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Analysis of transient ash pneumatic conveying over long distance and prediction of transport capacity

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ABSTRACT

Pneumatic conveying of the lignite ash from blow tanks to a nearly 600 m distant silo at the 620 MWe thermal power plant is analyzed based on pressure measurements along the telescoping transport pipeline. Transient character of the ash transport is shown with an occurrence of blockages. The ash transport capacity of the pneumatic conveying is determined by predicting a pressure drop in the steady-state compressible air–ash mixture flow for a defined air flow rate, inlet and outlet pressure values and lengths, diameters and inclinations of pipeline sections. The predicted transport capacity is in agreement with the lignite ash production calculated on the basis of lignite ash content and a lignite mills load. In addition, the calculated pressure change along the pipeline shows good agreement with mean values of measured pressure amplitudes at a number of locations along the pipeline. The presented modelling approach can be applied to the prediction of conveying capacity of ash transport pipelines.

1. Introduction

There is a need for the coal ash transport from the thermal power plant to the silo. Part of the ash can be further transported and delivered to various consumers, such as to cement or construction industry, while the rest is transported in mixture with water to the landfill. The coal ash at the thermal power plant is collected in blow tanks from the electric precipitator, from the steam boiler flue gas duct and from the regenerative air heater. The ash is transported from the blow tanks to the silos by one or more transport pipelines (depending on the plant capacity and corresponding coal consumption) with compressed air. The pressure drop in the flow of compressible air and ash mixture leads to a significant increase of velocity. In order to maintain the velocity increase, the telescoping pipeline design is applied [1]. Further, in order to reduce the power consumption for the generation of compressed air and to reduce the erosive wear on the transport pipeline walls and fittings, the low velocity transport is preferred, where the ash is transported in some mode of the dense phase pneumatic conveying [2]. Due to the pressure drop and velocity increase along the transport pipeline, the transition to the dilute mode of transport might occur.

Design and operating requirements for long-distance and large capacity pneumatic conveying are presented in [3]. It is shown that the problems of transport instability and blockage, which might occur in transport pipelines longer than 100 m – 200 m, can be eliminated by the combined fluidizing-discharge-cone and cone-dosing valve at the blow tanks. Also, deficiencies of the models for pressure drop prediction are addressed in [3]. Some models or correlations do not take into account the substantial air density change over long distance pipes; the transported ash particles size can vary in a wide range from 1 to 300 μm, and it is difficult to represent adequately such material by the single mean diameter required by most models, and most models are developed only for dense-phase mode of transport or only dilute-phase mode, while in practice both modes can occur in case of long pipelines (dense-phase starting from the ash injection point and dilute phase at the outlet part of the transport pipeline) or a kind of transitional mode can take place over long distances, such as dune-flow, sliding beds, irregular slugging, etc. [3].

Transient character of the dense-phase pneumatic conveying is presented in [4]. Three characteristic periods of the transport cycle are shown: the pre-pressurization and initial surge period, the quasi-steady-state period and the third one is the emptying period. The analysis is concentrated on the pressure fluctuations in dense-phase pneumatic conveying during quasi-steady-state period. It is found that the frequency of oscillations rarely exceeds 5 Hz, and the amplitude of oscillations increases along the pipeline. Measured pressure transients along the 203 m long pipeline with 80 mm diameter are presented in [5]. Pressure pulses along the pipeline are shown with time delays of their occurrence in accordance with the propagation of the front of

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transported particles. Particle velocities are calculated on the basis of measured time periods between pressure rises in adjacent locations and distances between these locations. It is shown that the particle velocity gradually increases along the pipeline due to the pressure decrease and expansion of air. Transient parameter analysis is further evaluated in [6]. Changes of pressure pulse amplitude, pulse frequency and pulse time vary along the transport pipeline, and they depend on the change of aeration of the material bed. Also, pulse variations indicate approximate locations of the transition from dense to dilute mode of pneumatic conveying.

In this paper, the long distance and high capacity pneumatic conveying of lignite ash at the 620 MWe thermal power plant is analyzed with the aim of determining the maximum transport capacity of the conveying pipeline. The ash collected in the blow tanks is transported over 565 m to the silo. During burning of lignite of a lower quality, which has a lower heat capacity and a higher content of ash, the amount of ash that should be transported is increased, and blockages in the ash transport occur.

In order to predict the transport capacity of the pipeline for the ash pneumatic conveying from the blow tanks in the electric precipitator building to the silo, measurements of the pressure changes along the transport pipeline are performed. A strongly transient character of the ash transport is observed, and blockages of the transport are indicated within the pipeline and during discharging of the blow tanks.

Pressure changes along the pipeline are calculated with a model of compressible, homogeneous and steady-state ash–air mixture flow and by applying the correlation for the friction factor developed by Dogin and Lebedev [7]. The transport capacity is determined by the pressure change result that satisfies defined inlet and outlet pressure values at the transport pipeline for the specified air flow rate and defined pipeline characteristics, such as lengths, diameters and inclinations of the pipeline sections. It is shown that the predicted transport capacity is in agreement with the ash generation calculated on the basis of the steam boiler load and lignite ash content. In addition, the satisfactory agreement of the measured pressure amplitudes along the transport pipeline and calculated data is obtained. The presented approach is proposed for the prediction of the maximum capacity of ash transport pipelines.

1.1. Pneumatic conveying system at the thermal power plant

Lignite ash is collected and delivered to the blow tanks from the electric precipitator, the flue gas duct at the steam boiler and from the regenerative air heater of the Ljungstroem type. Eight identical blow tanks are applied per thermal power plant unit. Two parallel transport pipelines are applied per one plant unit. The collected ash is discharged simultaneously from two blow tanks, while two pairs of blow tanks (in total 4 blow tanks) periodically feed one transport pipeline. One pipeline with two pairs of blow tanks is presented in Fig. 1.

The blow tank is presented in Fig. 2. The tank bottom is covered with the fluidizing membrane, which consists of a filter cloth sandwiched between perforated metal plates. The membrane evenly distributes the fluidizing air from the bottom to the bulk of ash in order to provide efficient tank discharging. The top part of the tank cylindrical vessel is covered with the perforated plate. This plate distributes compressed air in the tank during pressurization period and prevents ash outflow with the vent air during tank charging with ash. The inside free tank volume, which is available for the ash storage is 12 m^3. At the tank bottom, there is no control of ash discharging from the tank towards the transport pipeline, such as fluidizing discharge cone and cone dozing system [3]. During the tank charging period, ash is freely falling from the tank into the transport pipe. During this period, the downstream valve in the transport pipe below the pair of tanks is closed (these are valves V1 and V2 for two pairs of tanks in Fig. 1). The ash discharge from the pair of tanks starts with the opening of the corresponding valve V1 or V2. For instance, during the ash charging into the first pair of tanks from the left in Fig. 1, the valve V1 is closed. At the same time, ash is being discharged from the other pair of tanks, and the valve V2 is opened. During the next cycle, the valve V1 is opened, and the pair of tanks on the left is being discharged, while the valve V2 is closed and the pair of tanks on the right is being charged with ash.

The pneumatic transport pipeline has the telescopic design with 4 stepped-diameter pipes (Fig. 1). At the junction from the smaller to the greater diameter pipe, the velocity of air and ash mixture drops, which prevents the excessive velocity increase that would be caused by the pressure drop along the long pipeline and corresponding compressed air expansion. Two parallel transport pipelines have the same dimensions. Dimensions and inclinations of sections of these pipelines, from the exit of the electric precipitator building to the entrance to the silo, are presented in Table 1. The transport pipeline length from the exit of the precipitator building to the silo is 525 m. The inlet section of the transport pipeline, from the blow tanks to the exit of the building, is located before Section 1 from Fig. 1. Its length is approximately 40 m, and its diameter is 0.2604 m, the same as the diameter of Section 1 from Table 1. The overall length of the transport pipeline from the blow tanks to the silo equals 565 m, and it is the sum of the lengths of the pipeline sections presented in Table 1 and the inlet section in the electric precipitator building.

Ash is transported in mixture with air delivered by a compressor, which capacity is 5500 Nm^3/h (the corresponding air mass flow rate is

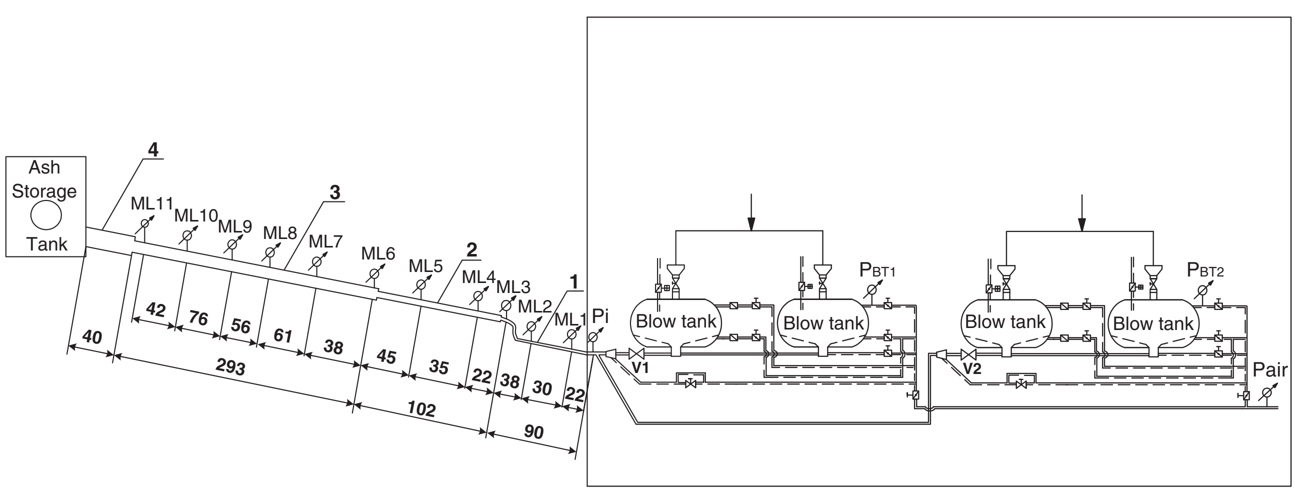

Fig. 1. Lignite ash transport pipeline at the thermal power plant (the telescopic pipeline consist of four sections, the distances between the pressure measuring locations ML are given in meters).