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Incorporating Skewness and Kurtosis in Improvement of Combine Harvester Cleaning System Performance

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Abstract: **Generally cereals are harvested by conventional or axial flow combines where the operations of gathering and cutting, threshing, separation, cleaning and conveying of grains to grain bin are done. The combine performance characteristics are related to threshing ability, minimum amount of loss and fuel consumption. Although the mean of combine losses is about 2-5% in advanced countries, unfortunately in Iran is about 20% and higher. The loss of combine harvester is divided to header loss, threshing loss, cleaning loss and the loss from different parts of of combine body. Cleaning is one of processes which has more effect on combine performance. The cleaning shoe performance is affected by the following factors: Design factors, operating conditions and crop properties. Material feed rate, fan speed (air flow) and chaffer openings are operating factors have more effect on cleaning unit performance of combine harvester. In order to evaluate effect of these parameters on cleaning unit performance, experiments were conducted in 3×3×3 factorial pattern with Randomize Blocks design. The results showed that all independent factors, are studied in this paper, have significant effect on two important distribution characteristics, namely Skewness and Kurtosis and subsequently on sieve losses. Also, this shows the importance of using mechanical and pneumatic grain separation from MOG in combine harvester's cleaning unit.**

Keywords: **Combine, Loss, Skewness and Kurtosis**

I. INTRODUCTION

Less than a dozen plant species provides over 80% of mankind's diet, and among these plants, the cereal crops has the first place [1].

The combine performance characteristics are related to threshing ability, minimum amount of loss and fuel consumption. Although the mean of combine losses is about 2-5% in advanced countries, unfortunately in Iran is about 20% and higher [10]. The loss of combine harvester is divided to platform cutting loss, threshing loss, cleaning loss and the loss of body. Cleaning refers to the final separation of grain from other materials, which consists mainly of chaff and broken straw pieces. The grain separated at the threshing cylinder and the separation unit is combined on an oscillating conveyor or a set of augers that feed the mixture of grain and chaff to the cleaner, often referred to as the cleaning shoe. The separation is accomplished due to aerodynamic and mechanical actions. The cleaning shoe design consists of two or three oscillating adjustable-opening sieves and a paddle-type fan to blow air through the sieve openings. The crop is dropped on the top sieve (chaffer sieve) near the front of the shoe. The chaff gets blown off by the air and the grain falls through the openings on to the lower sieve (cleaning sieve). The performance of a cleaning shoe is expressed in terms of (1) grain loss or cleaning efficiency, (2) cleaner capacity, and (3) grain dockage. Grain loss is calculated by determining the percentage of lost grain on the basis of the total grain entering the cleaning shoe. The cleaning efficiency is the percentage of grain recovered by the shoe. Grain dockage is the amount of chaff that is separated with grain. The cleaning shoe performance is affected by the following factors:

a) Design factors such as sieve size, oscillation amplitude and frequency.

b) Operating conditions including material feed rate, cleaning shoe slope, air flow, and chaffer openings.

c) Crop properties including grain to MOG ratio, chaff and grain properties [1].

German and Lee (1969) [1] reported on the effects of the frequency of oscillation on the shoe performance. German and Lee (1969) also studied the effect of air volume on cleaning performance. Kutzbach (2003) studied separation process on cleaning unit of combine harvesters and extracted important equations such as separation rate, The cumulative sum of the separated grain, The separation efficiency and remaining unseparated grain. Voicu and et al. (2009) developed a mathematical model of separation of the seeds on plane sieves by using dimensional analysis.

The particles movement through the material layer is random, due to the material heterogeneity and to the irregularity of the seeds, which have different dimension and form, smooth or raw surfaces, different degrees of humidity or density and so on. Because the grain separation process has a random nature, numerous surveys which are concerned with the modeling of this process are based on stochastic theory (Song, 1990; Wang, 1994). In addition, Empirical and physical approaches are presented to model the cumulated separated grain sum function SG, whereas analytical equations are used for kernel motion behavior modeling. Like empirical methods, stochastical and physical approaches need one or more exponential functions to describe the grain separation process. Mathematical models to describe the separation process in grain harvesters may have the following advantages: reduction in test expenditure, improved understanding of fundamental relationships, hints for possible improvements, simulations of the influences of different parameters, and the estimation of possible performance increases.

The distribution analysis of experimental data points for the separation intensity on upper sieve length of the cereal combine harvester's cleaning system indicate that curve profiles have a bell shape with a certain asymmetry degree. This profile can be described more or less adequately by means of different equation forms known in

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the mathematical models literature [4]-[5].

Two important distribution characteristics are captured by central moments of higher order, namely skewness and kurtosis [8].

Skewness, in probability theory and statistics, is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean. The skewness value can be positive or negative, or even undefined (Fig. 1). If one or more observations are extremely large, the mean of the distribution becomes larger than the median and the distribution is called positively skewed (SK>0). If one or more observations are extremely small, the mean of the distribution becomes smaller than the median and the distribution is called negatively skewed (SK<0).

The skewness or the coefficient of asymmetry of a sample is given by:

$$\mathrm{SK} = \frac{\mathrm{m}_3}{\mathrm{m}_2\sqrt{\mathrm{m}_2}} \quad (1)$$

$$m_2 = \frac{\sum(X-\bar{X})^2}{n} = \frac{n-1}{n}S^2 \quad (2)$$

$$\mathrm{m}_3 = \frac{\sum(\mathrm{X}-\bar{\mathrm{X}})^3}{\mathrm{n}} \quad (3)$$

Where $\bar{x}$ is the sample mean, s is the sample standard deviation, and the m_2 and m_3 are the second and third central moment of sample, respectively. Also, Skewness can be calculated from the following equation that is known Pearson's moment coefficient of skewness:

$$g_3^* = \frac{3(mean-modian)}{S} \quad (4)$$

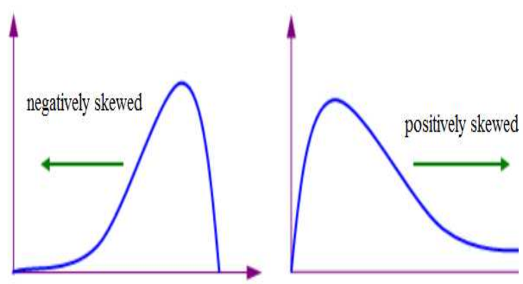

Fig. 1. positively and negatively skewed

Also A kurtosis is any measure of the "peakedness" of the probability distribution of a real-valued random variable. In a similar way to the concept of skewness, kurtosis is a descriptor of the shape of a probability distribution. The coefficient of kurtosis of a sample is obtained as:

$$\mathrm{KU} = \frac{\mathrm{m}_4}{(\mathrm{m}_2)^2} \quad (5)$$

$$m_4 = \frac{\sum(X-\bar{X})^4}{n} \quad (6)$$

Where m_4 is the fourth central moment of sample.

The kurtosis of the standard normal distribution is 3. A curve is called a leptokurtic curve (“lepto” means slender) if KU > 3. A curve is called a mesokurtic curve meso” means intermediate) if KU = 3. A curve is called a platykurtic curve (“platy” means flat) if KU < 3 (Fig. 2) [8].

Voicu and et al. (2008) illustrated how some of the continuous distributions can be used for describing the variation separation intensity of seeds on sieve length. In this study, the Pearson coefficients show that some curves are far from the normal distribution, and better fits can be obtained with other distributions which can describe more adequately different degrees of skewness and peakedness of the curves and in final the considered probability laws are: normal, gamma, Weibull and beta distributions. The best results were obtained with gamma and beta distributions.

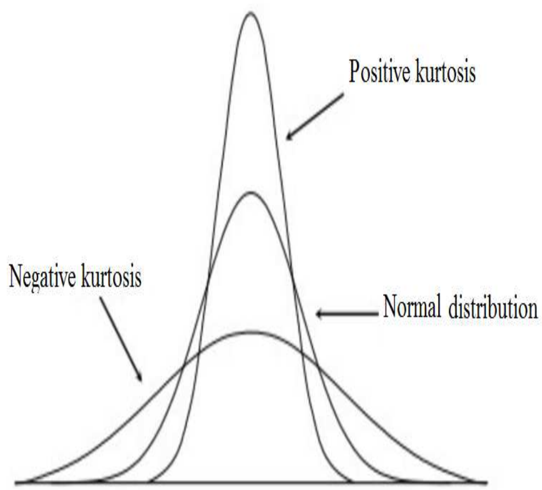

Fig. 2. Positive and negative kurtosis and normal distribution

In this paper, the effects of operating conditions including material feed rate, fan speed (air flow) and chaffer openings on skewness and kurtosis of separated grain graph along sieve are studied.

II. MATERIALS AND METHODS

This study was carried out in three stages:

Providing experiments condition — All experiments were carried out on the 68’s Sahand combine harvester, built in the Industry promotion of Azerbaijan Co. According to targets of this study, the parts of the grain pan, upper sieve, fan, adjustable wind deflector and fingers assembled on the main chassis. Then a woody grain tray with dimension of 160×102 cm^2 is devided in 11 parts with dimenshion of 14×102cm^2 (10 first parts to measure separated grain along sieve length and last part to measure loss), was made. Fig. 3 shows a schematic diagram of a cleaning shoe and woody grain tray used in this study.

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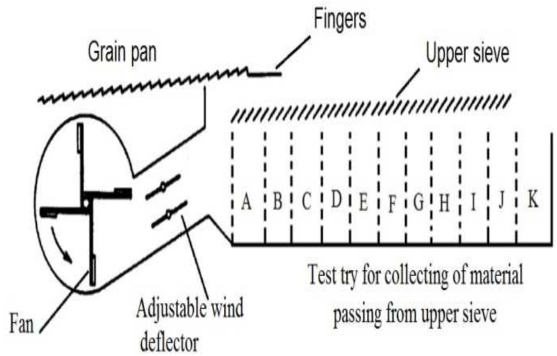

Fig 3. A schematic diagram of a cleaning mechanism

In order to oscillated move to upper sieve, the Tiller manufactured by Mitsubishi company was used. For adjusting the rotational speed of the fan, an electric motor and inverter were used. Fig. 4 shows this test stand.

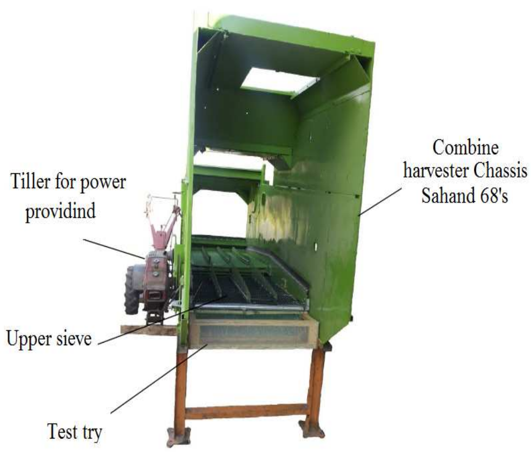

Fig 4. Test stand

Sampling — Irrigate-Shiroudi wheat- cultivar, was chosen for experiments.

The product (approximately 18-20% moisture content), a week before harvesting time, was harvested by 68's Sahand Combine(conventional combine) with the usual settings and transported to laboratory (Research and Development department of Industry promotion of Azerbaijan Co.)

To maintain the initial moisture of product and prevent the effect of its changes on experiments' results, samples were kept in plastic bags. Independent variables in this experiment were feed rate, fan speed and sieve openings. Skewness and Kurtosis of grain separation graph were dependent factors. In order to evaluating of these parameters effect on dependent factors, an experiment was conducted in 3×3×3 factorial pattern with Randomized Blocks design [6].

Table I shows levels of treatments in this study.

Run test—Before each test repetition, identification of each test was prepared and then in order to run test, crop was brought out from bag. According to test number, a necessary adjustment on the test stand (feedrate, fan speed and sieve openings) was performed and then materials feed in to grain pan.

The content of boxes within, after the record of test number and box number, were transferred into small bags. After separation of grain from MOG(Material Other than Grain), the grains' content of each test boxes was weighted by digital scale with 0.1 g sensitivity. Then the results of grain passing sieve were analyzed in SPSS software.

Table I. levels of treatments

Factors	Levels
Fees rate (A)	A_1= 1.56kg/s A_2= 1.93kg/s A_3= 2.33kg/s
Fan speed (B)	B_1=450 rpm B_2=600 rpm B_3=750 rpm
Sieve openings (C)	C_1=6 mm C_2=8 mm C_3=10 mm

III. Results and Discussions

Variance analysis of grain separation graphs skewness — The result of variance analysis of grain separation graphs was shown in table II.

According to table II, the effects of all factors and also Interactions effects of A×B and B×C were significant at 1% level. But the interaction effects of A×C and A×B×C weren't significant. Study of interaction effects of A×B and B×C showed these significant are changes in amount of these factors. Hence, in this section, the results of main factors' effect were analyzed.

Skewness mean of grain separation graphs are shown in table III at different levels of independent factors.

As shown in Table III, significant difference between all levels of feed rate factor is observed at 1%. So that, maximum skewness of grain separation along sieve with amount 2.49 obtained at firs level of feed rate (A1 =1.56kg/s) and minimum skewness with amount 2.29 take placed at last level of feed rate namely 2.33kg/s. This table (Table III) shows that skewness is decreased with increase of feed rate. In other words, with increase of material feed rate, the peak of separated grains graphs along sieve to be drawn to end of sieve. This subject increases probability of sieve grain loss. One reason for increase of sieve grain loss with feed rate increase,is decrease of grains penetration probability in thicker layer of material. So that, with increase of feed rate, grains has less possibility to influence between material layer and this increases reach time of grains to sieve surface and passing from openings. Last subject causes the increase of grain loss of upper sieve. The results of this section corresponded to Kutzbach study that loss increases with increase of material feed rate.

Table II. variance analysis of skewness

Source	DF	Mean square	F
Feed rate (A)	2	0.27	137.71**
Fan speed (B)	2	0.31	154.07**
Sieve openings (C)	2	0.16	81.58**
A×B	4	0.025	12.59**
A×C	4	0.004	2.16ns
B×C	4	0.02	9.47**
A×B×C	8	0.02	1.23ns
Error	52	0.02	

** and ns: significant at 1% level of probability and non significant, respectively.

The comparison between skewness of separated grains graphs at different levels of fan speed shows that there is significant difference between all levels of fan speed at 1% level. So that, the maximum skewness of grain passing from sieve openings with 2.46 at 450rpm and minimum amount of skewness with 2.26 at 750 rpm fan speed take placed. Also table III showed that the skewness is reduced with increase of fan speed. One of the main reasons for last event is more handling grains materials to sieve end by increasing fan speed. As a result, the amount of grain passing from sieve openings in front rows of openings is decreased but the amount of grain passing at rear rows of openings is increased. This means, the peak of separation process graph moves to rear of sieve. This subject causes to increase the rear loss of combine harvester.

Table III. Skewness mean

Factors	Levels	Mean
Fees rate (A)	A_1= 1.56kg/s	2.49a
	A_2= 1.93kg/s	2.37b
	A_3= 2.33kg/s	2.29c
Fan speed (B)	B_1=450 rpm	2.46a
	B_2=600 rpm	2.42b
	B_3=750 rpm	2.26c
Sieve openings (C)	C_1=6 mm	2.31a
	C_2=8 mm	2.37b
	C_3=10 mm	2.47c

Also in relation skewness with the amount of sieve openings, table III shows that there is significant difference between the skewness and all levels of amount of sieve openings factor at 1% level. This table also shows the amount of skewness increases with increase of the upper sieve openings amount. In other words, with increase of sieve openings, more percentage of grain materials can pass from front openings and this causes the peak of skewness go to higher amount. Also with increase of amount of sieve openings, the velocity of air passing from these openings is reduced. Because in fixed rate of air blowing, If the cross-sectional area is increased, the wind speed would decreased and this causes to move the peake of separated grains graphs to sieve front. These events means that less grain goes to end sieve and a result, the rear loss is decreased.

Variance analysis of grain separation graphs kurtosis — The result of kurtosis variance analysis of grain separation graphs was shown in table IV. Table IV shows that the effects of all factors and also Interactions effects of A×B, B×C and A×B×C were significant at 1% level and A×C at 5%. Study of interaction effects of A×B, B×C and A×B×C showed these significant are changes in amount of these factors. Hence, similar above section, in this section, the results of main factors' effect were analyzed.

Table V shows kurtosis mean of grain separation graphs at different levels of independent factors.

According to table IV, kurtosis of separated grains graphs is decreased with increase of materials feed rate. In other words, by increasing of feed rate, distribution curves of grain separation along sieve becomes flat. With increase of feed rate, the material layer becomes thicker. This event causes the probability of grain penetration in material layer is decreased. Also with increase of material feed rate and thicker layer of material on the sieve, grains need long time to arrive to the sieve surface. These are main reasons for reduction of kurtosis and increase of rear grain loss.

Associated with increasing of kurtosis of separated grains along sieve at level 1 to 2 fan speed factor, it can be noted that the results of this section and the results of the theoretical analysis and the previous section aren't match. Although, it can be possible to achieve reliability results with more frequent testing and also add more levels to this factor.

Also the comparison between kurtosis of separated grains graphs at different levels of sieve openings shows that there is significant difference between all levels of this factor at 1% level (table V). Last table shows this fact that with sieve openings increasing; the amount of kurtosis is increased. One of the major reasons for this increasing is increase of probability of grain passing among MOG and passing from first rows openings. It causes more grains passe from first section of sieve and subsequently, the kurtosis is increased. Also, similar above section, with increase of amount of sieve openings, the velocity of air passing from these openings is reduced. Because in fixed rate of air blowing, If the cross-sectional area is increased, the wind speed would decreased and this causes to less loss of rear combine.

Table V refers to this fact that the amount of kurtosis is reduced dramatically with increase of fan speed between level 2 and 3 level. This is relevant to terminal velocity of wheat. So that, with increase of fan speed, air velocity is increased and this causes the more grain be transferred to rear of sieve. This subject means that with increase of fan speed, curve goes to more flat. It causes the increase of grain loss of upper sieve.

IV. CONCLUSIONS

The results show that all independent factors, are studied in this paper, have significant effect on two important distribution characteristics, namely skewness and kurtosis and subsequently on sieve loss. Also, this shows the importance of using mechanical and pneumatic grain separation from MOG in combine harvester.

Table IV. Variance analysis of grain separation graphs kurtosis

Source	DF	Mean square	F
Feed rate (A)	2	7.67	151.65^{**}
Fan speed (B)	2	15.56	307.52^{**}
Sieve openings (C)	2	24.74	488.85^{**}
A×B	4	0.39	7.71^{**}
A×C	4	0.13	2.56^{*}
B×C	4	11.58	228.87^{**}
A×B×C	8	0.382	7.54^{**}
Error	52	0.051	

** and *: significant at 1% and 5% level of probability, respectively.

Table V. Kurtosis mean

Factors	Levels	Mean
Fees rate (A)	A_1= 1.56kg/s	6.36a
	A_2= 1.93kg/s	5.89b
	A_3= 2.33kg/s	5.3c
Fan speed (B)	B_1=450 rpm	6a
	B_2=600 rpm	6.52b
	B_3=750 rpm	5.03c
Sieve openings (C)	C_1=6 mm	5.1a
	C_2=8 mm	5.52b
	C_3=10 mm	6.92c

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