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DESIGN AND FABRICATION OF A LOCAL RICE SEPARATING MACHINE.

Abd El-Tawwab, I. M.; M. A. Balomy and S. El-Khawaga
Agric. Eng. Research Institute, A. R. C. Dokki, Giza, Egypt.

ABSTRACT

This study aims to develop and fabricate a separating machine which can deal efficiently with secondary productions resulting from rice milling operation. To achieve the optimum separating conditions, the physical and aerodynamic properties of rice grains were determined. The fabricated machine was evaluated and tested to determine the operating parameters such as sieve oscillation, sieve slope, sieve stroke length and feed rate and their effects on the separating efficiency. Results indicated that the optimum separating efficiency was accomplished with sieve oscillation of 300 cycle/min. To ensure a good separation efficiency of not less than 90 % the sieve slope should be limited to about 8 degree. The optimum separating efficiency resulted with kinematic factor ranged from 4 to 10 m/sec^2. The sieve stroke length needed to achieve the highest possible separation efficiency was 15 mm. The specific separating capacity increased by about 23 % when the feed rate per unit width increased to 6 kg/h. per cm width, then rapidly decreased by about 20 % when feed rate per unit width closed to 7 kg/h. per cm width. The variables affecting the separation efficiency were combined into dimensionless groups. The equation describing the relationship between (ϵ, $r\omega^2/g$, $F/\rho vd$, β) is: $\epsilon = 0.93 - 1.1(r\omega^2/g) - 1.37(F/\rho vd) + 0.01\beta$. This equation indicated that the separation efficiency (ϵ) was inversely related to kinematic factor ($r\omega^2/g$) and feed rate ($F/\rho vd$), while, it was positively related to sieve slope angle (β).

Generally the optimum performance of the fabricated machine resulted from 300 rpm sieve oscillation, 8 degree of sieve slope, 15 mm of sieve stroke length, feed rate per unit width of 7 kg/h. per cm width and acceleration (kinematic factor) of 10 m/sec^2.

INTRODUCTION

A high amount of secondary production may be produced accompanying the rice milling operation. It may reach to about 30 % from the processed rice crop. It consists of whole grain, broken grain, grass seeds, chaff and an amount of dust. By separating these components from the from the mixture, each one may represent a high economic values. Great difficulties are encountered for separating these components. Since, up till now the separation is essentially done manually. Therefore, it is very economical and favorable to design and fabricate a simple separating machine as it reduces labor time required and cost per ton.

Joseph (1974) reported that flat screen are widely used in processing plants and on combines to separate seeds and grains from foreign material according to size and shape.

Henderson (1979) mentioned that the plain sieves are used widely than any other device for cleaning and sorting grain products.

Ahmed, (1988) reported that the maximum efficiency of the sieving unit, was achieved by using the optimum number of sieve oscillations at a given feed rate. This could be evaluated by the coefficient (λ), which gives the possibility of increasing the efficiency of separation,

$\lambda=(\epsilon_n+\Delta_E)/\epsilon_n=1+\Delta_E/\epsilon_n$, Where Δ_E=increase the efficiency of separation and ϵ_n = efficiency of separation at n crank rpm.

Jinglu and Harrison, (1987) stated that increasing the screen slope and the mean hanger angle increased the index but the effect of the hanger was trivial. As already noted, that the screen slope cannot exceed the angle of friction between the particle and the screen surface otherwise the particle will accelerate down the screen and quickly exceeds the limit velocity with no opportunity to pass through the screen network.

Ahmed, (1987) reported that the separation efficiency reached the maximum at 420 rpm or at acceleration of 12.3 m/s^2 for circular mesh sieve while it reached the maximum at 550 rpm or at acceleration of 19.3 m/s^2 for oblong mesh sieve. It was found, that the oblong mesh sieve with the dimensions as stated above gives higher separation efficiency than the circular mesh sieve at 550 rpm.

Feller and Foux (1975) indicated that the frequency and amplitude of oscillation affect the passing of particles through the screen. Though their analysis was made for a horizontal screen with vertical linkage, they concluded that; the slope of the screen and the angle of the hanger control affect the screening duration. Either a surface inclination or a hanger angle is required to clear the screen of the oversized particles for continuous screening.

Person and Megnin (1992) showed that the layer velocity was correlated mainly to the stepping velocity. As acceleration in the direction of the surface increased, material layer velocity increased. Layer velocity increased with increasing stroke length, at least up to a stroke length approximately equal to the length of the corrugations. As feed rate increased, layer thickness increased, but average material layer velocity at the outlet was almost independent of the feed rate.

Abd-Eltawwab (1992) mentioned that the feed rate had a high significant effect on separation effectiveness. At sieve 5 deg. Angle backward and 400 cycle / min of sieve oscillation the grain recovery decreased by 2.5 % as the feed rate per unit width increased from 20 to 30 kg/h.cm width width but at zero sieve angle separation effectiveness slightly decreased as the feed rate increased from 20 to 30 kg/h. cm width and this permits easy increase of machine capacity.

Khan *et al.* (1975) reported the development of a small oscillating rice cleaner for farm-level operation. That machine had two major moving components: a dual oscillating screen assembly and centrifugal fan. The screen is horizontal and grain moves over the screen due to the vibrating action. Grains are fed into the screen from the hopper due to the vibrating motion of the screens. An adjustable gate of the hopper opening permits control on the feed rate. The screen oscillation 250 cycle per minute with a 2.6 cm stroke. The machine could clean one ton of grain per hour at 0.96 % grain purity.

Therefore, the objectives of the present study were to:

1- Design and fabricate a simple separating machine to replace manual separation.

2- Conduct the laboratory experiments to study the most important engineering factors affecting the locally fabricated separating machine performance.
3- Develop a simple model to relate the independent variables of the machine operation to help predict its performance.

MATERIALS AND METHODS

The proposed separating machine was designed and fabricated after considering most of the results of published researches in this area. Separation takes place on the basis of difference in size. The main components of the fabricated machine, as sketched and photographed in Fig. 1,2 are as follows:

1- The main frame:

All separating machine parts are mounted on a simple main frame which is constructed from steel squares of 50×50 mm. The frame dimensions are 0.75×230×1.48 cm (width × length × height) as shown in fig. (1)

2- Fan:

The air flow was produced by means of a multiple-bladed fan. The fan is of the radial type with 5-blades and 40-cm diameter. Air enters axially to the blower and leaves radially through an outlet. Two shutters are used to control the amount of air taken in and delivered by the fan. Wind dividers, located in the fan throat, to control the direction of the fan blast to the sieve. The fan may be adjusted to discharge air blast through the upper sieve perforations at an angle of 40 degree (Kepner, 1982). The air velocity over the upper sieve was adjusted to be 3 m/sec less than the terminal velocity of the principal components of the mixture. Where by lighter materials such as chaff and dust can be separated entirely by aerodynamic action.

3- Sieving unit:

The sieving unit consists of three removable oscillating sieves moving in the same direction. The upper, middle and bottom sieves are of perforated sheets with circular mesh with 4, 2.5 and 1mm diameter respectively. The sieves unit is mounted freely to the frame by four adjustable hangers, which provide the necessary flexibility required for the oscillation and to obtain suitable slope of the sieving unit. It gets its oscillation action by a lever fixed on a crank which takes its motion by means of pulleys and belts. Separation using three sieves is achieved by difference in size. Whole grains are retained over the upper sieve and delivered outside through a spout and are considered edible grade. Broken grains are retained over the medium sieve and the grass seeds are separated by the bottom grading sieve.

Flow performance of a particle through sieve perforations:

In constructing the machine, it is important to find the flow conditions of how to move the product on the sieve unit. This requires knowledge of the relationship between the motion characteristics of the product and other operating factors such as the number of oscillations per minute and amplitude of sieve vibrations (Kanafojski and Karwowski, 1976).

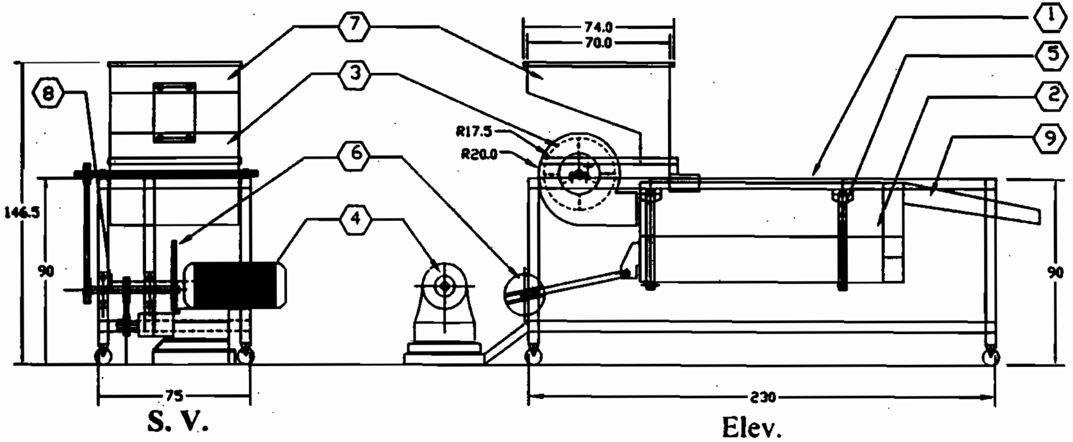

Fig. 1: Schematic diagram of the locally fabricated rice separating machine.

No	Main parts
9	3 Spout
8	Power trans.
7	Grain hopper
6	Eccentric
5	Hanger
4	Electric motor
3	Fan
2	Sieve unit
1	Frame

Dim.	Scale
mm.	1 - 20

Figure 2 shows the forces that affect the grain during separation on the sieve surface. When the crank shaft rotates, the inertia force and gravitational force mg sin β acts to the lift and parallel to sieve plane, tends to move the particles downwards. The friction force N tan ϕ act upwards against inertia force and gravitational force. It means that the particle move downwards when:

$$m\,r\,\omega^2\cos\beta + mg\sin\beta > N\tan\phi \quad\text{......(1)}$$

$$m\,r\,\omega^2\cos\beta + m\,g\sin\beta > (m\,g\cos\beta - m\,r\,\omega^2\sin\beta)\tan\phi \quad\text{......(2)}$$

It can be concluded that the particle will start sliding over the sieve downwards when:

$$r\omega^2 > g\tan(\phi - \beta) \quad\text{......(3)}$$

And the particle will start sliding over the plane upwards when:

$$r\omega^2 > g\tan(\phi + \beta) \quad\text{......(4)}$$

The maximum velocity of the grain (v) at which the grain can still pass through the sieve perforations and can't jump over the sieve will be expressed as follows:

$$V_{max} = (D - L/2\cos\beta)/\sqrt{\left[2(D - L/2)\sin\beta + d/2\cos\beta\right]/g} \quad\text{......(5)}$$

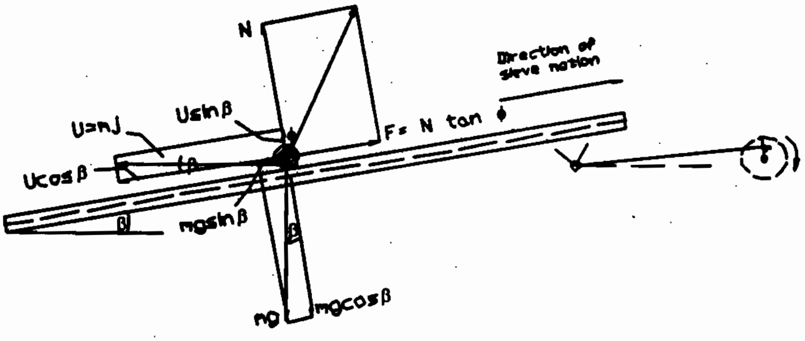

Fig. 2: Motion characteristics of a grain on the sieve surface.

where:

U = m r ω^2 cos ωt, Newton;
N = normal reaction force, Newton;
t = rotating time of the crankshaft, sec;
r = radius of the crank shaft, mm;
ϕ = friction angle, degree;
β = inclination angle of the sieve, degree;
ω = angular speed, sec^{-1};
m = the grain mass, kg;
g = acceleration due to gravity, m/sec^2;
D = diameter of sieve perforation, mm and

L, d = grain dimensions, mm.

Depending on the magnitude of the acceleration r ω^2 the grain may either slide only down the sieve or up and down or finally it may be thrown away from the surface of the sieve.

4- The hopper:

The hopper is made of iron sheets 1.5 mm thickness. It is mounted on the top of the frame. It has adjustable gate opening used for feeding material at the required feed rates. The capacity of the grain hopper is 10 kg. The hopper section is trapezoidal in shape to give a suitable slope for the mixture to slide smoothly.

5- Power source:

An electric variable speed motor of 2.21 kW (3 hp) was installed to the frame of the separating unit. The power is transmitted to the moving parts of the machine by means of pulleys and belts.

Physical and aerodynamic properties of the mixture:

Knowledge of the physical and aerodynamic characteristics of seed is essential to help design the separating machine. Physical and aerodynamic properties such as sizes (length, width and thickness), moisture content, coefficient of friction between grains and metal sheet and terminal velocity are presented in the following table.

Table1: The physical and aerodynamic properties of mixture.

Property	Seeds type		
	Whole grain rice	Broken grain rice	Grass seeds
Quantity, %	53.73	21.49	24.78
Size, mm			
Length	6.5	3.56	2.2
Width	3.14	3.14	1.78
Thickness	1.9	1.9	1.64
Density, kg/m^3	525	594	615
moisture content, %	14.2 %	15.7 %	14.8 %
1000 grain weight, g	79.5	49.8	36.4
Coefficient of friction	0.34	0.34	0.3
Terminal velocity, m/sec	6.3 – 7.2	5.2 – 4.7	4.9 – 3.9

The following engineering factors were studied to observe their effect on the efficiency of separation:

1- Sieve oscillation:

The machine performance was evaluated under sieve oscillations of 200, 300, 400 and 500 rpm.

2- Sieve slope:

Five different slopes for the sieving unit of zero, 4, 8 and 12 degree were studied.

3- Sieve stroke length (amplitude):

Three strokes were tested 5, 10, 15 and 20 mm.

4- Kinematic factor (rω^2):

The separation machine was tested and evaluated under the effect of the acceleration factor ranging from 2 to 24 m/sec^2.

5- Feed rate:

Sifting of grains through the sieve openings depends not only on the above mentioned factors, but also on the loading of the sieve and to be exact on the thickness of the material layer. Feed rate is defined as the initial loading of grains which falls over 1 cm of sieve width in the course of 1 hour. Four different feed rates per unit width of 4, 5, 6 and 7 kg/h. per cm width were studied.

$F = Q_p / S_m$, (kg/h. cm)..(6)

Where:

F = feed rate per unit width, kg/h. per cm width;
Q_p = amount of grain, kg/h. and
S_m = width of sieve, cm.

The following measurements were carried out to investigate the effect of the above-mentioned parameters on the experimental machine's performance.

1- Separation efficiency:

In the experiments conducted on the fabricated machine, the efficiency of separating was calculated from the following equation (Kashayap, 1965):

$\epsilon = (w_1 / w_2) \times 100$..(7)

where:

ϵ = efficiency of separation, %;
w_1 = mass of grain passing through the mesh of the sieve in the test, kg and
w_2 = maximum possible separation (mass of grain capable of passing through a sieve with a mesh of given size).

The variables affecting the efficiency of separation (Table 2) were combined into dimensionless groups.

Table 2: The variable affecting the efficiency of separation.

	Variable	Symbol	Dimension
1	Separation efficiency	ϵ	---
2	Angular velocity	ω	T^{-1}
3	Crank radius	r	L
4	Gravitational acceleration	g	LT^{-2}
5	Feed rate / unit width	F	$M L^{-1} T^{-1}$
6	Grains density	ρ	$M L^{-3}$
7	Maximum velocity of grain	v	$L T^{-1}$
8	Sieve opening diameter	d	L
9	Sieve slope angle	β	----

The statistical model suggested according to Buckingham Pi Theorem (stated by Glenn Murphy, 1950) is as follows:

$\epsilon = f\,(r\omega^2/g,\ F/\rho v d,\ \beta)$..(8)

2- Specific separation capacity:

The specific separation capacity is expressed according (Kashayap, 1965):

$P_s = P / S\,L$..(9)

Where:

P_s = specific separation capacity, kg / m^2 sec;

P = separation capacity (amount of grains sifted through the sieve openings in the course of 1 sec), kg / sec;

S = sieve width, m and

L = sieve length, m.

RESULTS AND DISCUSSION

1- Separation efficiency:

Figure 3 shows the relation between sieve oscillation (200, 300, 400 and 500 rpm) and separation efficiency. It is clear that the separation efficiency was significantly affected by the sieve oscillation. At low sieve slope (zero and 4 degree), the separation efficiency increased when the sieve oscillation increased up to 400 rpm. But, when the sieve oscillation reached 500 rpm, the separation efficiency was highly decreased by about 17 %. Moreover, at high sieve slope of 12 degree, the optimum sieve oscillation was recorded at 300 rpm sieve oscillation. This may be due to that at 400 rpm sieve oscillation causes adequate agitation of the separating sieves result in displacement of the pile of grain over their surfaces, so the separation is optimal. Also the layer of grain should be kept agitated so that air flows through it and removes the lighter straw particles.

Also figure 3 indicated that, for sieve stroke length of 10, 15 and 20 mm, the optimum separation efficiency was recorded at 300 rpm sieve oscillation. While, at 5 mm sieve stroke length, the highest separation resulted from 400 rpm sieve oscillation.

Moreover, the experimental results were found to be agreeing closely with the theoretical results. Where, according to the equation 5 the optimum sieve oscillation can be calculated in which the maximum grain dimension (L) = 6.5 mm, (d) = 3.14 mm, the sieve perforation D = 4 mm, and sieve inclination β = 8 degrees, the maximum grain velocity = 0.35 m/s therefore the optimum sieve oscillation must lie between 300 to 400 rpm. At this sieve oscillation the grain will slide down and upward without jumping and leads to achieve the highest separation efficiency.

Fig. 4 represents the relation between sieve slope and separation efficiency at different values of sieve oscillation, and sieve stroke length. It can be noticed that, the separation efficiency increased from 72 to 95%, and from 79 to 90 % as the sieve slope increased from zero to 8 degrees at sieve speeds of 300 and 400 rpm respectively. It can be also seen that efficiency started to decrease from 94 to 83.5 %, and from 89.5 to 74 % as the sieve slope increased from 8 to 12 degrees at speeds of 300 and 400 rpm respectively. On other hand, the data showed that, at speed of 500 rpm separation efficiency decreased from 73 to 54.5% as the sieve slope increased from zero to 12 degrees. Generally, the optimum separation efficiency 94 % was obtained at 8 slope degrees and 300 rpm sieve oscillation.

Also it can be seen that at small stroke length (5 and 10 mm) the separation efficiency increased by about 30 % when the sieve slope increased up to 12 degree. On other hand at high stroke length (15 and 20 mm) the efficiency decreased by about 26 % with increasing of sieve slope. It can be concluded that an increase in sieve slope was accompanies a decrease in separation efficiency after a certain sieve slope of 8 degree was reached.

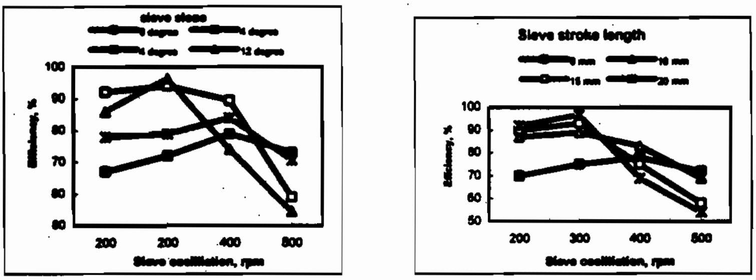

Fig. 3: Effect of sieve oscillation on separation efficiency at different sieve slope and sieve stroke length.

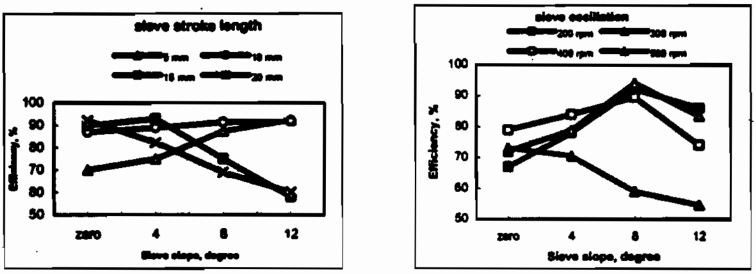

Fig. 4: Effect of sieve slope on separation efficiency at different sieve oscillation and sieve stroke length.

Data in Fig. 5 indicated that the sieve stroke length had an obviously effect on the separation efficiency. It was found that at sieve oscillation of 200 and 300 rpm the separation efficiency increased with increasing of stroke length up to 20 mm. Where at 300 rpm sieve oscillation the separation efficiency increased from 75 to 96.8 % (about 29 %) when the sieve stroke increased from 5 to 20 mm. On other hand, at 500 rpm sieve oscillation the separation efficiency decreased by about 27 % when the sieve stroke increased up to 20 mm. Therefore, it can be concluded that the optimum separation efficiency 96.8 % was achieved at 20 mm sieve stroke and sieve oscillation of 300 rpm.

In addition fig. 5 indicated that at sieve slope of zero degree the highest separation efficiency 94.2 % was obtained at sieve stroke of 20 mm. But at 12 degree sieve slope the highest efficiency 92.4 % resulted from 5 mm sieve stroke.

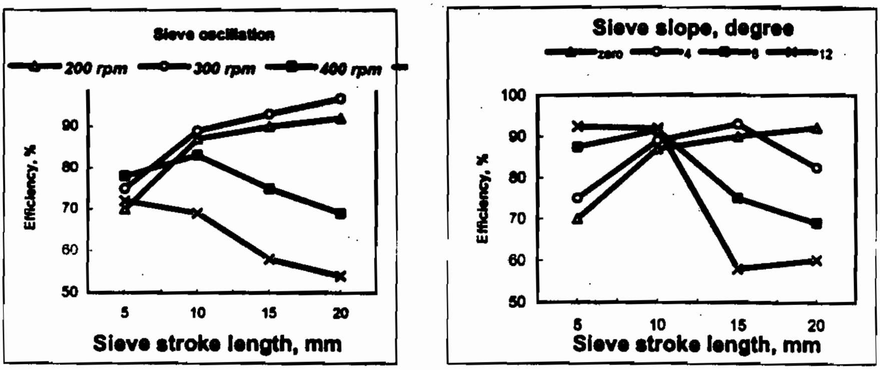

Fig. 5: Effect of sieve stroke length on the separation efficiency at different sieve oscillation and sieve slope.

The kinematic operating factor, the sieve oscillation and the inclination of the sieve significantly affect the nature of motion of the material over the sieve surface. Results in fig. 6 indicated that the separation efficiency was highly affected by kinematic factor and sieve slope. Where, the optimum separation efficiency was recorded at kinematic factor ranged from 4 to 10 m/sec^2 and from 4 to 8 m/sec^2 when the sieve slope of zero and 4 degree respectively. But at 8 and 12 degree sieve slope the optimum separation efficiency resulted from kinematic factor ranged from 4 to 6 m/sec^2. this may be due to with increasing of the kinematic factor to some limiting value, the passage of particles through the sieve holes increases and separation efficiency improves. Inclination of the sieve toward the delivery end reduces the relative path traversed by the material and its absolute speed toward the exit increases.

Theoretically, according to equation 3, 4, and 5, depending on the magnitude of the kinematic factor $r\omega^2$ the grain may either slide only down the sieve or up and down or finally may be thrown away from the surface of the sieve. To obtain the maximum separation efficiency, the sliding of grains up and down without break is the most favorable type of motion. Therefore the optimum magnitude of the kinematic factor can be calculated from the equations that for average condition in which sieve slope (β) = 8 degrees, friction angle (ϕ) = 19 degrees, and (r) = 10 mm, the best kinematic factor ($r\omega^2$) must lie between 5 to 7 m / s^2, the grain will slide up and down the sieve without jumping. Therefore, it is clear that the experimental results meet closely with the theoretically data.

Generally, the kinematic factor $r\omega^2$ should not greater than 10 m/sec^2 to achieve the optimum separation efficiency.

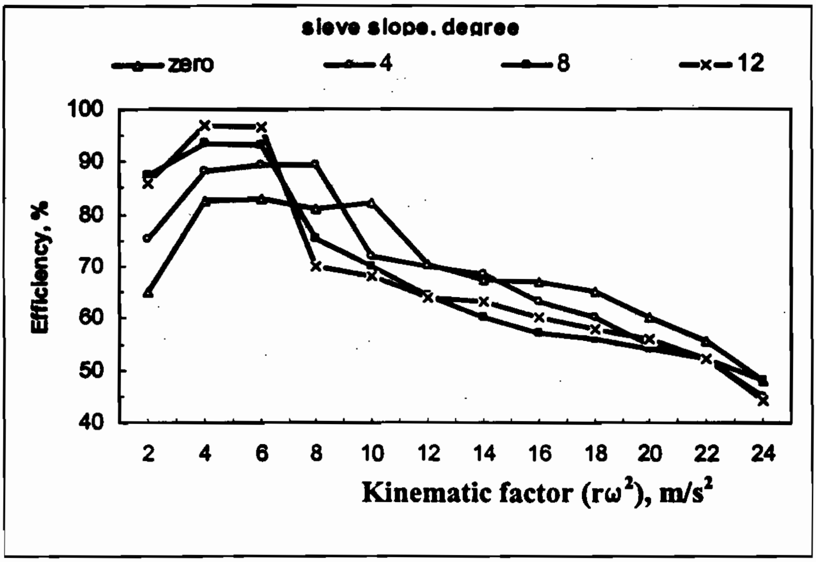

Fig. 6: Effect of the kinematic factor on the separation efficiency at different sieve slopes.

The analysis of variance of the separation efficiency as a dependent variable. The determination factor was found to be about 0.89. The test of significant for the independent variables (1- angular velocity, ω, 2- crank radius, r, 3- gravitational acceleration, g, 4- feed rate, F, 5- grain density, ρ, 6- max. velocity of grain, v, 7- sieve opening diameter, d, and 8- sieve slope angle, β). It is clear that the dependent variable (separating efficiency) was significantly affected by all independent variables. The regression equation obtained from the statistical analysis is as follows:

$$\epsilon = 0.93 - 1.13(r\omega^2/g) - 1.37(F/\rho vd) + 0.01\,\beta \quad \text{..........................(8)}$$

where: ϵ = separating efficiency, %;
r = crank radius, m;
ω = angular velocity, sec^{-1};
g = gravitational acceleration, m/sec^2;
F = feed rate per unit width, kg/h. cm;
ρ = grain density, kg/m^3;
v = maximum velocity of grain, m/sec;
d = sieve openings diameter, m and
β = sieve slope angle, degree.

This equation indicated that the separation efficiency (ϵ) was inversely related to kinematic factor ($r\omega^2/g$) and feed rate per unit width ($F/\rho vd$), while, it was positively proportional to sieve slope angle (β).

2- Specific separation capacity:

Results in Fig. 7 indicated that the separation capacity was highly affected by feed rate per unit width and sieve oscillation. Where, at lower sieve oscillation, the separation capacity increased by about 23 % when the feed rate per unit width increased up to 5 kg/h. cm width, and rapidly decreased by about 20 % when feed rate per unit width closed to 7 kg/h. cm width. But, at higher sieve oscillation, the highest separation capacity (0.175 kg/m^2 sec) was obtained at 6 kg/h. cm feed rate unit width. This may be due to the low feed rate per unit width the sieve will not be completely covered by grains, in such a case all grains shift individually directly over the sieve surface which is only partially loaded. While, at high value of feed rate per unit width a layer thicker than the mean transverse size of grains shifts was created, in such a case the upper grains which are not in immediate contact with the sieve surface cannot pass through its openings. Also, it can be reported that at low feed rate per unit width (4 and 5 kg/h. cm width) the sieve oscillation has not a clear effect on the separation capacity. This may be due to that the layer depth does not greatly exceed the size of the elements that are being separated, a small acceleration are enough to ensure separation. While at 6 kg/h.cm feed rate per unit width, the optimum separation capacity was achieved at 400 rpm sieve oscillation. Perhaps, the 400 rpm sieve oscillation resulted in a greater agitation, and higher transport rate of the material on the sieve.

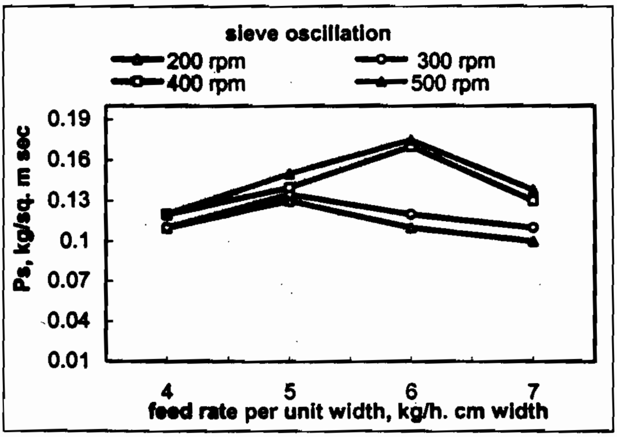

Fig. 7: Effect of feed rate per unit width on the specific separation capacity at different sieve oscillation.

CONCLUSION

The conclusion of the present study could be summarized in the following points:

1- At low sieve slope (zero and 4 degree), the separation efficiency increased when the sieve oscillation increased up to 400 rpm. Moreover, at higher sieve slope (12 degree) the optimum sieve oscillation was recorded at 300 rpm sieve oscillation.

2- To ensure a good separation efficiency to be not less than 95 %, the separation machine should be operated at sieve oscillation of 300 rpm.

3- The slope of the sieve was the main factor that affected on separation efficiency. The separation efficiency increased significantly with the increase of sieve slope at small stroke length and decreased at high stroke lengths. Generally, The separation efficiency increased by increasing the inclination of sieves up to 8 degree.

4- The optimum separation efficiency was recorded at kinematic factor ranged from 4 to 10 m/sec^2 and from 4 to 8 m/sec^2 when the sieve slopes of zero and 4 degree respectively. But at 8 and 12 degree sieve slope the optimum separation efficiency resulted from kinematic factor ranging from 4 to 6 m/sec^2.

5- The variables affecting the separation efficiency were combined into dimensionless groups. The equation describing the relationship between (ϵ, $r\omega^2/g$, $F/\rho vd$, β) is:

$$\epsilon = 0.93 - 1.1(r\omega^2/g) - 1.37\,(F/\rho vd) + 0.01\,\beta$$

6- This equation indicated that the separation efficiency (ϵ) was inversely related to kinematic factor ($r\omega^2/g$) and feed rate per unit width ($F/\rho vd$), while, it was positively related to sieve slope angle (β).

7- At 300 rpm sieve oscillation, the specific separation capacity increased by about 23 % when the feed rate per unit width increased to 5 kg/h. per cm, and rapidly decreased by about 20 % when feed rate per unit width was close to 7 kg/h. cm.

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تصميم وتصنيع آلة فصل محلية لنواتج تنظيف الارز.

إبراهيم محمد عبد التواب ، مجدي احمد بيومى وصفوت الخواجة
معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الدقى – مصر

يهدف هذا البحث الى:

١- تصميم وتصنيع آلة لفصل النواتج الثانوية لمضارب الأرز الآلية.
٢- دراسة اهم العوامل التصميمية والهندسية المؤثرة على كفاءة الفصل.
٣- استنتاج معادلة رياضية للتنبؤ بكفاءة الفصن للآلة المصنعة.

و كانت اهم النتائج المتحصل عليها هى كالاتي:

١- وجد ان انسب زاوية ميل للغربال هى ٨° للحصول على آعلى كفاءة للفصل.
٢- انسب سرعة ترددية للغربال هى ٣٠٠ لفة / دقيقة عند ازاحة ١٥ مم وذلك للحصول على اعلى كفاءة للفصل.
٣- تم تجميع العوامل المؤثرة على كفاءة الفصل فى مجموعات عديمة الوحدات. وكانت العلاقة الرياضية التى تربط بين المجموعات عديمة الوحدات هى:

$$\epsilon = 0.93 - 1.13(r\omega^2/g) - 1.37(F/\rho v d) + 0.01\,\beta$$

حيث: ϵ: كفاءة الفصل؛ r : نصف قطر الكرنك؛ ω: السرعة الزاوية؛ F : معدل التلقيم؛ ρ : كثافة الحبوب؛ v: سرعة الحبة على الغربال؛ d: قطر فتحات الغربال.

٤- كان لمعدل التلقيم التاثير الاكبر فى تحديد انتاجية الآلة وقد وجد ان انسب معدل تلقيم هو ٧ كجم / ساعة لكل سم عرض للغربال .