J. Agric. Sci. Mansoura Univ., 34 (10): 10281 - 10292, 2009

EVALUATING A NEW COMBINE THRESHING ROTOR DESIGN

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ABSTRACT

The aim of this study is to introduce new combine threshing rotor design to improve threshing process and increasing the field capacity, in addition to maintain a non harmful low noise level effect on the environment.

The main results in this study can be abstracted as follow:

- Using the new designed drum decreases the losses by 48% and 65% in wheat and rice crop, respectively.
- The new design threshing drum increases the field capacity to 0.49 and 0.57ha/h for wheat and rice crops, respectively than using the old drum which makes the threshing unit jam at 3.2km/h machine forward speed. Also, the new designed drum increases the ejected straw lengths by 50% and 40% in wheat and rice crops, respectively than using the old drum.
- Using the new designed threshing drum increases the energy consumed and power required in wheat crop, meanwhile decreases the energy consumed and the power required in rice crop.
- Also using the new designed drum improves cleaning efficiency in both crops.
- Using the new designed threshing drum emits low noise levels which ensure no harmful effects on the environment.

INTRODUCTION

Technological development in agriculture is very essential to increase the productivity of the land. Among other technologies, it involves mechanization of agriculture through the use of improved machinery. Harvesting operation is one of the most labor consuming operations. Combine harvesters represent a possible solution for these problems. Since many types and makes of combine harvesters are being used in Egypt. Meanwhile, manufacturing of the Egyptian combine still in the stage of research work only, through this work we introduce one of the new design idea to accomplish the threshing process.

A Combine harvester has to perform three processes on a crop: (1) the crop is gathered into the machine; (2) the grain is threshed from the plant material; (3) the grain is separated from the material other than grain (MOG). This middle stage is accomplished by two devices, threshing drum, and concave with the effect of the threshing factors. Huynh *et al.* (1982) stated that the seed separation from the stalks and passage of seed through the concave gate was a function of some variables such as crop feed rate, cylinder speed, concave length and cylinder diameter and cylinder concave clearance. These variables are also related to the threshing losses and seed separation efficiency. Ichikawa and Sugiyama (1986) developed a new combine harvester equipped with screw type threshing and separating mechanisms. They found that the harvesting performance of the new combine showed the total grain loss rate was lower than 3% and the percentage of damaged grains was less than 1% for rice, soybean, and wheat and barley crops. El-Haddad (2000) stated that the threshing efficiency increased with increasing of drum speed and decreasing of feed rate. The maximum threshing efficiency was 99.761% at drum speed 21.25 m/s (1400 rpm), feed rate 15 kg/min. He added that the maximum amount of visible wheat crop. El-Behiry *et al.* (1997) found that the feeding rate increasing linearly by increasing drum speed. The straw sizes decreased by increasing the drum speed, while the grain losses increasing. Also, the straw sizes decreased at lowest moisture content under all threshing process. El-Banna (1979) indicated that the useful horsepower required to thresh wheat is mainly affected by cylinder speed and depends on feed rate and more power would be consumed with higher feed rates. The unthreshed grain losses decreased with increasing the cylinder speed and decreasing the feed rate. Anwar *et al.* (1991) concluded that the cleaning efficiency was in the range of 88.4 to 93.5 %. The cleaning efficiency increased with increasing cylinder speed and decreased with increasing feed rate.

Within the last few years, concern about the protection of the environment has grown rapidly has it become generally recognized that the steady rise in pollution of all kinds cannot be allowed to continue indefinitely. The acoustic environment has likewise suffered from the increase in the use and power of machines, to combat this, many countries and communities have recently introduced legislation making it a legal requirement to measure community noise levels, to reduce emitted noise and to maintain acceptable noise levels especially to prevent hearing loss. Robinson (1977). Stated that although a maximum peak noise level, which should never be exceeded in a place of work, is quoted in most standards, the important recent concept is that of the maximum allowed noise dose which takes into account both the time-varying noise level and its duration. The allowable dose varies slightly between countries but is usually 85 or 90 dB(A) and is referred to as the criterion (or 100%) noise dose. The advantage of expressing the noise dose in this manner is that 100% will always represent the criterion dose whatever the measurement duration and however it is accumulated. Moussa (2008) found that the total grain losses for combine 1 (Fortschritt E514), 2 (Class) , 3 (John Deer) and mower were 10.36, 7.19 , 3.14 and 3.98 % respectively at field speed 3.9 km/h and grain moisture content 12.1%. Besides, the highest sickle loss is 2.01 % at 12.1 % MC. The highest un-threshing losses were 1.13 and 1.22 % for thresher 1 (Gabr) and 2 (Shams) respectively at grain MC 16.58%. The highest grain damage were 2.24 and 2.02 % at grain MC 12.1% for thresher 1 and 2 respectively.

MATERIALS AND METHODS

Field experiments were carried out during the harvesting seasons of, 2005 at Gemmiza Station, Gharbia Governorate to evaluate the new rotor design on two crops (Rice (Sakha 101 variety) and Wheat (Gemmiza 9 variety)). Soil mechanical analysis was shown in table (1).

Plants physical properties:

The data based on the physical properties of the tested crops (Rice (Sakha 101 variety) and Wheat (Gemmiza 9 variety)) were tabulated in table (2).

Table 1: Soil mechanical analysis.

Sand, %			Silt, %	Clay, %	Soil type
Coarse	Fine	Total			
0.51	14.07	14.58	29.08	56.34	Clay

Table (2): Mean physical properties of the tested crops.

Item	Wheat crop	Rice crop
Variety	Gemmiza 9	Sakha 101
Plant length, cm.	120	77.6
Grain length, mm.	10.7	17.8
Grain mass, g.	1.8	2.12
Plant N^o. per m^2	480	399
Cutting height, cm.	14.5	11.2
Grain / straw ratio.	2 / 1	2.1 / 1
Grain moisture content, %.	14	16
Straw moisture content, (d.b., %).	17	40

Crop measurements:

The following crop measurements were determined. The flowering time, number of plants per square meter, plant height and grain yield were measured according to normal methods.

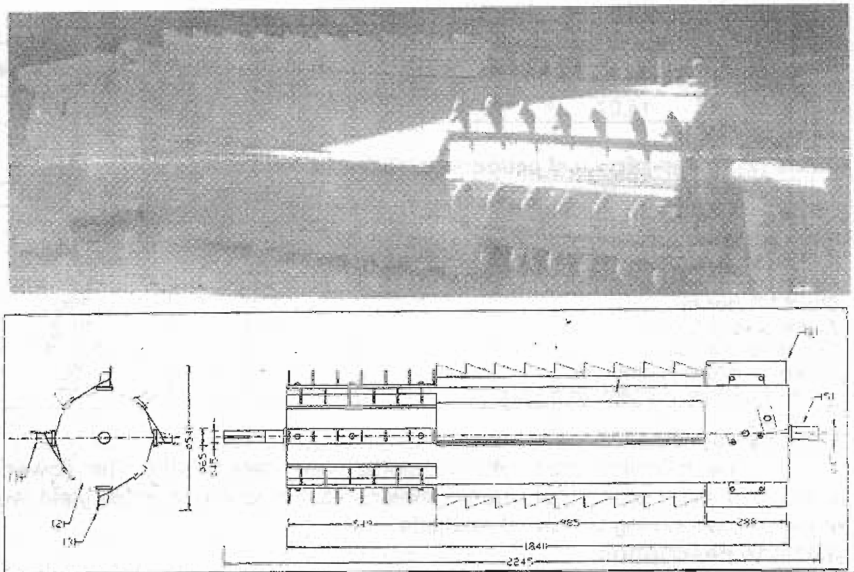
Machine description:

Self-propelled combine with 2.2 meter cutting width, with the fundamental design to deliver the cut materials to the side of the platform, and then up into the threshing unit (which located in the vertical position on the movement direction) using the delivery duct, then the threshing process accomplish to separate the grain from stalks and material other than grain (MOG), then grain and MOG pass through the concave opening area to the cleaning mechanisms which separate the grain from MOG and conduct the grain to the horizontal auger which deliver the grain to the conveyor duct to fall in the grain tank to the packing system to bags. Tall straw and big MOG fall beside the machine through the straw opening area in the other end of the threshing unit, meanwhile MOG which fall on the cleaning system plowed behind the machine. Un-threshed grains which fall over the cleaning box collected by the un-thresh box and conducted to the threshing mechanism by the horizontal auger and the side conveyor duct. The operator, seated high on the machine, has a clear, direct view of his work with all controls conveniently located so that he can change the operation of the combine to adapt to the changing field conditions.

Rotor description and specification:

The new design threshing drum (rotor) is consists of three parts one part for threshing, second for separation, and the third for ejecting the straw from straw thrower opening, as shown in Fig. (1).

The new in this design was in the middle part of the rotor, is four curved plates fixed under the toothed plates, to move the threshed materials in a centrifugal waves to develop the thresh process, and accelerate the grains which fall by gravity and finished the clogging of the threshed materials. 184cm, Rotor length, 54cm, diameter, and 190 kg weight. The rotor is consists of three parts, 56cm, for threshing, 99cm, for separation, and 29cm, for straw thrower.



5	Main Shaft	1	2	Tube	1
4	Thrower Part	4	1	Threshing Part	8
3	Separation Part	4	REF.	Name	OTY

Fig. (1): The new design rotor (threshing drum).

Experimental Procedure

The experimental area was planted in rectangular blocks of 50 m x 10 m, and the harvesting done conventionally by the combine for the field tests.

Field capacity and field efficiency

Machine field capacity and efficiency were calculated according to Kepner *et al.*, (1982).

$$C = ((SW)/10)(E_f/100)$$

Where:

C = effective field capacity, ha/h.
S = travel speed, km/h.
W = rated width of the implement, m.
Ef = Field efficiency, %.
$E_f = 100\ T_o / (T_e+T_h+T_a)$
T_o = Theoretical time per hectare.
T_e = Effective operating time = To x 100 / K.
K = Percentage of implement width actually utilized.
T_h = Time lost per hectare due to interruption that are not proportional to area. At least part of T_h usually tends to be proportional to T_e.
T_a = Time lost per hectare due to interruptions that tend to be proportional to area.

Energy consumed

The required mechanical energy, (EM) was calculated according to Taieb, (1990) as follows:

EM "MJ/fed" = (3.61 x fuel consumption) / (actual field capacity).

Capacity of machine (grain output)

Time of threshing process was measured by stop watch to determine the machine capacity, ton/h.

Cleaning efficiency:

It was calculated according to the following equation:

$$\text{cleaning efficiency } \% = (W_{cl}/W_t) * 100,$$

Where:

W_{cl} is mass of cleaned grains and W_t is a sample mass.

Grain damage:

The damaged seeds were procured manually and weighed. The percentage of seed-damage was calculated, related to the grain output (grain damaged due to threshing process + grain damaged due to grain handling process). Grain damaged due to threshing process were calculated by putting box between cleaning box and the threshing housing for the test period and procured the damaged grains, Meanwhile, the other grain damaged due to grain handling process calculated by the following equation:

$$GDhp, \% = GDt - GDth$$

Where:

GDhp = Grain damaged due to grain handling process, %

GDt = grain damaged in the tank, %

GDth = grain damaged due to threshing process, %

Losses*:* The grain loss was calculated as follow:

$$L_t = L_p + L_s + L_{st} + L_c + L_{am}$$

$$L_{tm} = L_t - L_p.$$

Where:

L_t = Total losses, %

L_{mt} = Machine total losses, %

L_p = Pre-harvest losses, %

L_s = shattering losses, %

L_{st} = straw thrower opening losses (lose grains + un-threshed grains) , %

L_c = cleaning losses, %

L_{am} = After machine losses (crop not cutting), %

Noise measuring procedure:

Measurements of noise level were done using a calibrated integrated sound level meter B&K 2230. Equivalent continuous sound level (L_{eq} -A), were measured. It was A-weighted energy mean of the noise level averaged over the measurement period. The measuring system was setup in situ. Four measuring locations centered outside and around the combine were selected and inside cabinet as well. Each location was one meter far from the combine, the first measuring location was in front of the combine, the second was to the right, the third was behind the combine, the fourth was to the left and the latter was inside the driver cabinet. The measurements were done in three stages, firstly, in static condition, then secondly, when the combine working in idling condition, thirdly, in dynamic condition (the combine was operating with all of its functions, even harvesting).

RESULTS AND DISCUSION

Threshing performance:

Wheat grain losses; Fig. (2) shows the relationship between threshing drum speed and grain losses for the new and old designed respectively of threshing drum. It is indicated that the threshing drum speed affected on the grain losses. By increasing the threshing drum speed from 24.75 to 26.8 m/s the grain damaged, straw thrower and cleaning system losses increased, from 0.5, 1.0 and 1.73% to 0.87, 1.42 and 2%, respectively. Meanwhile, the un-threshed grain losses decreased from 1.3 to 0.86%. There was no effect of increasing the threshing drum speed on the shattering and cutting losses. The grain losses decreased by about 48% than that in common machine.

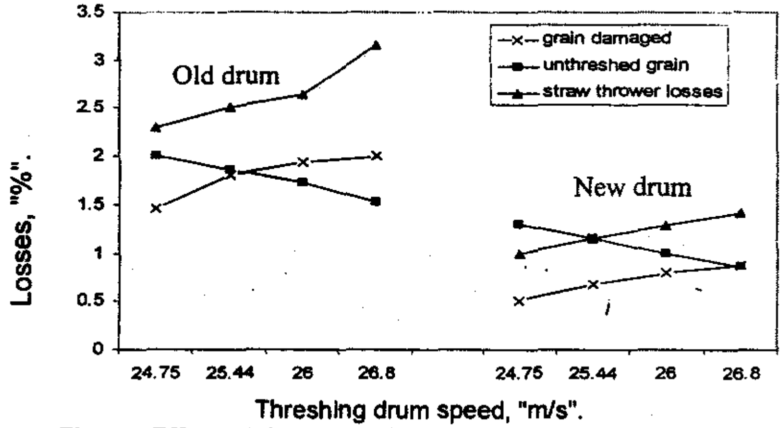


Fig.(2): Effect of threshing drums speed on the grain losses.

Rice grain losses; Fig. (3) Shows the relationship between threshing drum speed and grain losses for the new designed and old threshing drum. It's indicated that the threshing drum speed affected on the grain losses. By increasing the threshing drum speed from 19.8 to 24 m/s the grain damaged, and straw thrower loss increased, from 0.1 and 1.9% to 0.9 and 2.7% for the old drum, and from 0.05 and 0.9% to 0.45 and 1.75% for the new designed drum, respectively. Meanwhile, the un-threshed grain losses decreased from 1.3 to 0.75% for the old drum and from 1 to 0.6% for the new designed drum. The results improved using the new designed drum, that is may be due to the fourfold centrifugal action.

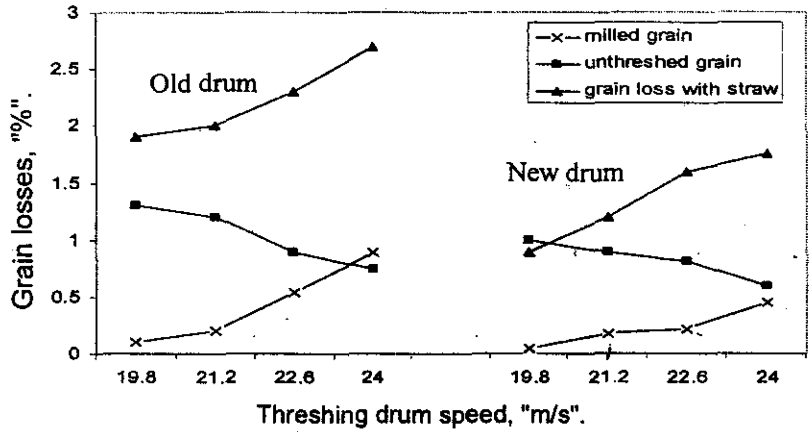


Fig. (3): the effect of threshing drums speed on the grain losses.

Field capacity and field efficiency:

Wheat field capacity; Fig. (4) Shows the relationship between forward speed and the field capacity, and field efficiency. By increasing the forward speed from 1.4 to 3.2 km/h, the field capacity increased by about 2 times, meanwhile the field efficiency decreased by about 1.1 times. Using the new design threshing drum increased the field capacity to 0.49 ha/h, than that using the old drum, which make the machine jam at 3.2km/h machine forward speed, this may be due to increasing the feed rate by increasing the forward speed and the threshed materials rabid to the drum. Meanwhile, the new design threshing drum loosens the material due to the effect of the fourfold centrifugal action. Also the new designed drum improves the ejected straw lengths by 50 % taller than using the old drum.

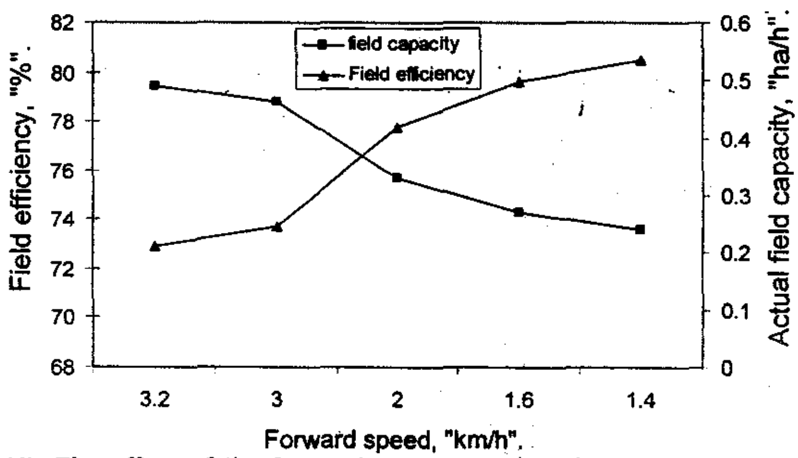


Fig.(4): The effect of the forward speed on the field efficiency and the actual field capacity for the combine using the new designed threshing drum.

Rice field capacity; Fig. (5) Shows the effect of forward speed on the field capacity and field efficiency. By increasing the forward speed from 1.6 to 3.6 km/h, the field capacity increased by about 2.28 times, meanwhile the field efficiency decreased by about 1.2 times. Using the new design threshing drum increased the field capacity to 0.57 ha/h, than that using the old drum which made the machine jam at 3.2km/h machine forward speed, that's due to increasing the feed rate by increase the forward speed and the threshed materials rabid to the drum. Meanwhile, the new design threshing drum loosen the material due to the effect of the fourfold centrifugal action. Also the new designed drum improves the ejected straw lengths by 40 % taller than using the old drum.

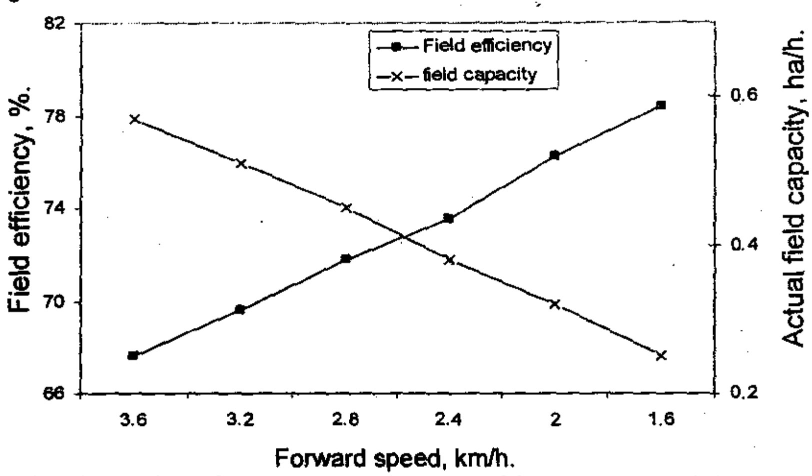


Fig.(5): Effect of the forward speed on the field efficiency and the actual field capacity using the new designed threshing drum.

Cleaning efficiency:

Wheat cleaning efficiency; Fig.(6) Shows the relationship between threshing drum speed and cleaning efficiency, it's shown that by increasing the drum speed the cleaning efficiency decreased. Also using the new designed drum improved cleaning efficiency, that is may be due to the straw cutting length using the old drum and affect on the cleaning than using the new designed drum.

Rice cleaning efficiency; Fig. (7) Shows the relationship between threshing drum speed and cleaning efficiency, it's shown that by increasing the drum speed from 19.8 to 24 "m/s", the cleaning efficiency decreased from 98 to 97%, and from 99.4 to 98.2% for the old and new designed threshing drum, respectively. Using the new designed drum improved cleaning efficiency, that is may be due to more cutting for the straw using the old drum and make the cleaning process difficulty than using the new designed drum which improved the threshing process. Also using the new designed drum improved cleaning efficiency, that is may be due to the straw cutting length using the old drum and affect on the cleaning than using the new designed drum.

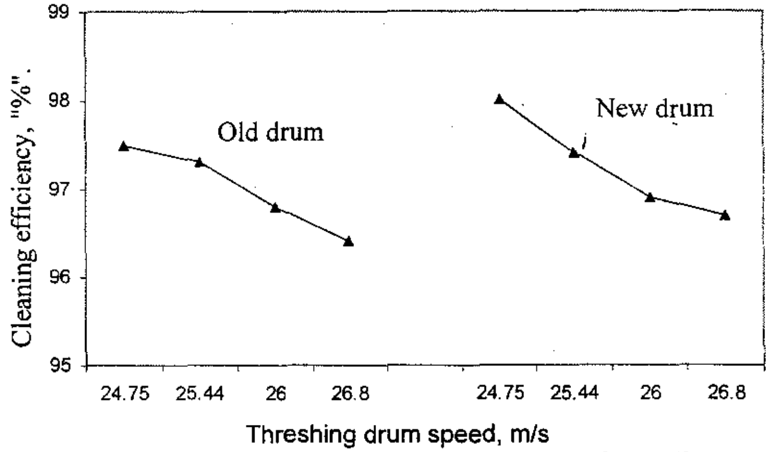


Fig.(6): The effect of the threshing drums speed on the cleaning efficiency.

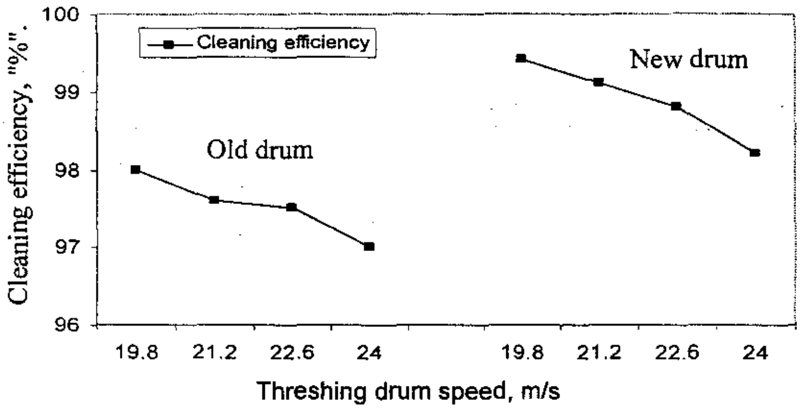


Fig.(7): The effect of the threshing drums speed on the cleaning efficiency.

Energy consumed:

Wheat energy consumed; Fig. (8) Indicates the effect of threshing drum speed on the energy consumed and power required for threshing process using the new designed and old threshing drum. It is indicated that by increasing the drum speed the power required and the energy consumed increased. Energy consumed and power required increased by using the new designed threshing drum, that is may be due to the weight of the new designed drum which heavier than the old.

Rice energy consumed; Fig. (9) Shows the effect of threshing drum speed on the energy consumed and power required for threshing process using the new designed and old threshing drum. It is indicated that by increasing the drum speed from 19.8 to 24 m/s the power required and the energy consumed increased from 5.8 to 6.9 kW, and from 13.2 to 15.74mJ/he, respectively. Using the new designed threshing drum decreased the energy consumed by percentage of 7% at range from 3.4 to 9.86%, meanwhile the power required, increased by percentage of 6.16% at range from 3 to 9.6% than using the old drum, that is may be due to the weight of the new designed drum which heavier than old, and actual field capacity increased using the new designed drum.

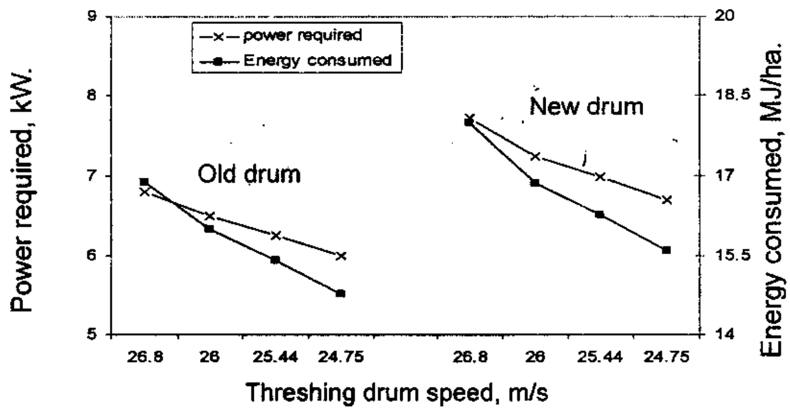


Fig.(8): The effect of the threshing drum speed on the energy consumed and power required.

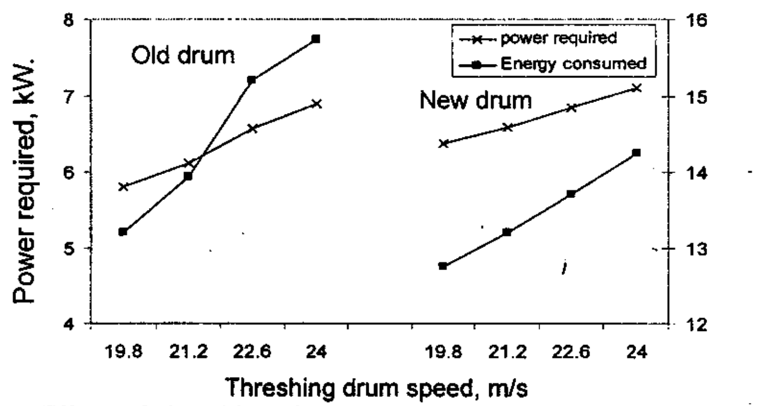


Fig.(9): Effect of threshing drum speed on the energy consumed and power required.

Noise level measurements results:

First, in static condition (the combine was stopped completely in situ), the average of five readings were recorded for each location around the combine, L_{eq} was 50 dB (A), which was regarded as background noise level of the combine and the field. Second, in idling condition(the combine engine was operating only without any other functions in situ), the average of five

readings were recorded for each location around the combine, L_{eq} was 80 dB (A) approximately, but it was higher slightly near the engine(about +1dB(A)). Third, in dynamic condition(the combine was operating with its full functions in situ, including harvesting), the average of five readings were recorded for each location around the combine, L_{eq} was 88 dB (A) approximately, but it was higher slightly near the engine
(about 1.5dB(A)). It is clear that the noise level is above background level by 60%, 76% respectively.

Inside the cabinet, the average of five reading in each case were 50 dB(A), 85.5 dB(A), 89,5 dB(A) respectively. It is clear that the noise level is above background level by 71%, 79% respectively.

CONCLUSION

1- Manufacturing of the Egyptian combine is still in the stage of research work only. The aim of this work is to introduce one of the new design threshing rotors to accomplish the threshing process and to increase the field capacity, and to keep the noise level at acceptable level.
2- For wheat threshing at increase the threshing drum speed by about 1.1 times the grain damaged, straw thrower and cleaning system losses increased by about 1.74, 1.42 and 1.16 times, respectively, Meanwhile, the un-threshed grain losses decreased by about 0.66 times. Increasing the forward speed by about 2.29 times, increased the field capacity by about 2.1 times, meanwhile the field efficiency decreased by about 0.9 times. Using the new design threshing drum increased the field capacity to 0.49 ha/h.
3- For rice threshing at increase the threshing drum speed by about 1.2 times the damaged grain, and straw thrower loss increased by about 9 and 1.42 times for the old drum, and 9 and 1.94 times for the new designed drum, respectively. Meanwhile, the un-threshed grain losses decreased by about 0.58 times for the old drum and 0.6 times for the new designed drum. Field capacity increased by about 2.28 times by increasing the forward speed by about 2.25 times, meanwhile the field efficiency decreased by about 0.86 times. Using the new design threshing drum increased the field capacity to 0.57 ha/h. Also, the new designed drum increased the ejected straw lengths by 40 % taller than using the old drum.
4- Generally; using the new designed of threshing drum increased the energy consumed and power required, for wheat and rice respectively. Meanwhile, for rice crop using the new designed of threshing drum decreased the energy consumed by percentage of 7% at range from 3.4 to 9.86% than using the old drum.
5- Noise level attenuation: Using the new designed threshing drum emits low noise levels which ensure no harmful effects on the environment. It is recommended to make some modifications to the cabinet design to be more comfortable to the driver hearing mechanism, and adhere some relevant noise absorbent materials inside the cabinet and under all the protection covers.

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تقييم تصميم جديد لدرفيل دراس آلة الحصاد الجامعة (كومباين)

جمال حسن السيد* ، الأمين محمد عارف* و أحمد الفاتح فرج**

*** معهد بحوث الهندسة الزراعية**

**** المركز القومى للبحوث**

لا تزال عملية تصنيع آلة حصاد جامعة قاصرة على المجال البحثى فقط فى مصر حتى الأن. تمت هذه الدراسة وكانت الإختبارات النهائية لهذا الدوار بموسم الحصاد ٢٠٠٥ بمحطة بحوث الجميزة – محافظة الغربية على محصولى القمح (صنف جميزة ٩) والأرز (صنف سخا ١٠١) بهدف تقييم أداء دوار الدراس/فصل.

وتتلخص أهم النتائج فيما يلى:

- إنخفضت نسبة الفواقد بنسبة ٤٨% و ٦٥% لكلا من محصولى القمح والأرز على الترتيب عند إستخدام التصميم الحديث.
- كما أمكن الحصول على سعة حقلية ٠,٤٩ و ٠,٥٧ هكتار/ساعة ، مع زيادة أطوال القش الخارج بنسبة ٥٠% و ٤٠% لمحصولى القمح والأرز على التوالى لإمكانية العمل على سرعة تقدمية أكبر للآلة ومنع حدوث زوران للمحصول على درفيل الدارس بإستخدام التصميم الحديث.
- إرتفع الإحتياج للطاقة والقدرة بإستخدام درفيل الدراس الجديد.
- حسن إستخدام الدوار الجديد نظافة المحصولين لزيادة أطوال القش وتقليل الحمل على جهاز النظافة.
- قلل التصميم الحديث التلوث السمعى بخفض الصوت الناتج عن عملية الدراس مما جعل قيادة الآلة أكثر راحة.

قام بتحكيم البحث

أ. د/ زكريا ابراهيم اسماعيل	**كلية الزراعة – جامعة المنصورة**
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