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# EXPERIMENTAL PERFORMANCE INVESTIGATION OF SWIRLING FLOW ENHANCEMENT ON FLUIDIZED BED DRYER

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## ABSTRACT

An objective of present work is an attempt to develop a low-cost swirling flowfluidized bed dryer that can lead to reduced drying time. In this study, a swirling fluidized bed dryer is designed and fabricated to increase the heat transfer rate between the air and the wheat particle. The swirl flow is generated by a swirl chamber which has an adjustable guide vane and tangential injection of air. The drying experiments are conducted at various air temperatures (36°C, 40°C and 50°C) and velocities (4.5 m/s, 6.2 m/s and 6.8 m/s) with correspondingvane angles of 25°, 45° and 65°. The performance of swirling fluidized bed dryer with different operating conditions are analyzed by considering the effect of inlet air temperature, inlet air velocities, initial moisture content and drying time. The results are shown that combination of 50° temperatures, 6.8 m/s velocity at65° blades angle in swirl chamber produces the best configuration for the common applications.

**Keywords:** Fluidized bed dryer, swirling flow, moisture content.

## 1. INTRODUCTION

The fluidized beds have developed for different physical and chemical operations, such as transportation systems and chemical reaction processes. Kunii and Levenspiel [1] the traditional and some commercial grain dryers consume considerable time and energy in their operations, and available dryers are very expensive. Therefore, there is the need to develop dryers that should lead to are duction in drying time of grain without compromising efficiency and also with reduced operating cost. Hideo Inaba [2] the experiments are carried out in fluidized bed heat exchanger made of transparent acrylic plate. The effect of gas velocity on the average and local heat transfercoefficient fluidized bed heat exchanger of silica sand particles. Queiroz *et al*. [3] Uniform processing conditions are achieved by passing air through a product layer under controlled velocity conditions to create a fluidized state. Heat may be effectively introduced by heating surfaces immersed in the fluidized layer. Ozbey and Soylemez [4] experimentally investigated swirling flow fluidized bed dryer and effect of mass flow rate by using axial guide vanes. Effect of swirling flow gives the better drying rate compare to the conventional dryers. Balasubramanian and Srinivasakannan [5] presents the effect of operating parameters in the fluidized bed dryer. It results that the solids material used shows a falling rate period, and the rate of drying is influenced by the air temperature and rate of flow of the heating medium, solids circulation rate and initial moisture content. Harish Kumar and Murthy [6], A swirl flow is developed in a dryer by passing air through multiple air inlets. It shows that the minimum superficial velocities required achieving swirling flow in the dryer bed at different operating conditions. A swirl flow in the drying chamber is more complex and important than the situations studied in earlier methods. The main objective of this study is to design a swirl chamber which gives better performance characteristics of the swirling fluidized bed. The proposeddesign focused on the effect of guide vanes in the

chamber including with inlet air temperature, inlet air velocities, initial moisture content and drying time.

## 2. MATERIAL AND METHOD

### 2.1 Experimental setup

An experimental setup consists of a centrifugal blower, insulated heating chamber, finned tube electric air heater, swirl flow chamber with adjustable guide vanes, drying chamber, 80 mm mild steel pipelines to connect the components, dimmer stat with voltmeter and ammeter, temperature indicator and anemometer. The schematic diagram of the experimental setup is shown in Figure-1.
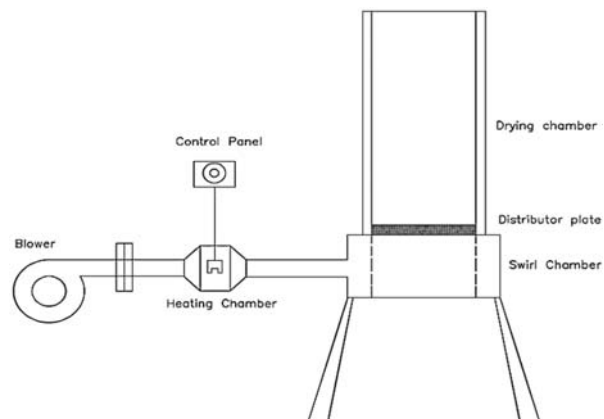


**Figure-1.** Schematic diagram of experimental setup.

The drying chamber has a diameter of 300mm and height of 900mm. It is made of 2 mm thick stainless steel. The selection of stainless steel in this regard is due to its strength and heat transfer properties. At the bottom end of this chamber, a perforated gas distributor plate is welded, and the top side is kept open to the atmosphere. The stainless-steel column and the distributor plate forms the fluidized bed. The hot air from the swirl chamber

enters at the bottom of the chamber through distributor plate and leaves at the top, and fluidization of grains takes place inside to the chamber. The distributor is made of a number of blades that are truncated sectors of a cylinder. The blades are arranged to rotate an angle of 0°-90° about its vertical axis. Swirl chamber is assembled below the distributor plate in the fluidized bed dryer setup. The swirl chamber is a cylindrical chamber has an outer diameter of 500 mm and height of 200mm. It is made of 2 mm thick mild steel. The bottom side of this chamberis welded with 500 mm diameter, 2 mm thick mild steel sheet and the top side has a partial open of 300 mm diameter of its centre to connect the drying chamber. The inner side of the swirl chamber is made up of a number of blades which are similar to the truncated sectors of 300 mm radius cylinder. The blades have a width of 50 mm and height of 188 mm. It is made of 2 mm thick mild steel. All the blades are welded to the centre portion of 200 mm height and 12 mm diameter mild steel rod parallel to its size. The blades are freely rotating in between the two flanges about its vertical axis. These blades are acts as guide vanes to direct the air from the heating chamber. A disk of diameter 260 mm and thickness of 6 mm which is having twenty-one radial slots of 232 mm outer diameter and 158 mm inner diameter is placed on the swirl chamber bottom sheet concentrically to the flange and chamber housing. The disc is pivoted by using a pivot pin about its centre on the bottom sheet of swirl chamber housing. A 67.50 mm length, 20 mm height and 2 mm thick rectangular strip is vertically welded at the bottom of each guide vane with an angle of 135° to the guide vane blade. Another end of the rectangular strip is welded with 5 mm diameter mild steel rod parallel to its height, and the rod has an extended portion of 5 mm from the bottom. This extended portion of the rod is placed in the disc slot. The guide strip rod slides within the disc slot when the disc turns. The disc slot guides the guide strip and guides strip guides the guide vane angle movement. Each guide vane connects one radial slot of the disc. All guide vanes are attached to each disc slot through guide strip to constrain the 21 guide vanes movement evenly to rotate from 0° to 90° about its vertical axis. The angular disc movement is limited from 0° to 20° by a stud and angular slot segment provided on the disc. The disc movement can be locked at any position in between 0° to 20° by a lock nut provided on the stud. This setup will enable the guide vanes movement to rotate from 0° to 90° and position lock in between at any required guide vanes angle. A hand lever welded on the disc is used to move the disc. The equal length between the guide vanes directs the air at the designed angle. Air pipeline from heating chamber is divided into two parts and connected tangentially to the vertical centre of swirl chamber housing and opposed directions, to create a swirling motion.

## 2.2 Experimental performance testing of swirling fluidized bed dryer

The experimental investigation is carried out to conduct the performance behaviour of the swirling fluidized bed dryer developed as shown Figure-2.



**Figure-2.** Photographic view of swirling fluidized bed drier.

Drying experiment tests are performed in the swirling fluidized bed dryer, and wheat is considered as a drying material. The air from the blower passes through the heater in which air is heated as required inlet temperature. The hot air is distributed into equal amounts by the connected pipeline and enters the swirl chamber, tangentially in opposed directions. Fabricated swirl flows chamber assembly as shown in figure 3. That creates a swirling motion to the air in between the guide vanes and the chamber wall. Then the air strikes the guide vanes and passes through the gap between the subsequent guide vanes as a result of its swirl flow increases. The hot air enters the drying chamber through the gas distributor plate. As air passes through the grain bed, it absorbs moisture under adiabatic drying; sensible heat in the air is converted to latent heat. When a gas is passed upwards through the material loaded in the chamber, the pressure drop across the particle layer will increase in proportion to the gas velocity until the pressure drop reaches the equivalent of the weight of the particles in the bed divided by the area of the bed. At this point, all particles are suspended in the upward flowing gas and the frictional force between particulate matter and gas counterbalances the weight of the particles.



**Figure-3.** Swirl chamber assembly.

A known quantity of wheat (500 g) is soaked in water till it gets completely saturated with water. The surface moisture of the particles is allowed to dry, and the

initial moisture content of the wet particles is determined. The blower and heater are switched on and allowed to run to attain steady state condition. The vane angle and bed temperature are set to conduct the experimental trail. The prepared wheat is weighed and charged into the drying chamber. The samples are withdrawn from the bed at the time interval of 5, 10, 20, 20 minutes, and weight is measured and recorded. The same procedure is repeated for different temperatures 36°C, 39°C and 50°C and various vane angles of 25°, 45° and 65°.

All the experiments are conducted and from the reading the moisture content of grain is determined on a wet basis.

Moisture content of grain, $MC = \dfrac{W_{initial} - W_{Final}}{W_{initial}}$

For all the drying experiments, 500 grams of dry wheat is used, and it is soaked in water till it gets completely saturated with water. Therefore, final weight of grain is 500 grams. The initial weight of grainis weighed before loading to the drier bed every time.

## 3. RESULTS AND DISCUSSIONS

The experiment results for various inlet air temperatures and inlet air velocities with corresponding vane angles (VA). The performance of swirling fluidized bed dryer for different operating conditions is analyzed by considering the effect of inlet air temperature, inlet air velocities, initial moisture content and drying time.

### 3.1 Effect of inlet air temperature

The drying experiments in the fluidized-bed dryer with various bed temperatures of 36°C, 40°C, and 50°C are presented in figure 4-6. Results show that increasing drying air temperature will increase the efficiency of the drying process, but there is the practical limitation due to the damage of the material furthermore.
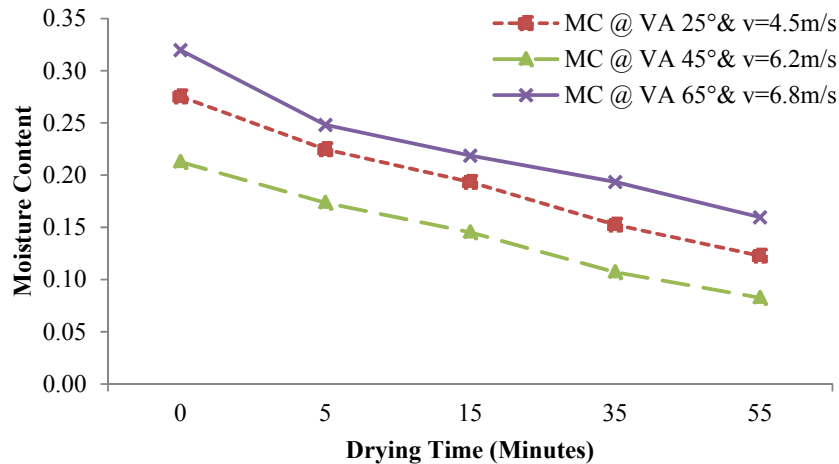


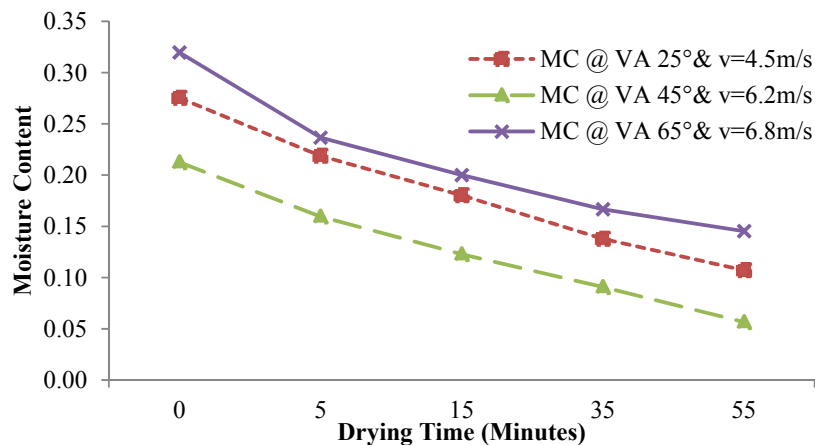**Figure-4.** Moisture content versus drying time at 36°C of bed temperature.



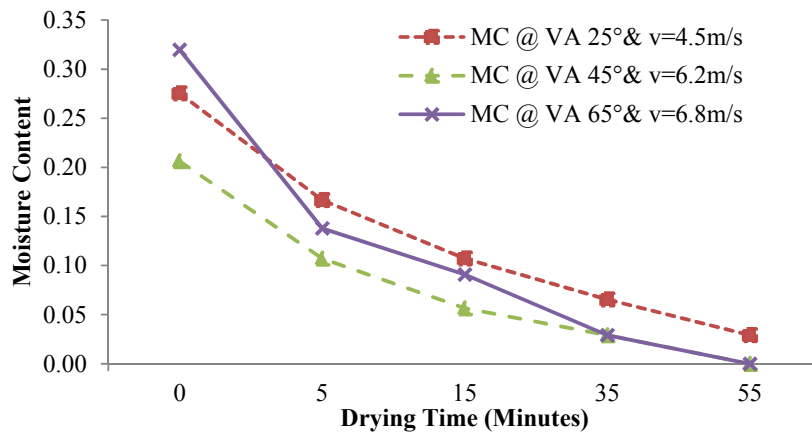**Figure-5.** Moisture content versus drying time at 40°C of bed temperature.

**Figure-6.** Moisture content versus drying time at 50°C of bed temperature.

**3.2 Effect of inlet air velocity**

Drying behaviour of fluidized-bed dryer with inlet air velocities at the swirl chamber outlet of 4.5m/s, 6.2m/s and 6.8 m/s for respective vane angles of 25°, 45°and 65° is presented in the Figures 7-9. The moisture content of wheat decreases with the rise of the drying air velocity. Results shows that the drying air velocity has a significant effect on the drying of wheat, especially at higher air inlet velocity with high temperature. As in the case of normal fluidized bed, the decreases in the moisture content with drying time are nearly the same for all velocities, especially at the higher velocity.
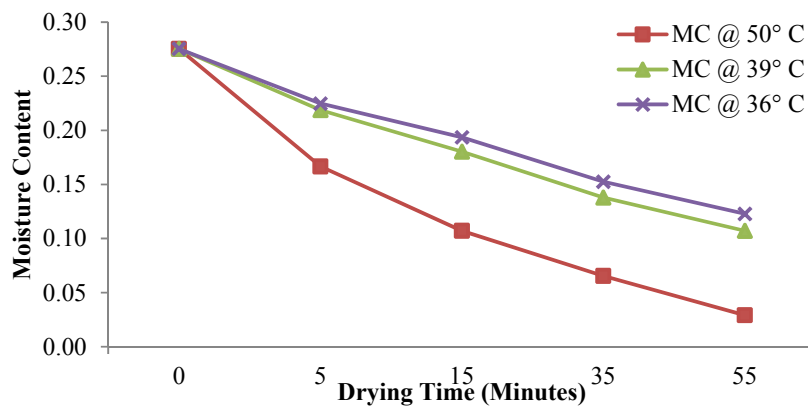


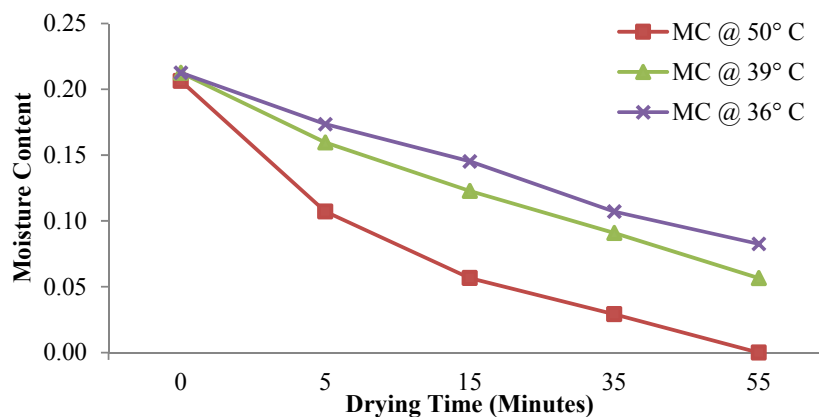**Figure-7.** Moisture content versus drying time at velocity 4.5m/s of vane Angle 25°.



**Figure-8.** Moisture content versus drying time at velocity 6.2m/s of vane Angle 45°.
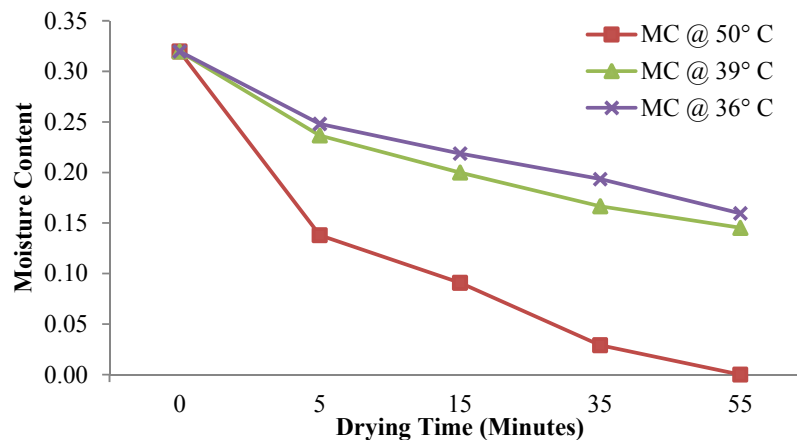
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**Figure-9.** Moisture content versus drying time at velocity 6.8m/s of Vane Angle 65°.

### 3.3 Effect of initial moisture content

The experiments are conducted at a various initial moisture content of wheat of 635g, 690g, and 735 grams. The efficiency is slightly higher for the grain material with higher initial moisture content.

### 3.4 Effect of drying time

Drying rate for the fluidized-bed with various bed temperatures of 36°C, 39°C, and 50° is presented in the graphs figure no 24 to 26 and various velocities of 4.5m/s, 6.2m/s and 6.8 m/s. From the charts, the drying time increases, the amount of water evaporated increased.

### 4. CONCLUSIONS

Experimental performance of moisture content reduction of drying wheat is carried out, and it may be concluded that swirl flow fluidized bed dryer technique is found to be better than the typical fluidized bed technique. The use of different velocities leads to no significant effect on drying rate for a conventional fluidized bed and it is recommended to use gas velocity as low as possible but the experimental results show that the use of different velocities provides substantial influence for the swirling drying method of swirling fluidized bed drier. The swirling drying bed performs better than the conventional fluidized bed. Among the experiment carried out in this study, the 50°C air temperature and 65° blades angle in swirl chamber offers the best configuration for the wheat grain.

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