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Statistical approach for evaluation of pipe conveyor's belt contact forces on guide idlers

Vieroslav Molnár *, Gabriel Fedorko, Beáta Stehlíková, Ľuboš Kudelás, Nikoleta Husáková

Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Kosice, Park Komenskeho 14, 042 00 Kosice, Slovak Republic

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ABSTRACT

The paper presents verification of the effect of emitted tension force of conveyor belt to the size of contact forces which are induced by the closed conveyor belt on the guide idlers in the hexagonal idler housing of pipe conveyor. The conveyor belt is an object with action of tension force and at the same time it takes the initiative in the contact force formation. The concept of the test equipment at the Technical University of Košice is designed so that it represents the section of pipe conveyor in which the conveyor belt is transformed to the pipe form. The measured data are presented by usual descriptive statistic characteristics and compared by nonparametric statistical methods. For comparision of position and tension force Nonparametric Friedman test and Shapiro–Wilk Normality Test were used.

1. Introduction

Japan Pipe Conveyor (JPC) developed enclosed pipe shaped conveying system with 6-idler panel and in early 1980s, JPC released that system with the name of pipe conveyor. Pipe conveyor system has been applied more and more in various bulk solid handling business. This is due to its unique characters; materials are fully enclosed by pipe shaped belt [1]. The use of pipe conveyor for transportation of bulk material has gained much popularity abroad over the past decade [2].

Knowledge of stress–deformation relations for conveyor belts is an important indicator which has effect on its operation factors, it interacts the lifetime and damages of conveyor belts. By their identification we can draw from the theoretical or experimental procedures. del Coz Díaz et al. [3] studied the stress and strain distributions and warping effects in a tubular pipe conveyor by the finite element method (FEM). The Finite Element Method (FEM) has proven to be a suitable tool in the modelling and nonlinear analysis of tubular pipe conveyors. The next who applied the finite element method for determination of stress–deformation states in the conveyor belt were Schilling et al. [4]. Authors drew conclusion that with the help of the rebar layer technology it was possible to model the behavior of the fabric reinforced belt of a Pipe Conveyor with only one shell element over the belt thickness. They also drew to the fact that in the future the computed reaction forces should be compared with measured forces to validate the model and bulk material loading should be added [4]. Hinterholzer et al. [5] studied the newly-developed belt return, however, is not as customary with the belt closed. Here, the belt is permitted to resume its original flat shape during the return path traveling on top of the already existing idlers for the loaded strand.

Hou and Wang [6] dealt with examination of rolling Resistance of Conveyor Belts based on the Maxwell Model. The result of their work is a new full two-dimensional semi-analytical method based on Maxwell model. This model is developed to rigorously and efficiently simulate and solve the indentation rolling resistance of conveyor belts. In this method, the solution is expanded into a set of Fourier series, a so-called Maxwell model characterizing the viscoelastic properties for the belt cover material is used to relate Fourier coefficients, and a special boundary

* Corresponding author. Tel.: +421 556023147; fax: +421 556028023.
E-mail address: vieroslav.molnar@tuke.sk (V. Molnár).

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element is developed to handle the rolling contact boundary condition [6]. Donis et al. [7] studied wow the Conveyor Belt Length Affects Belt Weigher Accuracy. Sarkar et al. [8] studied on adhesion between rubber and fabric and rubber and rubber in heat resistant conveyor belt. Decreasing the rate or increasing the temperature of testing reduced the peel strength of the joints. Rubber to fabric adhesion decreased with ageing time and temperature, while rubber to rubber joint strength initially decreased and then increased or remained constant.

Measurement of conveyor belt characteristics is realized by various types of special test equipments. Michalik and Zajac [9] used the computer integrated system for static tests of pipe conveyor belts. Hotte et al. [10] dealt with research on the form force behavior of pipe conveyors in different curve radii. A new conveyor belt wear test stand to simulate loading point stress conditions such as exist at impact points of lumpy material on conveyor belts was developed by Ballhaus [11]. A new contactless scanning technique based on ultrasonics was introduced to determine the abrasion of the cover plate experimentally. The experiments will allow the calculation and prediction of the service life of a conveyor belt in advance for specific operating conditions. A test rig was constructed by Chen et al. [12] to study the and noise behavior of rubber belt with interfacial ice film under low temperatures. They founded that the rubber belt friction is strongly dependent on temperature and the presence or absence of interfacial ice film. The belt friction is found to increase under dry-cold conditions when compared to room temperature conditions. The wet belt under cold conditions could form a thin ice film leading to high static friction and low kinetic friction. Williams et al. [13] investigated the feasibility of using an array of non-invasive tomographic sensors around a moving conveyor belt carrying solid particulates. Results from experimental and simulated data showed the importance of the position of electrode placement and the effect of the properties of the conveyor belt material itself.

Three major purposes of data processing by statistical methods are explication, interpretation and description [14]. Iyer [15] discussed statistical procedures used in the calibration of measuring devices or measurement procedures. D'Errico [16] dealt with systematic treatment of statistical methods for measurand estimation. Hajiyev [17] investigated measurements on the basis of the statistics of the relation of selection and theoretical variances, the simultaneous operative testing of mathematical expectation and variance of errors in the one-dimensional. The proposed measurement systems structure with the error self-correction is simpler, as it does not require a model for the errors as that proposed in the existing literature. Gadzhiev [18] dealt with operational methods for verifying the adequacy of mathematical models of multidimensional dynamical systems with biased measurements on the basis of statistical analysis of the sequence of residuals between output coordinates of systems and their models. Rank statistics in estimating missing parameters in measurement records dealt Ashmanets and Zolotukhin [19].

The known measuring systems for measurement of contact forces on the guide idlers are just based on theory [20–23]. The results of these measurements are inaccurate because it it difficult to determine the modulus of elasticity of the conveyor belt and other parameters. The conveyor belt is hyperelastic material with orthotropic behavior. Determination of forces in the conveyor belt is very complicated and used procedures are inaccurate. Often this is done by means of general coefficients, the calculated values from the theory can be determined only approximately. There are several authors in the world who are dealing with this problem [20–23] and built several test equipments [10,11]. These are used for measuring and examining of various effects on a conveyor belt.

The main goal of the paper is a statistical approach for evaluation of pipe conveyor's belt contact forces on guide idlers. Firstly, a review of the current state of the solved problem was presented in this section. The next section of the article determines the material and methods used by the paper. It means the aim of the experiment, characteristics of the test equipment and its basic parameters. The third section of the paper analyses the cause and effect diagram, analysis of the measured values and variability. The next section presents the obtained results of the measurements and statistical characteristics of measuring responses – contact force for tension force. The final part of the paper interprets the results of statistical evaluations and draws the conclusions.

2. Materials and methods

Before the experimental measurements we tested the sample of the conveyor belt. The aim of the tests was to verify that the parameters of the test sample of the conveyor belt for pipe conveyor satisfy the criteria for the operation. Evaluation criteria were four major indicators.

Measuring of the elastic elongation of the conveyor belt – informs about its ability to compensate the distance and speed of conveyor belt tension, its resistance to dynamic fatigue, ability to absorb additional side forces which are created by curve crossing and the change of operating status (start the conveyor, running with the transported material, change the transport capacity and stopping the conveyor).

Elastic elongation also exercises an influence on the characteristics of driving drum intervention and rearrangement of the conveyor belt. It results from Table 1 that the analyzed sample has suitable parameters of elastic elongation.

The values of permanent elongation of the sample – describes its properties by increase and decrease of the tension force of the conveyor belt. This parameter has been studied before the realization of measurement for exclusion of the effect of elongation of the sample for maximum extent of tension forces.

The modulus of elasticity of the conveyor belt – characterizes elastic properties of the conveyor belt, specifically its closing to the shape of pipe and it effects on the position of the place of conveyor belt covering [24].

These three indicators were measured in longitudinal direction and cross direction of the conveyor belt because of orthotropic properties of the conveyor belt.