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Monitoring of dependences and ratios of normal contact forces on hexagonal idler housings of the pipe conveyor

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ABSTRACT

Contact forces, which are induced due to a reciprocal contact between the conveyor belt and forming idler rolls during a current operation of the pipe conveyors, are influencing the operational characteristics of these conveyors significantly. Despite of frequent application of the pipe conveyors, the question of contact forces is neglected relatively. This paper analyses closely the contact force values and their dependence on tensional force in order to identify mutual relations taking into consideration the selected factors.

1. Introduction

On the present, transportation of mineral raw materials by means of conveyor belt is a phenomenon analysed from various points of view very deeply, because the transport of material using the belt conveyors is one of the most frequent conveying technologies in the given material handling area. There are applied many various kinds of the belt conveyors, which are able to fulfil not only the required technical specifications, but also the ecological requirements. The environmental aspect of belt conveyor transport also generates new questions that have to be answered.

The pipe conveyors are progressive transport facilities with an increasing amount of applications. They are in a compliance with the ecological criteria, however their usage is connected with a wide range of questions and problems. The pipe conveyor is a modern mode of bulk material transport, which is applied in such situations, where complicated route planning, problematic materials or environmental impacts have to be considered during the project phase of the pipe conveyor design [1]. The researches in many countries try to describe and to solve the whole process of pipe conveyor transport. One of the most often analysed problems is just the question of guiding idler rollers.

Many authors investigated the questions and problems relating to the idler rollers. Bartelmus et al. [2] presented the results of investigations performed on the test rig specified for a quality control of the conveyor belt idlers. Fiset and Dussault [3] researched the wear process, in which ore particles become trapped between the belt and roller, creating so abrasive wear under a slight stress. Kinoshita et al. [4] investigated effects of the normal force acting on the roller, together with influence of the roller speed on the resistance force. Another relevant topic is the conveyor belt itself. Hötte et al. [5] researched the forming force behaviour of pipe conveyor in the case of different curvature radii. For this purpose a test rig was designed in order to examine the forming forces of the belt. These forces depend on the given kind of conveyor belt and plant

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parameters. Therefore, different belt constructions are investigated concerning their form stability at varied belt tensions and adjustable curve radii.

Other authors investigated a simulation of conveyor belt deformations and analysed operational conditions during the material transport. Pang and Lodewijks [6] presented a design of the pipe conveyor test rig and the testing results. They applied the Finite Element Method (FEM) in order to model and to simulate the static behaviour of the belt, which is based on one idler housing of the pipe conveyor. The stress state on the six idler rolls and deformation of the belt were simulated when applying tensions to the both ends of the belt. He et al. [7] presented a mathematical model for analysis of relation between the total life cycle cost and belt as well as among the idler sets and driving units. Zamiralova et al. [8] described a new analytical method for determination of the concentrated reaction forces on each of the rolls in the individual supporting idler housings in the case of an empty pipe conveyor. Furmanik [9] analysed load application on idler roller bearing of belt conveyor by means of dynamic models. Marasová et al. [10] performed analysis of a pipe conveyor model, which was developed for determination of contact forces between the tube-shaped conveyor belt and idler rolls of pipe conveyor. The analysed model was created by means of the software product Simulia – Abaqus. Bocko et al. [11] researched the complex material and component testing of conveyor belts used for numerical analyses. He applied the Bergström–Boyce material model and the chain strain multi-axial failure criterion for rubber plies numerical simulations, using the software products Abaqus Standard and Explicit. Molnár et al. [12–15] researched in detail possibilities of mathematical simulation of the pipe conveyor belt contact forces on the idler rolls in the hexagonal idler housing. Fedorko et al. [16] investigated a moulding part of the conveyor belt during its transformation from the flat form to the tubular form. These analyses were performed by means of the Finite Element Method. Du et al. [17] investigated the dynamic characteristics of belt conveyor based on virtual prototyping. The virtual prototype technology is feasible and effective in belt conveyor dynamic design. Petrikova et al. [18] presented experimental and numerical behaviour investigation of the conveyor belt samples made from the carbon-black filled rubber and reinforced by plain weave textiles. There are presented the results obtained from the FE simulations of the elastomeric composite as responses of mechanical loading.

Another important aspect of ecological transport using the pipe conveyors is a correct orientation of conveyor belt. There are also various investigation approaches to this problem. Maton [19] investigated one of possible approaches, i.e. whether an elliptical shaped cross-section would be more preferable than a circular shape. He applied a theoretical approach in order to analyse an existing tubular pipe conveyor and hence he reviewed possible advantages and disadvantages of a tubular pipe conveyor with an elliptical shaped pipe and he also emphasised an importance of understanding how the belt specifications and construction are able to influence the operational characteristics of the tubular conveyor, e.g. twisting. Lodewijks et al. [20] discussed possibilities how to correct the pipe rotation and options for control of the piped belt orientation.

Energy consumption of the pipe belt conveyors is another decisive factor, which has to be taken into consideration during a pipe conveyor application. Zamiralova and Lodewijks [21] presented a detailed approach to calculation of the indentation rolling resistance forces of the pipe belt conveyors. Attention is also paid to determination of the normal contact forces as concentrated load forces, exerted on each roll of an idler housing. Guo et al. [22] performed a research concerning the idler spacing of belt conveyor with regard to the effective factors and furthermore they deduced a rational arrangement for mathematical expressions of idler spacing. Michalik and Zajac [23] described a system for automated measuring of strength in the conveyor belt of pipe conveyor. Prenner and Kessler [24] developed an energy recovery system, which allows to recover a large percentage of the kinetic and potential energy of the transported material. This energy can be returned to the conveyor in the form of electrical or mechanical power. The functional principle of the so-called "Solid State Material Driven Turbine" could be confirmed already by experiments at the transfer point of a belt conveyor test rig.

The question of energy consumption correlates closely with a low rolling resistance belt construction, as well. Zhang and Steven [25] researched next three aspects: belt construction, low rolling resistance and dynamic analysis. The improved belt construction offers a better stability in horizontal curves and a higher resistance to twist. The low-level rolling resistance rubber compound is able to reduce the power consumption significantly as well as to decrease the belt tensioning force and in this way to save the operational costs. The dynamic analysis of the conveyor's starting and stopping behaviour can improve design and reliability of the long overland pipe conveyor systems. Rudolphi and Reicks [26] researched the viscoelastic indentation and resistance to motion of conveyor belts using a generalised Maxwell model of the backing material.

Circular shape of piped belt is not always an advantage. Hinterholzer et al. [27] designed a belt, which permits to resume its original flat shape during the return path traveling on top of the already existing idlers.

However, many questions concerning operation of the pipe conveyors are remaining without answers. Mutual interaction among the conveyor belt and forming idler rolls induces force effects and these acting force effects require an experimental investigation with regard to the motional resistances taking into consideration influence of forces in one idler housing on the forces in other idler housing.

2. Material and methods of experiment

2.1. Problem formulation

Contact forces caused by a reciprocal contact among the conveyor belt and guiding idler rolls represent an