Experimental Study of the Flow Characteristics in a Coal Classifier

P. Mendis and S. Gao

Abstract—**Classifier device is one of the most important parts of the coal fired power plants. Increasing the performance of the classifier is important to help reduce the emissions and increase the fuel efficiency. The project is involved in studying the flow characteristics in a 1/8 size model of an industrial classifier device. It is assumed that the pneumatic coal particles would follow the same path as the air particles and achieve the same velocities as the air particles. Tangential velocity of the swirling flow and the static pressure are measured at two perpendicular planes, and five different diametric locations are measured at each plane. All the measurements are taken for three inlet air velocities, and for each inlet velocity, three different vane angles are used. Based on the measured results, suggestions are made to improve the balance of the air flow, and for further investigations and improvements.**

Keywords—**coal classfier, flow dynamics, experimental measurement, tangential velocity, vane angle**

I.   Introduction

Coal is still one of the most commonly used fuels to generate power. The raw coal lumps have to be grinded in to very fine powder before being sent into the furnace. To get the maximum fuel efficiency and reduce the emissions, the furnace has to be fed with at least 80% of coal particles with the cut size below 100 microns. An undesirable result of coarse particles being burned is the production of NOx and loss-on-ignition, unburned coal particles contaminating the ash by-product produced in the combustion chamber. It is accordingly important to maintain close control over the fineness of the pulverised coal fed into the combustion system [1], [4], [6].

Pulverizers are the devices which grind the coal into powder and separate the fine particles from the coarse particles and feed them into the furnace. The bottom part of a pulverizer has a grinding mill and the upper part is a classifier device. Shown in Fig. 1 is a diagram of a pulverizer, which has a classifier device (upper part) which uses the same techniques as the model which was used in this experimental study [2].

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The main aim of the project is to identify the flow characteristics of the model classifier device, in order to improve its performance. As the tangential velocity is the most important velocity component for the particle separation, behavior of the tangential velocity of the swirling flow inside the classifier with different inlet velocities and vane angles will be investigated.
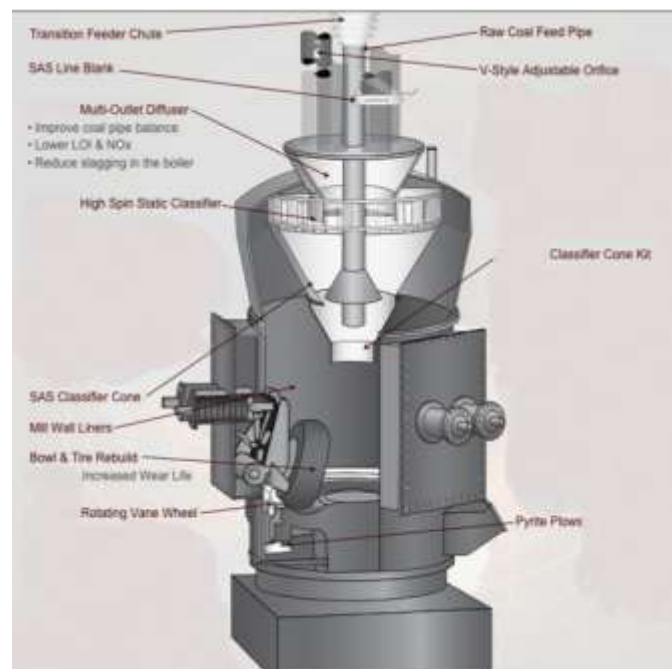

Fig. 1. A diagram of an industrial pulverizer used in a coal fired power plant [2].

II.   Classifier Model

This project is involved in modeling the particles flow in the classifier device. The classifier model, as shown in Fig. 2, is built similar to a 1/8 size of an industrial classifier device and is made from Perspex in order to be used for PIV measurements in a related project [3], [5]. It is assumed that the pneumatic coal powder particles would follow the path of the air flow closely, hence achieving same velocity as the air particles. A high velocity hot air flow is used to lift up the pulverized coal particles from the mill into the classifier device. The hot air can also reduce the moisture levels of coal powder. Coal particles follow the air flow which is a swirling flow. The classification is achieved due to the centrifugal and drag forces applied to the particles which follow a circular path, and the separation occurs because the centrifugal force is greater than the drag force.
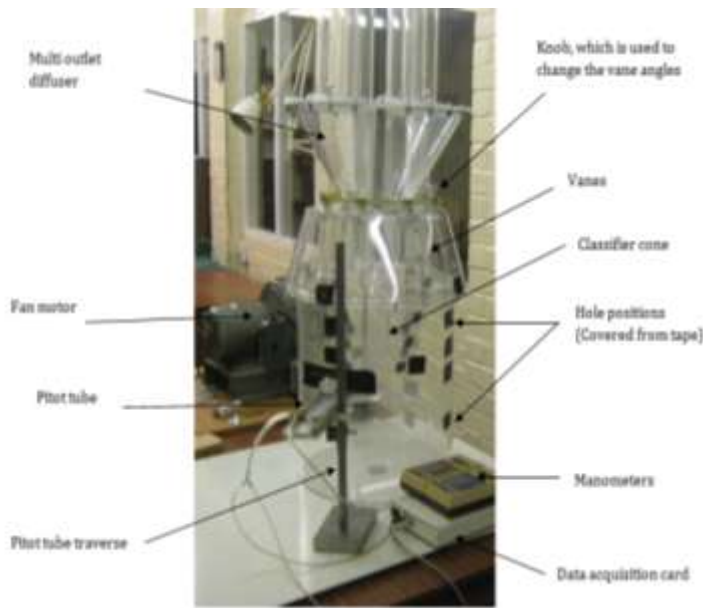
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Fig. 2. Experimental classifier model

Fig. 3. A cross section of the classifier device, along X-Y plane. Dimensions are in mm.

Measurements are taken with three different inlet air velocities (10, 15 and 18.5 m/s). The power supply to the centrifugal fan is from a variable transformer controller. Motor speed can be changed using the transformer. The velocity profiles across the duct are taken several times with different transformer settings in order to determine the appropriate transformer settings for the required inlet velocities. The accuracy and reliability of the data logging system are checked by comparing the manually measured pressure profiles taken across the duct against the same profiles taken by using the data logging system.

For each inlet air velocity, three vane angles (30˚, 45˚ and 60˚) are selected for measurements. All of those angles are measured with respect to the diameter of the cylindrical body. The maximum possible vane angle is 90˚. At that angle, the vanes would be completely closed. Vane angles are changed by rotating the knob which is connected to all the vanes, as shown in Fig. 2. A Pitot tube and two manometers are used to measure the tangential velocity and the static pressure profiles. The data are logged to a computer using the Labview software package. Measurements are taken along the diameter of the classifier at 5mm intervals.

To get the tangential velocity components, the tangential dynamic pressures are measured in two different planes, which are perpendicular to each other. In each plane, five different diametrical profiles are taken. For each profile, the tip of the Pitot tube is moved along the diameter of the cylindrical body of the classifier. Each single pressure reading is taken at 5 mm difference between each point. The distance is measured from the axis of the cylindrical body, which is marked as Y axis in the diagram of Fig.3. Mean values of dynamic pressure and static pressure readings are recorded using the Labview logging system. Atmospheric pressure and air temperature are measured and recorded manually during each experiment.
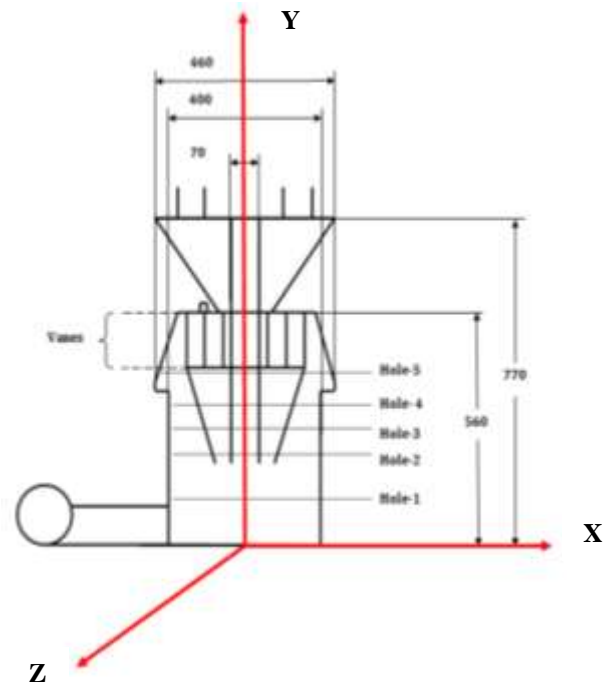
The heights of the holes one to five from the base of the classifier are 140, 245, 295, 350, 425 mm, respectively. All the data are logged at a 10000 sample rate. 30000 samples were taken for each reading. That means the system has taken the samples of 3 seconds per reading. Several tests are conducted in order to determine the appropriate sample rate and the number of samples. The above sample rate and the sampling time have proved to give a very accurate reading.

III.   Results and Analysis

Measurements are taken at two perpendicular planes. Five different diametric locations are measured at each plane. The planes, XY and YZ, are marked in Fig. 3. The origin of the coordinate system goes through the axis of the cylindrical body. Distances of all the positions are measured with respected to the Y axis, which is also the axis of the cylindrical body. Dynamic pressure is measured and converted into velocity, while static pressure is used directly. Temperature of the air and the atmospheric pressure are measured and used each time to convert the dynamic pressure in to velocity.

For the two planes (XY and YZ), 60 graphs are produced, and similar velocity and pressure profiles are observed at either plane. Generally speaking, for any given hole position, at any given vane angle, the velocity profiles change with the inlet velocity. High inlet velocities are associated with high magnitudes of the velocity profiles. Due to the page restriction only a few selected velocity distribution graphs at YZ plane are presented here to show the essential flow characteristics.
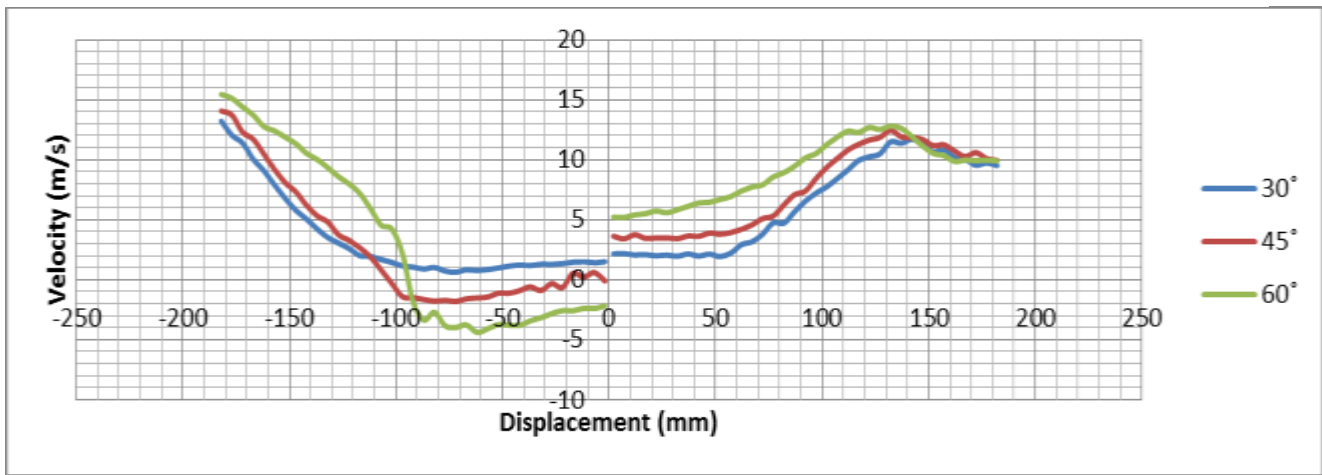
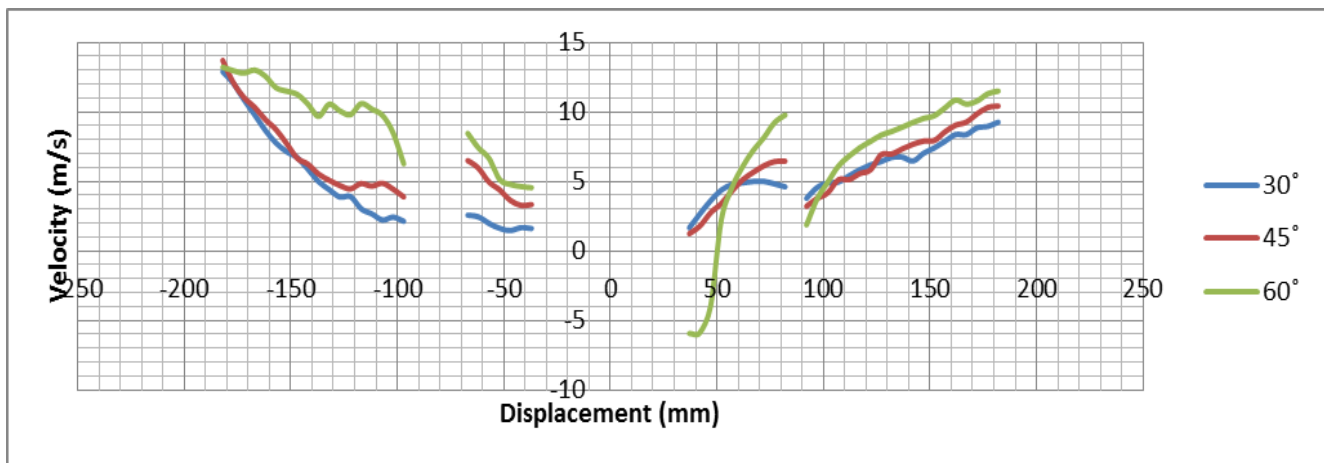Fig. 4. Velocity profiles with inlet velocity =15 m/s, hole position 1.

Fig. 5. Velocity profiles with inlet velocity =15 m/s, hole position 2.
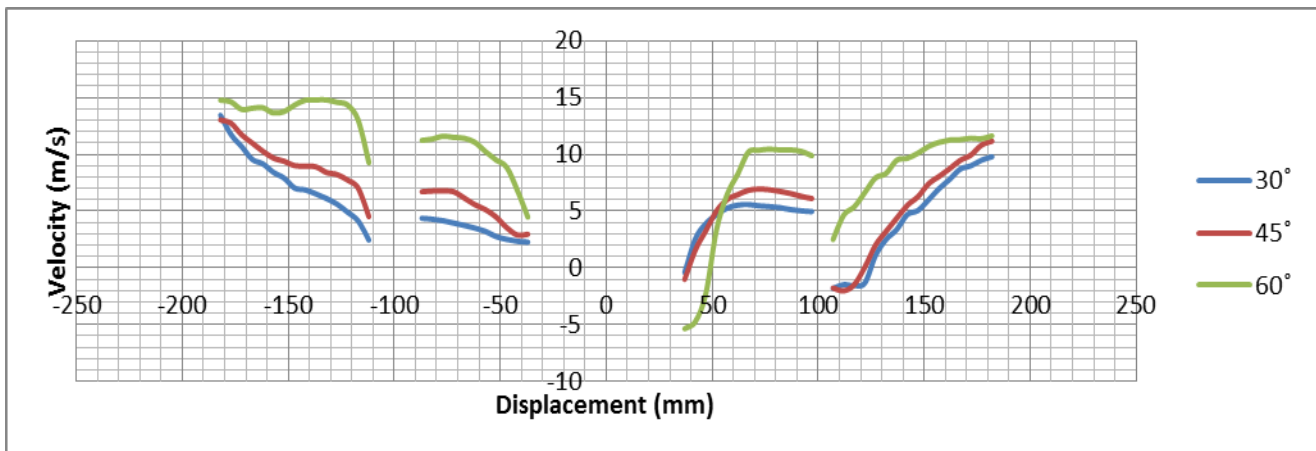

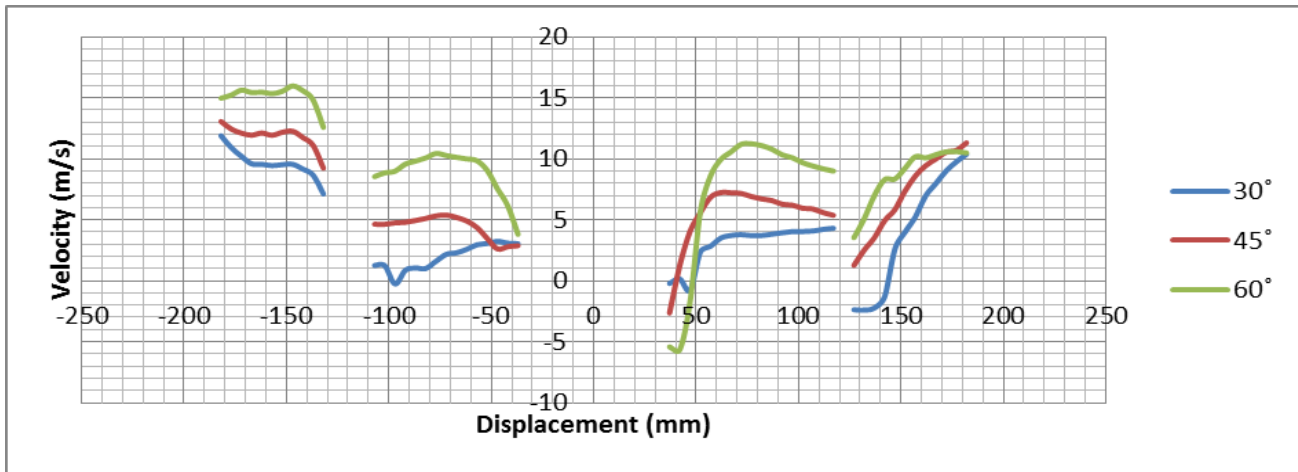Fig. 6. Velocity profiles with inlet velocity =15 m/s, hole position 3.

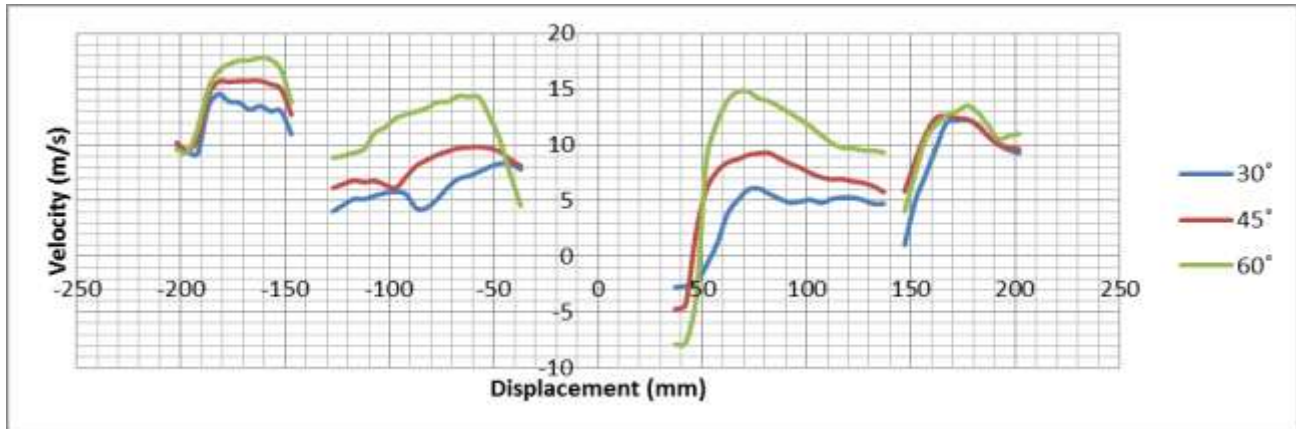Fig. 7. Velocity profiles with inlet velocity =15 m/s, hole position 4.

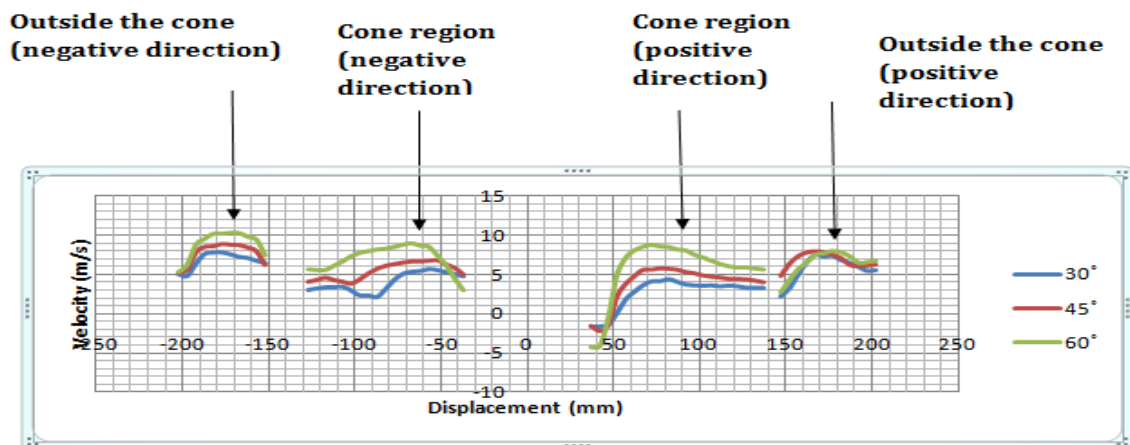Fig. 8. Velocity profiles with inlet velocity =15 m/s, hole position 5.

Fig. 9. Four regions of the velocity profiles at the hole positions 2-5.

All the velocity profiles are taken along the diameter of the cylindrical body. The velocity profiles with inlet velocity of 15 m/s at the hole positions 1 to 5 are shown in Figs. 4 to 8, respectively. Even though the velocity profiles of each half of the diameter are expected to be symmetrical, it is observed that they are asymmetrical. This can be due to the fact that the air flow is not symmetrical at the bottom, as shown in Fig. 4. This can cause problems in a real classifier, but can be simply eliminated using two (or multiple) inlets at opposite directions. Four separate profile sections can be identified in Figs. 5 to 8, and they are labeled clearly as shown in Fig. 9. This is due to the fact that these positions go through the cone section and some measurement points along the diameter are left without taking measurements because the Pitot tube is unreachable to those points.

It can be seen clearly that the hole position 1 has a different velocity profile to other hole positions. This is due to the fact that the hole position 1 is located below the cone region. All the other positions go through the cone region, allowing them to share similar physical characteristics of the classifier body, which determines the flow characteristics. The flow velocities of positive region and the negative region don't merge together. This is mainly because of the imbalance of the air flow in the classifier due to the fact that the air is entered from one corner inlet. As the hole position 1 is at the bottom region, the effect of the flow imbalance is greater in that region. Furthermore, it is observed that the shapes of the velocity profiles are similar for all three velocities. Only the magnitude of the profile changes according to the velocity.

It is also observed that the vane angle can change the angle of the air flow to go through the vanes. The higher the vane angle, the more tangential the path of the air flow. Because of this, it increases the tangential velocity component of the air flow. As a result, the strength of the swirling flow increases, making the separation process more effective. However, even though the higher vane angles can increase the tangential velocity, this can't be expected to happen for all the vane angles. At high vane angles close to 90˚, the space between the vanes becomes smaller. This would cause the air flow to choose an alternative path, which is to go through the cone. This process would reduce the tangential velocity of the swirling flow, leading to an unproductive particle separation.

For a given velocity, pressure profiles (not shown) don't have a significant difference outside the cone region. Pressure profiles don't have a significance difference inside the cone, except for the profiles associated with 60˚ vane angle. Higher vane angles increase the dynamic pressure by increasing the tangential velocity, hence decrease the static pressure. Higher vane angles also decrease the gap between vanes. As the gap is decreased, the air flow, which enters the cone from the bottom, also increases simultaneously. It is important to further investigate the proportion of the air volume which goes through the cone region compared to the vane.

IV. Conclusion

The flow characteristics and how they change against inlet velocities and vane angles have been successfully identified and analyzed. It can be suggested to use multiple air inlets to eliminate the velocity imbalance of the device. Furthermore, based on the results found in this work, an improved measurement method such as PIV can be used to identify flow characteristics for one inlet velocity and the results can be projected for other velocities, which would save time and effort when conducting further experiments.

It is also observed that the air flow can go through both the vane angles and the bottom of the cone. It is important to find out the proportion of air flow going through each way. If the air flow from the bottom of the cone is significantly lower than the air flow going through the vanes, the cone can be further extended to assist the cyclonic flow.

References

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