JKAU: Met., Env., Arid Land Agric. Sci., Vol. 4, pp. 111-121 (1413 A.H. / 1993 A.D.)

Separation of Wheat-Fines Mixtures by Miniaspirator Cleaning Machine

SULAIMAN A. AL-YAHYA
Agricultural Engineering Department, Faculty of Agricultural and Veterinary Medicine, King Saud University, Al-Gassim Branch, Buraidh, Saudi Arabia

ABSTRACT. A study was conducted in Agriculture and Veterinary Medicine College, King Saud University, Al-Gassim Branch in 1992 to design miniaspirator cleaning machine for separating wheat fines. The machine was then tested to measure its performance on cleaning the fines. Three grain feed rates were run through the machine and also three air velocity levels were used to separate mixtures of wheat fines and wheat kernels into heavies and liftings. As grain feed rate decreased, removal efficiency of fines increased. Removal efficiency increased for every size fraction when aspirator air velocity increased.

Introduction

The degree to which wheat is cleaned is very important. Having clean and good-looking wheat may increase its sale price, grade, and nutrient content. Hence comes the importance of research in the development of efficient and advanced cleaning devices.

Traditional cleaning processes, which still survive in many areas of the world, such as winnowing, are often very tedious and time consuming. In addition, such methods may cause health problems for laborers. Furthermore, the degree of cleaning and removal of fine materials achieved is not always adequate.

As a step in the development of the cleaning process, screening devices were developed that are widely used today. Screeners use particle size as the criterion for separation. Cleaning of the grain by these machines will be affected by the screen opening. Smaller openings will remove more oversized foreign material, but also reduce the throughput capacity; on the other hand, larger openings can do a better job of fines removal, but they increase the loss of acceptable broken grain to the fines.

Another development in cleaner devices is aspiration cleaning. Aspirator cleaners work on this principle: When stock, which is the whole wheat and fines, is dropped through a vertical air channel, air moving upward lifts and carries away some particles which will be called liftings, while other particles which will be called heavies will fall to the bottom.

When fines are removed by aspiration, cleaning is dependent upon particle density and shape as well as particle size (Kice 1985). Aspiration can remove the light foreign material from the whole grain even when the size of foreign material is very close to the size of the grain itself.

Inadequately cleaned grain, which still contains fine material broken particles and other foreign matter, will quickly deteriorate and be attacked by mold during storage. Consequently, its nutrient content may be affected.

In fact, not many researchers have extensively studied or discussed wheat cleaning, but several have studied some of the problems related to this study. Because of that, this study will attempt to find out the degree of wheat fines cleaning at various velocity levels.

Broken wheat and foreign material which implies pieces of wheat, fines, wheat products (cobs and chaff), weed seeds, other grain materials, or dust, will be one of the important factors examined in order to decide whether a high or low cleaning degree is preferable.

MacAuley and Lee (1969) suggested a method of increasing the amount of straw and chaff in wheat separated by aerodynamics in a combine. At low feed rates, they found that by introducing air over the sieve, the mat of material coming from the grain pan dispersed before it reached the upper sieve. At higher feed rates, they found that the mat of material is not dispersed by the airstream. The result of their work suggested a method of sharply reducing the volume of material to be sifted by the upper sieve. Their tests at high feed rates showed that for aerodynamic separation to occur, the particles straw and chaff must be accelerated rearward as free bodies and not as a mat.

Uhl and Lamp (1966) determined air velocities required to remove various materials encountered in combine threshing of wheat, rye, oats, corn, and soybeans. They stated that grain kernels removed at lower velocities are lighter kernels and probably have less nutrient value than those removed at higher velocities. They concluded that during cleaning of wheat, air separation of wheat, cobs, and stover does not appear possible without grain loss.

Kice (1985) reported that aspiration is a function of the "terminal velocity" of the particle which will be a function of a particle's weight relative to its surface area.

Kice (1983) indicated three main factors that are functions of velocity and which should be considered when judging the potential for success in application of a miniaspirator. These three are size, shape, and density. If density and shape are similar, a large particle will fall faster than a small one because it has less surface area in proportion to its weight. In regards to shape, the falling speed of a lead ball is obviously higher than the falling speed of the same amount of lead rolled out into thin lead foil. Density is the last factor for determining fall rate. Assume two round balls, of the same diameter, one of lead, the other of foam rubber. Size and shape are identical, but the lead ball falls faster because it weighs more per unit of surface.

Al-Yahya *et al.* (1991) conducted an experiment on aspirator separation of corn-fines mixtures. They separated fractions of corn using five air velocity levels and they found out that velocity level of 13 m/s was recommended to be the best level for separation all fines and a very small amount from the good one (Table 1).

TABLE 1. Cumulative size removal efficiency (%) resulting for each of five different air velocities.*

Air velocity m/s	Size (mm)							
	1.79	2.38	3.18	3.97	4.76	5.56	6.35	7.14
22	100.00	100.00	100.00	100.00	100.00	98.91	96.46	35.86
19	100.00	100.00	100.00	100.00	98.71	94.23	86.34	15.30
16	100.00	100.00	98.84	94.30	87.33	75.61	60.66	6.74
13	100.00	98.79	89.62	71.80	59.45	41.70	26.83	2.85
.8	73.78	62.09	37.67	26.40	18.02	12.16	7.43	0.78

*Al-Yahya *et al.* (1991).

Objectives

There are two major objectives for this study:

1. To design aspirator separation wheat-fines machine; and
2. To determine the relationship between air velocity and the degree of wheat-fines cleaning, which will be expressed by the term removal efficiency.

Material and Methods

An experiment was conducted in the Workshop of the Agricultural and Veterinary Medicine College to design an aspirator cleaner machine. The machine was then tested to measure its performance on cleaning prepared samples of wheat and fines in the grain lab.

Miniaspirator

The term miniaspirator was established in 1948 to describe the air classifier or aspirator. Designed and built for the purpose of removing dust, chaff, and other light foreign particles from wheat or corn, it has proven its ability to separate any dry free-flowing discrete particulate on the basis of terminal velocity, the lighter particles being lifted from the main stream of slightly heavier particulate (Kice 1983).

The aspirator designed in this experiment has six air intake slots, each with a cross-section of 102 mm in length by 10 mm in height (Fig. 1).

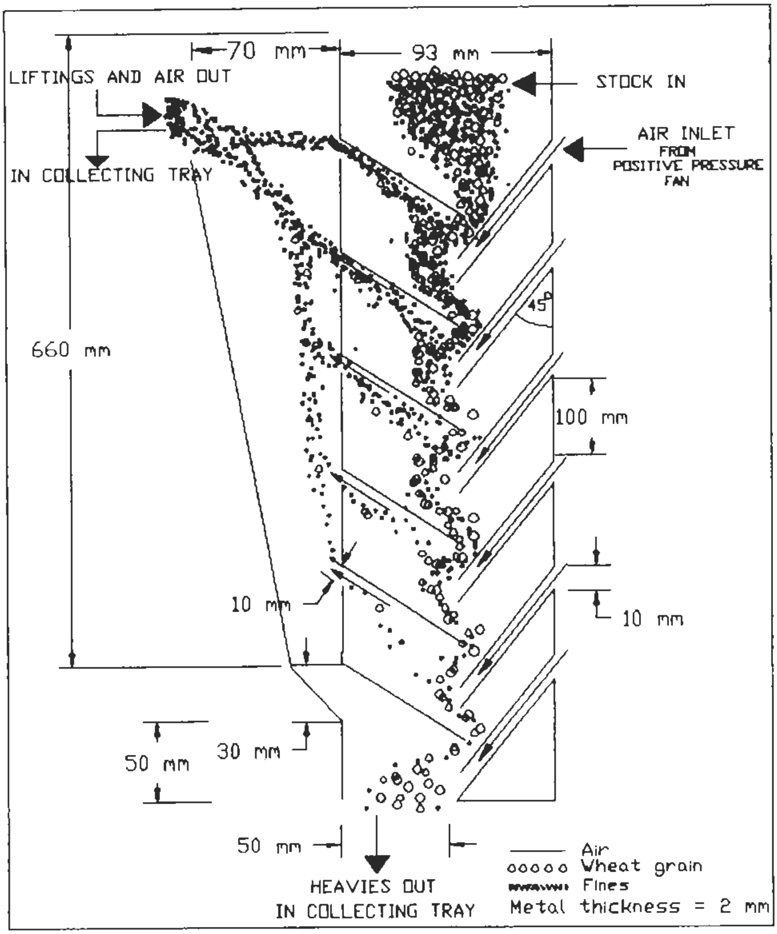

FIG. 1. Cross section of miniaspirator.

In this figure, grain flows over a series of slides within a rectangular cabinet. The grain free-falls from slide to slide in a zigzag flow. The air flow pattern consists of air intake slots that deliver jets of air under each slide, at each point where free-fall begins. Slots located up the opposite side of the cabinet push air up through the spread stream of free-falling grain. The geometry of the zigzag slide arrangment gives vertical air channels that vary in width, narrow initially, expanding to a maximum width about halfway up then reducing to fast again as it is pushed upwardly from the air inlet slot through the grain stream to the slot above. This velocity is high at the point of initial contact with the grain. The air speed slows down to a minimum velocity about halfway up (where the cross-sectional area is maximum). The low velocity at this midpoint determines whether a particle will lift or drop.

Wheat-Fines Mixture

Wheat and fines were obtained in February 1992 from the Research and Agricultural Station of Agriculture and Veterinary Medicine College in Al-Gassim. The well-mixed wheat and fines were divided into four sizes by using a Carter Dockage Tester-equipped with round holed sieves. Wheat-fines distribution of the averaged samples were fined to be as in the Table 2.

TABLE 2. Wheat-fines size distribution and mass.

Size	Definition	Mass (g)	%
1	Through 1.8 mm over 0.0 mm	95.28	2.58
2	Through 2.0 mm over 1.8 mm	247.00	6.70
3	Through 2.3 mm over 2.0 mm	124.55	3.37
4	over 2.3 mm	3221.56	87.34
Total		3688.4	

Experimental Design

The experimental design is summarized in Fig. 2. The prepared wheat and fines were divided into subsamples each is about 3.7 kg mass using a Boerner divider.

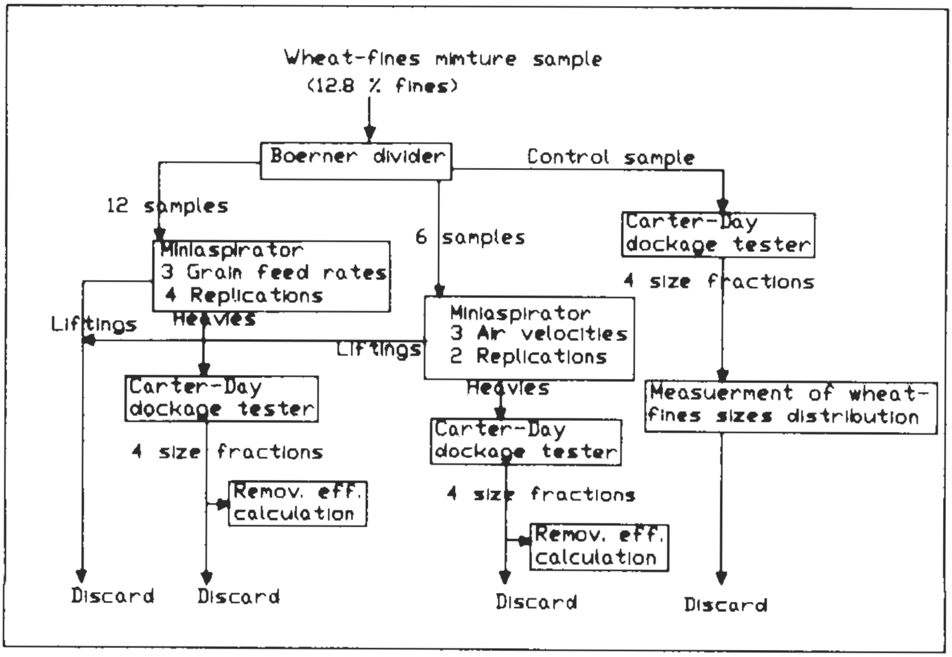

FIG. 2. Experimental design of the study.

Preliminary experimentation was done with the aspirator in order to determine the feed rate which would result in removal of fines when typical flow rate was used. Three feed rate levels, four replications for each, were used with three sample passes through the aspirator; 7.4, 15.3, and 21.1 g/s. Each sample mass was 3700 g (chosen to make sure that each wheat fines fraction has enough mass).

After feed rate level was selected, samples were run in the aspirator using three airflow levels. Airflow levels were obtained by multiplying air velocity leaving the machine with the cross-sectional area of the outlet pipe.

Manifold was designed attached to the aspirator slots to let positive air pass into the machine to separate the fines. Velocity of the air passing through the test sample in the machine was measured by Solomat meter (Fig. 3). They were 5.44, 6.3, and 10.1 m/s. Each rate separated the sample into two parts, heavy stocks and liftings, the latter sample being removed by the aspirator.

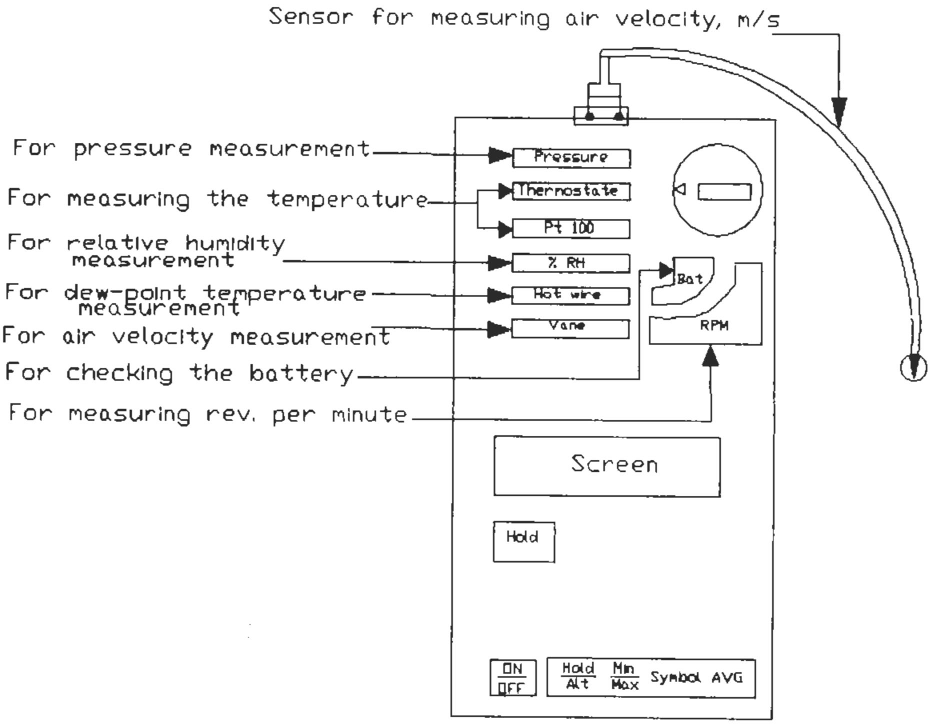

FIG. 3. Solomat; air velocity, relative humidity, and temperature meter.

Removal Efficiency

Hurburgh *et al.* (1989) defined removal efficiency as the percent of material that could be removed which actually is removed, and they calculated it by means of the following equation:

$$E_i = \frac{Po_i - Pc_i}{Po_i} \times 100 \quad (1)$$

where:

po_i = percentage of size i in uncleaned grain;
pc_i = percentage of size i in cleaning;
E_i = efficiency, %.

This equation will be used for calculating removal efficiency for all wheat-fines sizes at each grain feed rate and air velocity level.

Results and Discussion Feed Rate

The results of the study for deciding grain feed rate level are illustrated in the Table 3. Total removal efficiency which includes removing all fines sizes through 2.3 mm sieve size is calculated for each grain feed rate.

TABLE 3. Total removal efficiency of fines at different grain feed rates.

Feed rate, g/s	Total removal efficiency, %
7.4	83
15.3	67
21.1	59

From the above table, it was decided that grain feed rate of 7.4 g/s would be the best rate to be used since the total removal efficiency was highly significant comparing with other feed rates.

Table 4 shows percent of each size fraction of heavies in the cleaned part for each air velocity.

TABLE 4. Percent of heavies.

Air velocity		Size (mm)*		
m/s	1.8	2.0	2.3	>2.3**
10.10	0.0674	0.0692	0.159	99.70
6.30	0.0570	0.0980	0.143	99.60
5.44	0.1080	0.6100	0.236	99.02

*Size of particles for each entry lies between that sieve size and the next smaller one. For example, heavies percent at 5.44 m/s was 0.236% of material > 2.0 mm and < 2.3 mm.
**All material on top of 2.3-mm sieve.

Fines Removal Efficiency

Removal efficiencies were calculated using Equation 1. Table 5 represents the calculated size removal efficiency for each velocity level. Size removal efficiency % results for each of three different air velocities.

Numerical example for calculation of removal efficiency for size 2 mm at 6.3 m/s velocity is shown below:

$$\text{Removal efficiency} = \frac{6.698 - 0.098}{6.698} \times 100 = 99.53\%$$

TABLE 5. Size removal efficiency (%).

Air velocity		Size (mm)*		
m/s	1.8	2.0	2.3	>2.3**
10.10	97.4	99.00	95.30	14.15
6.30	97.8	98.53	95.76	14.14
5.44	95.0	90.00	93.00	13.37

*Size of particles for each entry lies between that sieve size and the next smaller one. For example, heavies percent at 5.44 m/s was 0.236% of material > 2.0 mm and < 2.3 mm.
**All material on top of 2.3-mm sieve.

Aspirator Air Velocity and Removal Efficiency Relationship

The relationship between velocity of air passing through the aspirator and aspirator-removal efficiency is illustrated in Table 5. Removal efficiency increased as

TABLE 6. Descriptions of Solomat*; air velocity, relative humidity, and temperature meter.

Unit	Range of measurement
Pressure	0 - 1.00 psid
Thermostat	− 80 − 1100°C
	− 110 − 1990°F
Pt	− 50 − 800°C
	− 110 − 1990°F
% RH	0 - 100% RH
Bat	6.5 - 10 VDC
Vane	1 - 40 m/s
	200 - 8000 ft/min
RPM	40 - 2000 rev/min

*Made in United Kingdom; Solomat Mfg Ltd, Devon., Ex 11, 1 BP., U.K.

the velocity increased for each fine's size. For fines sizes 1.8 mm and below, removal efficiency was 96.5% as average for all air velocity levels. 100% removal efficiency could not be obtained with this size due to the sand in the samples which is somewhat heavier than the small particles of wheat. About 10% of the size 2.00 mm and below was not removed at the smallest air velocity level which is 5.44 m/s, whereas the removal efficiency for this size in the other velocity levels were about 100%. The sizes fo 2.3 mm and below were about 95% removed during the 10.1 and 6.3 m/s air velocities; while 93% was removed with 5.44 m/s. When air velocity levels of 10.1 and 6.3 m/s were used, 14.1% of the sample was removed for the size larger than 2.3 mm. Removing this percent from this size can be considered a disadvantage because removing these particles will increase the loss of valuable grain. The previous two velocities may not be appropriate, however, as the producer will lose too much money by the loss of these high percentages of saleable material. When air velocity level of 5.44 m/s was used, 13.35% of the sample was removed for the size larger than 2.3 mm. This level of velocity decreased the loss of good grain about 1% and at the same time removed most of the bad ones. Thus, air velocity of 5.44 m/s can be considered the best flow rate, in this experiment, if the producer is interested in removing most of the fines while not losing a high percentage of good grain. Using this rate might cover and reduce the costs of cleaning, by improving the grade of the grain, which results in a higher selling price. Practicing more low velocity levels in the designed machine for removing grain fines is recommended in the future.

Conclusion

The study leads to the following conclusions:

1. Performance of the designed aspirator cleaner machine was very high, removal efficiency with some sizes reached about 100%.
2. Removal efficiency for all sizes of wheat particles generally increased as grain feed rate decreased.
3. Removal efficiency for all sizes of wheat particles generally increased as air velocity increased.
4. Air velocities of 10.1 and 6.3 m/s removed about 14.1% of the good grain.
5. An air velocity of 5.44 m/s removed most of the fines and only 13.35% of the good grain. Therefore; this rate is recommended for running the machine.

Acknowledgement

The author thanks and appreciates Ibrahim Musa and Saad Audh who help in building up the machine and collecting the data.

References

Al-Yahya, A.S., Bern, C.J. and **Hurburgh, C.R.** (1991) Aspirator separation of corn-fines mixtures, *Trans. ASAE,* **34**(3): 944-949.

Hurburgh, C.R., Bern, C.J. and **Brumm, T.J.** (1989) Efficiency of rotary grain cleaners in dry corn, *Trans. ASAE,* **32**(6): 2073-2077.

Kice, J. (1985) *Skilled Air Manual for Milling and Other Industries,* Kice Metal Products Co., Inc., Wichita, Kansas, Chapter 1:4-20.

Kice, R. (1983) Application for multistage aspirator, *Oil Mill Gazetter,* **June:** 36-38.

MacAulay, J.T. and **Lee, J.H.A.** (1969) Grain separation on oscillating combine sieves as affected by material entrance conditions, *Trans. ASAE,* **12:** 648-651.

Uhl, J.B. and **Lamp, B.J.** (1966) Pneumatic separation of grain and straw mixtures, *Trans. ASAE,* **9:**244-246.

فصـــل شوائب القمـــح باستخـــدام مكنـــة التنظيف الهـــوائي

سليمان عبد العزيز اليحيى
قسم الهندسة الزراعية ، كلية الزراعة والطب البيطري
جامعة الملك سعود ، فرع القصيم ، بريــــدة ، المملكة العربية السعودية

المستخلص . أجريت الدراسة في كلية الزراعة والطب البيطري بالقصيم في عام ١٩٩٢م بغرض تصميم مكنة تنظيف هوائي لتفصل شوائب القمح . تم اختبار المكنة بعد تصنيعها لمعرفة معدل أداءها وكفاءتها في فصل هذه الشوائب . اختُبرت ثلاثة معدلات تغذية في المكنـة لمعـرفة أفضل معدل لتشغيل المكنة ، كما استُخدمت ثلاث سرعات للهواء المـار لفصل الشوائب والقمح إلى جزئين : جزء خفيف مفصول وجزء ثقيل متبقٍ ، وذلك لمعرفة أنسب سرعة لتشغيل المكنة . يلاحظ أنه كلما قل معدل التغذية كلما زادت كفاءة المكنة في فصـل الشوائب . كذلك وجد أن كفاءة الفصل لوحدة الحجوم من الشوائب تزداد كلما زادت سرعة الهواء خلال المكنة .