

Ultrafine Air-Classification of Plant based Proteins: A step Towards Reducing Carbon Footprints

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Abstract— Air classification is vital for separating particles, with applications in industries such as food, pharmaceuticals, agriculture and many more. With the increased innovation and advancements of science, demands of smaller particle sizes, innovative and effective methods of classifications are needed. The performance of a rotor air classifier is effected by both its structural parameters which includes the design of the rotor cage, shell design, volute and much more, and operating parameters which include the classifier rotor speed, the feed rate and the air inlet velocity. With the increased demand of ultra fine classification of sub 10 micron the air classification method is within its limit of possibilities to achieve this range. Effect of change in rotor blade angle, rotor speed and feed rate are investigated. With extensive experimental work carried out and results are analysed to optimise the classification of sub 10 micron particle size.

Keywords: classification; efficiency; rotor cage; volute; blade angle;

1. Introduction

Powder classification divides raw feed material into fractions based on properties like size or density, ensuring uniformity. Various methods exist for size-based classification, each with pros and cons. Air classification using dynamic air classifiers is popular for meeting industrial demands, such as high throughput and low cut sizes. The cut size is the particle size with a 50% chance of being classified as fine or coarse fraction [1]. Perfect classification is theoretical, as factors like particle collisions and aerodynamic interactions can cause finer particles to form coarser ones or allow coarser particles into the fine fraction.

An improved uniform flow field inside the air classifier mainly in and around the classifier rotor blade can achieve fine cut size classification and improvement of separation efficiency. Studies have been conducted the performance of classifier. Adamcik studied the effect of performance parameter on classification mainly focusing on the feed rate, air flow and rotor speed [2]. Jia, et al. used Ansys-Fluent in order to conduct investigation on the effect of various rotor cage structure as well as diversion cone [3]. Shubo, et al. used Ansys-Fluent in order to obtain a discrete phase simulation between the single and double layer spreading plate [4]. The presented paper deals with the experimental investigation of the effect of various rotor cage structure design with varying feed rate and rotor speed.

This study uses a classifying system with a vertical rotor cage and no guide vane. Figure 1 illustrates such system whereby particles enter from the top, controlled by a rotary valve, while air from a fan enters from the bottom, rising into a conical chamber. The rotor cage, driven by an electric motor, whirls the air to create a centrifugal counter flow separation zone at the top. Around the blades, a centrifugal cross flow zone forms, enabling particle separation.

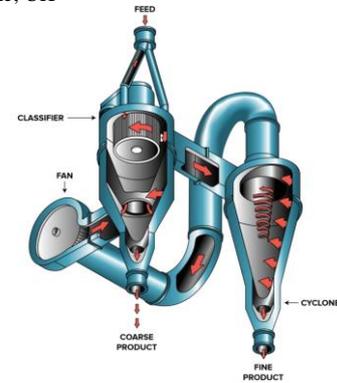


Figure 1. A Schematic Illustration of Particle Flow in a Typical Classification System [5]

2. Rotor Classifier

2.1. Introduction of Rotor Classifier

Rotor air classifiers are vital in industries like mineral processing, pharmaceuticals, food processing, and agriculture for particle size classification. They use centrifugal and aerodynamic forces to separate particles by size and shape, ensuring the desired product specifications [6].

Rotor air classifiers come in various designs, from them the main design variations include the inner and outer radius of the rotor cage, the height, width, and shape of the rotor blade, the rotor orientation (horizontal or vertical), the use of guide vanes, the design of feeding inlets and methods, and the air inlet and volute design.

When the relative velocity angle matches the rotor blade angle, the incidence angle between the airflow and rotor blade becomes zero. This reduces the impact of airflow and particles on the rotor blade, resulting in a well-distributed flow field in the rotor cage, which is the primary focus of this study.

Sharpness of separation and cut size are key performance measures when evaluating rotor air classifier performance.

Sharpness of separation is the ratio of a selected particle size in the coarse selection compared to the infeed. This is illustrated by an efficiency curve. The ideal situation places particles below the selected size in the fine collection and those above in the coarse fraction. In reality, this is represented by an S-shaped efficiency curve [7].

In air classification, the cut size is the particle size at which fine and coarse particles separate. Controlling the cut size is essential for achieving the desired particle size distribution, affecting product quality, yield, and energy consumption. Factors influencing cut size include airflow rate, particle properties, classifier design, and feed material characteristics. Determining the appropriate cut size involves understanding and optimising these factors.

3. Experimental Methods

The general classification process in air classifier is of the initial in-feed material entering from above to the classification zone, where particles follow one of two paths. If gravitational and centrifugal forces exceed the drag force, particles drop into

the coarse fraction collection bucket. Alternatively, if particles overcome these forces, they are transferred via the fine fraction air stream to the filter. Clean air passes through filter cartridges, capturing the fines inside. These fines are cleaned with timed pulse jets, which disturb particles on the inner filter surface, causing them to drop into the fines fraction collection unit. The clean air then escapes into the atmosphere.

Figure 4 shows the components of the air classifier in the experimental set up.

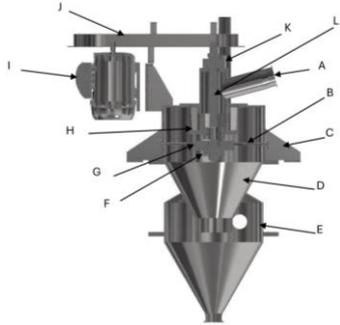


Figure 2. Main Components of an Air Classifier. (A) Rotor Housing; (B) Stay Bolt; (C) Upper Chamber; (D) Inner Cone; (E) Lower Chamber; (F) Lower Bearing; (G) Stay Bolt Ring; (H) Rotor Cage; (I) Electric Motor; (J) Drive Components; (K) Upper Bearing; (L) Shaft.

3.1. Experimental Measurements

The study examined the effect of rotor blade angle with varying operating parameters. A total of 27 experimental trials were conducted using three different rotor designs with blade angles of 0°, 30°, and 45°, varying feed rates of 15, 35, and 113 kg/s, and rotor speeds of 1600, 2000, and 2400 rpm. Each trial used 1 kg of pea powder, which was collected from both fine and coarse collection units, then weighed. Samples were analyzed using a Malvern Mastersizer 3000 to obtain particle size distribution curves. Classifier efficiency for each trial was calculated using the Bradley efficiency formula, considering yield, purity, and throughput of the desired particle size;

$$\eta = \frac{F_f}{F_t} \times \text{Percentage fines in the fine collection} \quad (1)$$

F_f – mass of fines content in the fine collection
 F_t – mass of fines content in the in feed

4. Results

The classifier efficiency for each trial is plotted on graph to visualise the effect of rotor blade angle and the varying operating parameters.

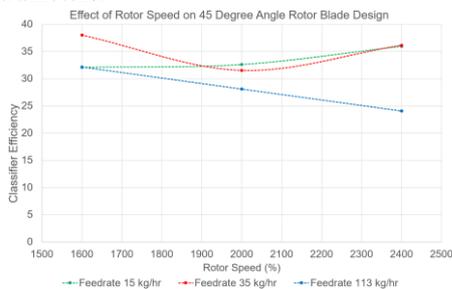


Figure 3. Graph Showing the Classifier Efficiency of 45° Rotor Blade Angle

Figure 3 shows the classifier efficiency with varying operating parameters for a 45-degree rotor blade angle. It indicates that as the feed rate increases significantly, the classifier efficiency reduces. However, at lower feed rates of 15 and 35 kg/hr, there is a crossover throughout the varying rotor speeds. Figure 4 illustrates that with a 30-degree rotor blade

angle, as the feed rate increases, there is a slight improvement in efficiency. Additionally, an increase in rotor speed results in a gradual improvement in efficiency. However, when the feed rate is 113 kg/hr, it follows a U-shaped parabola, with 1600 and 2400 rpm showing optimal efficiency and 2000 rpm being the most inefficient. Figure 5 demonstrates that for the 0-degree rotor blade angle, rotor speed has very little effect on efficiency. However, there is an improvement in efficiency when the feed rate is increased to 113 kg/hr.

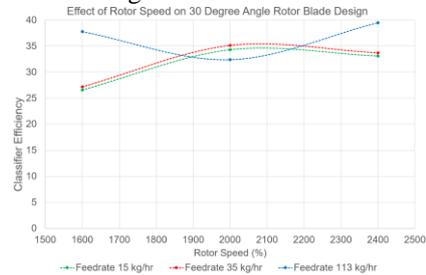


Figure 4. Graph Showing the Classifier Efficiency of 30° Rotor Blade Angle

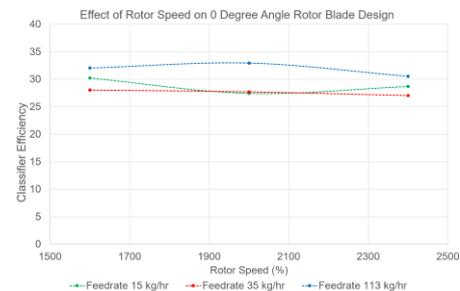


Figure 5. Graph Showing the Classifier Efficiency of 0° Rotor Blade Angle

5. Conclusion

The classifier efficiency was studied by using different rotor designs and varying operating parameters. The 30° and 45° rotor blade angles were identified as the most optimal designs, improving flow fields through the rotor cage compared to the 0° blade angle [8]. However, the 0° blade rotor showed a fairly consistent efficiency pattern. Further research with varied rotor speeds is needed to understand their impact on efficiency. Future work will focus on curved blade rotors to enhance the flow field.

Acknowledgement

The authors appreciate the financial and technical support of Bradley Pulverizer and the Wolfson Centre, University of Greenwich. The project is partly supported by the University of Greenwich through VC Scholarship (VCS-FES-05-21).

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