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## Enhancing The Performance of Rice-Grain Milling Machine By Attaching A Developed Primary Cleaning-Unit

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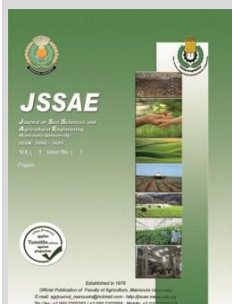


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### ABSTRACT

The present study aims to enhance the performance of the rice grain-milling machines by using an attached primary cleaning-unit. The performance of the developed rice grain-milling machine was studied in terms of four different sieve shapes "CSS" of the attached primary cleaning unit ("A", "B", "C" and "D") with four different feeding rates (1.00, 1.25, 1.50 and 1.75 Mg/h) and four different primary cleaning sieve "PCS" speeds (310, 360, 420 and 470 rpm). The machine performance was depended on measuring machine productivity, machine efficiency, cleaning efficiency, total grain losses, required power, energy requirements and both operational and criterion costs. Results indicated that the best performance was yielded with the use of primary cleaning unit sieve shape "D" side by side with adjusting the feeding rate at 1.25 Mg/h and "PCS" speed at 360 rpm. Under these conditions values of machine productivity, machine and cleaning efficiencies were 1.20 Mg/h, 94.80 % and 96.90 % respectively. Meanwhile, the required power and energy requirements were 17.0 kW and 20.53kWh/Mg respectively. Finally, minimum operational and criterion costs were 43.18 and 94.52 LE/Mg, respectively.

**Keywords:** Primary cleaning-unit; Rice-grain milling machine; Cleaning sieves; Machine productivity; Machine efficiency; Energy requirements.



### INTRODUCTION

Improving the performance of rice grain-milling machines in Egypt is underlined by many studies in recent years. In order to perform high performance during using rice-grain milling machines, many of stuffs should be removed from the rice grains such as straw bits, unpacked grains, and other foreign matter. Improper cleaning usually leads to loss of grain and bottom rice recovery in mills. Cleaning helps to reduce loading during the subsequent post-harvest process. Cleaning removes straw, soil particles and litter from the grains that improves grain storage capacity, reduces grounding during milling, gives good quality milled rice and improves milling yield. It also reduces the spread of insects, pests and diseases.

Cleaning can be done manually with wind power or mechanically with cleaning machines. Manual cleaning was conducted by many researchers such as Ashwin *et al.*, (2017) used traditional cleaning by basket winnowing and wooden perforated boxes. When a batch enters a cleaning plant, the contaminants are removed by using special equipment that takes advantage of natural gardening derivatives and ingredients in the mixture.

A cleaning machine was designed by Ahmed *et al.* (1993) to change the parameters affecting the separation effectiveness such as the sieve oscillation, amplitude, sieve angle and feed rate. They found that the separation effectiveness was 97% at sieve oscillations of 500 cycle/min, sieve angle of 2°, and feeding rate of 30 kg/h.cm at grain/straw ratio of 1:3. Amin (2003) found that the cleaning and separating efficiency increased by increasing sieving time, oscillating and rotary speed. Awady *et al.*

(2003) developed an eccentric and support linkages of screen assembly cause it to oscillate, moving the grain over the flat screen. During the operation, the upper screen separates the impurities that are bigger than the grain, and the lower screen separates those that are smaller and dust. El-Sahrigi *et al.* (2004) tested the performance of a cleaning unit under different parameters such that frequency of the sieve unit, feeding rate, air velocity and slope of the sieve unit. The maximum seed cleanliness and separation effectiveness were 99.01 and 89.75 %, respectively under frequency of 10.50 HZ, feeding rate of 300 kg/h, slope of 13 °, and air velocity of 3.2 m/s.

The theoretical analyses by Fouda (2009) revealed that the optimum sieve speed of 0.5 m/s (200 rpm) is recommended to prevent riding of material on the sieve surface. The experimental results reveal that the cleaner performance was in the optimum region under sieve angle of 15° and paddy moisture content of 14 %. Morad *et al.* (2013) found, during milling three rice grain varieties, that the highest values of rice-milling machine productivity and overall machine efficiency were 1.08, 1.17 and 1.35 Mg/h; and 95.00, 95.38 and 95.66 % for Sakha-101, Giza-171 and Sakha-105 varieties, respectively, while the lowest values of required power and specific energy were 13.0, 13.4 and 13.8 kW; and 17.40, 15.68 and 13.85 kWh/Mg, respectively, for the same rice varieties, furthermore the lowest values of both operational and criterion costs were 8.53, 7.87 and 6.82 L.E/Mg; and 35.96, 31.96 and 29.38 L.E/Mg, respectively, for the same rice varieties. A forced air from a rotary fan and reciprocating sieve driven by an eccentric shaft by Okunola *et al.* (2015) for separating impurity from grain- mixture.

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Two sieves of 8 mm diameter and 3 x 2 mm oblong apertures were used for the upper and lower sieves, respectively. Tested sieve tilt-angles were varied between 3 and 8°, while the hanger angle and fan speed were maintained at 5° and 240 rpm, respectively. They found that the machine optimum performance was 98 % product purity at a total separation efficiency of 71% for paddy rice at 3° tilt angle. Ashwin *et al.* (2017) developed an efficient low cost paddy cleaner in view of improving the quality paddy cleaning using conventional methods. To check the performance of the paddy cleaner, a total volume of 1.15 kg of un-cleaned stuffs of paddy consisting of 1kg of paddy, 0.05 kg of dust and 0.1 kg of sand was fed into the hopper. After the cleaning process, the output was 1.022 kg of cleaned paddy with 0.994 kg of paddy, 0.021kg of dust and 0.006 kg of sand. Okunola *et al.* (2018) established rice cleaner for cottage industry processors. Physical and aerodynamics properties of five varieties of rice were used to design the developed machine. The machine utilizes three reciprocating sieves with a blower revolving of 240 rpm to produce air velocity of 4.6 ms<sup>-1</sup> for separating the contaminants. For an effective grading, apertures diameter of 3, 5.5 and 7 mm were selected for the bottom, intermediate and top sieves of the machine. Parboiled milled rice produced from single-pass steel huller was fed into the machine and tested at tilt angles of 2, 3, 4, 5 and 6° for the intermediate sieve at blower inclinations of 0 and 5°. They found that as the tilt angle increases, the grading efficiency increases

Based on the above literature review, most of the locally rice-grain milling machines that used in Egypt are not having a cleaning unit. Therefore, the main objective of the present investigation was to improve the performance of the rice-grain milling machine by adding a primary cleaning-unit.

**To achieve the ultimate goal, the following criteria were taken into consideration:**

- Develop a primary cleaning-unit to be attached with the rice-grain milling machine.
- Optimize some different operating parameters affecting the performance of both the attached primary-cleaning unit and the rice-grain milling machine as a whole.
- Evaluate the rice-grain milling machine after development economically.

## MATERIALS AND METHODS

The rice-grain milling machine was provided with a primary cleaning-unit at a local workshop and tested through performance experiments at a private farm at Zagzig city, Sharkia Governorate in Eastern Delta, Egypt with Sakha 101 rice variety at paddy moisture content of 14 % (d.b).

### Materials

#### The rice-grain milling machine

The rice-grain milling machine consists of mill frame, ground wheels, draw-bar, milling unit (hopper, milling drum and concave) and mill sieves unit.

- **The mill frame:** The mill frame is made of I-section iron with length and width of 1500 and 2850 mm, respectively.
- **The ground wheels:** The machine frame is mounted on two ground wheels which are made of rubber with

diameter of 640 mm and width of 180 mm with wheel spacing of 2000 mm;

- **The draw-bar:** The draw-bar is made of iron plate with length of 1120 mm, width of 100 mm and thickness of 100 mm. The edge of pull bar has a hole with diameter of 50 mm;
- **The milling unit:** The milling unit is consisted of a hopper, milling drum and concave. The hopper is made of sheet steel with 2 mm thickness. The hopper top has a square shape with dimensions of 460 mm×460 mm and height of 430 mm. The hopper bottom has 150 mm height with sidewall slope of 45 °. The milling drum speed is adjusted at 800 rpm (Morad *et al.*, 2013).
- **The mill sieves unit:** The mill sieves unit consists of upper and lower sieves. The upper sieve separates the damage milled grains. The lower sieve separates the damaged grains exit from the machine, which are collected in a container. The upper and lower sieves are made of perforated iron-sheet with thickness of 1 mm, length of 1500 mm, width of 500, and height of 150 mm. The upper sieve has a hole diameter of 1.5 mm. The mill sieves-unit is inclined with an angle of 6° and its reciprocating speed is adjusted at 270 rpm.

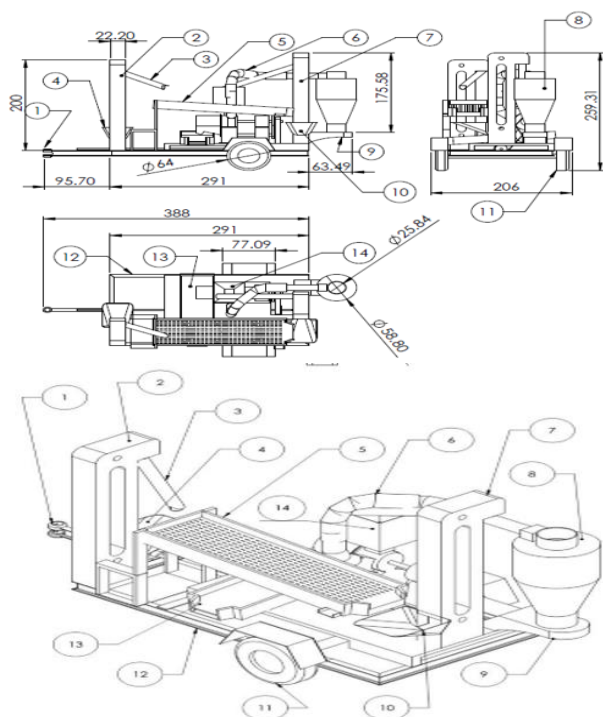
#### The rice-grain milling machine after adding the primary cleaning-unit

The rice-grain milling machine was provided with a primary cleaning-unit to the main machine. The function of the primary cleaning unit is to remove unwanted material from the rice grains so as to enhance quality of the final milled rice.

The components of the rice-grain milling machine with the attached primary cleaning-unit are illustrated in views and isometric as shown in Fig. 1.

#### The attached primary cleaning-unit consists of the following parts:

- **The first paddy rice-grain hopper:** The first paddy rice-grain hopper is made of sheet steel with 2 mm thickness. The hopper top has a square shape with dimensions of 500 × 500 mm. The hopper bottom has a triangular shape with dimensions of 240 × 550 × 460 mm length, width, and height, respectively. The slope of the hopper sidewall is 45° (more than the friction angle between rice grain and hopper wall).
- **The first conveying belt with buckets:** The first conveying belt with buckets is a vertical belt, conveys the rice grain after hopper to the cleaning sieves-unit. It is made of rubber with width of 200 mm, thickness of 10 mm, and length of 3600 mm. Twelve buckets with 150 mm spacing are fixed with the belt by rivets.
- **The primary cleaning sieves-unit:** The primary cleaning sieves-unit “PCS” consists of upper and lower sieves. The upper sieve separates the impurities such as plant stems and husks. While the lower sieve separates the rice grain on the top and the grass seeds and small soil particles pass through its holes. The grass seeds and small soil clods drop on a solid sieve and then exit from the machine. Reciprocating-speed of the primary cleaning sieves-unit is adjusted in such a way to can be changed during the experiments. The upper and lower sieves are made of perforated iron-sheet with thickness of 1 mm, length of 1950 mm, width of 600 mm and height of 230 mm. The primary cleaning sieves-unit is inclined with an angle of 8°.



No.	Part name	No.	Part name	No.	Part name
1	Draw-bar	6	Conveying tube	11	Ground wheel
2	First conveying belt with buckets	7	Second conveying belt with buckets	12	Machine frame
3	Outlet of grain	8	Bran turning hopper	13	Mill sieves-unit
4	First paddy rice-grain hopper	9	Bran outlet	14	Milling unit hopper
5	Primary cleaning sieves-unit	10	Second paddy rice-grain hopper		

Fig. 1. The three views and the isometric of the developed rice-grain milling machine

- **The second paddy rice-grain hopper:** The second paddy rice-grain hopper is made of sheet steel with 2 mm thickness. The hopper top has a square shape with dimensions of 400 × 300 mm and the hopper bottom has a triangular shape with dimensions of 50 × 310 × 290 mm for length, width and height, respectively. The slope of the second hopper sidewall is equal to the first hopper. The paddy rice-grains drop from the sieves-unit to the second hopper.

- **The second conveying belt with buckets:** The second conveying belt with buckets in a vertical location which conveys the rice grain to the main rice-milling machine. It is made from rubber with width of 200 mm, thickness of 10 mm and length of 4500 mm. Fifteen buckets with 150 mm spacing were fixed with the belt by rivets.

**Source of power**

A four-wheel tractor (Naser 65, Naser company, Egypt) of the standard type with 4 cylinders diesel engine, 65 hp (48 kW) power at rated speed, is used as a power source. The PTO revolution is 540-1000 rpm, and its mass is 2250 kg.

**Methods**

Experiments were carried out to assess the rice-grain milling machine with the attached primary cleaning-unit in order to optimize its performance.

**Experimental conditions**

The performance of the investigated machine was studied under the following parameters:

- Four sieves shapes “A”, “B”, “C” and “D”: “A”- The upper sieve unit has circular holes in parallel rows with a diameter of 6 mm, “B”- The upper sieve unit has circular holes in alternating rows with a diameter of 6 mm, “C”- The upper sieve unit has rectangular holes in parallel rows with dimension of 45 × 5 mm, “D”- The upper sieve unit has rectangular holes in alternating rows with dimension of 45 × 5 mm. On the other side, the lower sieve has a constant round holes with diameter of 2 mm connected with all the above mentioned cases (Fig. 2).
- Four feeding rates of 1.00, 1.25, 1.50 and 1.75 Mg/h,
- Four primary cleaning sieves-unit speeds of 310, 360, 420 and 470 rpm.

**Measurements and determinations**

The performance of the investigated machine was evaluated as follows:

**- Machine productivity**

Machine productivity was determined by the following equation:

$$M_p = \frac{m}{t} \tag{1}$$

Where:  $M_p$  - The machine productivity, Mg/h,  
 $m$  - The milled sample mass, Mg,  
 $t$  - The time of milling operation, h.

**- Machine efficiency**

Machine efficiency can be calculated using the following equation:

$$\eta_e = \frac{m_e}{m_i} \times 100 \tag{2}$$

Where:  $\eta_e$  - The machine efficiency, %,  
 $m_e$  - the output sample mass from milling operation, kg,  
 $m_i$  - The total input sample mass, kg.

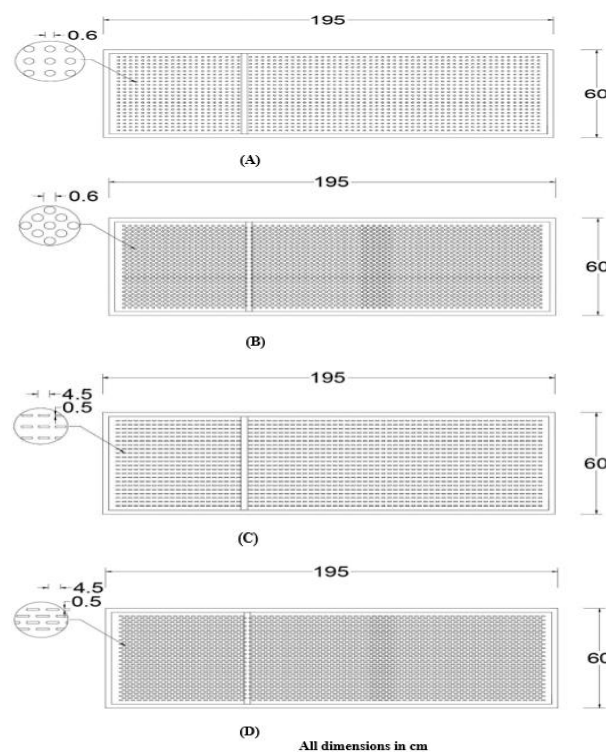


Fig. 2. The four sieves shapes of the primary cleaning unit A, B, C and D

- Cleaning efficiency

Cleaning efficiency was calculated by the following equation:

$$\eta_c = \frac{m_a - m_b}{m_b} \times 100 \quad (3)$$

Where:  $\eta_c$  - The cleaning efficiency, %,  
 $m_a$  - The sample mass after cleaning, g,  
 $m_b$  - The sample mass before cleaning, g.

- Total grain losses

Total grain losses are the sum of unshelled grain losses, broken grain losses and cleaning sieves losses.

The percentage of unshelled grains ( $Unsh_g$ ) can be calculated as follows:

$$Unsh_g = \frac{m_u}{m_t} \times 100 \quad (4)$$

Where:  $m_u$  - The unshelled mass of the sample, g.

The percentage of broken grains ( $Bg$ ) can be calculated as follows:

$$Bg = \frac{m_b}{m_t} \times 100 \quad (5)$$

Where:  $m_b$  - The broken grain mass in the sample, g.

The percentage of broken grains ( $CSL$ ) can be calculated as follows:

$$CSL = m_i / m_t \quad (6)$$

Where:  $m_i$  - The impurities mass from sieves of the sample, g.

- The required power

The following formula was used to estimate the required power (Donnell, 1983):

$$RP = 1/75 \times 1/1.36 \times 1/3600 \times 427 \times f_c \times PE \times LCV \times \eta_{thb} \times \eta_m \quad (7)$$

Where:  $RP$  - The required power, kW,  
 $f_c$  - The fuel consumption, l/h,  
 $PE$  - The density of fuel, kg/L (the density of Diesel = 0.85 kg/L),

$LCV$  - The lower calorific value of fuel, (11000 kcal/kg),  
 $\eta_{thb}$  - The thermal efficiency of the engine (35 % for Diesel),  
 $427$  - The thermo-mechanical equivalent, kg.m/kcal,  
 $\eta_m$  - The mechanical efficiency of the engine (80 % for Diesel).

Fuel consumption per unit time was determined using a calibrated tank (refilling method) to measure the volume of fuel consumed during the operation time.

- Energy requirements

Energy requirements (kWh/Mg) for the milling operation can be calculated as follows:

$$\text{Specific energy} = \frac{RP}{M_p} \quad (8)$$

- Criterion cost

The criterion cost required for the cleaning and milling operation was estimated using the following equation (Awady et al., 1982):

$$\text{Criterion cost} = \text{operating cost} + \text{grain losses cost, LE/Mg} \quad (9)$$

The operating cost was determined from the following formula:

$$\text{Operating cost} = \frac{\text{Machine cost (L.E/h)}}{\text{Machine productivity, (Mg/h)}}, \text{ L.E./Mg} \quad (10)$$

Where 1.0 \$ = 15.6 L.E

The machine cost is determined by using the fixed and variable costs method.

## RESULTS AND DISCUSSION

Preliminary experiments were conducted on the rice-grain milling machine before attaching the primary cleaning-unit to optimize its performance. Results of these preliminary experiments achieve that the optimum milling machine drum speed, rice-grain moisture content and mill sieve inclination angle were determined and adjusted at 800 rpm, 14 %, and 8°, respectively, to be constants during operating the rice-grain milling machine after attaching the primary cleaning-unit.

### 1. Machine productivity

Representative primary cleaning sieve-“PCS speed values versus machine productivity are given at different feeding rates for different shapes of primary cleaning sieves in Fig. 3. Concerning the effect of primary cleaning sieve unit speed on machine productivity, the obtained results show that machine productivity increased by increasing “PCS” speed. For example, with the use of primary cleaning sieve “C”, at feeding rate of 1.25 Mg/h, machine productivity increased from 0.76 to 0.783, from 0.783 to 0.788 and from 0.788 to 0.810 Mg/h, when the “PCS” speed increased from 310 rpm to 360 rpm, from 360 rpm to 420 rpm, and from 420 rpm to 470 rpm, respectively. This attributed to that the increase in sieve speed tends to mill more rice grains in the unit time resulting in high machine productivity.

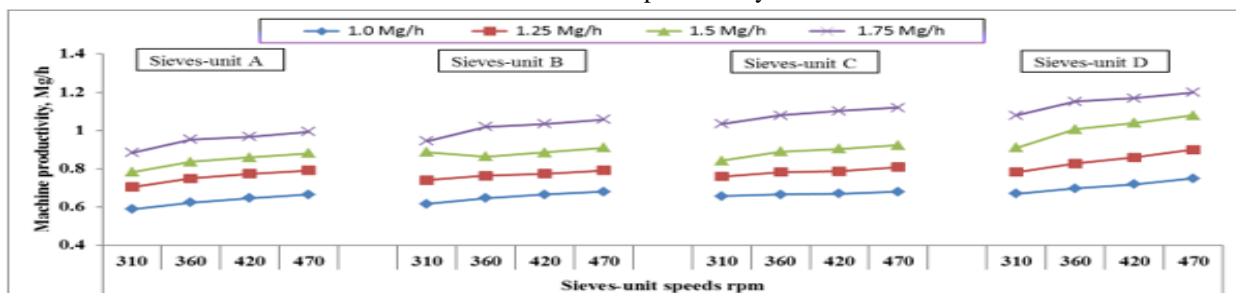


Fig. 3. Influence of primary cleaning sieve-unit speed on machine productivity at different feeding rates for different shapes of primary cleaning sieves

Relating to the effect of feeding rate on machine productivity, Results show a positive effect of feed rate on machine productivity under all “PCS” speed and all primary cleaning sieves shapes “CSS”. For example, with the use of primary cleaning sieve “D”, when the feeding rate increased

from 1.0 to 1.25, from 1.25 to 1.5, and from 1.5 to 1.75 Mg/h, machine productivity increased from 0.72 to 0.86, 0.86 to 1.04, and from 1.04 to 1.17 Mg/h, respectively, under constant sieve speed of 420 rpm. This trend may be due to

high feeding rates means more rice grains entered the machine, as a result high output is expected.

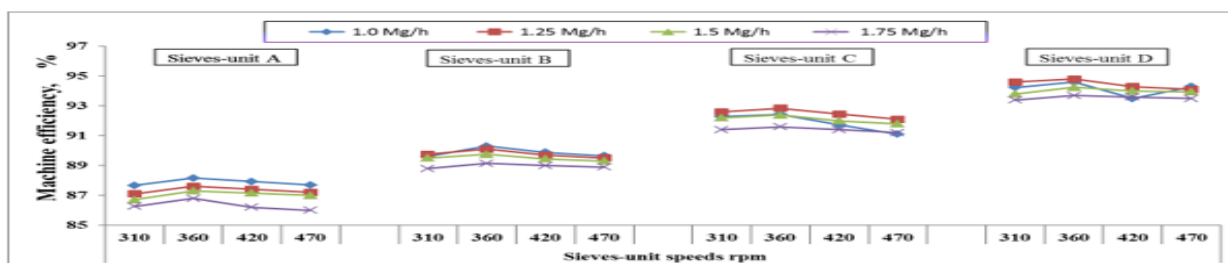
As to the effect of primary cleaning sieve unit shape on machine productivity, data show that the productivity was higher with the use of primary cleaning sieve unit shape “D” compared to the other sieves shapes “A”, “B” and “C” at all feeding rates and speeds. For example, at feeding rate of 1.5 Mg/h and sieve speed of 360 rpm, the productivity of sieve shape D was 1.008 Mg/h and for other types; “A”, “B” and “C” were 0.837, 0.864 and 0.891 Mg/h, respectively. These results indicated that sieve shape “D” yielded the best among other types of sieve units because its holes shape and distribution facilitate rice grains motion resulting in high values of machine productivity.

**2. Machine efficiency**

Fig. 4 illustrates the effect of primary cleaning sieve speed, feeding rate, and primary cleaning unit sieve shape on the machine efficiency. Referring to “PCS” speed, the machine efficiency increased when the sieve speed increased from 310 to 360 rpm and then decreased with increasing speed more than 360 up to 470 rpm, at all feeding rates and all sieve unit shapes. For example, the machine

efficiency increased from 86.7 to 87.3 % and then decreased to 87.15 and 87.0 % when the speed increased from 310 to 360 rpm and from 360 to 470 respectively, using sieve “A” at feeding rate of 1.5 Mg/h. The increased efficiency of the machine at sieve speed of 360 rpm and feeding rate of 1.25 Mg/h may be due to the smooth flow of the grain and the lack of crowding or clogging of the sieve openings.

Regarding feeding rate, results show that the feeding rate slightly influenced on the machine efficiency, it was fluctuated between increasing and decreasing with all sieve speeds and sieve shapes. The maximum differences between the lowest and highest values of efficiency were 1.72, 1.16, 1.25, and 1.20 % for sieve shapes “A”, “B”, “C”, and “D”, respectively. While, these differences were the lowest (0.80, 0.70, 1.33, and 1.10 %) for sieve shapes “A”, “B”, “C”, and “D”, respectively. These results indicated that increasing feeding rate influence slightly on the machine efficiency and a little increase yielded due to the increase of speed especially in sieve shapes “A” and “B”, as sieve shapes “C” and “D” yielded better.



**Fig. 4. Influence of primary cleaning sieve-unit speed on machine efficiency at different feeding rates for different shapes of primary cleaning sieves**

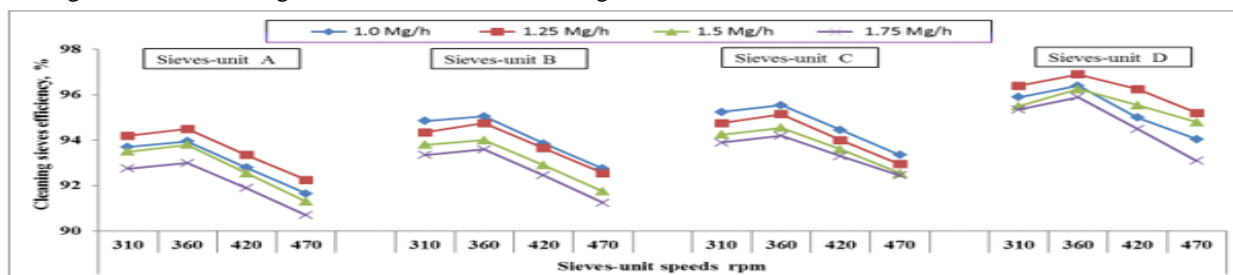
The most influencing factor affecting machine efficiency is sieve shape, where the machine efficiency increased significantly from 87.6 to 94.8 % by changing sieve shape “A” to sieve shape “D” at speed of 360 rpm and feeding rate of 1.25 Mg/h. Efficiency also increased when using “B” and then “C” instead of “A”, from 87.6 to 90.1 % and from 90.1 to 92.85 %, respectively, at the same previous speed and feeding rate.

**3. The cleaning efficiency**

The effect of primary cleaning sieve speed, feeding rate, and primary cleaning unit sieve shape on the cleaning efficiency is illustrated in Fig. 5. The cleaning efficiency of the rice-grain milling machine increased slightly when the primary cleaning unit sieve speed increased from 310 rpm to 360 rpm at all feeding rates with the use of all sieves shapes, it increased from 92.75 to 93.0, from 93.35 to 93.60, from 93.9 to 94.2 and from 95.35 to 95.90 % for sieve unit shapes “A”, “B”, “C”, and “D”, respectively at constant feeding rate of 1.75 Mg/h. In contrast, the cleaning

efficiency decreased sharply when the speed increased from 360 to 420 and from 420 to 470 rpm. While, at feeding rate of 1.75 Mg/h, it decreased from 93.0 to 90.7, from 93.60 to 91.25, from 94.20 to 92.45, and from 95.9 to 93.1 % when the speed increased from 360 rpm to 470 rpm for sieve shapes “A”, “B”, “C”, and “D”, respectively. The increase in the cleaning efficiency in the range of 310 to 360 rpm at feeding rate of 1.25 Mg/h is due to the disposal of a greater amount of impurities with the grain as well as the disposal of a greater amount of broken grain through a sieve final cleaning of the rice grains after the milling process.

Regarding feeding rate, using high feeding rates cause a decrease in cleaning efficiency under all sieve speeds and sieves shapes. The increase in cleaning efficiency at low feeding rate of 1.25 Mg/h under a sieve speed of 360 rpm is due to the smooth flow of the grain and the lack of crowding or clogging of the sieve openings.



**Fig. 5. Influence of primary cleaning sieve-unit speed on cleaning efficiency at different feeding rates for different shapes of primary cleaning sieves**

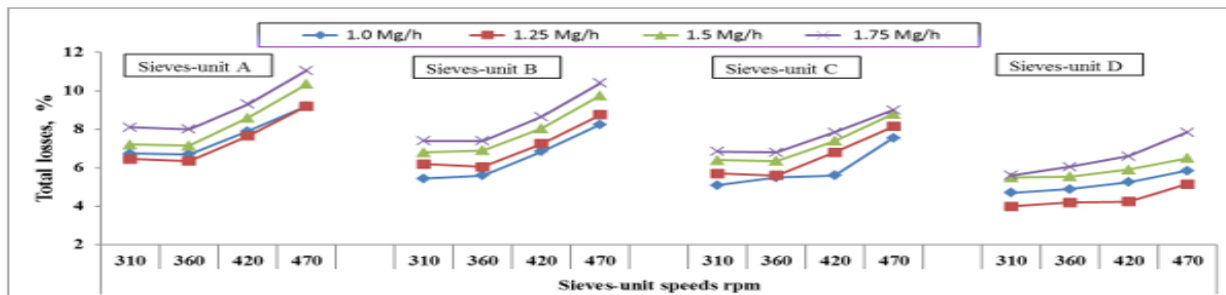
Sieve shape “D” achieved the best performance among others where the cleaning efficiency reached to 96.9 % as it was 94.5, 94.75 and 95.15 % for sieve shapes “A”, “B”, and “C”, respectively, at feeding rate of 1.25 Mg/h and sieve speed of 360 rpm.

**4. The total grain losses**

Fig. 6 illustrated the effect of primary cleaning sieve speed, feeding rate, and primary cleaning unit sieve shape on the total grain losses.

With regard to primary cleaning unit sieve speed, results show that increasing sieve speed, increased the total grain losses under the all different feeding rates and all different sieve units shapes. For example, the total grain

losses increased from 8.10 to 11.05, from 7.40 to 10.40, from 6.85 to 9.0 and from 5.60 to 7.85 %, when the speed increased from 310 to 470 rpm for sieve shapes “A”, “B”, “C”, and “D”, respectively at feeding rate of 1.75 Mg/h. While a slight decrease was yielded using sieve “A” when the speed increased from 310 rpm to 360 rpm for all feeding rates. The increase in broken grains is due to the high impacting force applied to the grains by the drum slices. While the decrease in unshelled grains by increasing sieve speed, is attributed to the high stripping and impacting forces applied to the grains, which led to improve milling operation and decrease unshelled grains.



**Fig. 6. Influence of primary cleaning sieve-unit speed on total grain losses at different feeding rates for different shapes of primary cleaning sieves**

Referring to feeding rate, increasing feeding rate caused increase in total grain losses using all types of sieve units shapes, where the total grain losses increased from 6.35 to 8.0, from 6.05 to 7.40, from 5.6 to 6.8 and from 4.20 to 6.05 % using sieve shapes “A”, “B”, “C”, and “D”, respectively at sieve speed of 360 rpm. In contrast, at low feeding rates, the total grain losses slightly decreased at all sieve speeds and all sieve units shapes except for sieve shape “C”, whereas, it increased. Increasing feeding rate led to increase unshelled grains due the excessive grains in the milling unit, consequently the material leaves the device without adequate milling tends to increase unshelled grains. So, the total grain losses including both broken grains and unshelled grains are essential to establish optimum working conditions.

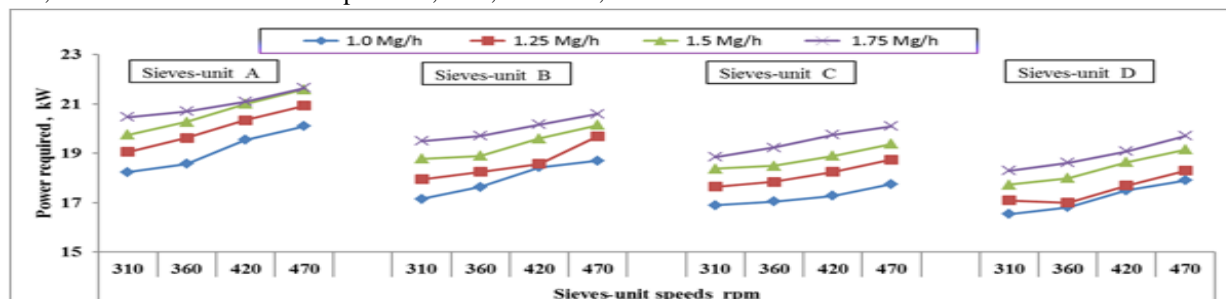
Using sieve unit “D” achieved lower total grain losses at all sieve speeds and all feeding rates, where the lower total grain losses was 4.0 % at speed 310 rpm compared with other sieve units shapes which were 6.45, 6.20, and 5.70 % for sieve shapes “A”, “B”, and “C”,

respectively at the same speed. The results indicated that sieve shape D achieved the best performance for total grain losses followed by sieve shape “C”, followed by “B” and “A”.

**5. Power and energy requirements**

Primary cleaning sieve speed, feeding rate, and primary cleaning unit sieve shape have a great effect on both required power and energy requirements as illustrated in Figs. 7 and 8.

Concerning the effect of primary cleaning unit sieve speed on required power, Fig. 7 show that the required power increased from 19.06 to 20.35 and from 20.35 to 20.94 kW when the sieve speed increased from 310 to 420 and from 420 to 470 rpm, respectively, at feeding rate of 1.25 Mg/h and using sieve shape “A”. Power increased by increasing sieve speed mainly because the increase in sieves speed is frequently accompanied by appreciable increase in fuel consumption, that tends to increase required power.



**Fig. 7. Influence of primary cleaning sieve-unit speed on the required power at different feeding rates for different shapes of primary cleaning sieves**

On the other hand, the required power increased with increasing the feeding rate for all sieve shapes and all sieve speeds, for example, at sieve speed of 420 rpm and sieve shape C, the required power increased from 17.28 to 18.25, from 18.25 to 19.38 and from 19.38 to 20.10 kW when the

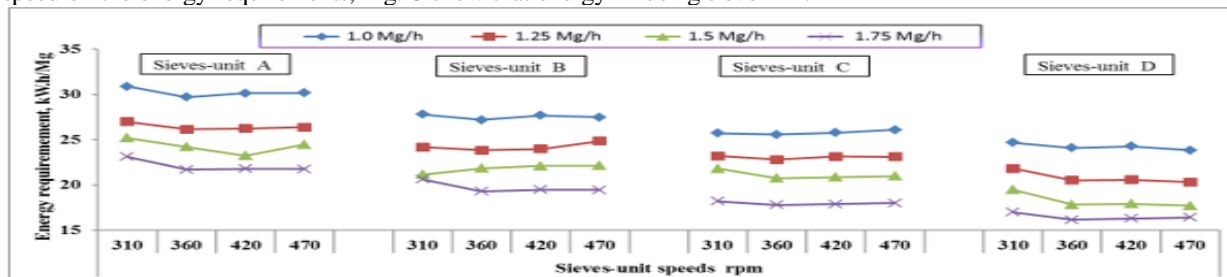
feeding rate increased from 1.0 to 1.25, from 1.25 to 1.50 and from 1.50 to 1.75 Mg/h, respectively (Fig. 7).

Furthermore, the lowest required power was achieved using sieve type “D” followed by “C”, “B”, and “A” for all speeds and feeding rates. Obtained data show that

at sieve speed of 310 rpm and feeding rate of 1.0 Mg/h, the required power for sieve shapes “D”, “C”, “B”, and “A” were 16.54, 16.90, 17.15 and 18.24 kW, respectively.

Considering the effect of primary cleaning unit sieve speed on the energy requirements, Fig. 8 show that energy

requirements decreased from 21.83 to 20.76, from 20.76 to 20.88 and from 20.88 to 21.0 kWh/Mg, when the sieve speed increased from 310 to 360, from 360 to 410, and from 410 to 470 rpm, respectively at feeding rate of 1.5 Mg/h using sieve “C”.



**Fig. 8. Influence of primary cleaning sieve-unit speed on the energy requirements at different feeding rates for different shapes of primary cleaning sieves**

Regarding feeding rate, energy requirements decreased from 25.0 to 22.80, from 22.80 to 20.76 and from 20.76 to 17.80 when the feeding rate increased from 1.0 to 1.25, from 1.25 to 1.50 and from 1.50 to 1.75 Mg/h, respectively, at sieve speed of 360 rpm using sieve shape “C”. Finally, sieve unit shape “D” yielded the best performance among others as it decrease energy requirements to a great extent.

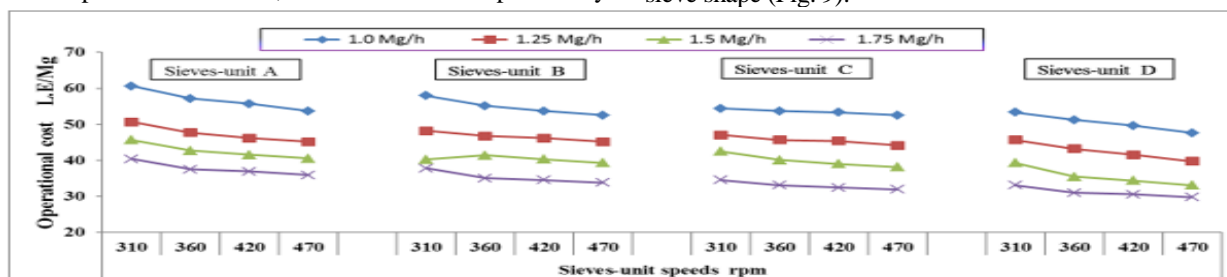
The increase in power by increasing sieve speed is attributed to that high speeds required high fuel consumption. Meanwhile, the increase in power by

increasing feeding rate is due to the excessive load of grains on the machine devices which consumed more fuel.

As the energy requirements are related to the machine productivity, hence it decreased with increasing both sieve speed and feeding rate as shown in Fig. 8.

### 6. Operational and criterion costs

A complete cost analysis was performed at different operating conditions related with machine productivity. The resulting operating cost was found to be affected by primary cleaning sieve speed, feeding rate and primary cleaning unit sieve shape (Fig. 9).



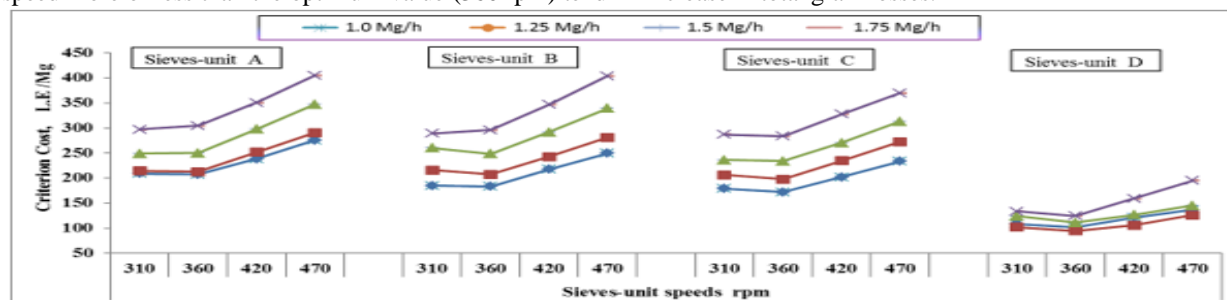
**Fig. 9. Influence of primary cleaning sieve-unit speed on the operational cost at different feeding rates for different shapes of primary cleaning sieves**

The criterion cost versus primary cleaning sieve speed, feeding rate and primary cleaning unit sieve shape were shown in Fig. 10.

Concerning the effect of primary cleaning unit sieves speed on the criterion cost, increasing sieve speed from 310 to 360 rpm decreased criterion cost from 102.00 to 94.52 L.E/Mg . Any further increase in sieve speed more than 360 up to 470 rpm, increased criterion cost from 94.52 to 126.10 L.E/Mg at feeding rate of 1.25 Mg/h using sieve shape D. Higher and lower values of primary cleaning unit sieve speed more or less than the optimum value (360 rpm) tend

to increase criterion cost due to the increase in total grain losses.

Relating to the effect of feeding rate on the criterion cost, increasing feeding rate from 1.00 to 1.25 Mg/h, criterion cost decreased from 101.50 to 94.52 L.E/Mg. Any further increase in feeding rate more than 1.25 up to 1.75 Mg/h increased criterion cost from 94. 52 to 124.30 L.E/Mg, at sieve speed of 360 rpm using sieve shape D. Higher and lower values of feeding rate more or less than the optimum value (1.25 Mg/h) tend to increase criterion cost due to the increase in total grain losses.



**Fig. 10. Influence of primary cleaning sieve-unit speed on the criterion cost at different feeding rates for different shapes of primary cleaning sieves**

As to primary cleaning unit sieve shape, results show that sieve shape "D" decreased criterion cost to a great extent (94.52 L.E/Mg) compared to the other sieve shapes. This attributed to the smooth motion of rice grains through the sieve holes and the high effectiveness of sieve shape "D" in removing unwanted materials from rice grains that tends to decrease criterion cost due to the decrease in total grain losses.

## CONCLUSION

The obtained results revealed that the highest values of machine productivity, machine efficiency and cleaning efficiency were 1.20 Mg, 94.80% and 96.90%, respectively. While, the lowest values of required power, energy requirements, operational and criterion costs were 17.0 kW, 20.53 kWh/Mg, 43.18 L.E/Mg and 94.52 L.E/Mg, respectively. These values were achieved under primary cleaning sieve speed of 360 rpm and feeding rate of 1.25 Mg/h with the use of sieve shape "D".

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## تحسين أداء آلة تبييض الأرز بأضافة وحدة تنظيف أولية مطورة

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تهدف الدراسة الى تطوير وحدة تنظيف أولية للاحاقها بالآلة تبييض حبوب الأرز من أجل تحسين أدائها ورفع جودة المنتج . تمت دراسة أداء آلة تبييض حبوب الأرز المرفق بها وحدة التنظيف الأولية تجريبيا تحت عوامل التشغيل التالية : أربعة أشكال مناخل لوحدة التنظيف الأولية ( أ ، ب ، ج ، د ) ، أربع معدلات تغذية: 1.00 ، 1.25 ، 1.50 ، 1.75 ملجم / ساعة ، أربع سرعات لغرابيل التنظيف الأولية 310 و 360 و 420 و 470 لفة في الدقيقة . اعتمد تقييم أداء الآلة على قياس كل من إنتاجية الآلة ، وكفاءة الآلة ، وكفاءة التنظيف ، وإجمالي فواید الحبوب ، والطاقة المطلوبة ، ومتطلبات الطاقة ، وتكاليف التشغيل والتكاليف الحدية. أشارت النتائج إلى أن أفضل أداء تم تحقيقه باستخدام وحدة التنظيف الأولية باستخدام غربال (د) جنباً إلى جنب مع معدل تغذية 1.25 ميج/الساعة وسرعة غربال التنظيف الأولية عند 360 دورة/الدقيقة. في ظل هذه الظروف كانت قيم انتاجية الآلة وكفاءة الآلة وكفاءة التنظيف 1.20 ميج/الرام/الساعة و94.80% و96.90% على التوالي وفي الوقت نفسه متطلبات القدرة والطاقة المطلوبة 17.0 كيلو وات و20.53 كيلو وات ساعة/ ميج/الرام على التوالي واخيرا كان الحد الأدنى لتكاليف التشغيل والتكاليف الحدية 43.18 و94.52 جنيه/ميج/الرام على التوالي.