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ENGINEERING PARAMTERS AFFECTING CLEANING OF SOYBEAN GRAINS

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ABSTRACT

The aim of the present study is to investigate the engineering parameters affecting the separation of soybean grains and study also the physical and mechanical properties of soybeans grains to obtain better cleaning efficiency and less losses. Cleaning machine was tested in Menofia Governorate to clean soybean grains (Clark variety). Physical properties of soybean grains such as length(L) , width (W) , thickness (T) , volume (V) , geometric diameter(Dg) , arithmetic diameter (Da) , percentage of sphericity (S) , transverse surface area (At) , flat surface area (Af) , bulk density(Bd) true density (Td), moisture content (Mc), and mass of 1000-seeds(km) were examined and determined. Mechanical properties of soybeans grain such as friction angle, coefficient of friction, angle of repose, hardness and terminal velocity for grains and their impurities, were tested and assessed. Engineering parameters such as air speed, sieve tilt angle, sieve oscillation, feed rate and moisture content, were also studied and determined.

The obtained results showed that, the separation increased by increasing sieve oscillation, air speed and sieve tilt angle. The total losses decreased by decreasing sieve oscillation, air speed and sieve tilt angle. The optimum performance was achieved at air speed of 19 m/s sieve tilt angle of 4 degree (0.07 rad) sieve oscillation of 2.6 Hz (220 r. p. m), feed rate of 1000 kg/h, and moisture content of 13%

Separation efficiency at these conditions was 99.65% and total losses were 0.35%. The operation cost was 5 LE/h (5LE/ton).

INTRODUCTION

Mechanization of cleaning operation is important due to saving in effort, operation time and reducing losses.

Cleaning of grain may be considered as the most important factors affecting the quality of crop after harvest.

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The annual cultivated area of soybean crop is about 20,000 Fadden producing about 1.25-1.50 ton/Fadden (Agricultural statistics Economic Affairs sector, 2003). The physical and mechanical properties of grain effect mainly on design and development of precision planting, handling system, storage, cleaning, separation and threshing.

IRRI (1978) recommended the top screen size for different crops as follows: Rice 8-9 mm, sorghum 6-7 mm, soybean 7-8 mm, wheat 8-9 mm, mungbean 5-6 mm and maize 10-12 mm.

***Klenin et al.* (1985)** stated that the agricultural product is cleaned and graded according to various criteria governing each material. These criteria are:geometric size of each particles, their aerodynamic properties, the shape and state of the surface, density and specific weight, electric conductivity and color.

Arora (1991) cited the engineering properties such as size, diameter, volume, bulk density, particle density, porosity, terminal velocity, drag coefficient and resistance coefficient of 3 varieties of rough rice (Oryza sativa, L) at different levels of (8.1, 14.20, 18.23, 23.40, 27.23% d.b.). Physical properties were found to be related to moisture content. physical properties were found dependent upon moisture content The aerodynamic properties (terminal velocity, drag- coefficient and resistance coefficient) also increased with an increase in moisture content.

Ahmed et al. (1993) developed a winnowing machine which can deal efficiently with threshers. This machine was designed to be attached to an aerodynamic set. They showed that the sieve angle had a very high significant effect on the separation effectiveness. At 400 cycle/min sieve oscillation, the grain recovery increased by about 5 % as the sieve angle increased from 0.09 to zero rad (5 to zero deg). On the other hand, increasing sieve angle up to 5 deg, the grain recovery decreased by 3.6 %. At low sieve oscillation (400 cycle/min), the sieve amplitude has a minor effect on the separation effectiveness and grain recovery in the range from 10 to 20 mm. But at higher sieve oscillation of 500 cycle/min, the grain recovery decreased by 2.3 % by increasing of sieve amplitude from 10 to 20 mm. They also showed that the separation effectiveness of 97 % was obtained at sieve oscillation 500 cycle/min, sieve angle 0.034 rad (2 deg) and feed rate 30 kg/h.cm. and grain/straw ratio 1:3.

Hanna et al. (1993) indicated that referring to the physical and mechanical results of wheat the slope of bottom surface of feeding tank ranged from 0.52 to 0.73 rad (30 to 42 deg). The feeding zone height was 150 cm from the center of blower. Minimum deviation values of air speed were found at 17 m/s (700 rpm) while the maximum deviation values were obtained at 25 m/s (1120 rpm).

Awady and El-Sayed (1994) explained that the objective of using a cleaning device is to separate grain from chaff, straw, weed seed, broken, and inferior seeds, dust and other rubbish. Such devices may make use of differences in surface characteristics. There are three types of separation that occur in cleaning device namely: aerodynamic, mechanical and combination of aerodynamic and mechanical. Aerodynamic separation depends upon the existence of a differential between suspension velocity (terminal velocity) of the components to be separated.

Ismail et al. (1994) studied the optimum operating conditions for achieving a high degree of cleaning wheat grains from impurities. Their results showed that the combination of airstream velocity, specific feed rate, percentage of total impurities and samples moisture content affected significantly cleaning efficiency and grain losses.

Awady and El Sayed (1994) concluded that the terminal velocity of different product components of shelled peanut can be predicted according to surface dimensions, mass and coefficient of drag. The mean values of terminal velocity were 4.3, 6.5, 6.8, and 7.2 m/s for shells, unshelled, split and intact seeds respectively. The air velocity of 7.5 m/s was recommended to separate 96% of shells with losses of 3% of unshelled seeds. Meanwhile, at high air speed of 6 m/s, 100% of shells could be separated with losses of 15, and 3% of unshelled and spilt seeds. At low speed of 5.3 m/s 78% shells can only be separated with air.

Owies (1995) mentioned that the suitable sieve hole diameter was 8.6 mm, and the suitable air velocity was 4.0 m/s (for rice varieties of Giza 175 and Giza 176) for separating according to their physical and aerodynamical properties, such as length characteristic and terminal velocity depending on the variation between grains and their associated foreign materials.

El-Raie et al. (1996) determined the terminal velocity of wheat, rice, and barley. They found that the terminal velocity ranged from5.85 to 9.70 m/s for wheat varieties, from 7.88 to 8.54 m/s for rice varieties and from 7.49 to 9.95 m/s for barely varieties.

Hindey and Tawil (1998) mentioned that separating and cleaning grains from material other than grain (straw, chaff, fine particles) could be improved by using a combined action produced, firstly from the formation of fluidized bed of these particles and secondly from the movement of the particies on tilted screen. The techniques of separation and cleaning by using the fluidized bed machine were examined over a wide range of airstream velocities (4.11 to 7.95 m/s), feed rates (20 to 50 kg/h.cm), proportion of material other than grain (8 to 16 %) and slope of separating duct downward of 0.26 to 0.52 rad(15 to 30 deg). They also suggested several equations for the predication of separation effectiveness, grain recovery, grain losses and degree of cleanliness of wheat grains.

Metwalli et al. (1999) mentioned that after harvesting, grain still contains leaves, stalk, other seeds, immature kernels and they often must be cleaned. The grade of the grain depends on its purity and cleanliness and the price depends on the percentage of the foreign and other undesirable materials. They also added that the seed production and cleaning efficiency decreased by increasing feed rate in all outlet vessels.

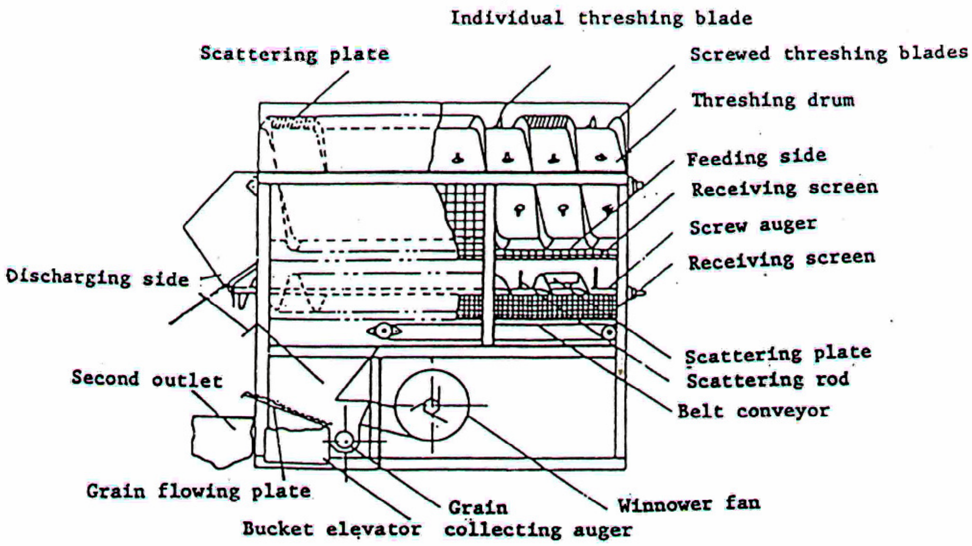
Ebaid (2001) concluded that the optimum conditions of thresher machine to be operated at the maximum efficiency are: air speed 21 m/s (sieve oscillation of 4.34 Hz), sieve tilt angle 0.10 rad (6 deg), moisture content 18%., round screen hole of 9 mm diameter, dimensions of sieve area of 110x30 cm^2 and optimum feed rate of 2200 kg/h. (6666.67 $kg/h.m^2$), with machine purity of 98.99% , fan losses of 0.14 % , and losses behind sieve of 0.04% .

Awady et al. (2003) showed that cleaning efficiency and total losses were positively affected by air speed, and sieve tilt angle, but purity was negatively affected by moisture content, and feed rate. The total losses were negatively affected by moisture content and feed rate. Purity increased when using round-hole sieve compared with slotted sieve. The optimum performance was at air speed of 4 m/s, moisture content of 18 %, sieve tilt-angle of 0.03 rad (2 deg), round-shaped sieve, and feed rate of 1200 kg/h. Purity and total losses at these conditions were 98.98 and 0.21 % respectively.

MATERIALS AND METHODS

1- Materials

The threshing machine was used for soybeans cleaning. All experimental tests were carried out in 2004 at El-Bagour distract, Menofia Governorate to clean Clark variety. The threasher machine consists of main frame, cover, threshing drum, concave, screw separating, winnower fan and elevator as shown in Fig.1. It has one input counter shaft through which the tractor P.T.O can connect. Power transfer from counter shaft threshing drum was through three v-belts.



Fig(1) : Sketch of Thresher Machine

A) Machine specifications and description:

General specifications of thresher are shown in Table 1.

Table 1: General specifications of thresher

Item	Specifications
Model	YST – 101S
Overall Length, mm	2540
Overall Width, mm	1880
Overall Height, mm	1330
Mass, kg	397
Capacity, kg/h	800 - 1000
Feeding system	Belt through in system

Threshing system	Screw threshing system
Threshing drum diameter ,mm	300
Threshing revolutions, rpm	440
Separation system	Screw separating and aspirating system
Fine grain collecting system	Bucket elevator system
Power source and transmission	Tractor and P.T.O
Engagement	Mounted with tractor

B)Instrumentations:

Speedo meter:

It was used to measure the rotation speed in three ranges. First range: 40-5000 rpm., second range 400-5000 rpm and third: range 4000-5000 rpm., direct reading. The accuracy was 1% full scale and made in Germany.

Measuring the coefficient of friction:

Device was designed and constructed at Kafr El-sheikh Governorate Rice Mechanization Center (RMC). Agric. Eng. Res. Institute (REn R I). It was used to measure the friction angle on metal surface and angle of repose with diameter 14x31.5 cm (width x length)

Floating apparatus specification:

It was used for measuring the terminal velocity, made in Japan, electrical source of power, work theory by vacuum. Maximum measuring is 20 m/s and accuracy is 0.1 m/s.

Moisture content meter :

A moisture content meter (wile 35 Moisture meter) was used for measuring the grain moisture content on wet basis.

Anemometer:

it was used for measuring the air speed, made in Japan and its range was from 0 to 50 m/s. The source of power is battery.

Digital dial caliper:

It was used to measure the grains dimensions length, width, and thickness of soybeans grains were determined in three axes (x x, y y and z z). its accuracy is 0.05 mm and reading up to 15 cm was used.

Anemometer instrument:
It was used for measuring the air speed. It made in Japan, and range was from 0 to 50 m/s. its source of power is battery.

C) Physical properties of soybeans grains (Clark variety):
Length, width, thickness, volume, geometric diameter arithmetic diameter, percentage of sphericity, bulk density, true density, transverse surface and flat surface areas mass of 1000 seeds and moisture content for grain reported by El-Raie et al. (1996). as follows: -

$V = \pi/6\ (L \times W \times T)$, mm^3 -----------------------1

$Dg = (L \times W \times T)^{1/3}$, mm ---------------------- 2

$Da = L + W + T/3$, mm ---------------------- 3

$S = 100\ (L \times W \times T)^{1/3} / L$, % --------------------- 4

$Bd = Wb / Vb$, kg/m^3 ---------------------- 5

$At = \pi/4\ (W \times T)$, mm --------------------- 6

$Af = \pi/4\ (L \times W)$, mm^2 --------------------- 7

Where:
L: Length of grains mm; W: Width of grains mm; T: Thickness of grains mm; V: Volume mm^3; Dg: Geometric diameter mm^3; Da: Arithmetic diameter mm^3; S: Percentage of sphericity % ; Bd: Bulk density Kg/m^3 ; Wb: Mass of the same quantity of seeds kg; Vb: Volume of the same quantity of seeds m^3; At: Transverse surface area mm^2 , and Af: Flat surface area mm^2

(D) Mechanical properties of soybean grains (Clark variety):
Friction angle, rads (deg), coefficient of friction, angle of repose, rad (Deg), hardness (W), and terminal velocity, m/s were measured to determine the mechanical properties.

(E) Crop used in investigation:
A random samples of soybean grains (Clark variety) was taken to determine physical and mechanical properties. At moisture content 13% (w.b.).

(F) Test procedures the experimental aeromechincal winnowing :
The following factors were tested to state their effect on separation effectiveness: -

1- **Air speed:** four different air speeds were used 15, 17, 19 and 21 m/s. (fan speed 700, 800, 900 and 1000 rpm.)

2- **Sieve tilt angle:** four different sieve tilt-angles were used zero, 0.03, 0.07 and 0.10 rad (0, 2, 4, and 6 deg).

3- **Sieve oscillation:** four different sieve oscillation were used 2.1, 2.33, 2.6 and 2.8 Hz (180, 200, 220 and 240 rpm).

4- **Feed rate:** 1000 kg/h feed rate was used

Moisture content: 13% moisture content (w.b.) was used

1- Methods: -

A) Purity:

Purity = cleaning sample mass/sample of mass before cleaning x 100 %, ----8

B) Losses:

Losses = Grain collected from fan/ Grain output x 100 %,-----------9

C) Cost analysis:

Its calculated according to equation given by Awady (1978) which has the following form:

C = P/H (1/Y + ½ + t + m) + (A.K.f.u) + s/144 ------------------------10

Where:

C: total hourly cost, P: price of machine, H: estimated yearly-operating hours, Y: estimated life expectancy of machines in years, I: interest rate, T: taxes and overhead rates, M: maintenance and repairs ratio, A: ratio of rated power and lubrication related to fuel cost (1.2), K: power in kW or hp ,F: specific fuel-consumption in l/kW.h or /hp.h., U: price of fuel per l, S: monthly salaries, and 144: estimated working hours per month

RESULTS AND DISCUSSION

1- Physical properties of soybeans grains (Clark variety):

Frequency of three dimensions of soyabean grains are shown in Fig 2.

Maximum dimensions of soybean grains is as follows:

Length (L) = 9.15 mm, Width (w) = 7.75 mm and Thiekness (t) = 6.04 mm

Data from Fig.2 show that the percentage of frequency values were is 55% at mean grain length of about 9.00 mm, for mean grains width of about 8 mm with percentage of frequency is 50% and for mean grains thickness of about 6 mm with. The percentage of frequency is 70% for soybean grains.

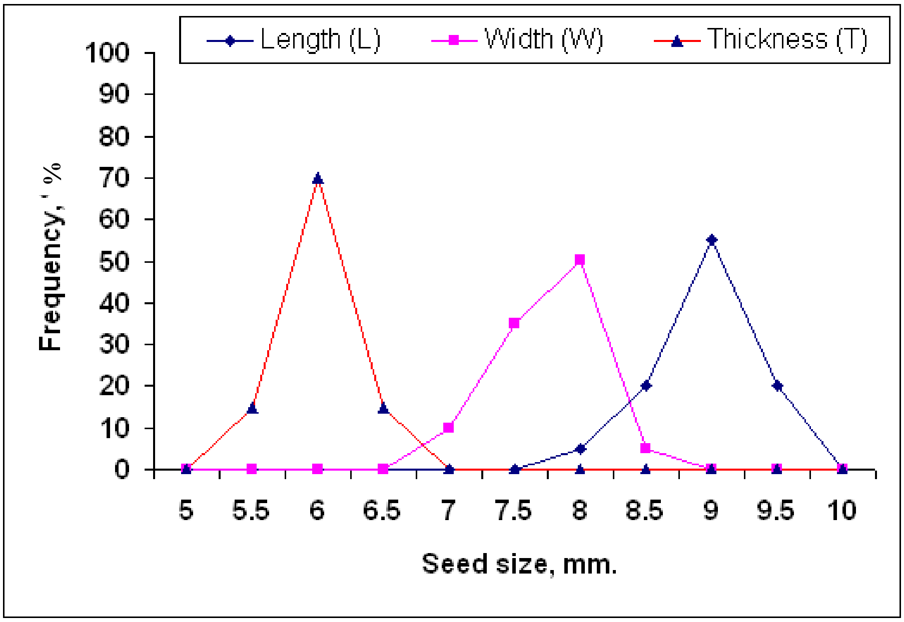


Fig.2: Frequency of three dimensions of soybean drains (Clark Variety) .

Using the mean values, the following general equation can be written to express the relationships between length (L) width (W) and thickness (T): of soybean grains (Clark variety)

$$L = 1.18W = 1.51T \qquad \text{--------------------11}$$

Also volume, geometric diameter, arithmetic diameter, percentage of sphericity, bulk density, true density, transverse surface area, flat surface area, mass of 1000 seeds and moisture content for soybean grains are shown in Table(2).

Table2: Some physical properties of soybeans (Clark variety).

V, mm^3	**Dg, mm**	**Da, mm**	**S, %**	**Bd, kg/m^3**	**Td, kg/m^3**	**Af, mm^2**	**At, mm^2**	**Km, G**	**M.c, %**
223.27	**7.640**	**7.53**	**82.40**	**782.35**	**1325.90**	**55.67**	**36.75**	**225**	**13**

Where: -

V: volume, mm^3 ; Dg: geometric diameter, mm ; Da: arithmetic diameter, mm; S: percentage of sphericity, %; Bd: bulk density, kg/m^3 ;Td: true density, kg/m^3 ; Af: flat surface area, mm^2 ; At: transverse surface area, mm^2 ; Km: mass of 1000-seeds, g and M.c: moisture content, %

2) Mechanical properties of soybean grains (Clark variety).

Data in Table 3 show the mechanical properties of soybeans grains (Clark variety).

Table 3: Some of mechanical properties of soybean grains (Clark variety).

Mechanical properties of Soybean grains (Clark variety)	Value
Friction angle for metal surface, rad (deg)	0.236 (18.71)
Coefficient of friction for metal surface	29
angle of repose, rad (deg)	0.611 (35)
Hardness, N	68.15
Terminal velocity for grains, m/s	21.25
Terminal velocity for impurities, m/s	13.59

3) Factors affecting separation:

a) sieve oscillation:

Data in Fig.3. reveal the effect of sieve oscillation on separation. By increasing sieve oscillation the purity increased, in general, at different sieve tilt angles and air speeds at moisture of content of 13% (w.b.) and feed rate of 1000 kg/h. At air speed of 17 m/s and sieve tilt angle 0.03 rad (2 deg.), separation increased from 97.05 to 99.59 % by increasing sieve oscillation from 2.1 to 2.8 Hz (180 to 240 r.p.m).

b) Air speed:

In general by increasing air speed, the separation increased at different sieve tilt angles and sieve oscillation values at moisture content of 13 % (w.b.) and feed rate of 1000kg as shown in Fig.3.

At sieve tilt angle of zero rad (zero deg.), and sieve oscillation of 2.33 Hz (200 r.p.m), the separation increased from 98.09 to 98.85 % by increasing air speed from 15 to 21 m/s.

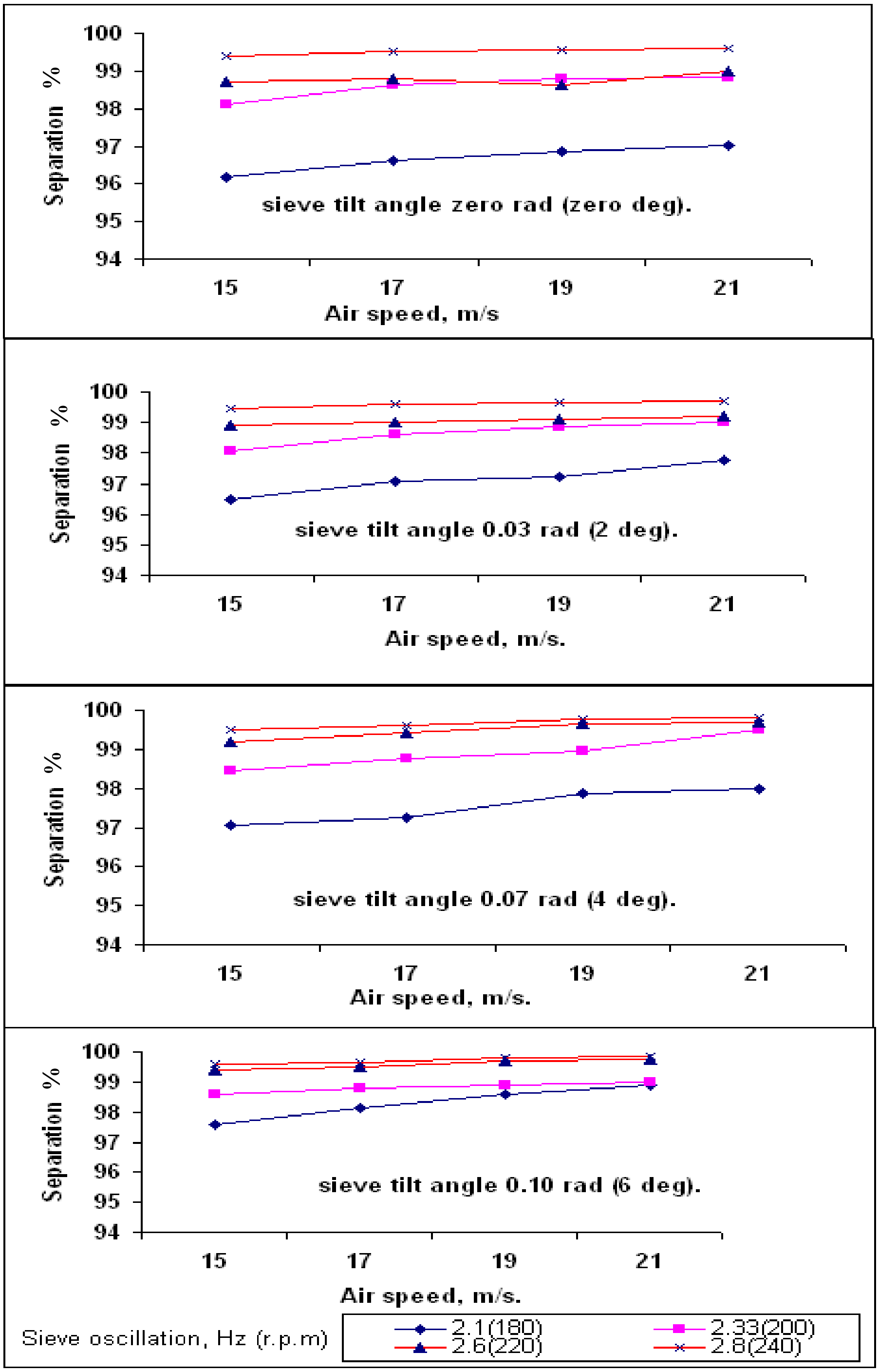


Fig 3 : Effect of air speed on separation at different sieve tilt angles and sieve oscillation values.

c) Sieve tilt angle:

From Fig.3. the separation increased as sieve tilt angle increased in general, at different air speeds and sieve oscillation values at moisture content of 13 % (w.b.) and feed rate of 1000 kg/h. The separation increased from 98.95 to 99.71 % by increasing sieve tilt angle from zero to 0.10 rad (zero to 6 deg.) at sieve oscillation of 2.6 Hz (220 r.p.m) and air speed of 19 m/s.

4) Parameters affecting on total losses:

a) Sieve oscillation.

Data in Fig.4 show the effect of sieve oscillation on total losses. By increasing sieve oscillation the total losses increased, in general, at different sieve tilt angle and air speeds at moisture content of 13% (w.b.) and feed rate of 1000 kg/h. At air speed of 19m/s and sieve tilt angle of 0.10 rad (4deg.), total losses increased from 0.25 to 3.0% by increasing sieve oscillation from 2.1 to 2.8 Hz (180 to 240 rpm).

b) Air speed:

By increasing air speed the total losses increased, in general, at different sieve tilt angle and sieve oscillation values, at moisture content at 13% (w.b.)and feed rate of 1000Kg/hr., as shown in Fig.4. At sieve oscillation of 2.6 Hz (220 rpm), and sieve tilt angle of 0.10 rad (6 deg.), total losses increased from 0.39 to 0.59% by increasing air speed from 15 to 21m/s.

c) Sieve tilt angle;

From Fig.4. the total losses increase as sieve tilt angle increased, in general, at different air speeds and sieve oscillation values at moisture content of 13% (w.b.) and feed rate of 1000 Kg/h. At sieve oscillation of 2.8 Hz (240 rpm), and air speed of 19 m/s. the total losses increased from 2.88 to 3.12% by increasing sieve tilt angle from zero to 0.10 rad (zero to 6 deg.).

5) Estimating the cost of using the machine

Operation cost of the machine was 5 LE/h. (5 LE/ton).

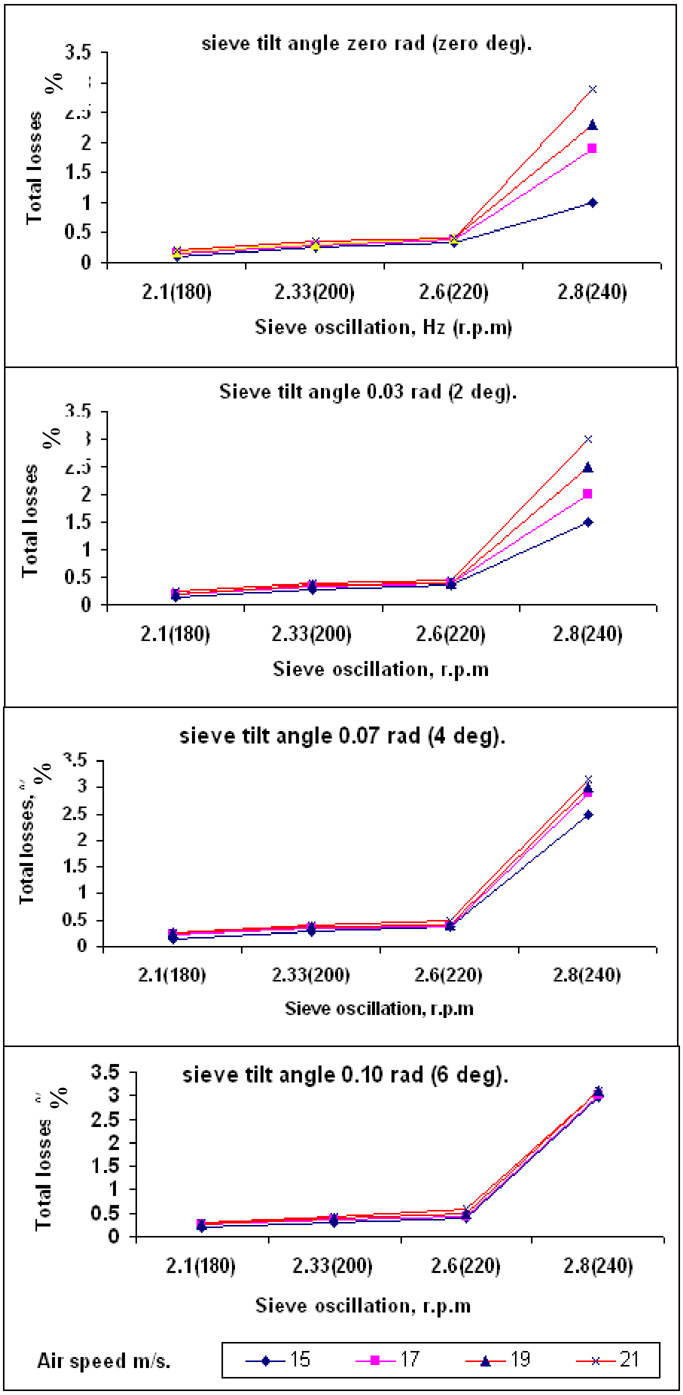


Fig 4: Effect of sieve oscillation on total losses at different sieve tilt angles and air speeds values.

CONCLUSION

The following conclusions have been drawn from this study :

Length, width, thickness, volume, geometric diameter arithmetic diameter, percentage of sphericity, bulk density, true density, transverse surface, flat surface area mass of 1000-seeds and moisture content for grain .was found 9.15, 7.75, 6.04, 223.27, 7.640, 7.53, 82.40, 782.35, 1325.90, 55.67, 36.75, 225 and 13 respectively, Friction angle, coefficient of friction, angle of repose, hardness and terminal velocity for grains and their impurities was found 18.711 and 29 degree, 68 and 15 N, and 17.25 and 13.59 m/sec respectively. The separation increased by increasing sieve oscillation, air speed and sieve tilt angle. The total losses decreased by decreasing sieve oscillation, air speed and sieve tilt angle. The optimum performance was achieved at air speed of 19 m/s sieve tilt angle of 4 degree. sieve oscillation of 220 r.p.m, feed rate of 1000 kg/hr, and moisture content of 13%. Separation efficiency at these conditions was 99.65% and total losses was 0.35 %. The operation cost was found 5LE/h (5LE/ton).

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<u>**الملخص العربي**</u>

العوامل الهندسية المؤثرة علي تنظيف حبوب فول الصويا

د/ جمال كمال عرفه

الهدف من هذا البحث هو دراسة العوامل الهندسية المؤثرة علي تنظيف حبوب فول الصويا اليا وكذلك دراسة الخصائص الطبيعية والميكانيكية لحبوب فول الصويا للحصول علي اعلي نظافة وأقل فواقد لحبوب فول الصويا (صنف كلارك) .

<u>**عوامل الدراسة :-**</u>

١) دراسة الخصائص الطبيعية من حيث الطول ، العرض ، السمك ، الحجم ، القطر الهندسي ، القطر الحسابي ، نسبة التكور ، الكثافة الحقيقية ، الكثافة الظاهرية ، ومساحة المقطعين الطولي والعرضي للحبة ، ومؤشر الحبوب (كتلة الالف حبة) ، والمحتوي الرطوبي للحبوب .

٢) دراسة الخصائص الميكانيكية من حيث زاوية الاحتكاك ، معامل الاحتكاك ، زاوية التكويم ، الصلابة ، سرعة التعليق لكل من الحبوب والشوائب .

٣) دراسة العوامل الهندسية المؤثرة علي النظافة والفواقد مثل سرعة الهواء ، زاوية ميل الغربال ، تردد الغربال ، معدل التغذية عند المحتوي الرطوبي الامثل .

٤) حساب تكاليف التشغيل للالة .

<u>**وكانت النتائج المتحصل عليها كالاتى :-**</u>

١) زادت كفاءة الفصل للحبوب بزيادة كل من سرعة الهواء وتردد الغربال وزاوية ميل الغربال.

٢) قلت فواقد الحبوب الكلية بتقليل كلا من سرعة الهواء وتردد الغربال وزاوية ميل الغربال .

٣) للحصول علي أعلي نسبة نظافة وأقل نسب شوائب فأنة يجب أن تكون سرعة الهواء ١٩ م/ث ، سرعة الغربال الترددية ٢,٦ هرتز (٢٢٠ دورة /د) ، زاوية ميل الغربال ٠,٠٧ دائرية (٤ درجات) ، ومعدل التغذية ١٠٠٠ كج/س ومحتوي رطوبي ١٣% .

٤) وفي هذه الظروف بلغت نسبة النظافة ٩٩,٦٥% ونسبة الشوائب ٠,٣٥%

٥) وجد أن تكاليف تشغيل الاله ٥ جنية/ساعة (٥ جنية /طن) .

باحث – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – مصر .