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Use of combined pneumatic conveying in the processing of granular waste materials

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Abstract. This paper focuses on the structural design, verification and operational functions of combined pneumatic and mechanical transport systems in processing granular materials. A pilot plant was designed in laboratory conditions, and the combined pneumatic and mechanical transport system was tested in operation. Subsequently, transport possibilities for granular waste materials, which varied in size and specific particle weight, were evaluated. A combined pneumatic and mechanical transport system was designed as a transport line for pneumatic conveying at low pressure in combination with a mechanical towing component. The combination of both modes was designed so that the towing component in the form of an axis-less helix was inserted into the conveying pipe. Transport efficiency was monitored by comparing common pneumatic transport and combined pneumatic transport (pneumatic and mechanical transport). Both systems were tested under the same operating conditions with various granular waste materials, which varied in size and specific particle weight. Crushed electric waste was used as granular material to assess the operational functions used. Properties of the proposed transport system were tested by constructing and operating the system. The evaluation of transport options featuring pneumatic and combined (pneumatic and mechanical) transport systems proved that the system was reliable and highly efficient for the transportation of dry granular waste.

Key words: pneumatic conveying, mechanical conveying, granular waste.

INTRODUCTION

Conveying granular material is a frequent part of production processes. The choice of specific equipment is always linked with the conveying conditions and properties of the material thus transported. There is a general requirement that the conveying equipment must allow vertical as well as horizontal transport, it must be dustproof and it must be able to convey granular material with a high degree of specific weight scattering with minimal energy costs. Pneumatic conveying meets such requirements. Material is conveyed in a closed pipeline either with negative pressure or overpressure of the air sucked in and ultimately released from the conveyor's surroundings (Mills, 2004). Ventilators are used for conveying air.

The previously defined pneumatic conveying is simple and functionally non-demanding without any specific constructional or material requirements. However, the simplicity of the system also limits the scope of applicability of such conveying. In practice this means that a lower pressure gradient and a smaller volume of air must be used, reducing the transport distance, elevation rise and lowering the output or weight scatter of the material conveyed (Mallick & Wypych, 2009).

The negative characteristics of low-pressure pneumatic transport suggested above can be neutralised in a variety of ways, while maintaining the functions of the processing lines prescribed in the project requirements. One option is changing the properties of the material conveyed (pre-sorting and reducing the size and weight spread of the particles conveyed), or adjusting the operation parameters of the conveying system, i.e., increasing the air flow volume and operating pressure (Baker & Klinzing, 1999). Affecting the material's properties or adjusting the operational parameters of the conveying system can be done in the framework of low-pressure transport only within a limited range and at the cost of increased energy requirements (Yan et al., 2012). This is why transport operation systems are often designed as combinations of pneumatic and mechanical conveying systems.

The incorporation of a mechanical conveyor before or after a pneumatic conveying unit can help to achieve a corresponding conveying output and reliability (Hilgraf, 1998).

This paper suggests a construction solution, discusses the verification of the operational function and assessment of conveying options in view of combined (pneumatic and mechanical) transport used in processing granular materials. A combined (pneumatic and mechanical) conveying system was designed and tested in pilot-plant laboratory conditions. Operating reliability was investigated in respect of conveying particles of a material with a high weight scatter, depending on the set operational conditions limited by the air flow volume and pressure gradient in a conveying pipeline.

MATERIALS AND METHODS

The combined (pneumatic and mechanical) conveying system was designed and tested in operation in pilot-plant laboratory conditions. The conveying options of this combined transport were then assessed with granular waste materials, which differed in size and specific particle weight. The system was tested on a waste processing pilot-plant line. The line is situated in the laboratories of the Czech University of Life Sciences in Prague.

Brief description of the design and functioning of the electric waste processing line

The electric waste is crushed in a two-roll crusher and then in a ring-type cutter. The material is conveyed into a dust-separator chamber from the cutter; the dust part is separated in the separator. The dust-free material is measured by a vibrating feeder into a fluid weir, where it is sorted by specific weight.

Description of a pneumatic conveying system incorporated into the electric waste material processing

Pneumatic conveying is designed as a low-pressure, negative pressure transport system. The material is conveyed in a closed metal pipe with the circular profile diameter of 150 mm both horizontally and vertically. The radial ventilator URBAN Technik, Type VE-6000A is the source of negative pressure with an output of 4,500 m^3 h^{-1} and with the negative operating pressure of 400 Pa.

Design and construction of the combined (pneumatic and mechanical) conveying system

A conveyer pipeline for low-pressure conveying in combination with a towing mechanical part is the main unit of the construction. The combination of the both types of conveying systems is designed in such a way that the towing part is in the form of an axis-less helix and it is inserted into the inner space of the conveying pipeline. The material is conveyed in this environment as a result of the dynamic effect of the flow medium, and, at the same time, it is carried forward by the mechanical movement of the turning axis-less helix. This technical solution allows conveying particles both by pneumatic and mechanical means in a single transport space (conveying pipeline).

Verification of the operational function of the combined (pneumatic and mechanical) conveying system

The operational function was verified by comparing the conveying reliability (i.e., the ability to convey material with specific physical properties at set operating conditions) of pneumatic and combined (pneumatic and mechanical) conveying systems. Conveying reliability was tested with two types of granular material that had various granular sizes and specific weight. Both materials were crushed and sorted into several granule-size groups. The first material was a mix metallic materials (electric conductor), grouped by grain size. The other material was a mix of plastic materials (electric insulating material), also grouped by grain size. Conveying reliability was tested individually in all material-size groups using pneumatic conveying followed by combined (pneumatic and mechanical) conveying. Different operational conditions were set for each subsequent grain-size group. The operational conditions were varied by setting different operational pressures to the conveying pipeline. The operational pressure was changed gradually by setting the ventilator revs. The value was measured by using the Testo 521-1 measure with a pressure sensor placed into the conveying pipeline at the distance of 1.9 m from the entering point of the conveyed material.

RESULTS AND DISCUSSION

The influence of the operational pressure in the conveying pipeline upon the transportation of particles with a specific size (and a constant specific weight) was explored for the purpose of assessing conveying reliability. Tables 1 and 2 feature operational data, i.e., the particle sizes in case of which and operational pressures at which materials are reliably conveyed using both pneumatic and combined transport. Table 1 lists values in view of the transportation of metal waste (electric conductor), while Table 2 lists values in view of the transportation of plastics (of an electric insulator).

The ways in which the operational data depends upon the aforementioned influences are shown in Fig. 1 and Fig. 2. In Fig.1 the values from Table 1 have been plotted to a graph and interlaid with a trend connecting line. The curves thus obtained show the conveying reliability for the transport of metal particles using both pneumatic and combined conveying systems. The given value of pressure always corresponds to the minimal value at which the material particles can be still conveyed using pneumatic transport.

Table 1. Values of operational pressure for conveying particles with a specific size (metal)

Pneumatic transport of metal	Combined transport of metal	
pressure (Pa)	pressure (Pa)	particle size (mm)
970	970	6
940	970	8
910	970	10
880	970	12
850	970	14
830	970	16

Table 2. Values of operational pressure for conveying particles with a specific size (plastics)

Pneumatic transport of plastics	Combined transport of plastics	
pressure (Pa)	pressure (Pa)	particle size (mm)
970	970	6
965	970	8
965	970	10
960	970	12
960	970	14
955	970	16

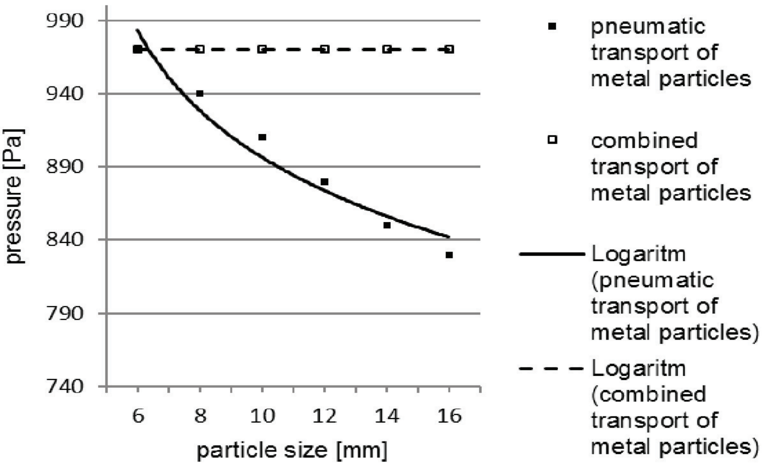

Figure 1. Dependence of operational pressure upon particle size (metal).

The course indicates that the pneumatic conveying of metal particles requires increasing the conveying sub-pressure depending on the size of the metal particles. Crushed plastics particles behaved similarly in the operational test, as shown in Fig. 2. As plastics are lighter to convey (their specific weight is smaller than that of metal), the transport pressures were lower. The course of pressures for conveying both metal and plastics is similar but the values of sub-pressure vary with particles of the same size.

As metal and plastics form a mixture during the processing of electric waste (electric cables), the operational pressure for the pneumatic conveying of same-sized particles must always be determined in view of transporting material with the higher specific weight (i.e., metal). This principle holds regardless of the proportion of the plastics and metal in the mix. In case the share of particles with a high specific weight is negligible in the mix (which is often the case in processing electric waste), the operational pressure must still accommodate conveying that share, i.e., it must be sufficiently high. Transporting such a mix in the given conditions is energy demanding.

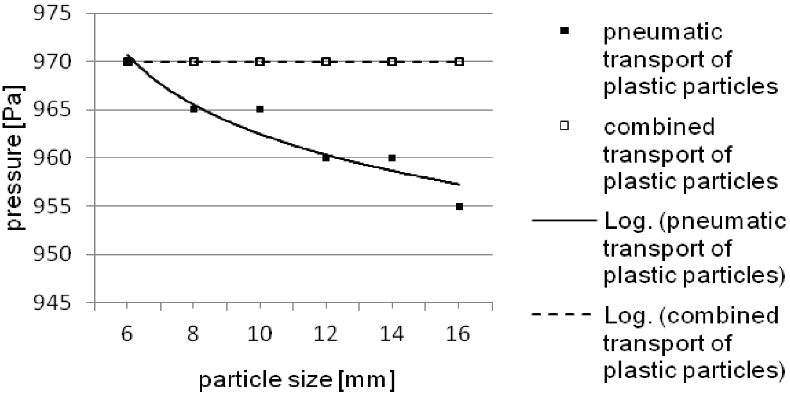

Figure 2. Dependence of operational pressure upon particle size (plastics share).

Adapting pneumatic conveying for combined (pneumatic and mechanical) transport allows both the metal and plastics share of the material to be conveyed in different operational conditions. Tables 1 and 2 list operational data, i.e., pressure, and the particle size which can be conveyed reliably at such a pressure while using combined conveying systems. The dependence of the data upon specific influences during conveying metal and plastics is shown in Fig. 1 and Fig. 2. The operational data show that the conveying reliability for both metal and plastics does not depend upon operational pressure. The transport of particles with a higher specific weight is facilitated by the inserted axis-less spiral. Operational pressure in the conveying pipeline allows conveying light, small and dust particles which emerge from the process of crushing the electric waste. For this reason it is possible to apply relatively low operational pressures in the combined transport system's conveying pipeline.

CONCLUSIONS

The advantage of the proposed combined (pneumatic and mechanical) conveying system is the possibility of transporting material with a wide spectrum of specific-weight particles. Particles with a lower specific weight and higher aerodynamic resistance are carried forward by the air flow mainly through the centre of the pipeline. Heavier particles are carried forward by the mechanical energy of the axis-less helix. The construction of a combined (pneumatic and mechanical) conveying system can be used to cover short distances at horizontal and oblique levels.

The values measured thus indicate that the conveying reliability for metal and plastics does not depend upon the operational pressure of the combined (pneumatic and mechanical) transport system. The axis-less helix conveys particles with a higher specific weight. The operational pressure in the conveying pipeline allows conveying light, small and dust particles. For this reason the combined transport system can be used with relatively low operational pressures in the conveying pipeline. Combined (pneumatic and mechanical) conveying is less energy demanding compared with pneumatic conveying.

The combined (pneumatic and mechanical) conveying system has an operational advantage in that its construction is simple, it needs less energy for material transport (smaller flow of volume and operational pressure), has minimal space requirements (the towing component is inside the conveying pipeline) and a small number of mobile parts.

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