

## Performance of Rice Grain Conveyor Vacuum Blower with Variations in the Number and Shape of Impeller Angles

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### ABSTRACT

Separating rice and bran, moving rice to storage, and other processes related to moving grain or rice. In the modern rice milling industry, the process of transferring grain material already uses a pneumatic conveying system; a vacuum blower system for transferring grain is needed when milling grain to become rice. The research method used to obtain the shape of a vacuum blower with strong inlet suction power and outlet thrust is carried out by Computational Fluid Dynamics simulation and testing several types and variations in the number of blades. Simulation of forward curved blade type impellers, backward curved blade, and straight radial blade with variations in the number of 8, 10, and 12 blades. From the impeller simulation, it was obtained that the straight radial blade with 8 blades was the best. The best impeller types were made using the manual method. Measurement results were on the straight radial blade type impeller with 8 blades, with a motor speed of 1,000 rpm; the results of measuring air speed at the inlet were 34.95 m/s and at the outlet 23.08 m/s. In addition, the difference in the results between in simulation and the experiment is due to the fabrication process and air leaks.

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**Keywords:** Blower, centrifugal blower, impeller, vacuum blower.

## I. Introduction

Blower is an important component in the rice milling industry [1]. Some processes that require a blower include drying wet rice [2] separating rice and bran, moving rice to a storage place, and other processes related to moving rice or paddy. In the modern rice milling industry, the process of moving grain material already uses a pneumatic conveying system [3]-[6] with a blower as its main component. Blower applications are also needed in other industries such as mining, oil, agriculture, chemicals, and other industries. A vacuum blower system for moving rice is very much needed during the process of milling rice to produce rice.

There are two types of blowers, which are pressure blowers and vacuum blowers [3], whose difference lies in how they work. Pressure blowers work by blowing air away from the blower. The material transportation system that uses a pressure blower is called a Pressure conveying system, which requires strong power at the outlet hole. While vacuum blowers work by sucking air into the blower, the material transportation system that uses a vacuum blower is called a vacuum conveying system which requires strong power at the inlet hole.



In addition to the Pressure conveying system and vacuum conveying system, there is one transportation system that combines the two systems, which is called the combined conveying system. An example of a combined conveying system is the portable vacuum grain conveyor [7]. This system requires a vacuum blower that has strong suction power at the inlet and strong thrust at the outlet. Several studies have developed blowers, including centrifugal blower simulations, but have not been applied to products [8]-[11]. Research on the inlet section [12], [13], and research on small-scale blades and impellers [13]-[20]. Jayapragasan [14] have been carried out by design optimization and experimental study to find the best impeller shape with an angle of  $80^{\circ}$  with 8 blades. However, the size of the blower is still small at 190mm. Then Umurani [17] has carried out experimental tests on impellers with the conclusion that the larger the impeller diameter will produce greater air velocity, but it is still small at 200mm.

In general, an industrial centrifugal blower is usually utilized in the agricultural industry for rice milling applications due to its compact design, less space requirement, and its simplicity to install [22], [23]. However, from the previous studies, the utilization of impeller varied in its impeller blade numbers and impeller angles has not been further investigated. This study aims to determine the inlet suction power and outlet thrust of the centrifugal vacuum blower for industrial purposes with variations in the shape and number of impeller blades. This should provide an adequate background and general context for the work, explaining its significance and indicating why it should be of interest to researchers.

## II. Material and Methods

### 1. Method

This study has been conducted to determine the performance of the rice grain conveyor vacuum blower by comparing parameter variations in the number and shape of impeller angles. The method used in this study begins with the design of the shape and number of blowers. A simulation is carried out with Computational Fluid Dynamics (CFD), which can describe the airflow that occurs in the impeller [24] to determine the effect of the number and shape of the impeller on the speed, followed by manufacturing a rice grain conveyor vacuum blower. Experimental performance testing is carried out with the following design of experiment, which is shown in Table 1.

**Table 1.** Design of experiment

Independent variables		Control variable	Dependent variable
Parameter	Level		
• Types of impeller blades	Forward curve, backward curve, straight	Rotational speed of impeller (1000 rpm)	Wind speed at the inlet and outlet
• Segment angles	$70^{\circ}$ , $90^{\circ}$ , $110^{\circ}$		
• Number of blades	8, 10, 12		

The rotational speed used in this study is 1000 rpm due to the limitation of the measurement apparatus used to measure the wind velocity at the inlet and outlet of the blower.

### 2. Design and Material

The volute vacuum blower has a length of 830 mm, a width of 794 mm, and a height of 915 mm, with material of ASTM A36. The shape of the volute can be seen in Figure 1. With

a volute like Figure 1, an impeller simulation was carried out with a diameter of 700 mm and a thickness of 6 mm.

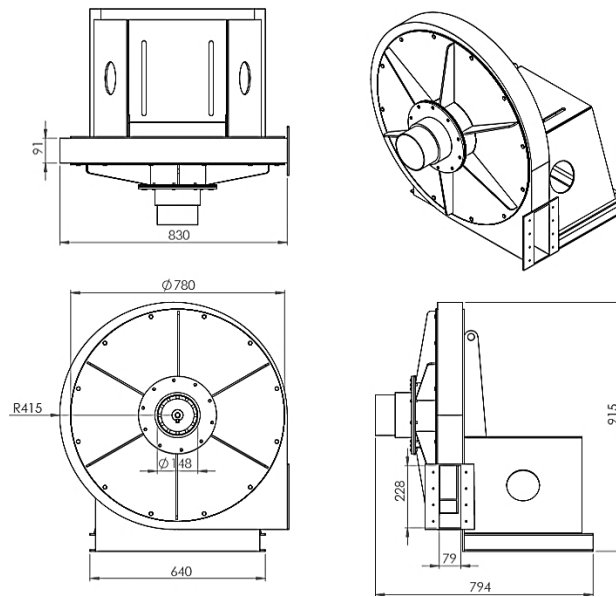


Fig. 1. Volute vacuum blower

**III. Results and Discussions**

*1. Computational Fluid Dynamics (CFD)*

The selection of the best vacuum blower is done with CFD of several types of impellers. Flow simulation software used in Solidworks 2021 with a small volute shape.

*CFD Forward curved blade*

CFD-type forward curved blades with different variations in segment angles of 70°, 90°, and 110° can be seen in Figure 2.

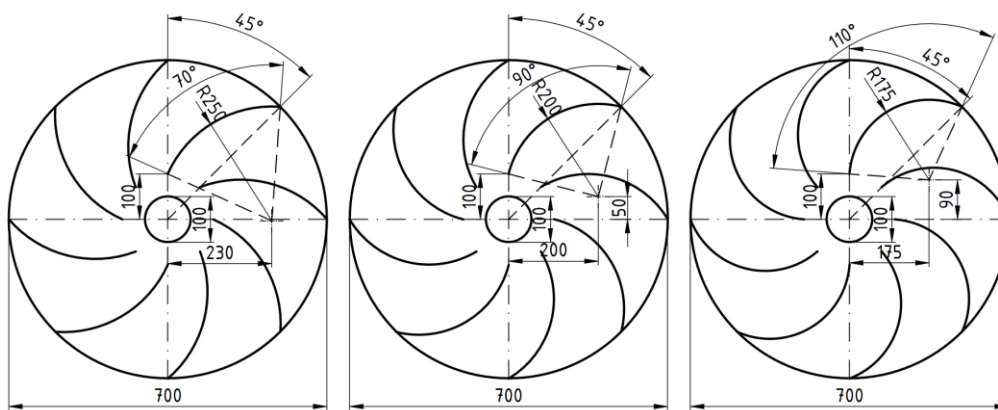


Fig. 2. Variations of forward curved blade shape

The result of the CFD simulation shows the air direction and distribution through the color difference of the streamline. Figure 3 illustrate the result of the impeller forward-curved blade. It is shown that the distribution of air flow is not well distributed, especially on the middle part. Furthermore, the highest air velocity which is around 45 m/s is concentrated on

the inlet. However, other location where high air velocity is located is the circumference of the volute. The CFD results of forward curved blades with section angles of  $70^\circ$ ,  $90^\circ$ , and  $110^\circ$  with variations of 8, 10, and 12 blades can be summarized in Table 2.

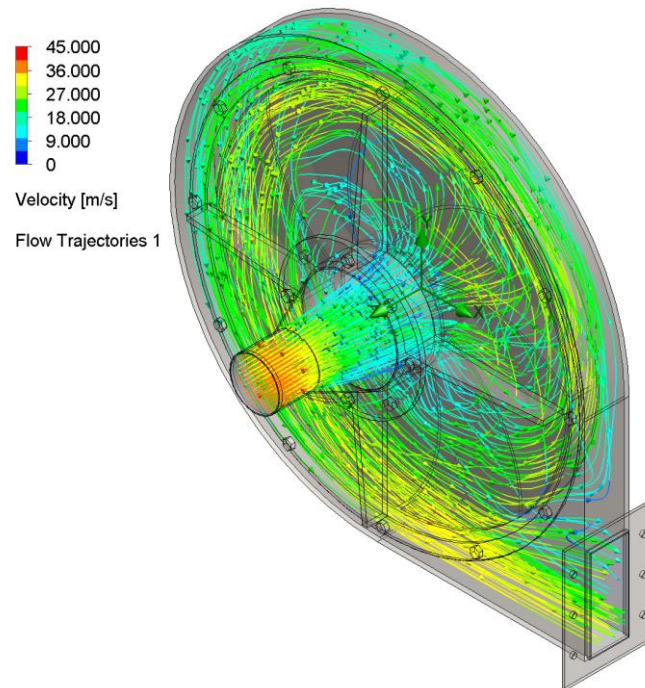


Fig. 3. Forward curved blade simulation

**Table 2.** Forward curved blade impeller simulation results

Type of blade	Number of blades	Velocity inlet (m/s)	Velocity outlet (m/s)
Impeller forward curved blade $70^\circ$	8	35.548	22.052
	10	34.557	21.689
	12	33.908	21.184
Impeller forward curved blade $90^\circ$	8	34.879	21.807
	10	33.965	21.369
	12	33.035	20.944
Impeller forward curved blade $110^\circ$	8	33.543	21.149
	10	32.213	20.561
	12	31.274	20.075

The selection of the blade is based on the result of the highest air velocity on both inlet and outlet from the simulation. The selected impeller from the CFD results of the forward curve blade shape is a  $70^\circ$  segment angle with a total of 8 blades with the air velocity of 35.548 m/s on the inlet and 22.052 on the outlet.

#### *CFD Backward curved blade*

CFD of the backward curved blade type with different variations in segment angles of  $70^\circ$ ,  $90^\circ$ , and  $110^\circ$  can be seen in Figure 4.

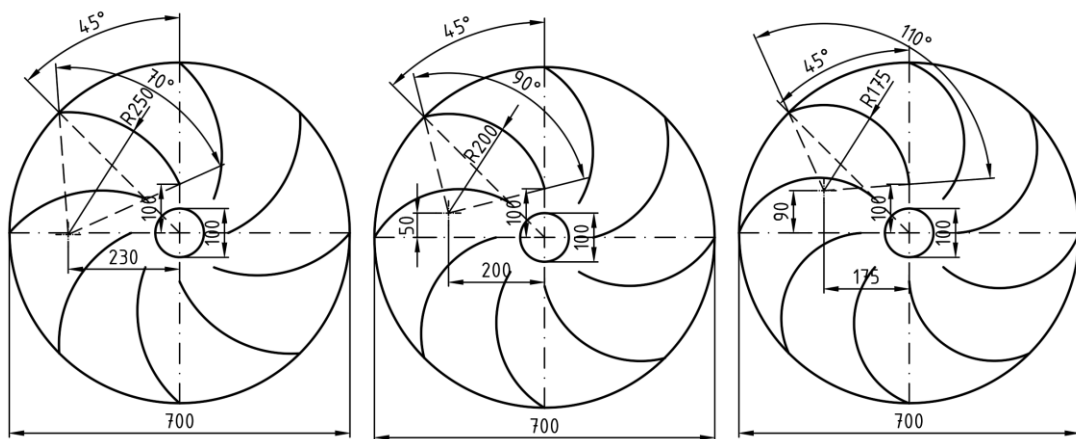


Fig. 4. Variations of forward curved blade shape

With the same method, CFD simulation is conducted to choose the best shape and number of backward-curved blade. The result is shown on Figure 5, where the air flow is distributed in the whole area of the volute. The red color shows the highest air velocity which is around 45 m/s and concentrated on the inlet and outlet of the volute.

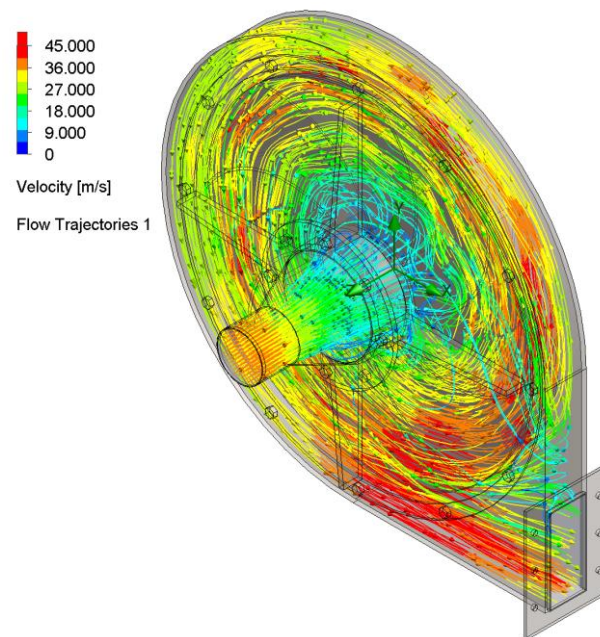


Fig. 5. Backward curved blade simulation

From Figure 5, air flow velocity increased on the inlet and the outlet. Because this blower is used to suck rice, the high air velocity on the inlet is more required. The selected impeller from the CFD results of the backward curve blade shape is a  $70^\circ$  segment angle with a total of 8 blades. There is an influence from the variation in the impeller angle, which can reduce the speed loss that occurs [25], resulting in the information that the larger the angle, the smaller the loss that occurs [26].

Table 2 shows the results of the backward curved blade simulation with a section angle of  $70^\circ$ ,  $90^\circ$ , and  $110^\circ$  and variations of 8, 10, and 12 blades.

**Table 2.** Backward curved blade impeller simulation results

Type of Blade	Number of blades	Velocity inlet (m/s)	Velocity outlet (m/s)
Impeller backward curved blade 70°	8	38.740	25.770
	10	38.577	26.056
	12	37.068	24.819
Impeller backward curved blade 90°	8	38.076	26.125
	10	37.696	25.872
	12	36.214	25.117
Impeller backward curved blade 110°	8	36.490	25.722
	10	34.272	25.935
	12	33.953	24.375

### 1.3. CFD Straight Radial Blade

The CFD straight radial blade impeller is different from the previous two types because there is no variation in the blade angle shape, so it only varies in the number of blades. The shape of the straight radial blade variation is shown in Figure 6.

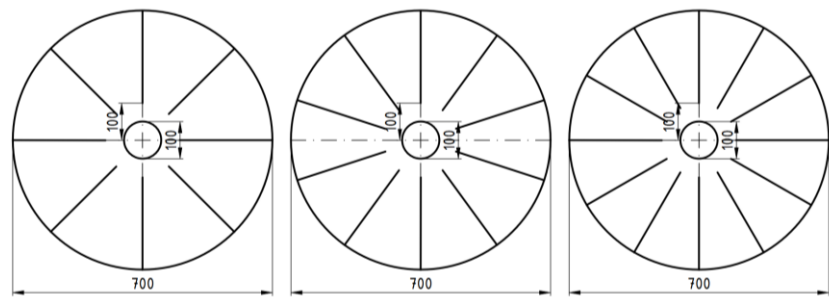


Fig. 6. Straight radial blade simulation

The CFD results of the blower with a straight radial blade shape are shown in Figure 7 where air flow is spreading on the whole area of the volute. Moreover, the highest velocity of 45 m/s is located on the inlet, outlet and the circumference of the volute.

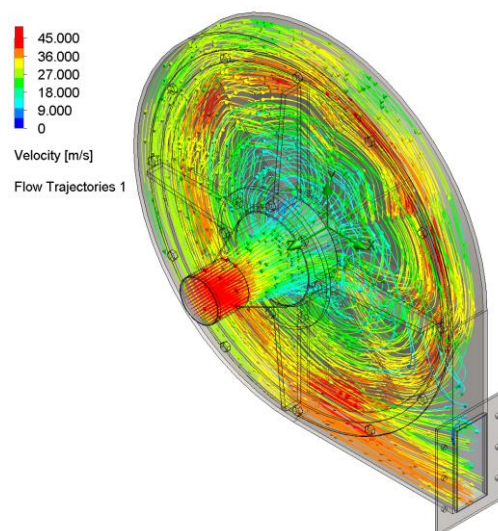


Fig. 7. Straight radial blade simulation

The results of the straight radial blade with variations of 8, 10, and 12 blades are shown in Table 3.

**Table 3.** Straight radial blade impeller simulation results

Number of blades	Velocity In (m/s)	Velocity Out (m/s)
8	45.043	25.238
10	43.937	24.958
12	43.359	24.646

From Figure 7, the inlet is filled with the air with the highest velocity that shows this variation is producing higher air velocity than other blade types. From Table 3, the highest air velocity of the straight radial blade impeller which is 45.043 m/s. The selected impeller from the CFD results of the straight radial blade impeller shape is an impeller with 8 blades. This is in line with research conducted by [27] regarding the effect of the number of impellers, stating that the more impellers can result in increased friction [25]. The impeller shapes that perform the highest will be fabricated and tested for performance to obtain the best impeller.

## 2. Fabrication

The best impellers are made manually using hands (not using CNC or laser cutting). The impeller material is made of medium carbon steel with front shroud

an outer diameter of 70 cm, a fin width of 6 cm, and a plate thickness of 5 mm. The impellers that have been made can be seen in Figure 8.

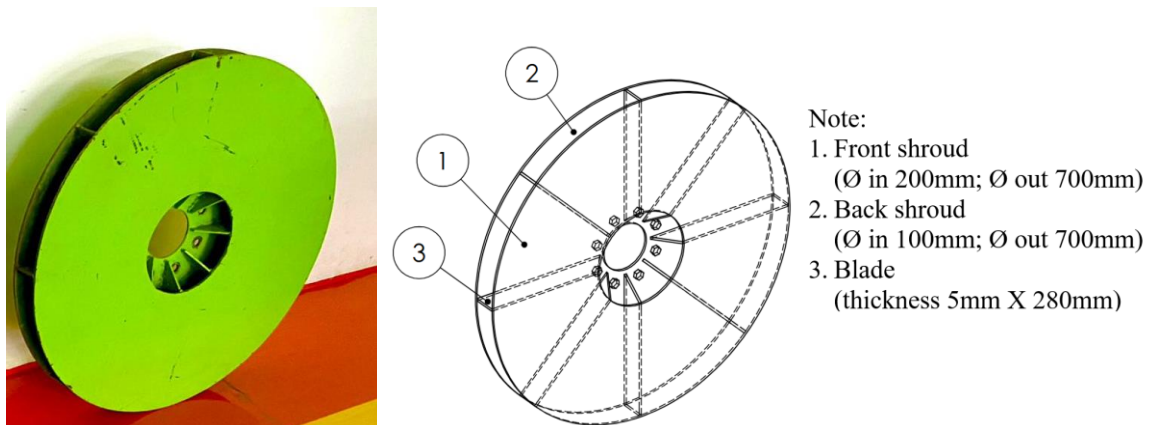
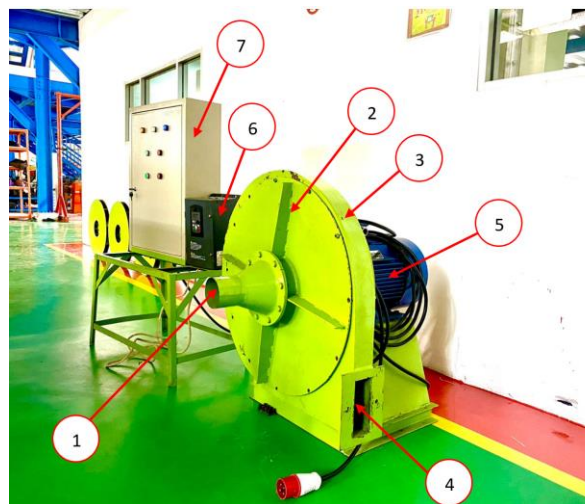


Fig. 8. Fabrication of impeler

Then the impellers were tested with the volute vacuum blower as in Figure 9. The vacuum blower is driven by a 3-phase electric motor of 20 HP, 15 KW, 1,500 rpm. The impeller rotation speed is regulated by a 20 HP 15 kW inverter.



- Note:
1. Inlet
  2. Volute cover
  3. Volute
  4. Outlet
  5. Electric motor
  6. Inverter
  7. Panel Box

Fig. 9. Vacuum blower

### 3. Performance Test

Vacuum blower testing was carried out alternately with the best impeller variations from the simulation results. This is done by using an anemometer to measure the airflow average velocity at the inlet and outlet. Furthermore, the average velocity at the inlet and outlet with an electric motor rotation of 0 to 1,000 rpm (limitations of measuring instruments) is measured. The airflow velocity testing process is shown in Figure 10.



Fig. 10. Airflow velocity test

The velocity value of the vacuum blower using a straight radial blade impeller with 8 blades is 34.95 m/s at the inlet and 23.08 m/s at the outlet. The airflow velocity graph from 0 to 1,000 rpm at the inlet and outlet is shown in Figure 11.

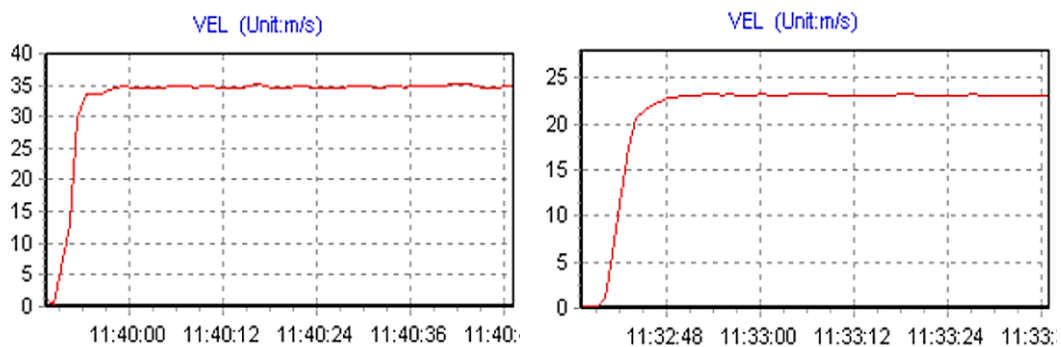


Fig. 11. Air velocity graph at the straight radial blade inlet and outlet

The simulation and impeller test get different results due to the process of manual fabrication process and air leaks.

#### IV. Conclusions

In this study, from the simulation and experiment results carried out with variations in the number and angle of the impeller. It is found that the more the number of impellers, the greater the air friction that occurs, and the greater the angle of the impeller can reduce losses. Moreover, the type of impeller that produces the highest air velocity for an impeller rotational speed of 1000 rpm is the straight radial blade type with 8 blades, which produces an airflow speed at the inlet of 34.95 m/s and 23.08 m/s at the outlet for the experiment. Meanwhile, from the simulation result, the airflow speed of this impeller type is 45.043 m/s at the inlet and 25.238 m/s at the outlet. In addition, the difference in the results between in simulation and the experiment is due to the fabrication process and air leaks that is also indicating of the limitation of this study.

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