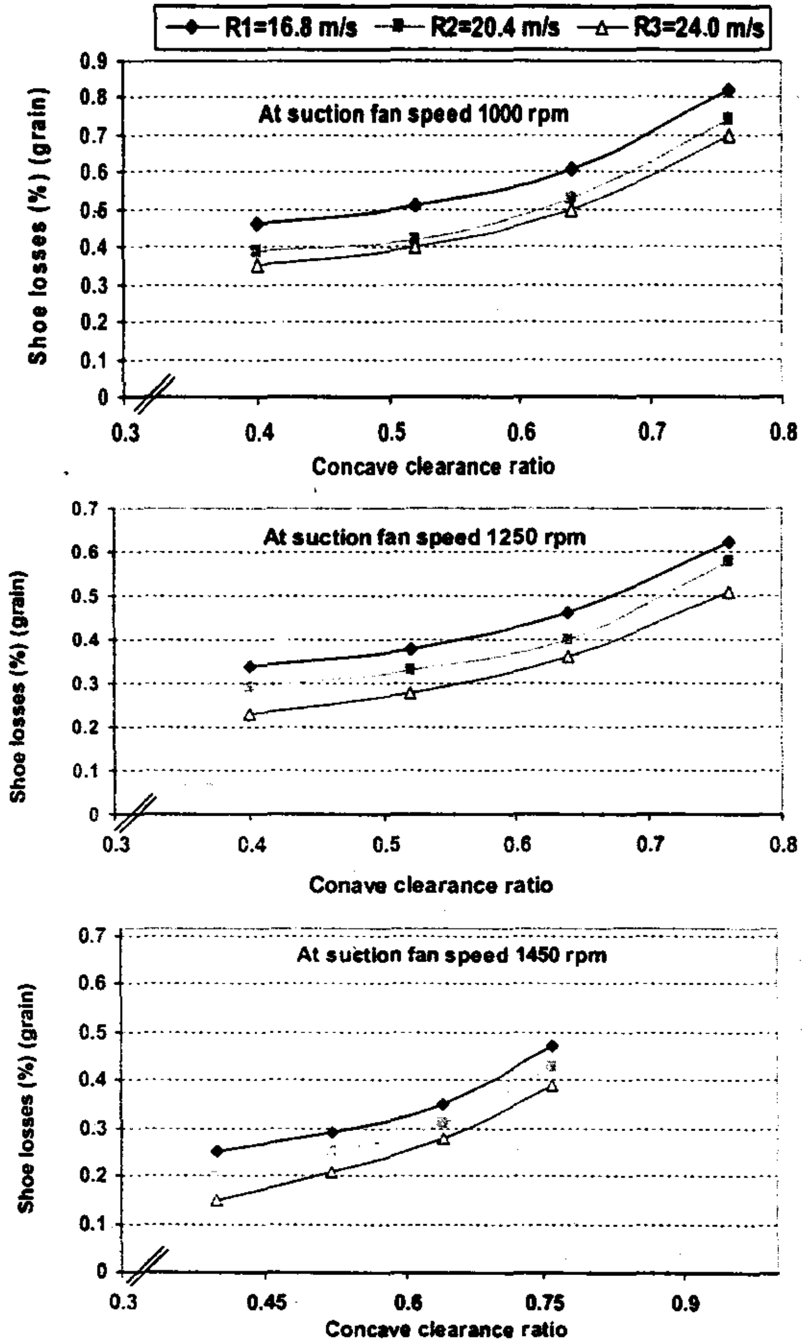

Fig.4. Effect of fan speed, concave clearance and rotor speed on shoe losses.

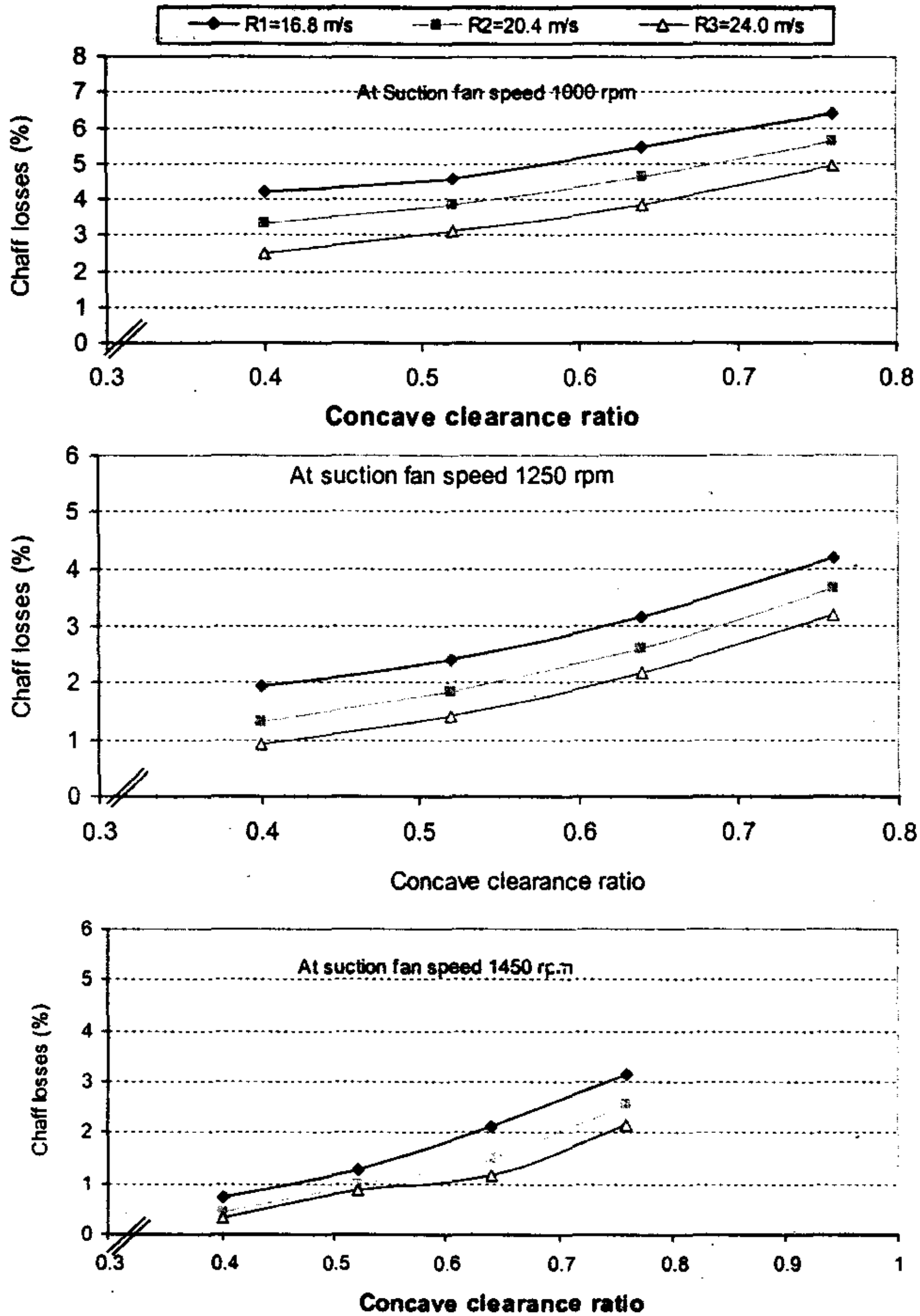

Fig.5. Effect of fan speed, concave clearance and rotor speed on chaff losses.

4. Effect of tested factors on the chaff length:

From data was graphically, in Fig. (6) show that the most fine chaff value (< 2 cm) of (48.9 %), the percent of course chaff of length range 2.5 to 4 cm (44.97%) and the more of course chaff of length range (< 4.5 cm) of (6.13%). These target values were found at the rotor speed (24.0 m/s), suction fan speed 1000 rpm concave clearance ratio 0.4. But the lowest fine chaff value (< 2 cm) of (13.86 %), the percent of course chaff of length range 2.5 to 4 cm (55.74%) and the more of course chaff of length range (< 4.5 cm) of (22.4%). These no target values were found at the rotor speed (16.8 m/s), suction fan speed 1450 rpm and concave clearance ratio 0.76. Also, the percentage of wispy chaff (< 2 cm and from 2 to 3.5 cm) increased linearly as the combine rotor speed and suction fan speed increasing. This may be because of increased rotor speed, increase the impact of spikes and increase straw breakage. The dense layers of the threshed material interact during threshing and intensively expose to impact against spike tooth of the rotor and sieve wall that cause more straw breakage increasing chaff fineness.

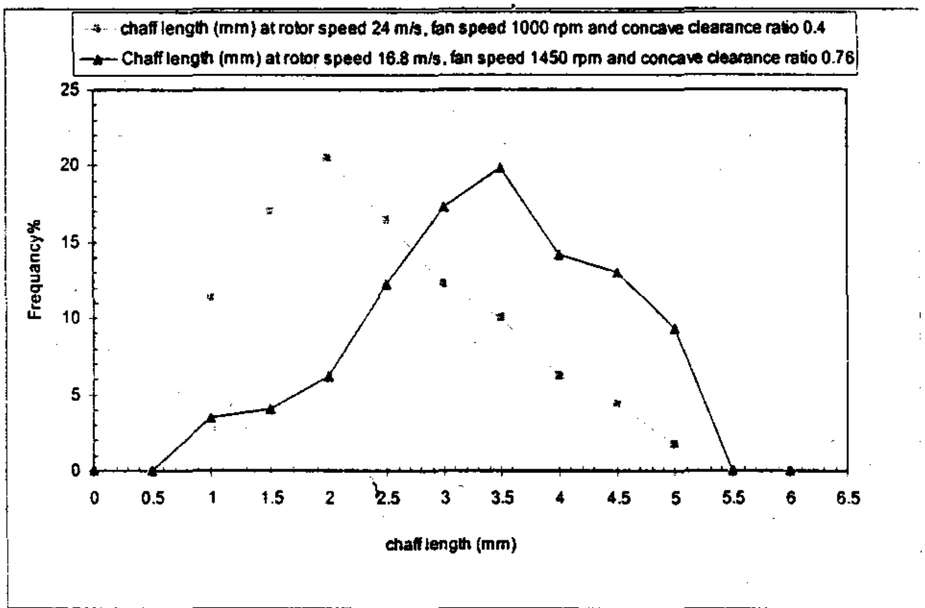

Fig. 6 Frequency of chaff lengths.

5. Effect of tested factors on energy consumption (kW.h/ton):

Data presented in Table (1) shows the effect of rotor speed and fan speed on the energy consumptions as affected by test factors. Increasing rotor speed from 16.8 to 24.0 m/s increased the energy consumed from 8.41 to 8.71 kW.h/ton at fan speed 1000 rpm and concave clearance ratio 0.4. This may due to increased throughput (ton/h). While increasing fan speed from 1000 to 1450 rpm increased the energy consumption from 8.41 to 8.91 kW.h

/ton at rotor speed 16.8 m/s. This may be due to the increased rotor speed and fan speed led to increased fuel consumption. Constant productivity 3.02 ton/h due to using one forward speed 2.8 km/h and constant of feed rate.

Table (1): Effect of tested factors on productivity, power consumption, (kW) and energy consumption (kW.h/fed.) for chaff at forward speed 2.8 km/h and concave clearance ratio 0.4.

Rotor speed (m/s)	Productivity (Ton/h)			Power consumed (kW)			Energy consumed (kW.h/ton)		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
16.8	3.02			25.4	26.2	26.9	8.41	8.68	8.91
20.4				25.8	26.4	27.3	8.54	8.74	9.04
24.0				26.3	26.8	27.9	8.71	8.87	9.24

CONCLUSION

1. The results showed a promising attempt to provide the combine harvester with some parts to brake wheat straw into chaff..
2. The optimum operating conditions of the developed combine were found to be as follows:

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تطوير وإختبار ملحقات لآلة الحصاد محورية السريان لتنعيم التبن

جمال حسن السيد ، أشرف السيد الشاذلى ، سميرعبد الحميد شلبى و رضا جمعه سالم
معهد بحوث الهندسة الزراعية ــ الجيزة

الآلات الجامعه تقوم بدراس محصول القمح حيث تكون درجة نعومة القش الناتج لاتفى باستخدامه مباشرة فى تغذية الماشية هذا بالإضافة إلى أن الكومباين يلقى القش موزعاً على الأرض مما يستلزم بذل الجهد والمال والتكلفة فى جمعه ثم يُعاد تغذيته إلى آلة دراس عادية لتنعيمه الأمر الذى يُضاعف تكلفة الحصول على التبن ويضاعف الفاقد منه. والورقة الحالية تتناول تصنيع أجزاء إضافيه تلحق بآلة الحصاد الجامعه لتنعيم التبن وسحبه فى انبوب حيث يسهل جمعه فى أجولة محققاً إتمام حصاد القمح فى عملية واحدة. وقد أخذ فى الإعتبار المتغيرات المهمة المؤثرة حيث جرى إختبارها والتوصل إلى الآتى:

١-استخدام سرعة درفيل ٢٤ م/ث .

٢-نسبةخلوص درفيل/صدر (خلفى/أمامى) ٠,٤ .

٣-سرعة مروحة شفط الهواء ١٤٥٠ لفة/دقيقة.

٤-سرعة تقدم الكومباين ٢,٨ كم/س (٠,٧٨ م/ث).

٥-زاوية ميل شوك الدراس ٢٠ درجة على المحور الطولى للدرفيل .

٦-قطر ثقوب شبكة صدر الدرفيل ١٤ مم وقطر ثقوب غرابيل التنظيف ٨ مم.

٧-استخدام رطوبة الحبوب فى القمح حوالى ١٦,٨٥% وفى القش حوالى ١٤,٣٥ % على أساس رطب.