A B S T R A C T

Key Words: pneumatic conveying, interactions, rough bends, interference, turbulent flow, two-phase flow, solid-gas suspension, lean-phase flow, 90 degree bends, wear, particle size degradation.

The technology of pneumatic transportation has already achieved a high degree of perfection to be used even for unconventional situations like removal of garbage in cities, cleaning of multi-storied building, removal of slag from blast furnace etc to name a few. But, bend remains the most troublesome component due to wear in a pneumatic conveying system.

Many researchers have studied the wear of bend in isolated manners. There is hardly any study to account for several inter-connecting factors. From time to time, some researchers have realised and pointed in detail the importance of non interfering conditions to be prevailing for correct evaluation of co-efficient connected to the element in question. In spite of that, many researchers

have gone for shortcuts. They even tried to have generalised correlations using experimental data generated on set-ups where clearly interference conditions prevailed.

After reviewing important literatures available till date, it could be said that wear rate determination is more complex than what has been conceived so far. The importance of interference from the connections from two end of the bend must be recognised while formulating the problem. While transporting materials, not only does the bend wear-out, but also the particles get increasingly diminished in size (degraded).

Correct prediction of wear in any case involves correct assessment of two-phase flow field which determines particle velocity that is mainly responsible for major share of wear of the surface (in the present case inside surface of the bend) coming in contact with the particle. In fact, the particle gets its forward motion due to the flowing fluid around it. In other words, the fluid energy is responsible for the motion of the particle which in turn spends its energy in its movement, damaging the surfaces which come in contact with it and also in damaging itself.

For obtaining drag co-efficient for non-spherical particles,- commonly used graphical plots of Brown [14], were explained by conceiving a 'Parameter Matrix' and using analogous equations [24] for spherical particles. For getting the parameters connected to a particular sphericity and Reynolds number, a simple interpolation program was used.

In general when the particles move through a horizontal tube, the field responsible for variation in particle-number-density at a cross section is gravity. When the particle has to move through a bend having a finite radius of curvature, the field enhances in a big way mainly due to centrifugal force. As such a reliable form of diffusion equation is needed to take care of extremely large concentration of particles due to enhanced field. Taylor's [110] assumption of particle diffusion co-efficient to be equal to the linear momentum diffusion co-efficient was found to be correct after comparing the theoretically obtained particle-number-density with the experimental plot of Jotaki et al.[53].

Using one dimensional particle dynamics approach, the dynamic effect of particles on the wall was obtained by solving ten coupled differential equations with proper boundary conditions. We can thus predict the wear of the duct and also the degradation of the particle as the two-phase moves down-stream.

After deciding the materials of up-stream pipe, bend, down-stream pipe and material to be transported, two types of bends (commercial and local made) were used for the experiment. Locally made bends were prepared from three materials - Brass, Aluminium & Lead by casting them in specially designed moulds for the purpose.

For the present study, the total piping system consisted of (i) the vertical up-stream pipe designated as "A" region, (ii) the bend for changing flow direction from vertical to horizontal and (iii) the horizontal down-stream pipe designated as "C" region. In the bend region itself a point x_{1mp} was imagined to divide the bend into (i) up-stream region designated as "B" region and (ii) down-stream region designated as "D" region.

Two material wear properties-one for the bend and the other for the solids conveyed along with flow parameters could explain the bend wear and the particle degradation as a function of time. Not only the total wear, but the wear profile matched in excellent manner by accepting the form of wear model similar to the one used earlier to explain particle degradation along flow line for Fluid Energy Mill [29]. In fact before arriving at this conclusion, five other wear models were tried. Those five models could not explain the wear profile as seen experimentally.

The nature and position of wear predicted through the present work was found to be in complete agreement with what was seen by many previous research workers including Bitter [10].

In a nutshell, an attempt has been made in this report to connect apparently disconnected item like pressure drop and wear in an unique manner where all three components of transfer processes - heat transfer, mass transfer, and momentum transfer are beautifully connected.

Organisation of the Thesis

Chapter-1 contains a general introduction of pneumatic conveying system. Towards the end of this chapter, the major parameters involved during transportation and motivation of the present study has been highlighted.

An update of past research work encompassing all the areas involved in answering the problem title "WEAR MODELLING OF 90^0 BEND CONVEYING AIR-SOLID MIXTURE-under interference conditions due to connecting end pipes" have been briefly discussed in chapter-2.

In chapter-3 a theory has been proposed which is based on one dimensional two-phase flow which is an extension of an analysis used earlier for prediction of flow behaviour through Fluid Energy Mill. The theory takes care of location of maximum impact point and interference due to end connectors.

Chapter-4 contains the details of main experimental rig. It was kept in mind that the experimental rig should be able to record pressure distribution along the flow line for both single phase and two-phase (lean phase) conditions and also to have provisions for varying air flow rate and quick assessment of obtaining the corresponding solid flow rates while the whole set-up was running under steady state conditions.

In order to have a reliable readings for pressure distribution along flow line and wear of bend, care taken for experimentation has been briefly discussed in Chapter-5.

In Chapter-6, the comparison between the theoretical and experimental data has been shown. The effect of important parameters on wear has also been highlighted in this chapter.

Important conclusions are listed together in Chapter-7 which is followed by appendixes and references at the end.