VOL. 17, NO. 15, AUGUST 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DESIGN AND EVALUATION OF VILLAGE-TYPE RICE GRAIN CLEANER

Michael A. Gragasin, Trixie Marie P. Magtalas, John Rey A. Cargamento and Genaro M. Tolentino
Philippine Center for Postharvest Development and Mechanization, Department of Agriculture Science City of Muñoz, Nueva Ecija, Philippines
E-Mail: kitgragasin@yahoo.com

ABSTRACT

A new type of efficient rice grain cleaner with de-stoner was successfully developed in line with the absence of village-type rice grain cleaner in the Philippines that can both remove light impurities and stones at the same time. This was developed because of the inevitable accumulation of stones during drying and the high presence of impurities in the rice grain during harvesting that could cause damage to the rice mill and eventually affect the efficiency and operation of the milling machine. The developed technology relates to a rice grain cleaner with de-stoner that efficiently separates rice straws, rice chaffs, immature grains, tiny stones, dried leaves, dirt and other impurities from the rice grain through the combination of two-stage air-screen and pressure-type separation processes. The results of laboratory analysis of the collected rice grain samples revealed that the developed rice grain cleaner has a cleaning efficiency of 98.7 percent with de-stoner efficiency of 100 percent. These results indicate that the output of the rice grain cleaner has purity of 98.9 percent. The developed rice grain cleaner has passed the set Philippine agricultural engineering standard for seed cleaner of 98 percent. The results of test performance indicate that the design of the said machine is successful in utilizing the same amount of air that initially used at the de-stoner for the air-screen cleaner so that it can both functions as air-screen cleaner and de-stoner.

Keywords: cleaning efficiency, de-stoner efficiency, purity of output, blower loss.

INTRODUCTION

The successful diffusion of modern rice combine harvester in the Philippines necessitates the need to develop an efficient rice grain cleaner. It is highly evident that the rice output of some rice combine harvesters, especially when the field is wet, have high presence of rice straws, rice chaffs, immature grains and other foreign matters such as grass leaves and dirt. Aggravating this problem is the current practice of farmers of drying their produce in the highway wherein the accumulation of stones during drying is unavoidable.

Cleaning rice grain before milling is essential in producing good quality milled rice. The high presence of impurities in the rice grain could significantly affect the quality output of the milling machine particularly its technical performance such as milling capacity, hulling efficiency, and milling recovery. As such, it is imperative that the rice grain should undergo thorough cleaning process before milling. Removal of foreign materials from the rice grain not only increases milling efficiency, but also protects the rice mill parts from abrupt damages and lessens the power load requirement of the rice mill (Wrigley *et al*., 2016; Bhattacharya and Ali, 2015).

Based on the Philippine Agricultural Engineering Standard (PAES) for Paddy Seed Cleaner (PNS/PAES 260:2015) as shown in Table-1, the performance criteria of a paddy seed cleaner with purity of output of lower than 98 percent indicates the production of poor-quality paddy given the high presence of rice chaffs, rice straw and other foreign materials. On the other hand, a paddy seed cleaner with blower loss of more than 1 percent indicates the incidence of high post-harvest losses during cleaning operation.

New designs of grain or seed cleaners to separate grain/seed from contaminants or impurities are available (Tieben, 1987; Misra *et al*., 1991; Bayshugulova *et al*., 2015; Bilde, 2015). Among the rice seed cleaner developed in the Philippines is a compact triple-airstream, triple-screen (Pasikatan *et al*., 1996).

Table-1. Performance criteria for paddy seed cleaner.

Criteria	Performance Data
Purity of Output, %, minimum	98
Blower Loss, %, maximum	1
Noise Level, dB(A), maximum	92*

*Allowable noise level for six (6) hours of continuous exposure based on Occupational Safety Health Standards, Department of Labor and Employment, Philippines, 2013.

The purpose of this study was to develop a compact yet powerful rice grain cleaner that is capable of removing rice chaffs, immature grains, stones, leaves and other impurities in one operation to produce clean rice grain for continuous milling operation.

MATERIALS AND METHOD

Design of the Rice Grain Cleaner

In the design of the rice grain cleaner with de-stoner, the following basic technical considerations were fully considered: (1) capacity should be 300-600 kg/h; (2) removal of stones, rice straws, rice chaffs, immature grains, and other foreign matters such as grass leaves and dirt in single machine operation; (3) cleaning and de-stoning mechanisms can be done simultaneously; (4) air

current coming from the de-stoner and blower can be utilized for the air-screen cleaner; and, (5) reciprocating movement of de-stoner caused by the eccentric shaft can be utilized for oscillating movement of the air-screen cleaner.

To achieve the above design considerations, the principles of air-screen and pressure-type separation processes (Harmond *et al.,* 1968 and Klein *et al*., 1961) were adopted. The main principle of operation of a de-stoner as described by Kannan *et al.* (2015) is that it removes stones from a given input feed using a combined effect of deck vibration and fluidization. The inclination of the deck plays a major role in creating the necessary slope needed to convert vertical stratification (achieved by the fluidizing air) into horizontal separation zones along the deck surface. On the other hand, the separation of impurities from the seeds or grains in an air-screen cleaning machine is done on the basis of differences in seed size, shape and density using screen and air pressure, respectively (Oladimeji *et al*., 2020).

The design of the rice grain cleaner with de-stoner were drawn using Solid Works software. The details of each part were fully configured showing label and measurement of every part of the design. The manufacturing drawing have served as the primary basis in the fabrication of the prototype unit.

The design was subjected to simulation structural analysis through Finite Element Analysis (FEA) through the Solid Works software. The FEA predicted the behavior of varied types of physical systems such as deformation of solids, heat conduction, and fluid flow of the rice grain cleaner.

Fabrication of Prototype Unit

The fabrication of the rice grain cleaner with de-stoner was awarded to ACT Machineries and Metal Craft Corporation located at Cauayan City, Isabela, Philippines. A non-disclosure agreement was signed with ACT Machineries and Metal Craft Corporation to protect the Intellectual Property Right of PHilMech on the design of the rice grain cleaner technology.

Test Materials and Instruments

In the conduct of test trials, the rice grain samples were prepared in sufficient quantity and identical characteristics in terms of moisture content, purity, and variety. For all test trials conducted, the same variety was used and originated from the same lot. Total samples used for each test trial was 50 kg with 11.7% moisture content. The test material samples were mixed with 5% impurities by weight consisting of the following: (a) 500 pieces of stones at varying sizes (small, medium, large) with distinct color for easy identification; and, (b)2.5 kg of light impurities such as immature grains, rice chaff, rice straw and dried leaves to establish the de-stoner and cleaning efficiencies, respectively. The utilization of 2.5 kg of impurities is designed to conform with the Philippine National Standard/Philippine Agricultural Engineering Standards - Methods of Test for Paddy Seed Cleaner (PNS/PAES 261:2015) that the maximum purity of test materials to be used shall not exceed to 95 percent (with 5% impurities).

Exhaust air velocity was measured using a digital impeller anemometer. The speed of the rotating components was measured using a Tachometer. Noise emitted at operator's ear level was measured using a digital noise meter. An AC clamp power meter was used to determine the power input of the electric motor and the total electric power consumption of the rice grain cleaner. The moisture content of rice grain samples was measured using the PHilMech Grain Probe Moisture Meter. A digital 30-kg capacity and an analog 120-kg capacity weighing scale were used to measure the weight of samples.

Test Trials

Performance tests were conducted to determine the workability and viability of the design following the Philippine National Standard/Philippine Agricultural Engineering Standard - Methods of Test for Paddy Seed Cleaner (PNS/PAES 261:2015).

During the conduct of test trials, the rice grain samples weighing 50 kg each were purposely mixed with 500 pieces of stones at varying sizes (i.e. small, medium and large) with distinct color for easy identification during retrieval and counting of stones.

The performance of the developed pressure-type de-stoner was evaluated based on its effectiveness to remove stones at varying sizes. The effectiveness of the rice grain cleaner in removing stones from the grains was established by determining the de-stoner efficiency using the formula:

$$\text{De-stoner efficiency, \%} = \frac{\text{Total number of stones collected by the destoner}}{\text{Total number of stones used in the experiment}} \text{x } 100$$

Likewise, the performance of the air-screen cleaner was evaluated based on its effectiveness to remove rice straws, rice chaffs, immature grains and other foreign matters such as grass leaves and dirt by determining the corresponding cleaning efficiency of the air-screen cleaner. The efficiency of air-screen cleaner was determined using the ratio of the weight of the clean seeds collected at the main output chute to the total weight of the seeds input in the rice grain cleaner multiplied by the initial purity, expressed as:

$$\text{Cleaning Efficiency, \%} = \frac{\text{Weight of Output}}{\text{Weight of Input x Purity}_{\text{Initial}}} \text{x } 100$$

The purity of the output of the rice grain cleaner was also estimated by determining the ratio of the weight of clean rice grain, to the total weight of unclean rice grain samples, expressed as:

$$\text{Purity of Output, \%} = \frac{\text{Weight of clean rice grain}}{\text{Weight of unclean rice grain}} \text{x } 100$$

Moreover, the blower loss of rice grain cleaner was estimated. During the test trials, three samples were collected from the fan outlet for the duration of 15 seconds per collection and placed in a zip lock plastic. Each sample were cleaned and weighed.

The blower loss was determined using the ratio of the weight of clean rice grain blown and mixed with the impurities in the fan outlet to the weight of rice grain input, expressed as:

$$\text{Blower Loss, \%} = \frac{\text{Weight of blownrice grain}}{\text{Weight of clean rice grain}} \text{x } 100$$

Laboratory Analysis

Laboratory analysis were conducted to determine the moisture content, grain purity and blower loss following the Philippine National Standard/Philippine Agricultural Engineering Standard - Methods of Test for Paddy Seed Cleaner (PNS/PAES 261:2015).

Experimental Design and Statistical Analysis

The technical performance of the developed rice grain cleaner with de-stoner in terms of its cleaning efficiency (%), purity of output (%), blower loss (%), and de-stoner efficiency (%) were compared based on the initial and final designs.

The gathered data were consolidated and analysed using Analysis of Variance (ANOVA). Statistical analysis was performed using Sirichai Statistics 6.0, statistic package software that performs and explains basic and advance statistical functions.

Modification/Improvement of the Initial Set-Up

Based on the results of performance testing, the initial design was modified to further improve the safety, ease of operation, technical performance, and financial viability of the rice grain cleaner. The fabrications of new or modified design were all undertaken at the PHilMech Fabrication Shop located at Science City of Muñoz, Nueva Ecija, Philippines.

RESULTS AND DISCUSSIONS

Technical Description of the Developed Rice Grain Cleaner

The design of the rice grain cleaner is shown in Figure-1. The developed rice grain cleaner has an overall dimension of 1,055 mm length, 744 mm width and 1,640 mm height. The machine is comprised of the following major components: main frame, hopper, air-screen cleaner, de-stoner, blower, and the prime mover which is a single-phase electric motor. It has an input capacity of 350 kg/h with power requirement of 5.41 kW. The maximum noise at operator's ear level is 78.1 dB(A). The machine can be operated by one person only.

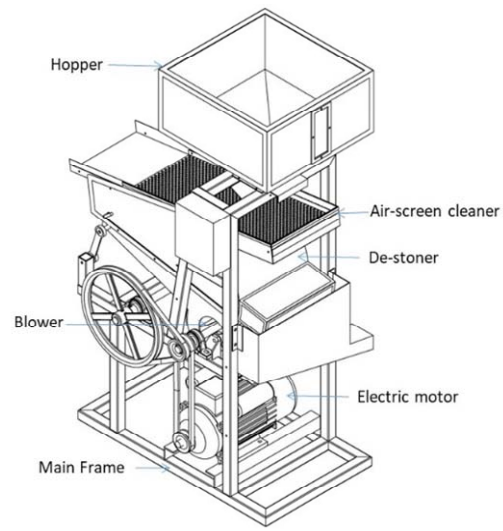

Figure-1. Design and components of the rice grain cleaner with de-stoner.

Process Flow during Operation

Figure-2 shows the schematic diagram of the rice grain cleaner showing its parts and operation and flow of materials. Rice grains with impurities are loaded into the 30-kg capacity feeding hopper. A feeding gate regulates the opening. Grains with impurities fall to the spreader plate for uniform feeding and distribution. Large impurities are agitated at the top end of the air-screen cleaner while the rest of the rice grains were collected on a catching tray below the air-screen cleaner. As the grains fall from the end of the catching tray, an air stream blows away the light impurities and immature grains while the rest of the grains fall into the de-stoner screen which separates the stones from the sample. Cleaned grains and stones were discharged to the main outlet chute and de-stoner outlet, respectively.

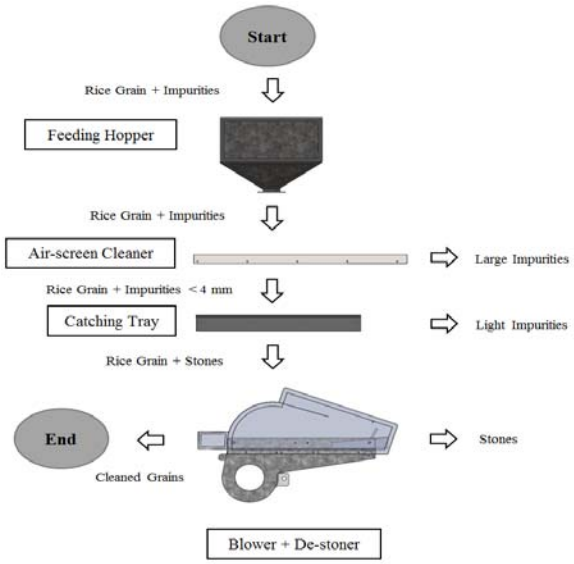

Figure-2. Process flow of rice grain in the rice grain cleaner.

Technical Performance

Table-2 shows the technical performance of the final design of the rice grain cleaner as compared to the original design. As evident, the developed rice grain cleaner is effective in removing rice chaffs, rice straw, dried leaves and other impurities from the rice grain given the significant improvement of the cleaning efficiency from 95.8 percent to 98.7 percent. As such, the results of test trials confirmed that the concept of design is successful in using slotted screen and in re-using air stream from the de-stoner for the air-screen cleaner.

Test performance also revealed that the de-stoner efficiency of the developed machine is 100 percent. The result indicates that the machine can efficiently remove all the stones that is mixed with the rice grain. Significant improvements were made by inclining the de-stoner screen at 10 degrees and by maintaining air velocity of 3.5 meter per second on the de-stoner screen.

Table-2. Performance of the rice grain cleaner.

Performance Parameter	Initial Design	Final Design
Cleaning Efficiency, %	95.8[b]	98.7[a]
De-stoner Efficiency, %	98.5[a]	100[a]
Purity of Output, %	96.6[b]	98.9[a]
Blower Loss, %	0.16%[a]	0.15[a]

Means across row having the same letter are not significantly different at 5% level of significance.

Overall, the developed rice grain cleaner has passed the Philippine Agricultural Engineering Standard for paddy seed cleaner given its purity output of 98.9 percent and blower loss of 0.15 percent. The standard for the minimum purity of output and maximum blower loss of a paddy seed cleaner in the Philippines were set at 98 percent and 1 percent, respectively (Table-1).

The analysis of variance (ANOVA) show that there is a highly significant level of improvement on the purity of output of the rice grain cleaner as a result of series of modifications made from the initial design, particularly on the blower speed, utilization of right screen, and the aerodynamics of the design of the de-stoner cover so that the air stream coming from the de-stoner can be re-used efficiently for the air-screen cleaner.

Table-3. ANOVA on the purity of output variable.

Source of Variation	df	SS	MS	F	F.05
Treatment	2	5.36	2.68		
Error	3	0.045	0.015	176.14**	9.55
Total	5	5.41			

* significant
** highly significant

The modifications made on the rice grain cleaner were as follows: (i) The material used in the mainframe was modified from 1x1 inch angle bar to 1.5x1.5 inches square tube to minimize the vibration; (ii) The size of rotating shafts was changed from 0.75 inch to 1 inch diameter to withstand load and avoid shaft failure during cleaning operation; (iii) The screen of the air-screen cleaner was changed from 10 mm perforated screen to 4 mm slotted screen to efficiently separate large impurities; (iv) The upper-end portion of catch basin was made adjustable using continuous hinge to control the flow of air and to avoid high incidence of losses especially at the start of operation; (v) The angle of inclination of de-stoner screen was adjusted from 5 degrees to 10 degrees to improve the de-stoner efficiency; (vi) The offset distance of eccentric was changed from 1.5 mm to 3 mm to increase the oscillating and reciprocating movement of the air-screen cleaner and eccentric, respectively; (vii) The de-stoner cover at the lower-end portion of the de-stoner screen were removed to improve the air velocity coming from the de-stoner; and, (viii) Manual mixer was attached at the hopper bottom opening to avoid clogging given the unavoidable accumulation of rice straws in the feeding gate area.

Operating Cost

Table-4 shows the annual operating cost of the developed technology and the cost of cleaning per unit weight of output. The total annual fixed cost that includes the depreciation cost, interest on investment and the taxes, insurance and shelter was estimated at US$363. The total annual variable cost was US$1,453 that covers the cost of repairs and maintenance, electricity cost and labor. The total cost for a 720-hr annual operation is estimated at US$1,816. Based on this, the estimated cost of cleaning per ton is about US$10.30/t.

Table-4. Total annual operating cost and cost of cleaning per ton output.

Particulars	Amount (US$)
Fixed cost	363
Depreciation cost	173
Interest on investment	138
Taxes and insurance	52
Variable cost	1,453
Repairs and maintenance	87
Electricity cost	674
Labor cost	692
Total cost	1,816
Cost of cleaning per ton	10.30

Note: Investment cost (IC)=US$1,731;Output capacity=245kg/h; Operating time=720h/yr; Power consumption=5.41kW; Lifespan=10 yrs; Interest on investment=8% of IC; Taxes and Insurance=3% of IC; Repairs and Maintenance=5% of IC; Electricity cost=US$0.17/kWh; Wage rate of laborer=US5.8/d; US$1=Php52

CONCLUSIONS AND RECOMMENDATION

The developed technology relates to a rice grain cleaner with de-stoner that efficiently separates stones, rice straws, rice chaffs, immature grains, dried leaves, dirt and other impurities from the rice grain through the combination of two-stage air-screen and pressure-type separation processes. This was developed because of the inevitable accumulation of stones during drying and the high presence of immature grains, rice straws, dirt and other impurities in the rice grain that could cause damage to the rice mill and eventually affect the efficiency and operation of machine.

The results of test trials revealed that the developed rice grain cleaner with de-stoner is efficient in removing impurities and stones from the rice grain given its cleaning efficiency and de-stoner efficiency of 98.7 percent and 100 percent, respectively. But most importantly, the developed rice grain cleaner has passed the set minimum quality standard for paddy seed cleaner given its output purity of 98.9 percent with blower loss of only 0.15%.

The test trials results indicate that the design of the said machine is successful in utilizing the same amount of air that initially used for the de-stoner for the air-screen cleaner so that it can both functions as air-screen cleaner and de-stoner.

It is recommended that the developed rice grain cleaner technology shall be adopted by the farmers to ensure that the rice grains are free from impurities during milling operation.

REFERENCES

[1] Agricultural Machinery Testing and Evaluation Center (AMTEC). 2015. Philippine Agricultural Engineering Standard Specification for Paddy Seed Cleaner. 260: 2015. University of the Philippines at Los Banos, Laguna, Philippines.

[2] Agricultural Machinery Testing and Evaluation Center (AMTEC). 2015. Philippine Agricultural Engineering Standard Methods of Test for Paddy Seed Cleaner. 261:2015. University of the Philippines at Los Banos, Laguna, Philippines.

[3] Baker-Arkema F. W., Debaerdemaeker J., Amirante P., Ruiz-Altisent M. and Studman C. J. 1999. CIGR Handbook of Agricultural Engineering Volume IV. Retrieved on May 19, 2017 from https://bookpdf.services/ downloads/ cigr_ handbook_of_agricultural engineering_ volume_ii.pdf.

[4] Bayshugulova Sh. K., Eskhozhin D. Z., Capov S. N. 2015. To Improve the Quality of Grain Cleaners Cleaning Machines. Journal of Science S. Seifullin Agro Technical University. 87(4): 74-82.

[5] Bhattacharya K. R. and Ali S. K. 2015. An Introduction of Rice-Grain technology. WPI Publishing. India.

[6] Bilde M. L. 2015. Combine harvester grain cleaning apparatus: US Patent 8,968,065.

[7] Chakraverty A., Mujumdar A., Vijaya Raghavan G. S. and Ramaswamy H. 2003. Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices. Marcel Dekker, Inc. New York.

[8] Gragasin M. A., Suan C. R. D., Illustrisimo J. P. and Martinez R. C. 2019. Design and Development of Pre-cleaner for Corn. Asian Journal of Postharvest and Mechanization. 2(1): 25-36.

[9] Harmond J. E., Brandenburg N. R., Klein L. M. 1968. Mechanical Seed Cleaning and Handling. USDA. Washington, D.C.

[10] Kannan A. S., Hansen M. A. E., Carstensen J. M., Thorn P., Lund J. and Sasic S. 2015. Studies on Grain Segregation Patterns on a De-stoner Using a CFD-DEM Approach. WIT Transactions on Engineering Sciences. 89: 287-298.

[11] Klein L. M., Henderson J. and Stoesz A. D. 1961. Equipment for Cleaning Seeds. Yearbook of Agriculture. USA: USDA. Washington DC. pp. 307-321.

[12] Misra M. K. and Shyy Y. Y. 1991. Automation of an Air-screen Seed Cleaner: US Patent. 4, 991, 721.

[13] Oladimeji A. O., Imoukhuede O. B. and Ayodele B. B. 2020. Design and Construction of a Multi-purpose Air-Screen Grain Cleaner. International Journal of Applied Research. 6(5): 204-207.

[14] Pasikatan M. C., Quick G. R., Barredo I. R. Lantin R. M. 1996. A Compact Triple Airstream, Triple-screen Rice Seed Cleaner. Philippine Journal of Crop Science. 21(3): 53-60.

[15] Republic Act No 10601: An Act Promoting Agricultural and Fisheries Mechanization Development in the Country. 2013. Congress of the Republic of the Philippines.

[16] Tieben J. B. 1987. Seed cleaner: US Patent. 4, 699, 713.

[17] Wrigley C., Corke H., Seetharaman K. and Faubion J. 2016. Encyclopedia of Food Grains. Elsevier. Oxford.