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Analysis of influence of conveyor belt overhang and cranking on pipe conveyor operational characteristics

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ABSTRACT

Conveyor belt, which is installed in a pipe conveyor, is subjected to various processes during its current operation, whereas these processes are causing a wear-out of the conveyor belt. The wearing process of the conveyor belt is induced predominately by influence of the transported material as well as due to improper operational conditions that are often caused as a result of an incorrect design of the idler housings. One of the possible consequences of the idler housing incorrect design is an irregular guiding of the pipe shaped belt. The incorrect guiding of the pipe shaped belt is manifested usually by an overhang and cranking of the conveyor belt. There are presented in this paper the experimentally obtained results based on a simulation of the cranking and overhang of the conveyor belt. The negative phenomena of the conveyor belt cranking and overhang were induced by means of an intentionally incorrect setting-up of the idler roller positions, in order to analyse their influence on the operational characteristics of the pipe conveyor. The experimentally investigated influence was verified by means of the developed regression models specified for description of a dependence among the normal contact forces and the tension force, as well as by the regression models, which are describing interrelations among the normal contact forces in two neighbouring idler rollers.

1. Introduction

Environmental aspects of bulk material transport are relevant presently with regard to a protection of the surroundings against pollution. A close interconnection between the bulk material transport and the living environment is evident. The producers and users of the belt conveyor transport systems are looking for new solutions in the given engineering area, in order to eliminate possible negative environmental impacts of the existing or newly projected conveying systems, which are specified for bulk material transport. If the transported goods have to be protected against the environmental influences or if the environment has to be protected against dust originated from the goods being transported, the closed pipe conveyor is just the suitable transport system or the system of a first choice. The pipe conveyor is an enclosed and curve shaped transportation system, which is specified for all kinds of bulk materials. This conveyor system is identical with a "classic" open trough conveyors in its loading and discharging point. A significant difference occurs behind the loading point, where the belt is formed into its typical pipe shape by means of a special idler roll arrangement over a certain distance and, finally, the pipe shaped conveyor belt is guided through the hexagonal idler

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housings. The pipe conveyors permit especially tight curve radii and steep angles of inclination. This low-cost and low-maintenance transport equipment also offers a possibility to transport two different materials in the upper and lower strand separately.

In addition, the correct conveyor belt alignment is important in order to prevent that the transported product is being spilled from the pipe conveyor along its length due to the overlap incorrect position.

An incorrect position of the pipe shaped conveyor belt in the hexagonal idler housings with the idler rolls is one of the most frequent problems, which has to be solved just after installation of the conveyor belt itself into the pipe conveyor supporting structure during a testing operation. There are several approaches how to set-up a correct position of the pipe shaped conveyor belt and how to control it. Taking into consideration the above-mentioned facts it is very important to analyse all the external and internal impacts that are influencing the conveyor belt.

Lodewijks et al. [1] discussed a nature of pipe rotation. They also discussed possibilities for a correction of the pipe rotation and limitations for a control of pipe orientation. Maton [2] presented a theoretical approach how to analyse the existing pipe conveyor. He also reviewed possible advantages and disadvantages concerning installation of a pipe conveyor with elliptical shaped tube, as well as he emphasized an importance of understanding how the conveyor belt specification and construction are influencing the operational characteristics of the piper conveyor, such as twisting.

The new approaches to measuring and analysing of the acoustic emission from a belt, at different conditions inside an enclosure, investigated Fazenda et al. [3]. This method allows an extraction of the useful diagnostic information concerning operational conditions of the belt and indicates the future research areas. Li et al. [4] proposed and verified a system, which is able to locate a position of the faulty idlers with a limited number of sensors what is important for current operation of the belt conveyors. He and Li [5] are oriented into the area of a non-linear modeling, simulation and vibration analysis of a large scale conveyor system. Kozhushko and Kopnov [6] studied the fatigue behaviour of a fabric conveyor belt subjected to a shear loading.

The conveyor belt simulation is a very difficult task. Hu and Guo [7] suggested a new method for belt conveyor dynamic design, i.e. the virtual prototyping technology. The results confirm the correctness of a simplified virtual prototyping and the feasibility of a heavy-duty belt conveyor virtual prototyping.

Determination of the total energy loss of the rubber conveyer belts is a very difficult problem, especially in the case of pipe conveyors, [8]. Kinoshita et al. [9] proposed a method, which is applicable for estimation of the total energy loss of the rubber conveyer belts on the idler rolls. Maton [10] discussed and presented a method for estimating of friction between the belt and idlers, as well as for determination of the power consumption. Liu and Wang [11] proposed a method, which presents a fact that this method offers a reasonable evaluation concerning quality of the belt conveyor. Adolfo et al. [12] developed and proposed the test methods and field measurements for the energy-optimized conveyor belts. Reicks et al. [13] compared the calculate and measure indentation losses in rubber belt covers. Gallagher [14] researched low rolling resistance for conveyor belts.

Many authors are applying the Finite Element Method for modeling and simulation of the conveyor belt static behaviour in the pipe conveyor idler housing [15,16]. Marasová et al. [17] dealt with a model developed especially for determination of the contact load values, which are induced by an interaction of the pair: pipe conveyor belt – idler rolls. Pang and Lodewijks [18] simulated stresses on the six idler rolls and deformation of the belt caused by a tension force, which is acting on both ends of the belt. Qin et al. [19] presented a complete system of simulation and calculation, which is specified for a steady state visco-elastic stress analysis. Bocko et al. [20] researched a complex material and performed experimental testing of the conveyor belts, together with numerical analysis.

It is necessary to describe exactly the resistance forces, especially the rolling resistance, in order to obtain the accurate results from a computer simulation of the conveyor belt dynamic behaviour. You-fu and Fan-sheng [21] developed a new two-dimensional semi-analytical method based on the Maxwell's model in order to perform the simulation process rigorously and efficiently and to solve the rolling resistance of conveyor belts. Zamiralova and Lodewijks [22] presented a detailed approach to calculation of the rolling resistance forces of the pipe conveyors, too. An adequate attention is also paid to a determination of the normal contact forces and concentrated loading forces on each idler roll in the idler housing. The loading forces depend on the mass of the transported material, pipe-filling ratio as well as on the mass and stiffness of the belt. Wennekamp et al. [23] created of various DIN standards. Which will include the test methods and the use of test results for the calculation of the belt width related indentation rolling resistance of belt conveyors. The main reason for performing of the research activities just in this area is a fact that in spite of the several tens installed pipe conveyors worldwide, the knowledge base, which could be able to describe the contact force relations in the pipe conveyor belt, is still insufficient.

2. Materials and methods

The pipe conveyor, in comparison to the "classic" troughed belt conveyor, is able to transport material not only in horizontal curves, but also in vertical curves thanks to its special tubular construction. This attribute of the pipe conveyors is one of decisive factors with regard to their application on the real operational conditions.

During a projection of the pipe conveyor trajectory it is necessary to pay a special attention to a proposal of the horizontal and vertical curves of the pipe shaped conveyor belt. The curvature of horizontal and vertical pipe conveyor bends has to be designed without any sudden changes of direction, i.e. without a conveyor belt cranking. A curvature trajectory of the piped belt should be continuous and gradual.