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Review

Novel, unusual and new videos and pictures in pneumatic conveying

George E. Klinzing *

University of Pittsburgh, United States

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ABSTRACT

This review will present a number of novel, unusual and new videos and picture that have been observed over the last four decades in our solids processing laboratory and others. The regimes of flow will cover both the dilute phase and dense phase pneumatic transport regions. The phenomena discussed are in general non-obvious ones. The non-obvious statement comes into play when competing physical processes interact in a non linear manner so that one's experience in solids processing of experimental observations is challenged.

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1. Double minimum pressure drop near the saltation point

When one explores that dilute phase flow regime in pneumatic conveying, one finds that the pressure drop increases with an increase in the transport velocity but near the point where saltation of the particles is observed as the transport velocity decreases, there is a minimum pressure drop point with a rather abrupt increase in the pressure drop. This sudden increase is unstable in nature which can be observed both visually and with the pressure fluctuation behavior. The plot of the transport velocity versus the pressure drop at constant solids flow rate is often termed the Zenz plot. This phenomenon has been observed in many laboratories. The unusual phenomenon that has been observed by Zaltash [1] is a doubling over the pressure drop as the gas velocity decreases before the unsteady regime is traversed. This observation was carefully explored and established as being real. The rationale for such behavior was attributed to the clustering and de-clustering tendencies of the particles as the gas velocity approaches the minimum pressure drop region. Fig. 1 shows the behavior of the pressure drop with transport velocity with the actual experimental data of superimposed on the theoretical plots for the pressure drop for two different size particles, 474 μm and 79 μm. The experimental data lies between these two theoretical plots leading us to conjecture that as the gas velocity decreases the clusters are broken apart and then revert to the actual smaller

* Tel.: +1 412 624 4604.
E-mail address: klinzing@pitt.edu.

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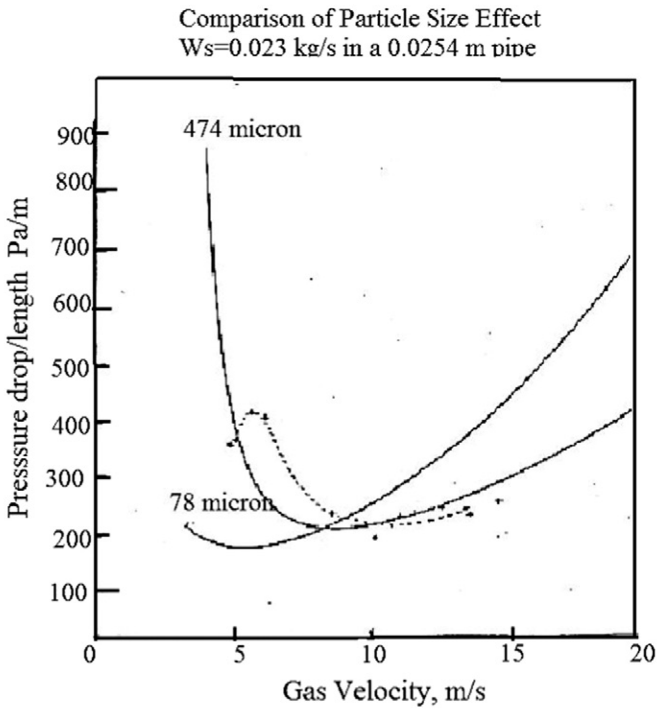

Fig. 1. Double minimum pressure drop near the saltation point.

particles initially. This observation was not clearly seen by other researchers due to the unstable character of the flow and experimental technique that did not slowly decrease the transport velocity. See Fig. 1.

2. Rolling particles in dense phase conveying

In general observations in dense phase flow have been made without a clear picture of the actual particle movement in the dense phase plugs. Resolution of the cameras employed had suggested that the particles remain relatively stationary in position so that the entire plug moved as one entity. Tashiro [2] has been able to explore the movement of particles both in dilute and dense phase flow. A recent study in a 30 mm diameter pipe with 6 mm tagged spherical particles showed that the particles are actually rotating within the plug. This observation was unique and leads to question as to why this rotation was seen. One can try to attribute this rotation to the spherical shape of the particles and to the relatively high ratio of the particles size to the tube diameter. If this is true, one then asks where is the cutoff point between rotation and non-rotation and does this point exist. The modeling of such dense phase systems have in general not considered rolling as a mechanism for energy loss in the plug transport. A new mechanistic model would have to be incorporated into the analysis both analytically and numerically due to the particle rotation. The shape of the particles and the ratio of particle size to the diameter of the pipe must also be varied. See Fig. 2.

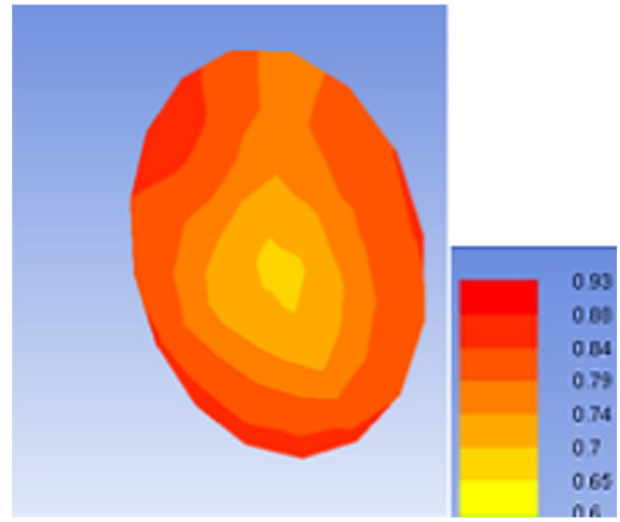

Fig. 3. Center of a plug having a higher voidage than the wall region.

3. Internal structure of dense phase plugs

Recently Nied [3] has observed some unique behavior of particle in the formation process of dense phase plugs. His observations were made using tomographic analysis of the flow both in perpendicular and parallel arrangements. This is one of the first times that both these analyses were performed at the same time. The parallel arrangement yields the longitudinal behavior of the plug and generally and one has assumed that the phenomenon was equally the same across the pipe diameter. With the perpendicular tomographic arrangement one sees that the particles rise from a deposited layer of particles to climb the walls of the pipe before enclosing the plug completely. The particles used in these experiments were polystyrene with an average diameters of 3 mm. With these experiments the center of the plug had a higher voidage that the perimeter of the plug. See Fig. 3. Such a structure had not been observed previously. In the past the plugs have been assumed to be homogeneous in cross-sectional structure. Some initial testing has been performed utilizing the same size, polyolefin particles that have a stickiness property. The stickiness property causes the particles to have an additional force binding them loosely together. Initial experiments on such particles show just the opposite to those in the structure of the polystyrene particles. The voidage in the center of the plugs is less that the wall region for the polyolefin polymer.

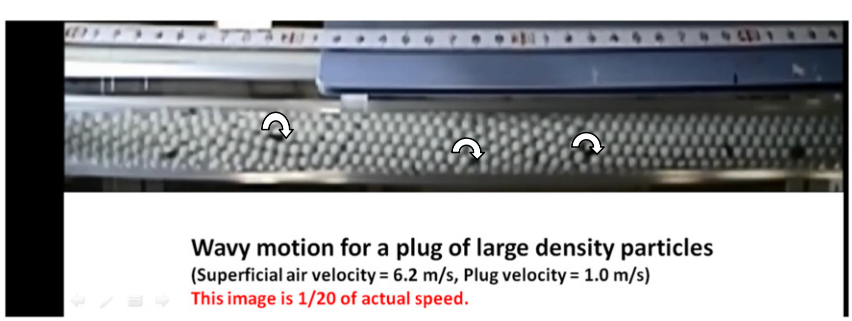

Fig. 2. Rotating particles in dense phase plug conveying.