Design and Analysis of Zigzag Classifier in Food Industry Applications

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Abstract. In a zigzag classifier the material is being entertained utilizing varied channel velocities and mass load of the air. Specialty of zigzag classifier is it is being used in separation of particles having about the same size, but differing specific gravity, Separation of bulk materials which cause challenges and expensive costs if sieved. In this Zigzag classifier, sugar, salt, flour and grain, starch, milk products; spices; tea, gelatin, and vegetables are included in a typical application for the food sector. Zigzag classifiers are usually maintenance free, wear-resistant, overload-resistant and not sensitive to changes in the composition of the feed material. Due to these properties, the classification system can be operated without any oversight for lengthy durations. Even under overload situations, the goal output is clean particles or lightweight material.

Keywords: Zigzag classifier, Velocity, Food Industry Applications, Materials

1. Introduction
In recent years, serious food safety accidents have been often experienced, people are highly concerned about excess metal and additive content, residues of pesticides, and food safety has become a worldwide topic [1]. The classification of particles is significant and developed as the key control parameter for most industrial solid processing activities, based on the terminal deposition velocity. This adjustment velocity depends on typical particle features such as size, density and form. The other major property that controls the separation efficiency is turbulent particle diffusion [2].

The theory of gravitational classifiers is founded on the idea that, under the influence of various forces, particles suspended in fluid streaming commonly air or water migrate to various places so that they can be distinguished [3]. A straight, rectangular channel with several steep turns consists of the divider. Air is blasted from the ground to the top, while portion is fed to the channel through a feed aperture around halfway upwards. The movement of particles is caused by the interaction between gravity, fluid forces and collisions with other particles and the walls of the device [4]. These particles are not controlled by quality; rather, they have been subject to circumstances. Accordingly, the performance from an operational point of view is generally stated as alternating with the air velocity for the vertical air classification of solid waste particles [5].
In the design and operation of a waste to power generation facility, the essential characteristics of zigzag air classification designs are examined. The construction of an operating scope determined performance assessment approach is studied. In the past, the air classification in mineral extraction, calcareous sizing and seed and grain cleaning has been used in the industries and in agriculture. However, due to the complex and changing character of the waste, air classification is adapted to resource recovery and residue in power generation installations. A number of setups are tested which offer a continuous array of components for the zigzag classification. To assess its separation and operating air speed sensitivity, each configuration shall be studied. Results show that the Zigzag classifier setup does not affect its maximum separation efficiency. However, the results show clear restrictions on operating parameters that result in the highest efficiency of the various combinations. These numbers show the air classifier's sensitivity to air fluctuation variations. One notable observation is that smaller particles are affected by changes of configuration and larger particles don’t seem to influence the distribution of the particles found in the classifying material: A novel method is created and deployed to classify performance assessment [6].

Kaiser's first attempt to define the classification of particles in a zigzag canal in 1963 was based on the concept of particles making a random move from stage to stage. Subsequently no modelling was completed until Senden and Tel's work was published in 1978 and 1979. They examined the behaviour of individual particles at very low particle concentrations in zigzag air classifiers and calculated the transition probabilities of these particles (i.e. the probability of moving to the next level). These probabilities were found to rely on the "history" of the particles. There could be two different sorts of probabilities of particle transfer the possibility for particles entering the stage in a dropping stream that will increase the likelihood for particles entering the stage in an increasing stream the following higher level. In addition to their experiments, fine particulate density and coarse particle density were independent at these low particle input rates from the classifier phase [7-9].

The release of building debris through the commenting generates a primarily mineral mixture with a density \( \rho_s \) distribution of 1.8 - 1.7 g/cm\(^3\). The requirements for sharpness of the method used to separate the partially released aggregate and concrete brick scrap are high because of the relatively small density range. A test rig consisting of the zigzag canal, fan, air cyclone, filter and particle feeding system was constructed for the gravity separation. The specific mass flow levels 3 to 16 t/(m\(^2\).h) for the transverse area of the device and the accompanying mass energy consumption were achieved between 0.2 and 8 kWh/t. The separation function for the efficiency is determined and is compared to a multi-stage turbulent cross-flow separation theoretical model. Due to the well known separation sharpness and geometric flexibility for a zigzag device, this separation principle may be demonstrated to be well suited for the separation gravity of mineral materials [10].

In the single stage behaviour of particles, and the interplay of stages, the separation performance of zigzag air classifiers with an angle of section 90°, 120°, and 150° were tested with low particle levels. On the basis of an examination of air flow pattern and trajectories, the influence of stage geometry on the single-stage behaviour has been explained. A stochastic one-step-memories model that ties multi-stage performance to single-stage characteristics has been described as the particle interchange between stages. The separation of particles is significant and is designed as the main operating parameter for most industrial solid processing applications based on the terminal settling speed. This settling velocity depends on the qualities of particles such as size, density and shape. Multi-stage sand and gravel separation studies were done in this study employing various channel velocities and air mass loads. In the separation functions and characteristic parameters of separation sharpness and product quality, the performance has been studied and commented [11].

Classification is essentially a process of separation of particle size. When air is commonly utilized as a fluid medium, classification can be described as separating solid particles into two or more products according to their velocities. Classification takes place every time the zigzag tube changes in direction, and allows extremely high, step-less adjustable cutting accuracy [12]. This classification is a classifier that is upstream. The zigzag design of
the classification tube guarantees that the raw material gets washed again and again by the air. This leads to a multi step grading and the grader obtains a very high cutting precision. The cutting point can be set between 0.1 and about 10 mm. The classifier is used mainly for the sorting and separation of various materials. For sharp separations in range of approx. 0.1 – 10 mm, the Zigzag classifier is excellent.[13-15].

Classifiers are usually maintenance-free and wear-resistant, overload-resistant and insensitive to changes in the composition of feeding stuffs. As a result of these features, the classification system can be operated without any supervision over long time periods. Even under overload situations, the goal output is clean particles or lightweight material. In this paper, design and experimental analysis of zigzag classifier for food industry applications has been discussed. Based on the experimental results, fine and coarse particles of materials with various size ranges plotted the graphs. It is suitable for commercial applications like food industries.

2. Materials and methods

In industry, hoppers must be constructed such that they can be loaded easily in order to protect and store powdered products. More importantly, hoppers need to be constructed to be unloaded easily. The design of the trunk impacts the flow rate of the powder out of the trunk when it is at all flowing. Also, the way the hopper is structured influences the amount of material stored that may be released and if solid sizes or dead space are mixed to limit the effective hopper holding capacity. These issues are vital to take into account in the design of Feed Hoppers (Figure 1).

![Design layout of Hopper](image1)

Figure 1. Design layout of Hopper

This system is designed to continuously feed bulk solids, e.g. powders, grains, chips, flakes and fibres, gravimetric- and gravimetric-size. The motivating source or power, at the appropriate angle, is attached to the feeding tray. Because of the physical features of the goods, this angle is different. The entire feeder is moved forward or upward, either hanging or insulated. The complete feeder moves the material forward and up. Then the tray returns to its proper place. However, because of the slower gravity action, the material does not go backwards. This gives a slowly advanced position to the substance before the procedure is repeated, bringing the material forward in a number of quick jumps undetectable to the sight (Figure 2).

![Design layout of Vibrating Feeder](image2)

Figure 2. Design layout of Vibrating Feeder

The major duty is to control the flow of material from one room to another while
ensuring that the airlock is good. The material or product is frequently flowing with dry powder, dust or grains. A Rotary Air-lock Valve's major role is to control the flow of material from one room to the next, while maintaining a healthy air condition. Usually, the material or product is dry, free powder, dust or granules. The engine and the drive chain turn the rotor shaft in operation and rotate the rotor inside the box and the headboards. As the blades rotate a defined volume of material goes from the material intake into the areas between neighbouring blades (called rotor pockets) and is sent to the material exit in the pockets.

Rotary Air-lock Valves are used to load materials at a controlled pace or act as an airlock on the bottom of the containers, cyclones, powder collectors or feed hopper. They are also utilized in positive or negative transport systems for the introduction of material. A rotary feeder/Airlock valve comprises of a rotor that revolves close to its housing at a certain RPM to keep the material flow rate consistent and provides a screening. The Rotary Air-locks offer high pressure, high temperature and other serious service requirements reliable services. Valves can be operated in several industries like food, plastics, chemistry, asphalt, mining, baking, cement and painting. The material is supplied from hopper or bin into rotor bags (a gap between two vanes). The shaft vanes revolve as well. The material in the rotor pockets shall be moved from the airlock valve inlet to its outlet due to the spinning of the valves (Figure 3). The pneumatic conveyor system will be driven from the output.

![Figure 3 Design layout of Rotary Valve](image1)

The blowers are formed by a dynamically balanced impeller that revolves in a cum-filtering chamber with very fine clearances between them, and the pulls are directly mounted on the motor shaft and the pressure opening is situated at the external periphery of the stator, thereby reducing the impedance of air flow (Figure 4).

![Figure 4 Design layout of Blower](image2)

The blower is a positive displacement machine which does not develop a constant volume pressure within the blower; the system releases pressure accordingly vary in order to meet the pressure and the flow volume of the systems is nearly constant, with fluctuating pressure except a slight increases in the slip as the pressing pressure increases by horsepower.

Cyclones provide for relatively low costs or removal from exhaust gas streams of particulate particles. Cyclone dividers are a bit more complex than just gravity control systems and so their removal efficiency is significantly better than the dividing chambers (Figure 5).
However, cyclones are commonly deployed as pre-cleaners in front of those efficient devices and not as efficient as electrostatic precipitators.

![Design layout of Cyclone Separator](image)

**Figure 5** Design layout of Cyclone Separator

The fundamental principle of isolation stays the same. Particles streaming gas into the gadget the gas stream is forced to turn, however, larger particles are more dynamic and cannot swing with the gas these larger particles affect the cyclone wall and tumble down and are gathered in hopper. Indeed, gas stream swirls in a helical pattern a number of times, much like a tornado funnel, the repeated turns allow particles to flow through streamlines, which hit the slaming cyclone wall. The range of particle size gathered in a cyclone depends on the relative size of the device throughout all diameters. Cyclones can be stored in series or in parallel to improve overall efficiency of the collectors.

The entry of the cyclone, the dust discharge and the discharge all affect the total cyclone efficiency. The inlet which is instrumental in the development of the vortex is directing gas into cyclone. The particle matter is driven to the wall in the cyclone body. The gas continues down to the cone of the cyclone body, giving the gas sufficient rotating speed to retain particles at the wall. Gas shifts the direction from downhill to upward at the bottom of the cone. The ascent turbo enters a rope extension which is called the turbo finder in summary times and leaves the cyclone.

The collected particles in the meantime fall into a hopper where they are removed periodically or permanently. The cyclone removal effectiveness is largely reliant on the dimensions of the cyclone for a given size particle. Diameter most affects the efficiency of a given volumetric flow rate. The total length of the vortex dictates the number of turns. The inlet width and longitude or also, as the smaller the inlet, the more the inlet speed is extended the more efficient the inlet speed is, but the more pressure loss is increased.

A butterfly valve is a valve which can be used for isolating or regulating flow. The closing mechanism has the form of a disk. The operation of a ball valve is similar, which enables rapid shut-off. Butterfly valves are often favored since they have lower costs and also less weight, which means that less support is necessary for other valve types. The disk is located in the center of the pipe, a rod connected to an actuator outside the valve is passed through the disk. The actuator rotates parallel to or perpendicular to the flow of the disk. In contrast, the disc is always present in the flow; therefore, no matter the position of the valve, a pressure drop in the flow is always induced.

3. **Working principle**

Once the product is recognized, the hopper is initially filled with a small amount needed for a dosing test. The dosing test can provide us the feeding rate in which the product is charged via vibratory supplies to the zigzag classification. This will also give us an idea of the zigzag classifier's fine cutting performance.
Again, the vibration feeder is used for the specific dosage test performance for our tests. Then add product to the hopper and keep it ready. The rotary vacuum valve 1 and the rotary vent 2 start one by one from the Blower. Check the air velocity in the zigzag tube and adjust to the speed at which the product is separated by the exhaust butterfly valve and air inlet butterflies valve.

When all parameters are ready and the vibration feed starts, the product is entered from above via a rotating airlock valve into the zigzag tube. The air stream from the bottom is rinsed or cleaned. The lighter particles will be transmitted by the air to a cyclone separator at the setting speed that we have maintained in the system. The tumultuous particles that can withstand the upstream air draws the force out of the zigzag classifier and falls down. The lighter particles are separated from the air in the cyclone separator and collected on the bottom via a relative airlock valve. And the air coming out of the cyclone separator is re-cycled to the zigzag classifier again and the process of classification continued.

4. Design of Zigzag Structure

![Figure 6. Schematic layout of Zigzag Classifier](image)

Zigzag classifier contains a simple, vertical, indoor tube with a rectangular cross-section, tilted to the right and to the left at the same angle to the vertical (Figure 6). A flow channel divided into 15 uniform height segments \( h = 250 \) mm, width \( b = 1980 \) mm, and depth \( t = 250 \) mm comprises of a zigzag classifier utilized. These segments are connected under a bending angle \( \alpha = 120^\circ \). The air flows upwards and generates eddies in each corner of the channel. This leads to an additional particle dispersion and enhances separation. Each stage acts as a single cross-flow unit (Figure 7).
5. Results and Discussion

The studies were undertaken to remove tiny contaminants which are present along with the plastic granules sample. Each time in the zigzag classification the experiment was done three times with variable air velocity. After each experiment, the material was recovered from its proper place in both the coarse and fine fractions. The laboratory was supplied with a modest amount of coarse and fines, and the distribution of the particles were assessed. Air jet sieve analyzer has been used to detect particle size. It is essentially a screwdriver with the vacuum press for sewing.

5.1 Experiment 1

All tests have maintained a constant feed rate in order to observe how the air velocity in the zigzag tube solely varies. The cutting point was considered to be $d_{97}=2\text{mm}$ and the air velocity calculated as described in the previous chapters. Settling speed $V_s = 4 \text{ m/s}$ is the result. With both butterfly valves in exhaust as well as in the air inlet in the zigzag classifier system, the airflow was controlled. At a place from which the air enters the zigzag classifier, a pilot tube has been used to measuring air velocity. The results are estimated at least $d_{97} < 2\text{mm}$ if the cut point is set at 2 mm, i.e. 97 % of the finished goods are smaller than 2 mm and lightweighted contaminants. Vice versa, the products in the coarse fraction are larger than 2mm in size.

![Figure 8. Performance chart of Experiment 1](image-url)
The figure 8 is relatively limited that the overlap between the curve of the fines and the curve of the coarse fraction. And the zigzag classification is therefore particularly efficient for product segregation at the settling velocity.

5.2 Experiment 2

All tests have maintained a constant feed rate in order to observe how the air velocity in the zigzag tube solely varies. Settling speed of \( V_s = 6 \) m/s is obtained. With the assistance of both butterfly valves, the air flow in the exhaust and the inlet was controlled in the zigzag classifier system. The air speed was monitored using a pilot tube where the air enters the zigzag classification. The results are expected to at least \( d_{97} < 4 \) mm if the cut point is set at 4 mm, that is, 97% of the products contained in the fines are smaller than 4 mm and the impurities are slightly weighted. The coarse proportion of the products will be larger than 4 mm vice versa.

![Performance chart of Experiment 2](image)

Figure 9. Performance chart of Experiment 2

Figure 9 has extremely marginal overlapping between the curve of the fine fraction and the coarse fraction curve. The zigzag classifier is hence particularly efficient for distinguishing items at the settling velocity.

5.3 Experiment 3

The feed rate was kept as constant for the entire experiment to investigate the effect that air speed only varies within the zigzag tube. The settling velocity (\( V_s \)) results = 8 m/s. With both butterfly valves on exhaust and air inlet, the airflow was controlled in the zigzag classifier system. The air velocity was measured using a pilot tube from where the air flowing into the zigzag classification system. If the cutting point is 6 mm, the results should be \( d_{97} < 6 \) mm at least, i.e. 97% of the products in the finished fraction should be smaller than 6 mm and impurities should be light weighted. The products in the coarse portion are greater than 6 mm in size vice versa.
Figure 10. Performance chart of Experiment 3

The overlap between the curve of the thin fraction and the crude fraction is quite marginal from figure 10. The zigzag classifier is hence particularly efficient for distinguishing items at the settling velocity.

6 Conclusions

The 15 vertical tube multi-stage zigzag classifier has been successfully designed and produced with an angle $\alpha = 120$ degrees. Effective product breakdown tests were also carried out on the same basis. The findings of trials demonstrate that finer and coarser of the product have only a minimal overlap. The tests can study various drag forces operating on the product. We may also learn the capacity of the machine to handle by means of the dosing test. The zigzag classifier can be employed as a high capacity separator in accordance with the dimension of the zigzag tube. The entire experiment was effectively carried out and readings with various speed were conducted for different divisions. The only parameter that we affected was throughout the experiments velocity. All other factors such as feed rate remain unaltered. The manufacturing and assembly process is correctly conducted at all levels with all the safety measures needed.

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