## (A) Schedule of PhD Viva-voce

Date (and day): 5th August 2021 (Thursday)
Time: 3 pm

## (B) Ph.D. thesis title

Numerical and experimental investigation of gas solid flow through pipelines

## (C) Student's detail

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## (D) Abstract

Transportation of powdered and granular materials through pipelines using a carrier gas, normally air, is termed as Pneumatic Conveying. It is widely used in the industry to handle a range of powdered and granular materials through closed loop pipelines. There are principally two modes of conveying viz. dilute phase suspension flow and dense phase non-suspension flow. Since the particles are conveyed in suspension in the dilute phase, a higher gas velocity is required at the material feed point. On the other hand, when the conveying gas velocity is relatively low, the particles drop out of suspension resulting in a layer at the bottom of the pipeline. Hence, the particles flow in dunes or as pulsating moving bed flow which is referred to as fluidized dense phase. The material must have good air retention property for being successfully conveyed in fluidized dense phase flow. Particles having good permeability like plastic pellets are transported in slug flow as full-bore plugs separated by gas pockets. In the case of dilute phase conveying, the particles impact on the bend surface at high velocity. If the material being conveyed is hard and abrasive like silica sand, the bends are subjected to erosion due to the high velocity impact of the particles. As a result, the particles also suffer attrition leading to changes in particle size and shape. On the other hand, the mechanism of the flow of bulk materials in fluidized dense phase pneumatic conveying is transient and complex, involving highly turbulent air flow, particle-particle collisions, and particle–wall/air interactions, which makes the design of such systems and determining the location of the transition from the dense to dilute phase are difficult.

The expansion and collapse of the material bed during transportation of fine powders in fluidized dense phase pneumatic conveying are mainly responsible for generating pressure pulses. In this research work, these pressure pulses were structured by pulse amplitude, pulse duration and pulse frequency. The wavelet analysis (Daubechies db4 wavelet) of signals of air pulses revealed that the moving bed

flow possessed the transient feature and pulsatile vi phenomenon characterized by multiple amplitudes and random frequencies. Variations of pulse structures along the length of the pipeline have been observed due to the occurrence of frequent aeration and de-aeration of dunes during the conveying process. The investigation has also been carried out to understand the relation between pressure pulse characteristics and specific power consumption and pneumatic conveying parameters. Substantial variations in pulse structures have also been found with different types of bulk materials. Pulse velocities of air between two data points were found higher at high solids loading ratio leading to low voidage in the case of dense phase flow.

Pressure fluctuations generated during conveying of bulk materials in fluidized dense phase pneumatic systems can be quantified to understand the transient nature of the flow. Pressure fluctuations are mainly due to the highly turbulent nature of the gas–solid flow. Characteristic information stored in fluctuating pressure signals provides an alternative method for studying the flow pattern and understanding the flow mechanism in the conveying process. The objective of this research was to relate the experimental pressure fluctuation behavior to the transition in the mode of flow observed in fluidized dense phase pneumatic conveying of fly ash. Shannon entropy and wavelet analysis have been utilized to extract the features of the flow regimes. Variations of Shannon entropy values along the length of the pipeline have been assessed to determine the location at which the flow converts from dense to dilute phase mode. The effects of conveying parameters and specific power consumption on the mechanism of the flow of bulk materials, which was analysed by Shannon entropy, and variations of the local power consumption coefficient have been presented and discussed.

The flow of fine powder in fluidized dense phase pneumatic conveying through a section of pipeline having uniform pipe diameter has been modelled and analysed using Computational Fluid Dynamics (CFD). Besides considering a single solid phase with the mean particle diameter, several solid phases based on the particle size distribution (PSD) have been vii incorporated in the developed CFD model. For the CFD simulation, particle size distribution with the Eulerian approach based on the kinetic theory of granular flow (KTGF) has been adopted for analysing the behavior of the flow of fine powder in the dense phase. The validity of the developed CFD model has been evaluated under different operating parameters of pneumatically fine powders flow in the horizontal pipeline. The results of the simulation demonstrated an excellent matching with experimental pressure drop data with an error margin of ±15%. Furthermore, variations of pressure drop, air velocity and void fraction along the downstream of flow, and distributions of solid volume and void fractions spatial profiles have been presented and discussed. Then, the flow regimes have been investigated under the effects of conveying velocity, solids loading ratio and PSD. The numerical observation showed that the dense regime was mainly dominated by the behavior of large-sized particles while the fine particles controlled the dilute regime and there was intense contact between these two regimes through the intermediate regime.

Bulk materials like sand particles, which do not possess good air retention properties or high permeability, are generally conveyed in the dilute phase, suspension flow in conventional pneumatic conveying systems. High inlet conveying air velocity is thus necessary to successfully convey such materials. As a result of high air velocity, the particles impact on the bend surface and cause erosion of bends and attrition of particles. The study of bend erosion has been a subject of research for a long time and the influence of various operating parameters has been widely investigated. An extensive experimental plan has been carried out to study the influence of recirculation of material on the erosion of bends and attrition of particles. Silica sand having a mean particle size of 435 micron was conveyed in the pneumatic conveying pilot plant. The pipeline test loop is 48 m long and 67 mm bore. The bends were placed in horizontal orientation with R/d ratio of 4.0. The solid particle erosion behavior of three test bends (B1, B2 and B3) and particle attrition have been analysed. A 300 kg batch of sand was viii recirculated 29 times through the test pipeline, thus conveying a total of 8.7 tonnes. The mass loss and bend wall thickness were regularly monitored. Material sample during each run was collected to assess the extent of particle attrition and changes in the particle morphology. The experimental results of a comprehensive analysis of the erosion and particle degradation with a change in particle morphology have been presented. A correlation has been developed between the extent of material recirculated through the test and its influence on the erosion of bends and degradation of particles.