Modeling the Grain Cleaning Process of a Stationary Sorghum Thresher

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ABSTRACT

Cleanliness is an important quality characteristic for market acceptance of food products. One of the most important valuable additions is reduction of the contaminant to the barest minimum. This research work was carried out between 9/12/2003 and 15/01/2004 with the aim of developing a prediction equation describing the cleaning process in a stationary sorghum thresher using a mathematical model based on physical-aerodynamic properties of sorghum and machine characteristics. Dimensional analysis was used to obtain a functional relationship between the cleaning efficiency and independent variables such as grain moisture content, straw moisture content, grain bulk density, straw bulk density, feed rate, sieve oscillation frequency, threshing cylinder speed, diameter of sieve hole, air velocity and particle density. The developed cleaning efficiency model was verified by comparing the predicted cleaning efficiency with measured experimental data from the sorghum thresher-testing rig. The cleaning efficiency model showed a good agreement between the predicted and experimental result at 5% level of significance.

Keywords: Sorghum thresher, modeling, aerodynamic properties, dimensional analysis, Cleaning efficiency, grain cleaning process.

1. INTRODUCTION

There is an increasing demand for sorghum on domestic and international markets due to many ethnic and dietary foods, snacks and other identity – preserved products with excellent properties appreciated by consumers.

Rooney (2003) reported that a major limitation in producing excellent food products from sorghum is a lack of consistent supply of good quality grain for processing. Contaminants affect the quality of grains and make grains less attractive in appearance therefore they constitute easy habitants for pests, increase handling cost, and ultimately cause low market value (Hurburgh Jr, 1995).

Hopfen(1969) postulated that the cleaning process presents more difficulties than actual threshing process. Choudhury and Kaul (1979) reported that winnowing time is 46.6% higher than the threshing time. Mazvimavi(1997) classified threshing and winnowing of sorghum , which accounts for 50% of total labour used in the production as an arduous task.

The cleaning process is a mass transfer process involving segregation of particles on a pan before coming to the air stream, motion in the air stream and motion after coming out of the air stream (Kashayap and Pandya, 1965). Knowledge of the dynamics of grain –air interaction is essential to adequately understand the cleaning process and to design appropriate cleaning equipment (Freltag, 1968). Modeling the cleaning process in a stationary thresher would help to save energy consumption, thereby reducing the time and cost of winnowing when the knowledge gained is put to use. A better understanding and quantification of the cleaning process would provide means of predicting cleaning efficiency and improve the decision – making process. An analytical description, using mathematical models combining physical-aero-dynamical properties of sorghum with machine constructional and functional parameters would contribute to existing knowledge of the cleaning performance in a conventional grain thresher. The objective of this study is to develop a mathematical model for describing the crop-machine interaction in the cleaning process.

2. THEORETICAL DEVELOPMENT

2.1 Grain Cleaning Approach

Mechanical processes such as threshing and cleaning in a thresher involves dependent variables, which are functions of several independent variables. Grain cleaning can be considered a stochastic process with particles changing orientation in a random manner both in time and space. The physical parameters affecting the cleaning process obtained from literature are broadly grouped into: crop characteristics and machine parameters (Simonyan, 2006).

(i) Crop factors are: crop variety, maturity stage, grain moisture content, straw moisture content, bulk density of grain, bulk density of straw, stalk length, grain diameter.

(ii.) Machine factors: frequency of sieve oscillations, amplitude of oscillation, sieve slope, length of sieve, width of sieve, sieve hole diameter, threshing speed,velocity of air, air stream pressure, air density, angle of air direction and terminal velocity of particles(both grain and other materials).

2.2 Assumptions made in Model Development

There is a need to make simplifying assumptions in order to reduce the number of involved parameters to manageable level, thereby reducing the complexity. The stalk length of the sorghum head was assumed fixed at the peduncle, close to the panicle for all samples. The geometric mean diameter of sorghum grain was assumed constant. Other factors taken as constant during the study were:

(i.) Air density, atmospheric air density was assumed uniform.
(ii.) Sieve slope, was horizontal throughout the experiment
(iii.) Sieve hole diameter was fixed.

These simplifying assumptions reduced the variables to the following: grain moisture content, straw moisture content, bulk density of grain, bulk density of straw, feed rate, frequency of sieve oscillation, threshing speed, velocity of air and sieve hole diameter.

The mathematical expression for cleaning efficiency (η) between the dependent and independent variables given by Simonyan (2006) is:

$$\eta = f_e\,(\theta_g,\ \theta_s, \beta_g, \beta_s, f_r, \alpha, V_t, D, V_a, \rho_p) \qquad 1$$

where

η = Cleaning efficiency (%)
θ_g = Grain moisture content (%)wb
θ_s = Straw moisture content (%)wb
β_g = Grain bulk density (kg/m^3)
β_s = Straw bulk density (kg/m$^{3)}$
f_r = Feed rate (kg/s)
α = Sieve oscillating frequency (1/s)
V_t = Threshing speed (m/s)
D = Diameter of sieve hole (m)
V_a = Air velocity (m/s)
ρ_p = Particle density (kg/m^3)

2.3 Use of Dimensional Analysis.

A mathematical model, using dimensional analysis, was used to characterize the cleaning process of sorghum in a stationary thresher. Degirmencioglu and Srivastava (1996) described dimensional analysis as a useful tool for developing prediction equations of various physical systems. Dimensional analysis reduces the physical quantities pertinent to a system to dimensionless groups. Dimensional analysis is based on the Buckingham Pi theorem. The Buckingham Pi theorem states that "the number of dimensionless and independent quantities required to express a relationship among variables in any phenomenon is equal to the number of quantities involved minus the number of dimensions in which those quantities may be measured (Murphy, 1950). The variables and their corresponding dimensions used in model development are given in Table1.

Table 1: Variables and their corresponding dimensions

Variables	Symbol	Unit	Dimensions Symbol
Grain moisture content	θ_g	%	$M^0L^0T^0$
Straw moisture content	θ_s	%	$M^0L^0T^0$
Grain bulk density	β_g	kg/m^3	ML^{-3}
Straw bulk density	β_s	kg/m^3	ML^{-3}
Feed rate	f_r	kg/s	MT^{-1}
Sieve oscillating frequency	α	1/s	T^{-1}
Threshing speed	V_t	m/s	LT^{-1}
Sieve hole diameter	D	L	L
Air velocity	V_a	m/s	LT^{-1}
Particle density	ρ_p	kg/m^3	ML^{-3}

The dimensional matrix of variables is given as:

	η	θ_g	θ_s	β_g	β_s	f_f	α	V_t	D	V_a	ρ_p
M	0	0	0	1	1	1	0	0	0	0	1
L	0	0	0	-3	-3	0	0	1	1	1	-3
T	0	0	0	0	0	-1	-1	-1	0	-1	0

θ_g, θ_s are dimensionless, hence excluded from the dimensionless terms determination exercise, it was added when the other dimensionless terms were formed.

$$\eta = f_e (\beta_g, \beta_s, f_r, \alpha, V_t, D, V_a, \rho_p) \quad 2$$

The grouping of variables to form the π-terms for the cleaning efficiency is given below

$$\eta^a = \beta_g^b \beta_s^c f_r^d \alpha^e V_t^f D^g V_a^h \rho_p^i = 1 \quad 3$$

while the corresponding dimensional equation is

$$(M^0 L^0 T^0)^a (ML^{-3})^b (ML^{-3})^c (MT^{-1})^d (T^{-1})^e (LT^{-1})^f (L)^g (LT^{-1})^h (ML^{-3})^i = 0 \quad 4$$

When equation four (4) was solved the dimensionless Pi π terms obtained are:

$$\pi_1 = \frac{\beta_g V_t D^2}{f_r} \quad 5$$

$$\pi_2 = \frac{\beta_s V_t D^2}{f_r} \quad 6$$

$$\pi_3 = \frac{\alpha D}{V_t} \quad 7$$

$$\pi_4 = \frac{V_a}{V_t} \quad 8$$

$$\pi_5 = \frac{\rho_p D^2 V_t}{f_r} \quad 9$$

θ_g and θ_s, which are dimensionless, are included with other dimensionless terms obtained from the dimensional analysis.

The functional equation for describing cleaning efficiency involving dimensionless terms is given as:

$$\eta = f_e\left(\frac{\beta_g V_t D^2}{f_r}, \frac{\beta_s V_t D^2}{f_r}, \frac{\alpha D}{V_t}, \frac{V_a}{V_t}, \frac{\rho_p D^2 V_t}{f_r}, \theta_g, \theta_s\right) \qquad 10$$

These dimensionless terms were combined to reduce the number of terms to manageable level.

$$\frac{V_a}{V_t}\eta = f_e(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5) \qquad 11$$

$$\frac{V_a}{V_t}\eta = f_e\left(\frac{\beta_g V_t D^2}{f_r}, \frac{\beta_s V_t D^2}{f_r}, \frac{\alpha D}{V_t}, \frac{V_a}{V_t}, \frac{\rho_p D^2 V_t}{f_r}, \theta_g, \theta_s\right) \qquad 12$$

These dimensionless terms were combined to reduce the number of terms to manageable level.

$$\pi_1^{1} \text{ x } \pi_2^{-1} = \frac{\beta_g V_t D^2}{f_r} \text{ x } \frac{f_r}{\beta_s V_t D^2} = \frac{\beta_g}{\beta_s} \qquad 13$$

$$\pi_3 \text{ x } \pi_4^{-1} = \frac{\alpha D}{V_t} x \frac{V_t}{V_a} = \frac{\alpha D}{V_a} \qquad 14$$

Also combining $\frac{\theta_g}{\theta_s}$ with $\frac{\beta_g}{\beta_s}$ gives

$$\pi_{12} = \frac{\beta_g}{\beta_s} \text{ x } \frac{\theta_g}{\theta_s} = \frac{\beta_g \theta_g}{\beta_s \theta_s} \qquad 15$$

$$\pi_{13} = \pi_5 \text{ x } \left(\frac{\alpha D}{V_t}\right)^{-1} = \frac{\rho_p D^2 V_t}{f_r} x \frac{V_a}{\alpha D} = \frac{\rho_p D V_t V_a}{\alpha f_r} \qquad 16$$

From eqn 11

$$\eta = \frac{V_t}{V_a} f_e(\pi_{12}, \pi_{13}) \qquad 17$$

$$\eta = C f_e(\pi_{12}, \pi_{13})$$

where

η = dependent term

π_{12}, π_{13} = independent terms

C =1.067 which is approximately 1

Hence,

$$\eta = f_e\left[\frac{\beta_g\theta_g}{\beta_s\theta_s}, \frac{\rho_p D V_t V_a}{\alpha f_r}\right] \qquad 18$$

3. MATERIALS AND METHODS

3.1 Laboratory Determinations

To understand the cleaning unit's design better, values of the appropriate design parameters influencing cleaning of sorghum from its constituents were determined.

3.1.1 Diameter of Samples

Micrometer screw gauge (Sheffied S 139 Br) (least count 0.01 mm) was used to determine the diameter of the grains and stalk. The diameter of sorghum grain was measured triaxially (along its three axis) and geometric mean diameter d_e determined as given in equation 22 by Mohsenin, (1980).

$$d_e = (abc)^{1/3} \qquad 19$$

where, a,b,c = diameters along three axes (all in mm).

3.1.2. Bulk Density of Samples

A rectangular container dimensioned 210 by 145 by 72 mm was used. The sample, which filled the container, was weighed using electronic mettler balance (Sarturious 2355, maximum 160g, d 0.001d). The bulk density of the samples were determined using the method given by Mohsenin(1980).

$$\beta = \frac{m}{v} \qquad 20$$

where:

m = mass of grain, chaff or straw (kg)
v = volume of container (m^3)

3.1.3 Moisture Content.

Moisture content of samples was determined using the procedure detailed by Henderson et al (1997). The samples were dried at 130^0C for 18 hours (ASAE, 1983). The weight loss of the samples was recorded and the moisture in percentage determined. This was replicated three times. The moisture content was calculated as:

$$MC_{wb} = \frac{W_i - W_d}{W_i}.100 \qquad 21$$

where:

MC_{wb} = Moisture content, wet basis, %.
W_i = Initial weight of sample, kg.
W_d = dried weight of sample, kg

3.1.4 Time

Crop feeding times in seconds were measured with stopwatch. A stopwatch (Precista max 60, d =15) was used to determine the measurement of air velocity in meters per second.

3.1.5 Shaft Speeds

A tachometer (Smith Industrial Division, London HW2, max 50,000 rpm, d=1 rpm) was used to determine the speed of cylinder shaft.

3.1.6 Air Velocity

Air velocity from radial blade centrifugal fan was determined using anemometer (Pruufschein Fur Anenometer, L-Nr, 3010/112546). The anemometer was placed in the air stream between the upper and lower sieve when the threshing began.

3.1.7 Feed Rate:

Approximate feed rate was computed as weight of crop fed into machine per unit time (hr).

3.1.8 Cleaning Efficiency:

Cleaning efficiency (Purity) was obtained by the procedure detailed by National Institution of Agricultural Engineering (NIAE, 1952):

$$\eta = \frac{G_0}{G_0 + C_{cg}}.100 \qquad 22$$

where:
η =cleaning efficiency, %

G_o = weight of pure grain at the outlet, kg
C_{cg} = weight of contaminant (MOG), kg

3.1.9 Linear Velocity

For a rotating shaft with speed n and pulley of radius r

$$V = \frac{2\pi rn}{60} \qquad 23$$

In which n is speed in revolutions per minute and V is m/s

3.1.10 Sieve Oscillation Frequency

The sieve oscillation frequency, α, was obtained from Eq. 24

$$\alpha = \frac{N}{t} \qquad 24$$

where:
N = number of reciprocations
t = time in seconds

3.2 Sorghum Thresher Test Rig Configuration

The sorghum thresher test rig prototype was built at Agricultural Engineering Technology Programme, Samaru College of Agriculture, Ahmadu Bello University, Zaria, Nigeria. Figure 1 shows a view of the sorghum thresher-testing rig whose overall dimensions are 1323mm height, 1474 mm length and 386 mm width.

Figure 1: Side view of the sorghum thresher testing-rig

3.3 Principle of Operation of Sorghum Thresher Testing Rig

Sorghum head samples, which have already been weighed, were fed manually into the hopper and they flowed under gravity into the threshing chamber where impacts from the revolving threshing cylinder threshed the grain out of the head. Grains were detached from sorghum heads by a combination of stripping, rubbing and impact actions. After contacting the threshing cylinder, the straw and detached kernels accelerate round the concave at different rates due to variation of the coefficient of restitution of straw and grains. Threshed and partially threshed heads and grains fall through the concave on the reciprocating upper sieve. As the sieves reciprocate due to horizontal and vertical displacement, the straws move to the back of the thresher to be discharged.

Air stream helps to disperse grain and straw allowing grain to pass through the upper sieve openings to the lower sieve. As grain and chaff passed across air stream, the lighter materials are blown off, while clean grain was collected in collector compartments.

3.4 Data Analysis.

The method of regression analysis as described by Gomez and Gomez (1984) was used to describe the relationships. General Linear Model (GLM) procedure of Statistical Analysis System (SAS, 1989) was used to analyze the data. The standard error (SE) of each mean was calculated. The means of the cleaning efficiency obtained from the collectors were statistically compared using the least significance difference (LSD).

4. RESULTS AND DISCUSSION

4.1 Cleaning Efficiency Prediction

The general prediction equation for the cleaning efficiency is

$$\eta = 0.41\pi_{12} - 10.21\,\pi_{13} + 93 \qquad 25$$

Substituting the dimensionless parameters gives:

$$\eta = 0.41\frac{\beta_g\theta_g}{\beta_s\theta_s} - 10.21\frac{\rho_p L V_t V_a}{\alpha f_r} + 93.09 \qquad 26$$

4.2 Verification of Cleaning Efficiency Model

The cleaning efficiency is influenced by various factors, which act in a complex manner that prevent their effects to be separately evaluated. Nevertheless, their influence on the cleaning process was studied. Quadratic function was used to describe the relationship between cleaning efficiency and variables. Rumble and Lee (1970) and Farran and Macmillan (1979) reported that the effect of material rates on separation efficiency is parabolic.

4.2.1 Effect of Grain Bulk Density

Figure 2 shows the effect of grain bulk density on the cleaning efficiency. As seen in the figure there is non-linear increase in the cleaning efficiency with increasing bulk density of sorghum grain, although there was an initial decrease in the cleaning efficiency with increase in grain bulk density. The increasing behaviour could be due to the material having more resident time on the oscillating sieve. The matting effect resulting from increase in bulk density might have caused the grain to trickle through the sieve holes, thereby reducing the load intensity of material presented across the air current.

$$\eta = 499.44 - 1.49\beta + 0.001\beta^2 \qquad R^2 = 0.99$$

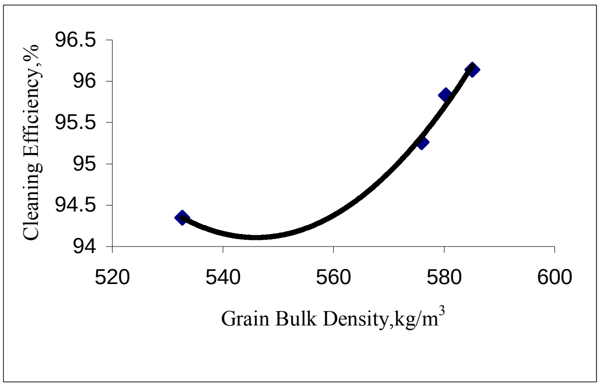

Figure 2: Effect of grain bulk density on cleaning efficiency

4.2.2 Effect of Straw Bulk Density

The behaviour of the cleaning efficiency with increasing straw bulk density is presented in Figure 3. There is an increase in the cleaning efficiency from 95.26 % when the straw bulk density was 35.31 kg/m^3. The maximum cleaning efficiency of 96.14 % was obtained at straw bulk density of 36.5 kg/m^3. Thereafter, the cleaning efficiency decreased with increasing bulk density. This behaviour shows that increasing the straw bulk density above a threshold leads to a subsequent decrease in the cleaning efficiency. This may be due to increase in load intensity of materials being cleaned. A constant air current and increasing load may lead to a decrease in the cleaning efficiency. The magnitude of the load intensity depends on the bulk density of the input material (Mkomwa, 1988). Rumble and Lee (1970) noted that for aerodynamic separation to occur, the particles in a mixture must be accelerated as free dispersed bodies and not as a mat. Foster (1967) reported that presence of short straws creates problems of sieve blockage and reduction in the quality of final cleaned product.

$$\eta = -897.33 + 54.52\beta - 0.75\beta^2 \quad R^2 = 0.95$$

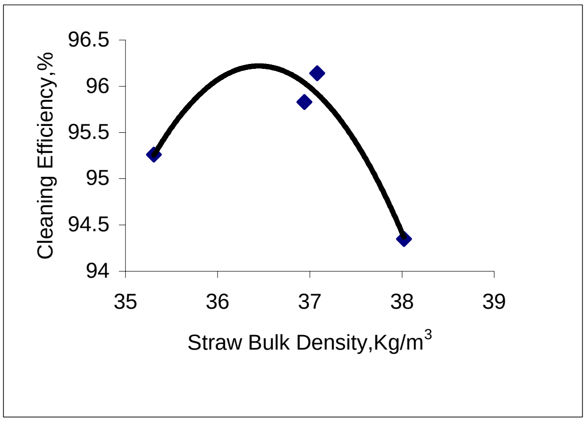

Figure 3: Effect of straw bulk density on cleaning efficiency

4.2.3 Effect of Grain Moisture Content

Figure 4 presents the effect of grain moisture content on the cleaning efficiency. There is a decrease in the cleaning efficiency with increasing grain moisture content. The cleaning efficiency was 96 % at 7.63 % wb and 94.4 % at 10.37 % wb moisture content respectively. Increasing moisture content may lead to more adhesiveness between the sorghum grain and other constituents to be separated. Mohsenin (1980) reported that the difference in moisture content between the grain and threshed constituents is advantageous since it will increase the weight surface area ratio differences on which the terminal velocity depends would increase. Phillips and O'Callaghan (1974) published that the efficiency of both primary and secondary grain /straw separation is reduced with increasing moisture content.

$$\eta = 106.72 - 2.01\theta + 0.08\theta^2 \quad R^2 = 0.83$$

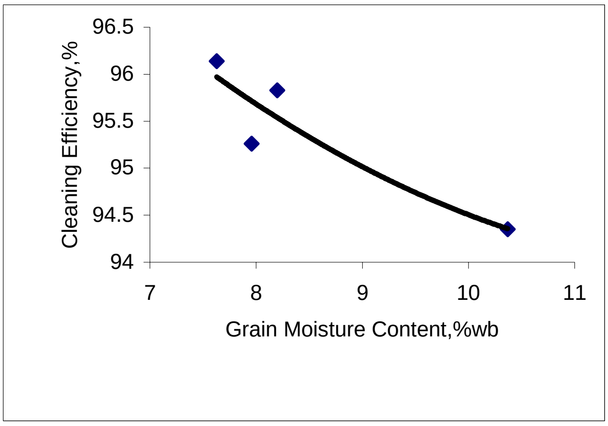

Figure 4: Effect of grain moisture content on cleaning efficiency

4.2.4 Effect of Straw Moisture Content

The relationship between cleaning efficiency and straw moisture content is depicted in Figure 5. There was a decrease in the cleaning efficiency with increasing moisture content between 6.52 and 9.3 % wb. At straw moisture content of 6.52 % wb, the cleaning efficiency was 96 % while at 9.3 %wb the cleaning efficiency was 94 % respectively. The decrease in cleaning efficiency may be due to increased adhesiveness between the sorghum grain and the straw. Phillips and O' Callaghan (1974) noted that as the surface of the straw becomes damp, the coefficient of straw – metal friction increases, causing transport problems. Mkomwa (1988) reported that an increase in the moisture content affects the cohesion and frictional properties of particles. An increase in moisture content within the bound-water-region increases the molecular and/or coulomb forces between particles. Therefore, increasing moisture might cause increased "stickiness" effect between particles.

$$\eta = 113.05 - 3.99\theta + 0.21\theta^2 \quad R^2 = 0.88$$

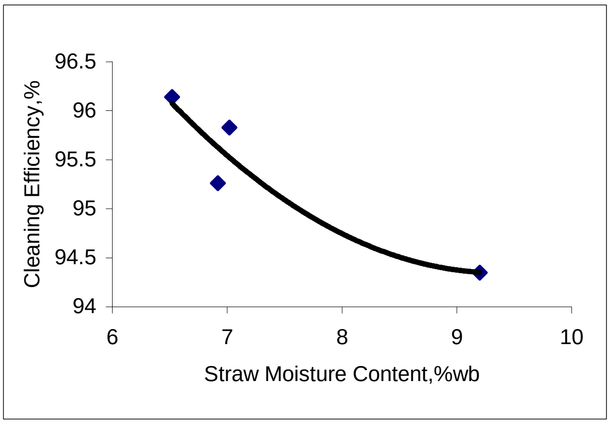

Figure 5: Effect of straw moisture content on cleaning efficiency.

4.2.5 Effect of Threshing Cylinder Speed

Figure 6 shows the effect of the threshing cylinder speed on the cleaning efficiency. There is a decrease in the cleaning efficiency with increasing speed of the cylinder. When the threshing cylinder speed is 3.5 m/s, the cleaning efficiency is 96% while the threshing cylinder speed is 5.6 m/s the cleaning efficiency is 94.4%. . Increasing the threshing cylinder speed results in more imparts on the sorghum head introduced to the concave. The materials other than grain are also chopped into fine particles, which results in more materials load being delivered to the sieve for separation. Also, the increased cylinder speed results in an increased range of particle sizes and formation of minute particles, which aerodynamically resembles sorghum grain thereby creating challenges in cleaning operation.

$$\eta = 92.34 + 2.12V_t - 0.31\,V_t^2 \quad R^2 = 0.67$$

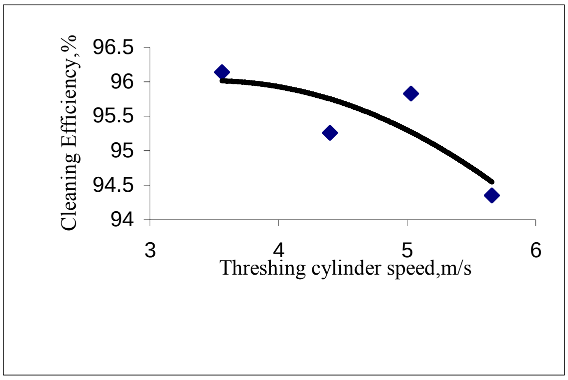

Figure 6: Effect of threshing cylinder speed on cleaning efficiency

4.2.6 Effect of Air Speed

The effect of the air speed on the cleaning efficiency is given in Figure 7. There is a decrease in the cleaning efficiency with increasing air speed. When the air speed was 4.67 m/s, the cleaning efficiency was 96.4 % and 94.4 % when the air speed was 7.33 m/s. The decrease in the cleaning efficiency as a result of increasing air speed may be due to reduction in the resident time of flight of materials to be cleaned within the air stream. Grochowicz (1980) reported that when the resident time is longer, it positively affects the efficiency of separation, as there is greater likelihood for lighter particles being displaced in the air stream.

$$\eta = 89.21 + 2.09\,V_a - 0.16V_a^2 \quad R^2 = 0.55$$

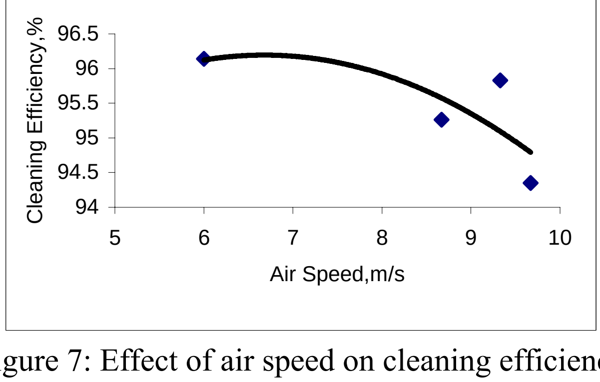

Figure 7: Effect of air speed on cleaning efficiency

4.2.7 Effect of Sieve Oscillation Frequency

The effect of the sieve oscillating frequency on the cleaning efficiency is given in Figure 8. There was a decrease in the cleaning efficiency with increasing sieve oscillation frequency within the range of 6 oscillations/ sec and 12 oscillations /sec. When the sieve oscillations frequency was 6 oscillations /sec, the cleaning efficiency was 96 % and this decreased to 94.6 % when the sieve oscillations frequency increased to 12 oscillations /sec. The decrease in the cleaning efficiency with increasing sieve oscillations may be due to less resident time of the materials to be separated on the sieve and the increase agitations allows more materials to pass through the sieve holes. The increase load intensity of materials resulting there from may be the reason for the decrease in cleaning efficiency. Harrison and Blecha (1983) described the transport of particles along the oscillating sieves, which is a function of sieve oscillation frequency, affects the efficiency of the process and affects the metering of particulate substances along the sieve. Feller and Foux(1975) indicated that the frequency affects the passage of particles through the sieves.

$$\eta = 94.71 + 0.44\,\alpha - 0.04\,\alpha^2 \quad R^2 = 0.67$$

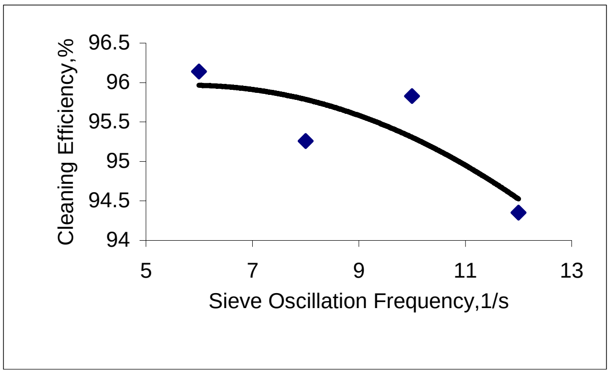

Figure 8: Effect of sieve oscillation frequency on cleaning efficiency

4.2.8 Effect of Feed Rate

Figure 9 gives the effect of feed rate on the cleaning efficiency. There was an initial increase in the cleaning efficiency with increasing feed rate until a maximum value of 96.5 % was obtained at 9.58kg/s. After this, there was a decrease in the cleaning efficiency with increasing feed rate. The behaviours of the cleaning efficiency against the feed rate may be due to increasing load intensity on the sieve. Multiple particles act as obstructions to the airflow. An increase in the number of particles causes turbulence while a decrease lowers the free stream turbulence intensity, which causes the drag coefficient to decrease (Mkomwa, 1988) for alfalfa.

$$\eta = 44.23 + 649.65F_r - 2031.8\,F_r^2 \quad R^2 = 0.97$$

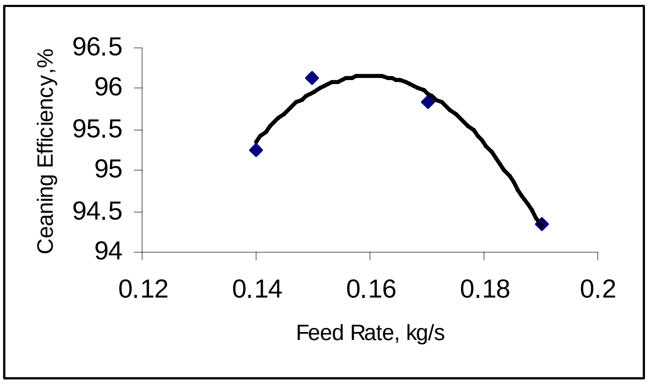

Figure 9: Effect of feed rate on cleaning Efficiency

Verification of the predicted cleaning efficiency model is important before it can be used for any research or design work. The result of the predicted cleaning efficiency was compared with the measured experimental data from the sorghum thresher-testing rig.

The predicted was compared with measured cleaning efficiency model, applying the hypothesis b-β = 0, which will only happen when $\eta_p = \eta_m$.

To test the significance of β the residual mean square was computed using equation 27 given by Gomez and Gomez (1984).

$$S_{y.x}^2 = \frac{\sum y^2 - \frac{\left(\sum xy\right)^2}{\sum x^2}}{n-2} \qquad 27$$

=0.02855

The t value was computed using equation 28.

$$t_b = \frac{b}{\sqrt{\frac{S_{y.x}^2}{\sum x^2}}} \qquad 28$$

= 0.455

To test the significance of β, the computed t_b value was compared with the tabular t value. The tabular t values at the 5% and 1% level of significance, with (n-2) =2 degrees of freedom, are 4.303 and 9.925 respectively is greater than the computed t_b value of 0.455 even at the 5% level of significance. β is judged significantly different from zero if the absolute value of the computed t_b value is greater than the tabular t value at the prescribed level of significance. Since the tabular values are greater than the computed values, there is no significance difference between the predicted and measured slope. In that case b -β = 0

The hypothesis that $\alpha = \alpha_0$ was further tested using equation 29 given by Gomez and Gomez (1984):

The t_a value was computed as:

$$t_a = \frac{a - \alpha_o}{\sqrt{S_{y.x}^2\left(\frac{1}{n} + \frac{\overline{X}^2}{\sum x^2}\right)}} \qquad 29$$

=0.0104

The tabular t value was compared with the computed t value with (n-2) degrees of freedom at 1 % and 5 % levels of significance. The computed t_a value of 0.0104 is smaller than the tabular t value with (n-2) = 2 degrees of freedom, 4.303 and 9.925 for 5% and 1% level of significance respectively. Since the tabular t value is greater than the computed t value even at 5% level of significance, there is no significance difference between α and α_0. That is, the intercept is zero.

Hence, the two tests showed that the predicted model is not significantly different from 1:1 model equation. Figure 10 gives the plot of the predicted against measured cleaning efficiency.

$\eta_m = 0.918\eta_p + 3.36 \qquad R^2 = 0.97$

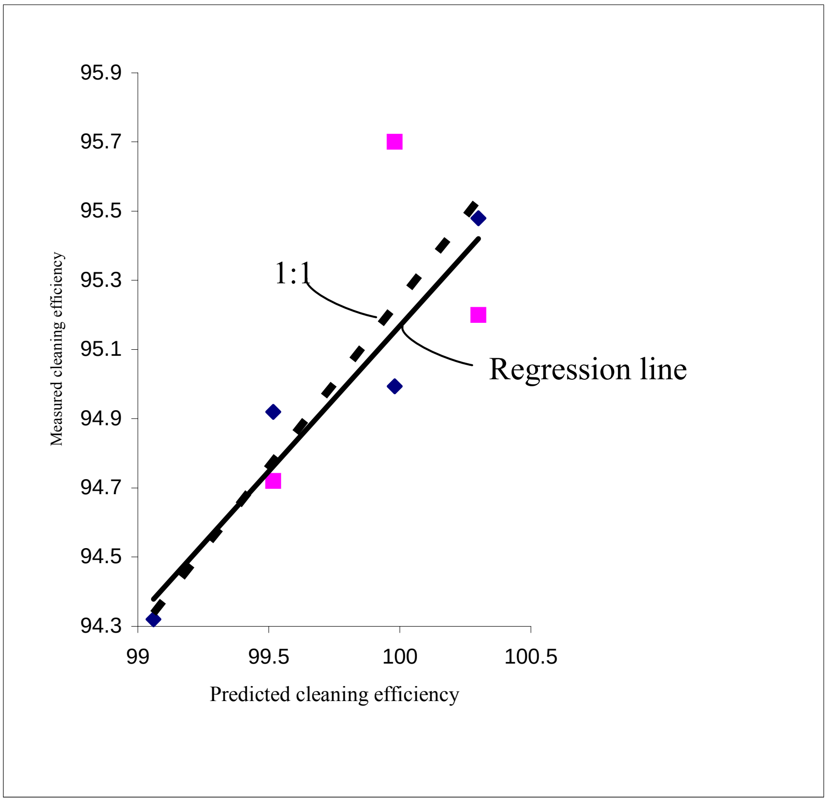

Figure 10: Plot of measured against predicted cleaning efficiency

5. CONCLUSIONS

The grain cleaning is a stochastic process with particles changing orientation randomly in an unprescribed manner both in time and space.

Mathematical model using dimensional analysis was developed and used to characterize the cleaning process in a stationary sorghum thresher. The dimensional analysis approach was used to obtain functional relationship between cleaning efficiency and independent variables, grain moisture content, straw moisture content, bulk density of grain, bulk density of straw, feed rate, frequency of sieve oscillation, fan speed, velocity of air and sieve hole diameter.

The developed cleaning efficiency model was verified by comparing the predicted with measured experimental result from a sorghum thresher test rig. Result showed a good agreement between the predicted and experimental results at 5% level of significance.

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