Studying a New Combine Threshing Rotor Design

Elsaied, G.H., A. Elfatih and E.M. Arif

National Res. Center.

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 0.57he/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 wheat and rice crops.
- Using the new designed threshing drum emits low noise levels which ensure no harmful effects on the environment.

Key words:

INTRODUCTION

Technological development in agriculture is very essential in increasing 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 r.p.m.), feed rate 15 kg/min. He added that the maximum amount of visible wheat crop. El-Behiry et al. (2000) 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, D. W. (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.

MATERIALS AND METHODS

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

<table>
<thead>
<tr>
<th>Table 1: Soil mechanical analysis and soil type.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse %</td>
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<tr>
<td>0.51</td>
</tr>
</tbody>
</table>

Plants Physical Properties:

This section aimed to provide some data based on the physical properties of the two tested crops (Rice (Sakha 101 variety) and Wheat (Gemmiza 9 variety)) these data were tabulated in table (2).

<table>
<thead>
<tr>
<th>Table 2: Mean physical properties of the tested crops.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>Variety</td>
</tr>
<tr>
<td>Plant length, cm.</td>
</tr>
<tr>
<td>Kernel length, cm.</td>
</tr>
<tr>
<td>Kernel weight, g.</td>
</tr>
<tr>
<td>Plant No. per m²</td>
</tr>
<tr>
<td>Cutting height, cm.</td>
</tr>
<tr>
<td>Grain straw ratio, %</td>
</tr>
<tr>
<td>Grain moisture content, %</td>
</tr>
<tr>
<td>Straw moisture content, %</td>
</tr>
</tbody>
</table>

Experimental Procedure:

a- The experimental area was planted in rectangular blocks of 50 x 10 m², and the harvesting done conventionally by the combine for the field tests.

Measurements:

Field Capacity and Field Efficiency:

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

\[
C = \frac{(SW) \times 10}{100 \times (E_\text{f})}
\]

Where:

- \( C \) = effective field capacity, hectare/hour.
- \( S \) = travel speed, km/h.
- \( W \) = rated width of the implement, m.
- \( E_\text{f} \) = Field efficiency, %.

\[
E_\text{f} = \frac{100 \times T_\text{s}}{T_\text{s} + T_\text{h} + T_\text{a}}
\]

Where:

- \( T_\text{s} \) = Theoretical time per hectare.
- \( T_\text{a} \) = Effective operating time = \( T_\text{s} \times 100 / K \).
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_{a}.

T_{a} = Time lost per hectare due to interruptions that tend to be proportional to area.

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

\[ EM = \frac{3.61 \times \text{fuel consumption}}{\text{actual field capacity}}. \]

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 cut 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 eject the straw from straw thrower opening, as shown in Fig. (1).

The new design is located in the middle part of the rotor in four plates located under the toothed plates, it is designed in a inclined plats shape to make like eject plates to enforce the threshed materials to move in a centrifugal movement, those plates do as a centrifugal four waves to develop the thresh process to be fast and easy in separate the grain from straw and finished the clogging of the straw from the grain. 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.

Capacity of Machine (Grain Output):
Time of threshing process was measured by stop watch to determine the machine capacity.

Cleaning Efficiency:
It was calculated according to the following equation:

\[ \text{cleaning efficiency} \% = \left( \frac{W_c}{W_i} \right) \times 100, \]

Where \( W_c \) is weight of cleaned grains and \( W_i \) is a sample weight.

Grain Damage:
The damaged seeds were procured manually and weighed. The percentage of seed-damage was calculated, related to the grain output (grain damaged losses due to threshing process + grain damaged losses due to grain handling process). Grain damaged losses 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 losses due to grain handling process calculated by the following equation:

Grain damaged losses due to grain handling process, \% = grain damaged losses percentage in the tank - grain damaged losses percentage due to threshing process.
The grain loss was calculated as follow:

Total losses = Pre-harvest losses + shattering losses + straw thrower opening losses (lose grains + un-threshed grains) + cleaning losses + (after machine losses – pre-harvest losses - shattering losses).

Machine total losses = total losses – pre-harvest losses.

**Noise Measuring Procedure:**

Measurements of noise level were done using a calibrated integrated sound level meter B&K 2230. Equivalent continuous sound level (L\text{A})\text{eq}, 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 (due Standard recommendations) 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 DISCUSSION**

**Threshing Wheat Performance:**

**Grain Losses:**

Fig. (2) Shows the relationship between threshing drum speed and losses for the new designed and old 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. Comparing the new designed threshing drum with the old drum, it can be seen that the new drum decreasing the losses by percentage of 48%.

Fig. 2: The effect of threshing drums speed, "m/s" on the grain losses, and "%" for the new designed and old threshing drum.

Field Capacity and Field Efficiency:
Fig. (3) Shows the relationship between forward speed, "km/h" and the field capacity, "he/h" and field efficiency, "%" by increasing the forward speed from 1.4 to 3.2 km/h, the field capacity increased from 0.24 to 0.49he/h, meanwhile the field efficiency decreased from 80.5 to 72.9 %, respectively. Using the new design threshing drum increase the field capacity to 0.49 he/h, than using the old drum which make 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 increased the ejected straw lengths by 50 % than using the old drum.

Fig. 3: The effect of the forward speed, "km/h" on the field efficiency, "%" and the actual field capacity, "he/h" for the combine using the new designed threshing drum.

Energy Consumed:
Fig. (4) Indicates the effect of threshing drum speed, "m/s" 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. Using the new designed threshing drum increased the energy consumed and power required, that is may be due to the weight of the new designed drum which heavier than the old drum and need more power, also, the actual field capacity increased using the new designed drum.

Cleaning Efficiency:
Fig.(5) Shows the relationship between threshing drum speed, "m/s" 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 cutting the straw using the old drum and made the cleaning done difficulty than using the new designed drum which improved the threshing process.
Fig. 4: The effect of the threshing drum speed, "m/s" on the energy consumed, "MJ/he" and power required, "kW" using the new designed and old threshing drum.

Fig. 5: The effect of the threshing drums speed, "m/s" on the cleaning efficiency, "%" using the new designed and old threshing drum.

Threshing Rice Performance:
Grain Losses:
Fig. (6) Shows the relationship between threshing drum speed and 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 milled grain, 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 good results obtained using the new designed drum, that is may be due to the fourfold centrifugal action.

Fig. 6: The effect of threshing drums speed, "m/s" on the grain losses, "%" for the new designed and old threshing drum.
Field Capacity and Field Efficiency:
Fig. (7) Shows the effect of forward speed, "km/h" on the field capacity, "he/h" and field efficiency, "%". By increasing the forward speed from 1.6 to 3.6 km/h, the field capacity increased from 0.25 to 0.57 he/h, meanwhile the field efficiency decreased from 78.4 to 67.6 %, respectively. Using the new design threshing drum increased the field capacity to 0.57 he/h, than using the old drum which made the machine jam at 3.2 km/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 result the straw ejected as a ball, and increased the ejected straw lengths by 40 % than using the old drum.

Energy Consumed:
Fig. (8) Shows the effect of threshing drum speed, "m/s" 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 15.74 MJ/he, respectively. Using the new designed threshing drum decreased the energy consumed by percentage of 7% at range from 3.4 to 9.86% than using the old drum, meanwhile and 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 the old drum and need more power, and actual field capacity increased using the new designed drum.

Cleaning Efficiency:
Fig. (9) Shows the relationship between threshing drum speed, "m/s" 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 difficult than using the new designed drum which improved the threshing process.

![Fig. 9: The effect of the threshing drums speed, "m/s" on the cleaning efficiency, "%" using the new designed and old threshing drum.](image)

**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.

**Summary and Conclusion:**
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 increasing the field capacity, and keep the noise level at acceptable level.

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

**Threshing Wheat Performance:**
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%.

Increasing the forward speed from 1.4 to 3.2 km/h, increased the field capacity from 0.24 to 0.49he/h, meanwhile the field efficiency decreased from 80.5 to 72.9 %, respectively. Using the new design threshing drum increase the field capacity to 0.49 he/h, than using the old drum which make the machine jam at 3.2km/h machine forward speed.

Power required and the energy consumed increased by increasing the drum speed, meanwhile cleaning efficiency decreased. Using the new designed threshing drum increased the energy consumed and power required, also, the actual field capacity increased using the new designed drum and cleaning efficiency improved.

**Threshing Rice Performance:**
By increasing the threshing drum speed from 19.8 to 24 m/s the milled grain, and straw thrower loss increased, from 0.1 and 1.99% 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.
Field capacity increased from 0.25 to 0.57 he/h by increasing the forward speed from 1.6 to 3.6 km/h, the, meanwhile the field efficiency decreased from 78.4 to 67.6 %, respectively. Using the new design threshing drum increase the field capacity to 0.57 he/h, than using the old drum which make the machine jam at 3.2 km/h machine forward speed. Also the new designed drum result the straw ejected as a ball, and increased the ejected straw lengths by 40 % than using the old drum.

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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.

**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 adhering some relevant noise absorbent materials inside the cabinet and under all the protection covers.

**REFERENCES**


