



The Behavior of Fly Ash on the Vibrating Vertical Conveyor

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Abstract

This article deals with the transportation of three types of fly ashes on the vertical vibratory conveyors. Monitored department is influence of mechanical and physical properties of each fly ash on efficiency vibrating transport in vertical direction. Parameter monitored on the transport route is transport efficiency for each fly ash under the same operating conditions. The article also describes a comparison of mechanical and physical properties of the three types of fly ashes originating from different sources burning coal. Were measured following mechanical and physical properties: bulk density, angle of wall friction, flow function, particle distribution and particle shape. The resulting values of mechanical and physical properties of individual fly ashes in some cases are different and the others are only slight differences. Different values of the properties of fly ashes are reflected on the transport efficiency of vertical vibration conveyor. Mechanical and physical properties of granular materials serve as the basic input parameters for the design of each transport or storage system.

Keywords: vertical transport, material, vibration

Introduction

Recently, attention is focused on improving and more effective use of waste or secondary raw materials. These issues related to transportation, storage, sorting, blending, etc. The current and highly discussed issue is process fly ash [4,13,14]. The aim is to explore new technological methods for processing, transportation, storage and follow use of fly ash in various industries. One of the industries where the fly ash is frequently used the construction industry [7,10,15]. The fly ash used in construction are characterized as waste material produced during the combustion of pulverized coals mainly. Fly ash is obtained by electrostatic or mechanical separation of dust particles that arise mostly from high temperature burning of black or brown coal powder. The chemical composition of fly ash from coal-fired powder is characterized by a several basic elements. Of the total fly ash content has a main representation SiO₂ (silicon dioxide), which is contained in about 90%. Furthermore, in the fly ash appears Al₂O₃ (aluminum oxide), Fe₂O₃ (iron oxide), CaO (calcium oxide), SO₃ (sulfur trioxide) TiO₃ (titanium dioxide), and others. Fly ash is mainly used in the building industry as an additive into concrete [1,5,6]. Fly ash obtained from the combustion process it is necessary first to cool and subsequently transported to the storage facility. For cooling and transport of fly ash is preferably used

pneumatic systems [11]. This article focuses on three transport fly ash, which have different mechanical and physical properties. To transport of fly ash is used vertical vibrating conveyor, where material is conveyed by vibration after the screw conveyor trough in the vertical direction. The advantage of this conveyor screw is long route, where the hot material has enough time to cool. Basic mechanical and physical properties were measured for all three fly ashes and were compared [12]. The article describes how the mechanical and physical properties influence the efficiency of the transport of fly ash on the vertical vibratory conveyor.

Materials and Methods

Mechanical and physical properties fly ashes

Figure 1 shows three types of fly ashes prepared for an experiment.

a) Angle of wall friction

The best known principles that are used to measure an angle of wall friction are Jenike (translational) and Schultze (rotational) methods. In our case was used Jenike shear tester. Wall friction was measured for sheet steel with comaxit coating- RAL5015. The shear cell of Jenike shear tester consists of a upper ring lying on the contact material, and it is covered a lid. The lid is loaded centrally with a normal force. The upper part of

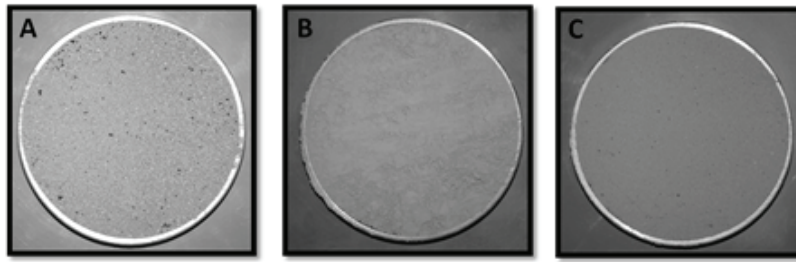


Fig. 1 Three types of fly ashes A, B, C
Rys. 1 Trzy typy popiołów lotnych A, B, C

Tab. 1 Classification of flow function

Tab. 1 Klasyfikacja funkcji przepływu

Type of flow	Flow Function Value
Free – flowing	$10 < FF$
Easy – flowing	$4 < FF < 10$
Cohesive	$2 < FF < 4$
Very cohesive and non-flowing	$FF < 2$

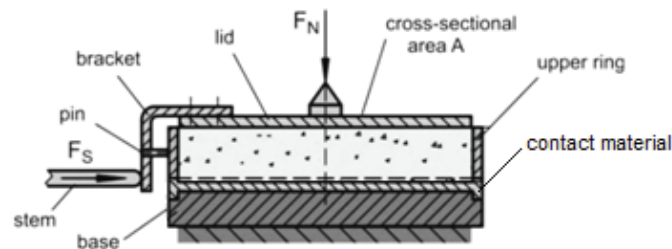


Fig. 2 Shear cell of Jenike shear tester
Rys. 2 Komora ścinania testera Jenike

the shear cell is displaced horizontally against the fixed contact material by a motor driven stem which pushes against a bracket fixed to the lid. The shear force – exerted by the stem is measured. Due to the displacement of the upper ring and the lid against the contact material, the bulk solid undergoes a shear deformation. The normal stress and the shear stress, acting in the horizontal plane between the upper ring and contact material are determined by dividing normal force, and shear force by the cross-sectional area of the shear cell. Figure 2. shows the principle of the shear cell of Jenike shear tester [2,3].

b) Flow function

The most commonly used parameter for the description of flowability of powders is the Flow Function as proposed by Jenike. It considers the Unconfined Yield Strength of a powder (with respect to the Major Princi-

pal Stress under which the powder is consolidated) to be the most relevant indicator of the powders ability to flow. He thus defined a ratio of these two parameters as the flow function – FF. Flow function was measured at the instrument FT4 Powder Rheometer [8]. Flow function is defined by the equation:

$$FF = \frac{\sigma_1}{\sigma_c} \quad (1)$$

σ_1 – is the Major Principal Stress acting on the powder
 σ_c – is the Unconfined Yield Strength of the powder

c) Particle distribution and shape

The Cilas 1190 laser particle size analyser was used for particle characterization. This research instrument incorporates three lasers ensuring the highest level of accuracy for product development and research. The three laser design allows the highest level of accura-

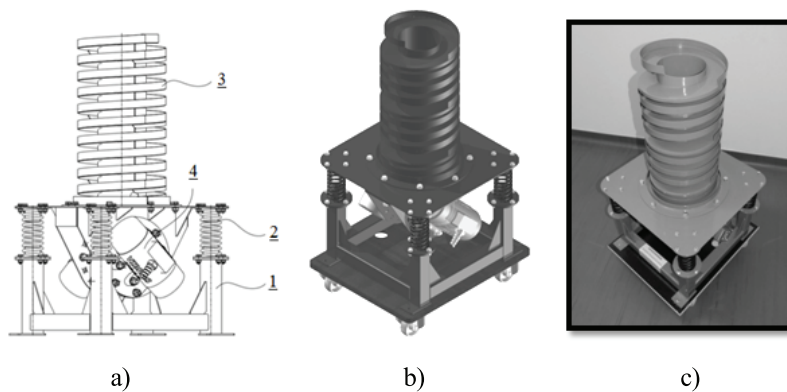


Fig. 3 Vertical vibrating conveyor: a) schematic representation, b) 3D model, c) real device
 Rys. 3 Pionowy przenośnik wibracyjny a) schemat, b) model 3D, c) prawdziwe urządzenie

Tab. 2 Parameters of the vibration motion

Tab. 2 Parametry ruchu wibracyjnego

Sinusoidal linear displacement in the z- axis z	0,5 mm
Sinusoidal rotation motion around z- axis φ	0,57°
Frequency f	30Hz

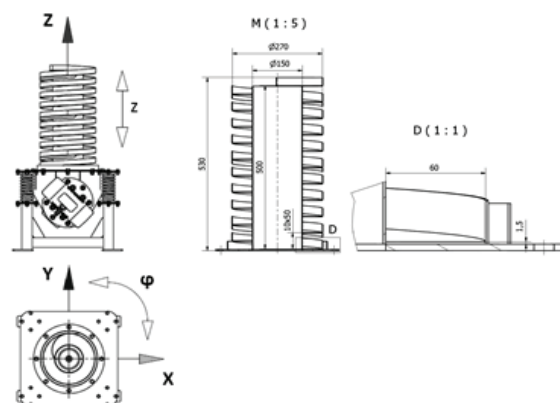


Fig. 4 Representation of the coordinate system and parameters conveyor trough

Rys. 4 System współrzędnych i parametry koryta przenośnika

cy and precision for the entire measurement range between 0,04 and 2,500 microns. Measurements can be made in either liquid or dry dispersion modes and switching modes can be done with a single click of the mouse. Cilas' new dry jet dispersion technology guarantees even the most difficult particles can be analysed accurately. For samples fly ashes was used liquid mode and measurement was performed in a water. The particle shape was evaluated from photographs created by electron microscopy.

d) Bulk density

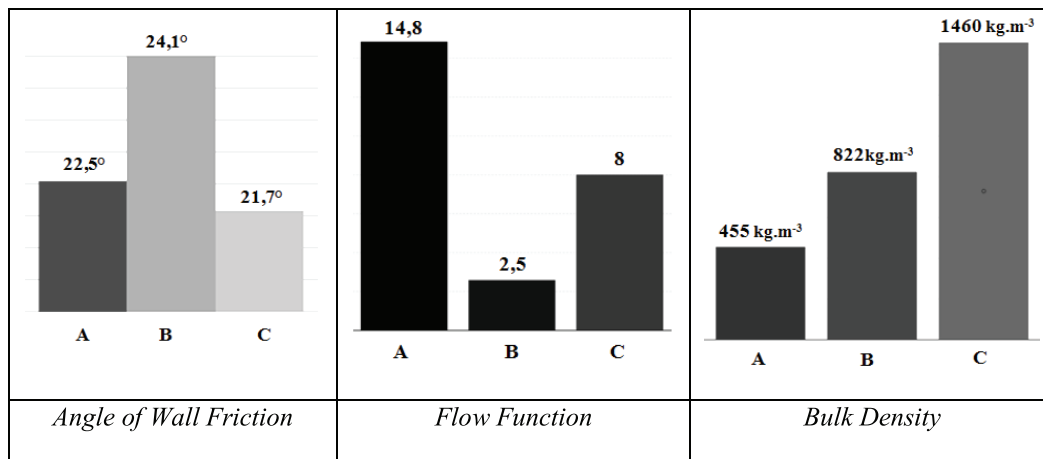
Bulk density for each sample was measured by the classical method, which is based on volume and mass ratios.

Description of the transport system

The device consists of four basic parts and some other elements. The main parts are: fixed frame (1), elastic elements (2), the conveyor trough (3) and a pair of vibration engines (4). Conveyor trough (3) is fixedly connected to a pair of vibration engines (4) which together form a vibrating unit. Conveyor trough (3) is a welded steel screw having a pitch of 50 mm and total length of the transport route is approximately 6 meters. Parameters of the conveyor trough (3) are shown in Figure 4. Elastic elements (2) capture and dampen vibration which would otherwise be passed into the fixed frame (1). Elastic elements (2) consists of four compression spring with a given stiffness. The basic parts

Tab. 3 Comparing of different properties of fly ashes

Tab. 3 Porównanie różnych właściwości popiołów lotnych



of the device are shown in Figure 3. The vibrating unit, when running pair of vibration engines, creates harmonic motion which consists of two simple movements which are sinusoidal linear displacement in the z- axis and sinusoidal rotation motion around z-axis. The composition of these two movements get harmonics in a spiral. The material being conveyed on the transport route moved by micro litters.

Coordinate system together with the parameters of the conveyor trough shown in Figure 4. Behaviour of bulk materials on the transport route of the vertical screw conveyor affects the operating frequency pair of vibration engines and their angle of rotation, the stiffness of the spring elements and the actual weight of the vibrating unit. To the bottom of the static conveyor trough was filled a sample of fly ash on the total volume of 2000 ml. After starting the vibration engines occurs oblique circular oscillatory movement vibrating parts and thus to transport of fly ash in the vertical direction. Parameters of the vibration motion was find out using high-speed camera-PIV. During transport process was monitored behaviour for each sample. The aim is to find out information about how the mechanical and physical properties influence the efficiency of transport performance. Parameters of the vibration motion are show in the Table 2.

Results and Discussion

Results mechanical-physical properties fly ashes

Table 3 shows the results of measuring the angle of wall friction, flow function and bulk density. The resulting value of angle of wall friction of the sample B is the highest in comparison to samples A and C. The difference is about 2°. Larger differences have proved in flow function. Sample A was evaluated as the free-flowing material. Sample B is characterized as low flowing or cohesive. Sample C then falls into the

category of easily flowing. Large differences in the results are also seen with the values bulk density. Sample C is relatively heavy, and its density is 1460 kg.m⁻³. Sample A has a density about 1005 kg.m⁻³ smaller than sample C.

Table 4 shows the results of particle distribution and particle shape. Sample A is composed of particles of irregular shapes similar to an cube and a cuboid. The particles have rounded edges.

The particle size distribution of the sample A ranges from 61µm to 350 µm. Sample B is composed of particles having a spherical shape with a distribution ranging from 2,7µm to 17,7 µm. In sample C are emerging spherical particles and particles of irregular shape. The distribution of this sample is from 8 µm to 187 µm.

Results vibrating transport

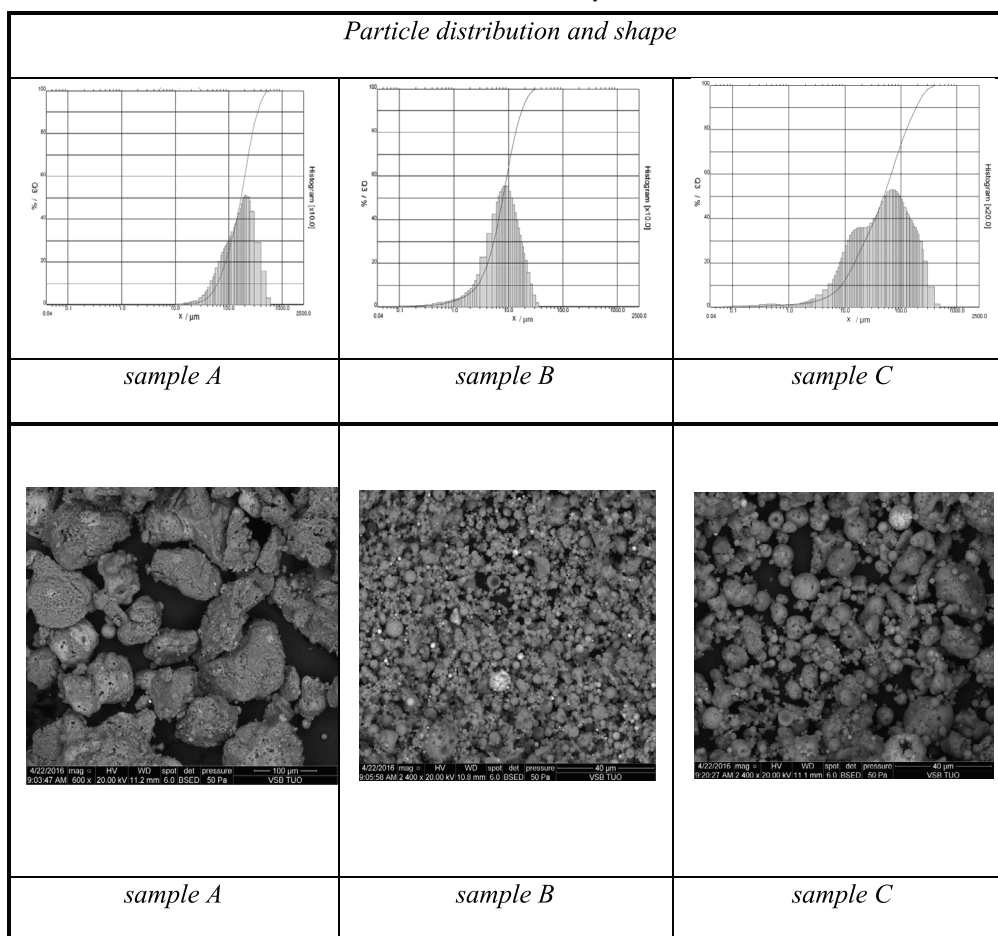
Sample A was moving continuously on the transport route. The material is transported in a layer with a height of approximately 15 mm. Material during transportation never have been collected and there are no complications. On the contrary sample B on the transport route does not move ever. The material was initially stuck to the conveying the chute and copied motion vibrating parts. This is due to the low value of the flow function. Sample B is very cohesive and for vibratory applications is inappropriate. Movement of sample C was relatively a continuous, but the conveying speed was significantly lower than the sample A. It was also caused by lower value of flow function.

Conclusion

This article describes comparison of mechanical and physical properties of the three ashes of different origins. Significant differences were shown in the distribution and shape of particles, bulk density and flow function. Results of flow function for each fly ash

Tab. 4 Particle size and distribution

Tab. 4 Skład ziarnowy



proved to be the dominant property that influences the efficacy of the vertical vibratory transport. Sample A of the transport route moved continuously and smoothly. Flow function of this material was measured as free flowing. Sample B was included in a group of cohesive materials. The material on the transport route does not move at all because it is stuck to the conveyor trough. Sample C is moved on the transport route, but its conveying velocity was significantly less than Sample A.

Sample C falls within the group of easy flowing. Flow function is the main mechanical and physical property that strongly influences the efficiency of transport on the vertical vibratory conveyor.

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Zachowanie popiołów lotnych na pionowym przenośniku wibracyjnym

Przedmiotem artykułu jest transport trzech typów popiołów lotnych na pionowych przenośnikach wibracyjnych. Monitorowanym zagadnieniem był wpływ właściwości mechanicznych i fizycznych każdego popiołu lotnego na skuteczność transportu wibracyjnego w kierunku pionowym. Badanym parametrem na trasie transportu była efektywność transportu dla każdego popiołu lotnego w tych samych warunkach operacyjnych. Artykuł opisuje także porównanie właściwości mechanicznych i fizycznych trzech typów popiołów lotnych pochodzących z różnych źródeł spalania węgla. Mierzono parametry mechaniczne i fizyczne: gęstość nasypowa, kąt tarcia ściany, funkcja przepływu, skład ziarnowy oraz kształt ziarna. Parametry mechanicznych i fizycznych każdego popiołu lotnego są różne, co wpływa na skuteczność transportu za pomocą pionowego przenośnika wibracyjnego. Cechy mechaniczne i fizyczne materiałów uziarnionych służą jako główne parametry wejściowe do projektowania systemu transportu lub składowania.

Słowa kluczowe: transport pionowy, materiał, wibracje