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Experimental Study of Splitting Device for Horizontal Pipeline

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Abstract. The flow distribution within a reduced scale model pipeline to study and determine the best splitting device for a horizontal pipeline through experiments were conducted. In this research, five splitting devices are designed and tested on the model rig. Out of five, only one splitting device has been chosen that achieved the objective the best; to improve airflow to be a homogeneous flow in the pipe, or at least reducing and improving from the roping condition. The process of selecting the best device had been done through qualitative analysis of velocity profile and airflow distribution obtained from Pitot Tube measurements, besides the airflow pattern and behavior through PIV results.

Introduction

The splitting or separating method that works well, ensuring the complete combustion of coal. The splitting devices are designed to be placed apart of pneumatic conveyor line. The main issue here is to encounter the roping problem. In turning or bending condition of the pneumatic conveyor line, the roping will definitely occurred. So this device is needed in order to split the roping of coal back to a normal flow.

Yet, serve the conveyor line with steady and consistent flow of coal, before entering the furnace or combustion chamber. There are several splitting devices invented and widely used, but then it is more for the vertical pneumatic conveyor line and also for dense-phase conveying system.

Literature Review

Pneumatic systems are power systems using compressed air as a working medium for the power transmission. The air compressor converts the mechanical energy into pressure energy of compressed air. This transformation facilitates the transmission, storage, and control of energy. After compression, the compressed air should be prepared for use [1]. The compressed air is stored in compressed air reservoirs and transmitted through transmission lines: pipes and hoses.

Pneumatic conveying can be used for particles ranging from fine powders to pellets and bulk densities of 16 to 3200 kg/m^3 (1 to 200 lb/ft^3). As a general rule, pneumatic conveying will work for particles up to 2 inches in diameter or typical density. By "typical density", it means that a 2 inch particle of a polymer resin can be moved via pneumatic conveying, but a 2 inch lead ball would not [2]. Pneumatic conveying system can be classified in a number of ways. It was depend of two major aspects which are system pressure and the mode of conveying [3]. Roped flow means that the particles are concentrated in a small area of the cross section and the rest of the cross section is sparsely populated by particles [4].

Methodology

The experimental work is carried out on the experimental rig, the model of horizontal pipeline, at the Tun Hussein Onn University Malaysia. The experimental rig is designed specifically to test the splitting devices which are the main purpose for conducting this project. This is to model the pipeline. The rig is acting as the real system of horizontal pneumatic conveyor line while the splitting devices will be tested on this scaled rig model. The effects on the controlled parameters are tested accurately on a scaled rig and compared among the candidates of splitting device. The outcomes will be different for each design of splitting device.

This rig model is a scaled down version of the average range of pneumatic conveyor pipeline inner diameter. The rig model been fabricated by using the high transparency material, so the best material to use it Acrylic. It is designed with clear body or transparent body for ease of monitoring the flow. The removable slots are the concern in the design, to allow an interchangeable variety of the splitting devices; use of flanges.

The Splitting Device

The designs of splitting devices was decided based on evaluation and conceptual of existing patents, even the one that been applied out of pneumatic conveyor line purpose. The main working mechanism of splitting device is to overcome the roping condition of particles flow, yet providing the uniform and consistent flow along the pipeline. The splitting device is already developed in various types and design. For example the design by Research Group of Multiphase Flows from Germany [5] in 2002. For this research, five devices were designed. The materials for these devices are made from perspex. Figure 1 shows the designs of splitting device for this research. It is applied the basic concept of splitting device where rope breaker is place at the middle of device to breaker roped flow that flow through it.

Noted that the airflow velocity measurement been taken along the x-axis or horizontal line and in y-axis or the vertical line of the pipeline's cross-section. The readings been taken at the inlet just before the device and the outlet of device. The more readings, the more precise the results for velocity distribution profile along the pipeline. This is to validate the velocity distribution of air within the pipeline. With this information, velocity distribution helped to describe the velocity profile, instead of visualization.

The Particle Image Velocimetry (PIV) is an optical method of flow visualization that been widely used in education purpose and researches. In PIV, the blowing air motion within the pipeline is made visible by adding fog and from the positions of these fog particles at two instances of time, such as the particle displacement, it is possible to infer the flow velocity field. Standard PIV measures two velocity components in a plane using a single CCD or CMOS camera. Besides, the airflow images, airflow velocity contour map, and vector images been captured.

Fig.1: The Hollowed Tube Splitting Device (Device 1)

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Result and Discussion

Testing been made on Pitot Tube measurement and PIV. The data of results been recorded in Pitot Tube Datasheet, while the PIV results been captured in images and figures of airflow, vectors and contour map. Data presentation been done to compared the output from each devices at different initial velocity; 5 m/s, 10 m/s, and 15 m/s, and also comparing the each device at a single airflow velocity.

Each device came out with different velocity profile, that been influenced by the design and mechanism of the splitting device itself. The roping problem at the inlet been detected in the 4^{th} Quadrant of the pipe cross section area as shown in Fig. 2. The qualitative analysis been made on the airflow behavior; velocity profile, airflow pattern, and distribution.

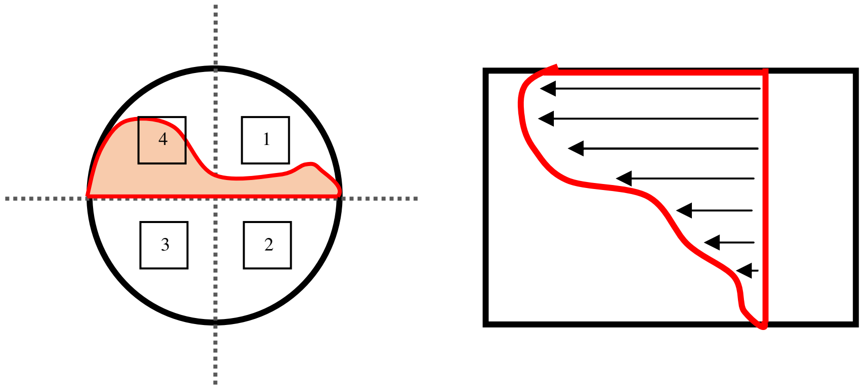
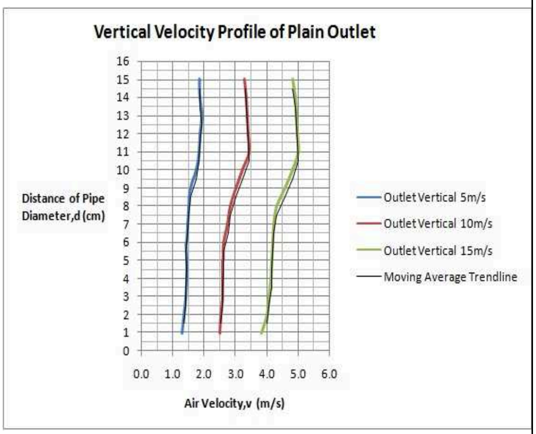


Fig. 2: The Inlet Airflow Distribution through the Pipe Cross Section

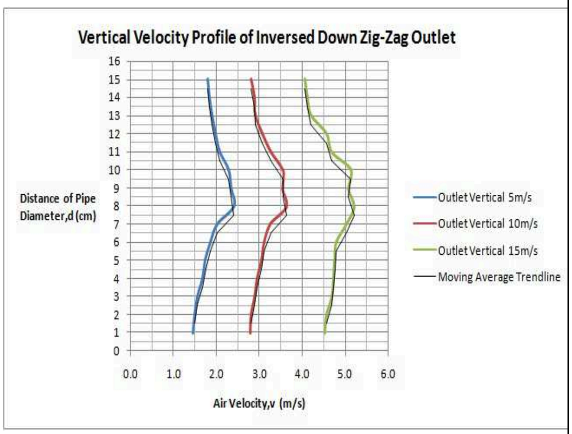
At the inlet airflow of 15 m/s, the roping condition is at its worst, based on this experiment scale. The discussion made mostly at this condition of this airflow velocity. The maximum velocity of each velocity profile could obviously been observed and behaviour of the airflow could be describe as in homogeneous and convergence; or otherwise.

VERTICAL AXIS

WITHOUT SPLITTING DEVICE

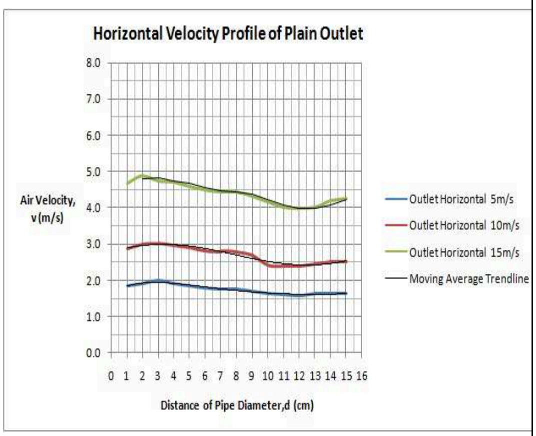


WITH SPLITTING DEVICE



HORIZONTAL AXIS

WITHOUT SPLITTING DEVICE



WITH SPLITTING DEVICE

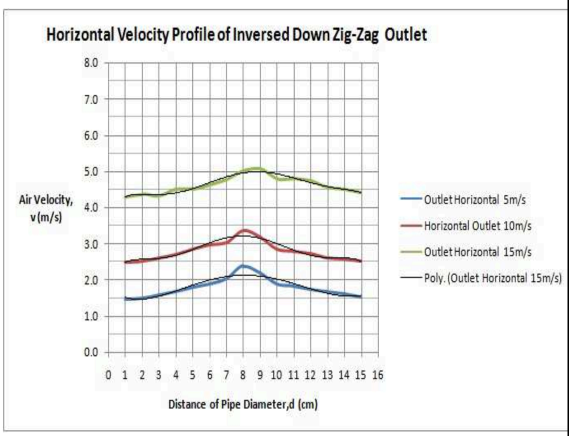


Fig. 3: Velocity Profile Comparison at Inlet and Outlet for Inversed-Down Zigzag Tube

The device of Hollowed Tube, Inversed-Hollowed Tube, Zigzag Tube, Inversed-Zigzag Tube, and Inversed-Down Zigzag tube were all five splitting devices that been tested on the model rig. From these devices, Inversed-Zigzag Tube and Inversed-Down Zigzag were shortlisted as the best two splitting devices based on their outputs in term of velocity profile, airflow pattern and behaviour. Both outputs were closely to achieve the objectives of this research.

The Fig. 3 above shows the comparison of velocity profile at the inlet and outlet for Inversed-Down Zigzag Tube type, which is Device 5. The comparison been made between the Vertical and Horizontal Velocity Profile of Inversed-Down Zigzag Tube Outlet towards the Vertical and Horizontal Velocity Profile of Straight Tube Outlet, which means the airflow condition without installation of splitting device.

Conclusion

The study will be helpful to come out with the new design of pneumatic conveyor's splitting device in horizontal pipeline, that able to provide more consistent and uniform flow of medium before and after the turning in horizontal line. Experimental analysis on a quarter-scaled model will be used to demonstrate the effectiveness of the new concept and design of splitting device.

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