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Review

A review of pneumatic conveying status, advances and projections

George E. Klinzing

University of Pittsburgh, Pittsburgh, PA 15261, United States

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ABSTRACT

This article offers to those pursuing new research in pneumatic conveyance an extensive, deep-background review of the current state of pneumatic conveying around the world. This synopsis of the knowledge presented is designed to identify for researchers gaps in the research field that still need to be addressed.

Contents

E-mail address: klinzing@pitt.edu..

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1. Introduction

Pneumatic conveying is a pervasive technology that touches on all branches of solids processing, from mining to food stuff to plastics. The solids processing industry estimates that the conveying system market will grow to $30 billion by 2025 [1].

1.1. Characterization of particles for conveying

Before one considers whether a given material should be conveyed pneumatically, one must understand the character and many properties of the material. Not taking the time to understand these properties likely will lead to multiple operational difficulties. One should assess the following property information before considering pneumatic transport applications:

- Average particle size and size distribution
- Percent of particles <200 μm
- Assessment of the characteristic of stickiness
- Moisture content
- True density and bulk density of the particles
- Supplier of the material and consistency of the product

1.2. Applications

As mentioned in the introduction, pneumatic conveying is applied in a wide variety of industries to transport the following: coal, iron ore, alumina and bauxite, plastic particles and powders, flour, sugar, dog food and others.

- While such systems can be applied easily and more cost-effectively than mechanical conveyors, creating optimal operating conditions is a whole different matter. Ensuring reliability proves difficult without paying considerable attention to the basic physics and mechanics of particle and powder movement.

1.3. Advantages

- Lower initial cost
- Clean, totally enclosed
- Easy to automate
- Savings in bulk shipments
- Less maintenance

1.4. Disadvantages

- Requires higher horsepower
- Requires more-complex technology to operate
- Pipe erosion

2. Dilute phase pneumatic conveying

Dilute phase pneumatic conveying has been documented in the literature since 1924, beginning with the work of Gasterstadt [2]. The technology likely had been employed industrially even before that, since putting the components together is rather simple. The most crucial piece of the system is the air mover, which employs a blower, although high-pressure compressors also could be used. The Roots blower [3], in fact, dates back to the mid 1800s. With a literature that dates back almost 100 years, the dilute phase pneumatic conveying field is rich and varied, with many fundamental and practical studies. The advent of the simple vacuum cleaner, for instance, allowed one to put together a system quickly that easily could collect particles by filters and cyclones. Klinzing [4] gave a detailed historical review of the technology, noting its development in Europe, Japan and the U.S. Applications can be found in many different and varied industries, from mining and food processing to chemicals and plastics. The use of dilute phase conveying also is very prevalent in the energy industry with the handling of coal and fly ash. The question now is, Since we already have this intensive literature on the subject, is there room for more advancement and study? On the surface, one may think all is known about dilute phase pneumatic conveying, and, in some respects, this is true for simple designs. Still, the answer is a resounding yes. Interactions between various phenomena do continue to cause problems and make dilute phase transfer just as challenging as dense phase transfer. Among the phenomena that still can make the design and operation tasks difficult: electrostatic effects, heat transfer and unique powder properties. On analysis and with the advent of more advanced computer simulations, we now can focus more accurately on the basic physics of dilute phase conveying. We still lack some very fundamental knowledge showing how particles individually and in groups move and interact with themselves and their enclosed environments. The ease at which we can now employ high-speed videos [5–8] to analyze the movements and dynamics of such conveyance systems can provide a more accurate finding of the basic physics than previous analytical tools. One can review many of the findings which, by and large, have been correlated by empirical means to predict the energy loss in the conveying operation. This leads to the question of how to design an optimal system that uses minimal amounts of energy and still can guarantee reliability of the operation. One finds that older system designs wasted energy as users concerned themselves only with whether a system worked in moving the material from point A to point B. This philosophy was keenly demonstrated in the conveying of cement to build the Grand Coolie and Hoover dams [9]. Focusing again on the fundamentals with new analytical tools will provide for both the designer and simulator a more realistic analysis.

3. Computational approaches

The research into computational modeling and simulations of pneumatic conveyance continues as it also advances in other fields of solids processing. Computational fluid mechanics and discrete-element modeling, for instance, have been used alone and in conjunction with each other. These models do have assumptions, the largest one being the proper designation for the frictional behavior of the solid-gas and solid-solid interactions with themselves and the enclosed container. The results that have been seen graphically showing global pressure drops and velocity distributions seem to follow what experimental data has been documented in the literature. While this is encouraging, new research still is needed to better understand the basic physics of such systems. Cleverly crafted new experiments could give us the insights that we need to continue addressing these phenomena. One should begin by reviewing a number of the findings explored in the last few years, especially the work of Yu and his colleagues [10–15]. One also should review the works of Tsuji et al. [16], Sommerfeld and Zivkovic [17], and Sommerfeld [18]. These researchers have carried out realistic modeling of pneumatic conveying.