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Rubber Roller Angular Velocity Affect an Air Flow of Small Rice Husking Machine using Computational Fluid Dynamic

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Abstract

This paper aims to investigate the influence of the rubber roller angular velocity of the small three roller rice husking machines in Thailand. This is used to analyze the air flow behavior in rice husk separation domain. The behavior of air in the chamber is investigated using Computational Fluid Dynamic (CFD). Mesh independence is used to find a stable model to analyze. After that, the speed of rubber roller is adjusted to predict a behavior of the air flow rate, velocity inlet and pressure each point of interested. The optimum element size was used for the analysis of 43.1 mm. The speed of rubber roller affected all of the flow rate, speed, and pressure of the air inside the domain when speed of rubber roller increases, all the above variables will be increased. The relation graph will lead to the design of the small rice husking machine.

Keywords Rice husking machine, Brown rice, Simulation, Computational Fluid Dynamic, Finite volume method.

INTRODUCTION

Rice is intended to remove the hull and bran layers of rough rice that final product is white rice. The products of rice are composed of head rice, broken rice, husk and brain of layers that is milled. The ratio of husk to brown rice is 3:7 by weight [1, 2]. The removed husk density is 70 kg/m^3 [3]. Rice mill process is important for reducing cost operation. For example, Lim et al. presented an IRE tool, which can be used to reduce the cost of rice to USD 2,077,300 per year [1, 4]. Research of used rice husk to renewable energy tend is increase. Such as, Okeh etal, this work show producing biogas from rice husk [5] and Mahin research, a power plant that used rice husk is presented [6]. Rice milling process is based on three types of operations: single-step mill process, double-step process, and multilayer process. Each of them has different advantages and disadvantages, for example a single step of rice mill has more contaminants than a two-stage. This is because it has low efficiency of separation system for removal of husk from the brown rice. Head rice yields of single step rice mill was yield 30% of the original grain. If it is multi-step, it was about 60% of the paddy. Although profit margin of head rice is more than 50% of the selling price of broken rice, in the countryside of Thailand people currently use a single step of rice milling. Therefore, the improvement of the rice milling machine in order to increase the efficiency is required. Whether it is in the rice husking or rice husk separation from the brown rice to reduce energy and working time. Figure 1 shows the internal components of a small rice mill used in the community of Thailand.

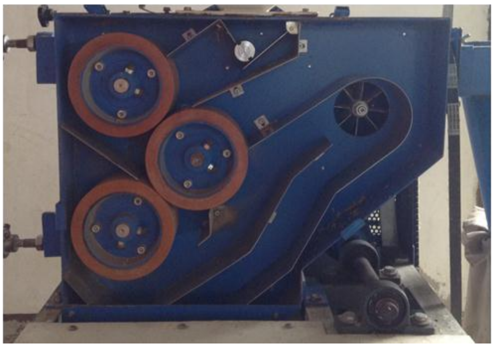


Figure 1. The community rice husking machine

Currently, more communities of rice mills in Thailand still use their experience in building rice husking than implementing engineering principles. Good designing requires analysis of relevant factors of machine parts [7]. Therefore, this paper is intended to study the influence of angular velocity of rubber roller that affect air flow behavior in the housing of rice husking machine made in Thailand. A CFD model is used to design of the Thailand rice husking machine. The studies investigate variables of interest including air flow rate of brown rice and rice husk, the velocity and pressure of the air at the point of separation of the brown rice and the husk using the CFD model of air flow in a rice husking machine.

Computational fluid dynamics (CFD)

Computational Fluid Dynamics (CFD) is a mathematical method that is used to predict fluid behavior, heat and mass transfer, chemical reaction etc. The advantage of this methodology can be used to conceptual design, optimization analysis and solve an engineering problem. The equations were used to solve the problem can be show as (1) and (2) [8, 9].

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho U) = 0 \quad (1)$$

$$\frac{\partial(\rho U)}{\partial t}+\nabla\cdot(\rho U\otimes U)=-\nabla p+\nabla\cdot\tau+S_M \tag{2}$$

The models used in the study were performed by finite volume method. The element used in the calculation is a tetrahedral with nodes in the middle. Automatic segmentation is provided by the program, but an element size can be adjusted. Before applying the model to the analysis, it is necessary to examine the quality of the element as a preliminary confirmation that the applied model is sufficiently stable to predict the behavior. An element size is controlled for testing orthogonal quality that using the face normal vector from the cell centroid to the centroid of each of the adjacent cells, and the vector from the cell centroid to each of the faces to compute. Because it is important for an analysis. Their value is between 0 and 1 if it close to 0 that is low quality but it close to 1, it is good quality for using to analysis [8, 9, 10, 11, 12]. The equations used to calculate the orthogonal quality are shown in equations 3 & 4. These equations are compared, if any of the equations is less, then the value is used to represent equation of an element.

$$\frac{\vec{A}_i\cdot\vec{f}_i}{|\vec{A}_i||\vec{f}_i|} \tag{3}$$

$$\frac{\vec{A}_i\cdot\vec{c}_i}{|\vec{A}_i||\vec{c}_i|} \tag{4}$$

When $\overline{A_i}$ is a perpendicular vector to the surface? The vector $\overline{f_i}$ is dragged from the centroid center of the cell to the centroid of the contiguous surface of the element. The vector is drawn from the centroid to the centroid of the neighboring cell [10]. After mesh independent process is complete for searching element size to stable analysis. Then analysis air flow behavior to simulation velocity and pressure each point when separation blower air flow is changed using $k-\varepsilon$ model for analysis turbulence flow.

Single stage husk removing model

The husking rice machine model is a small size machine that used in a single-step rice mill and used in the countryside of Thailand. Feed rate is 24.85 kg/hr. Source of powered is single motor, when the electrical frequency changes, the flow rate of the air in the rice husk and rice husk separator housing and angular velocity of the roller will be affected. The frequency in the laboratory is between 35 and 60 Hz. The first frequency used in the analysis is at 45 Hz. The angular velocity of roller is 73.18 rad / s or linear speed equal to 5.15 m/s. An angular velocity of roller rubber is 116.34 rad/s or a linear speed is 9.13 m/s. Outlet air flow through the exit fan is 2.43 g/s. An analysis starts with a modeling of air domain at separation zone. Because agricultural materials is mixed between brown rice and rice husk move through husking rubber roller into this section. Whole ingredients are separated by the difference between rice husk and brown rice density. A model is shown in Figure 2.

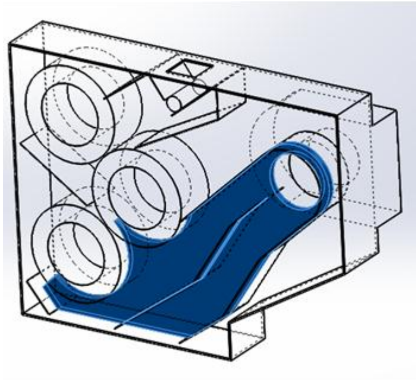


Figure 2. The rice husking machine model

In this research, only the air flow analysis of the rice husk separation is analyzed as shown in Figure 2. Analyzes of air behavior within the rice husking machine is shown in Figure 3. Within a domain of separation, there are three boundaries of air permeability: brown rice-husk inlet, left brown rice outlet and right brown rice outlet. A boundary where air is the only out of a boundary of a blower. High speed roller and low speed roller are husking rubber roller. Therefore, it is defined as an angular velocity wall. The points of interest are set to 10 points, separated by a Cartesian coordinate system that specifies each point uniquely in a space to capture pressure and speed at each point.

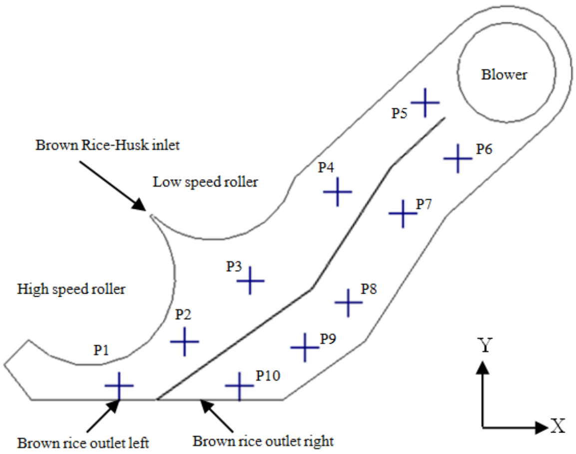


Figure 3. Rice husking draft

Using a CFD analysis program, it is necessary to define a model with a realistic and stable condition before it can be used for analysis. The methodology starts with the modification of the size of the element to find the size that makes the model stable before applying it to the analysis that is mesh independent. Then, an appropriate size of analytical elements is used to analyze the effect of angular velocity to inlet air flow rate, speed and pressure of an air in domain at the point of interest.

RESULTS

The results of computational fluid dynamics for air flow analysis in separation domain of small rice husking machine in Thailand can be shown in Figures 4 and 5. It is shown that speed and pressure of the air in initial domain. Lower rubber roller angular velocity is 66. 18 rad/ s, high rubber roller angular velocity is 116. 34 rad/ s. Flow rate of air through a blower is 2.43 g/s. Air flow speed is different in each point. Pressure is high at the entrance of brown rice, rice husk and blower. In other areas, the value decreases respectively. Direction of air flow in domain can be shown in Figure 6.

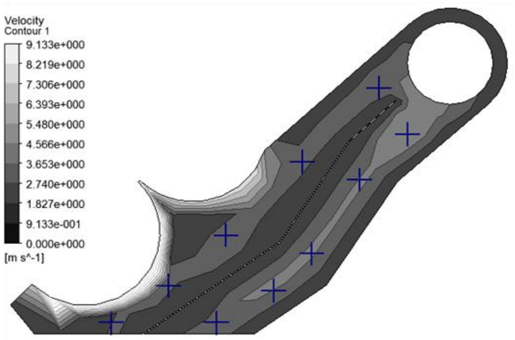


Figure 4. Velocity contour of air

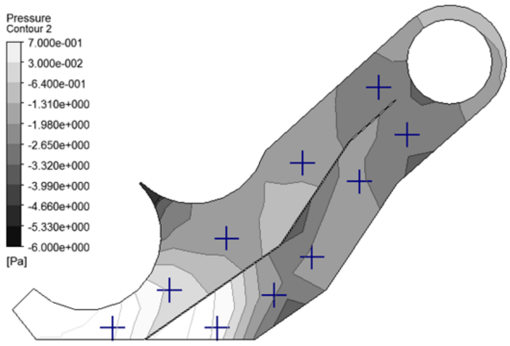


Figure 5. Pressure contour of air

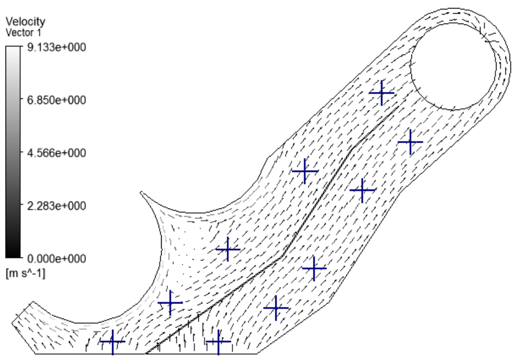


Figure 6. Velocity vector of air

After defining conditions, program can predict behavior of air flow of domain. The stable and suitable models are used to analyze for this study.

Figure 7 the relationship between air velocities at each point of interest when the size of the element is changed from 10 to 100 mm. It shows that the speed of each point is stable when the size of the element is greater than 40 mm. When the size of the element decreases, the value of orthogonal quality decreases but is at an acceptable level of more than 0.9.

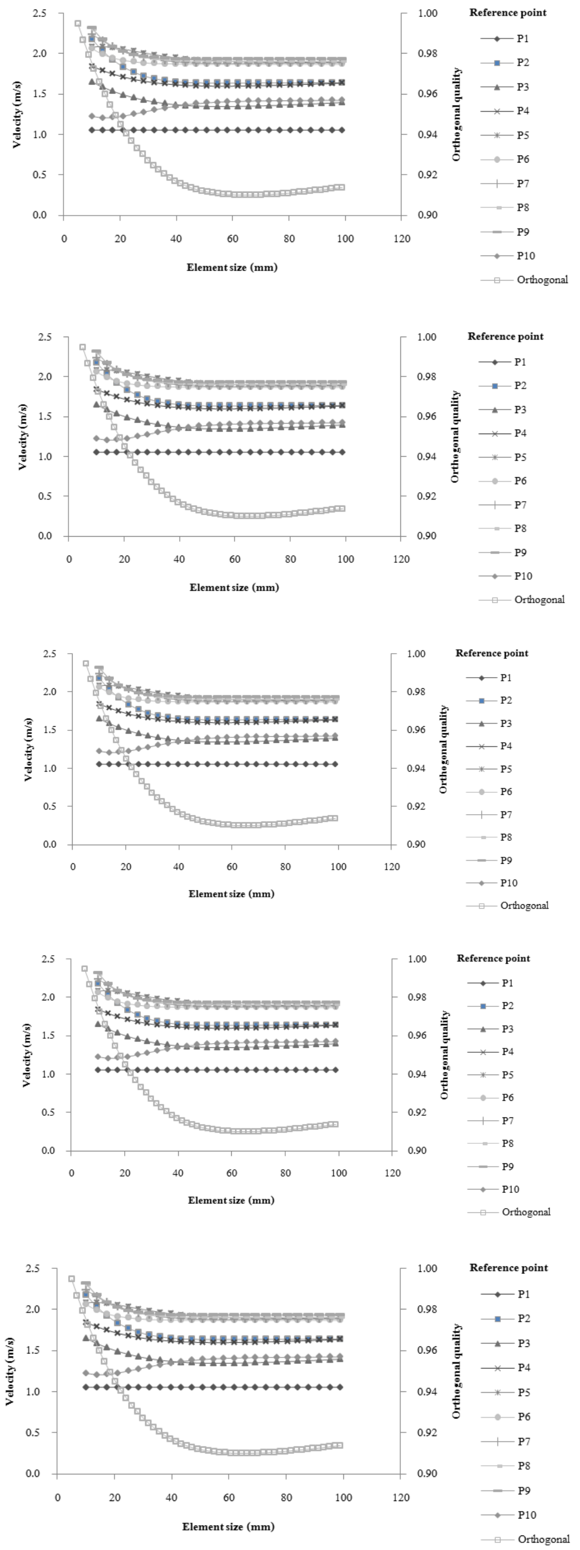


Figure 7. Element size versus each point velocity

Then meshing independence, fine collecting is performed by comparing difference mass flow inlet and out let are zero. Figure 8 was shown meshing independence tend of the inlet and the outlet flow rate.

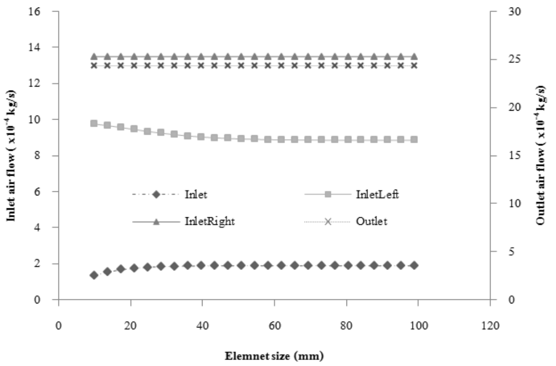


Figure 8. Inlet air flow and element quality versus element size

The air inlet and outlet air flow testing showed that the flow rate and flow of air were similar when the size of the element was 43. 1 mm. Therefore, in analyzing the air flow rate and pressure at each point in this study, this element size will be used in the simulation. Figure shows a relationship between an air flow through a brown rice- husk inlet and rubber roller angular velocity. It can be seen air flow rate was increase as well as a top and a bottom angular velocity increase.

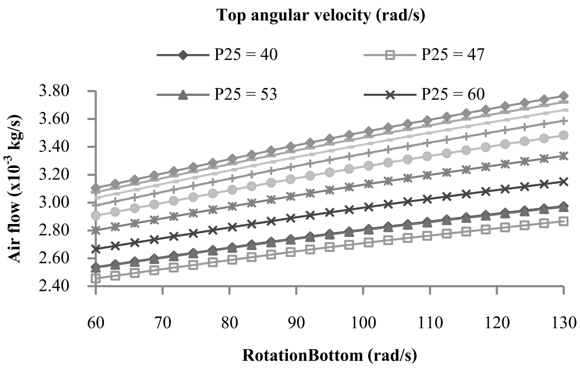


Figure 9. Inlet air flow subjected to the roller speed.

In designing a small rice husking machine, an air flow is important. Additionally, pressure of each point of interest is also the main factor which has an effect on productivity. Interested points in this simulation are 1 and 3 at the outlet of brown rice, which is important because it is the point of separation between brown rice and rice husk. Figure and Figure shows the relationship between angular velocity and the pressure at points 1 and 3 of two rubber roller. Both images show that when angular speed rises, pressure in both point also increases.

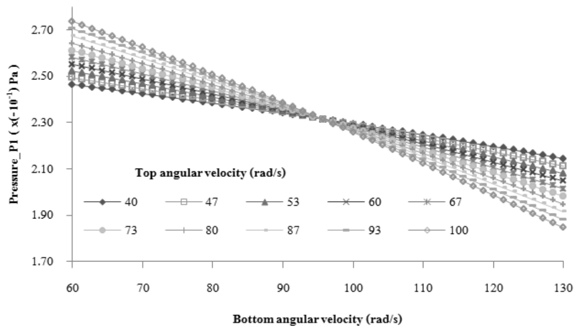
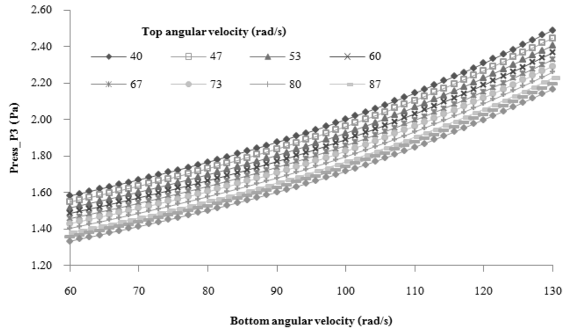


Figure 10. Pressure at P1 versus rubber angular velocity



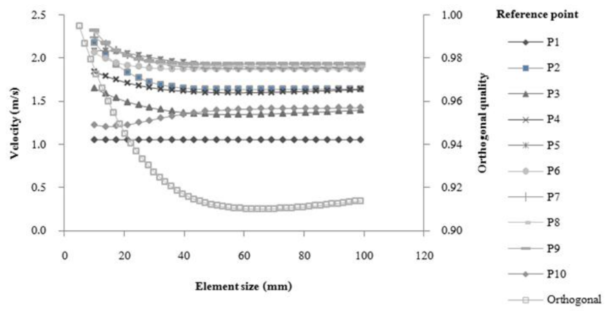


Figure 11. Pressure at P3 versus rubber angular velocity

CONCLUSIONS

Results of simulation on an influence of rubber roller angular velocity in a small rice husking machine were used the Computational Fluid Dynamic in this paper. The mesh independence was shown appropriate element size is 43.1 mm. The result can be shown rubber roller angular velocity to increases, it will cause air flow in domain. The increased rubber roller angular velocity also results to pressure at different points. A separation between rice husk and brow rice have to know behavior air flow in rice husking domain. Therefore, a relationship presented in graph form can be lead to the design of small rice husking to be the most effective in the next research.

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