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Measuring and comparative analysis of the interaction between the dynamic impact loading of the conveyor belt and the supporting system

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A B S T R A C T

The paper presents the results of experimental and regression analysis of dynamic effects and reactions in the system consisting of a conveyor belt and a supporting system with idlers and a conveyor belt without a supporting system. On the basis of experimental measurements, regression models were created for conveyor belts with and without the supporting system. Created models describe the process of dynamic impact loading of the conveyor belt when the material falls down onto the conveyor belt in the idle regime.

The main objective of the paper is to present the mathematical and statistical approaches to the conveyor belt quality assessment in terms of their impact resistance. The paper points out the possible uses of regression models in practice in order to identify the basic technical parameters of transfer points in the operational conditions, such as the drop height, falling material weight, and the supporting system.

1. Introduction

In the last years, belt conveyors belong to the most frequently used means of transport in various industries. Such frequent use enables fast development of their structure and discovery of new uses in various operating conditions, especially for continuous transportation of bulk materials (e.g. loose materials and piece materials) [1,2]. Priority in engaging belt conveyors is to arrange continual material flow with the lowest possible exposure [3,4]. Risks accompanied with the belt conveyor operation are discussed in the book [5]. The highest exposure is at the transfer point, i.e. the fall of the material onto the conveyor belt and its damage due to the dynamic load. Conveyor belt damage rate is much higher than the damage to other parts of the belt conveyor, whereas the cost of the belt is about 25–50% of the total cost of the conveyor system [6].

The process of conveyor belt damaging by the dynamic load was dealt with by many authors, theoretically and experimentally [7–17].

One of the first papers on the experimental research of conveyor belt resistance to the dynamic load is the Köttegen's paper [7] in which the author performed the registration of the (record) impulses of the impact force impulses.

Another paper dealing with this topic is the Lübrich's paper [8]. Author tried to present the theoretical expression of the impact process in the conveyor belt. In his work, Flebbe [9] is focused on the observation of belts of various structures containing anti-impact inserts in both, rubber-textile and steel cord conveyor belts. The papers in which their authors tried to illustrate the conveyor belt loading situation at the impact site (loading site) on a real conveyor belt were the papers of Ballhaus [10,11]. Hardygora

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and Golosinska [12], Hardygora and Wachovwicz [13] state that conveyor belt impact resistance significantly affects their life service. Conveyor belt service life was discussed in papers [18,19].

Conveyor belt damage analysis at the loading site was dealt with by authors Vierling [20] and Maier [21]. Belt loading at the impact site was also discussed by Komander et al. [22].

Theoretical knowledge, experimental measurements, and operational experience show that the rate and method of conveyor belt damaging by the impact of the material onto the conveyor belt at transfer points depends mostly on the supporting system structure, structure of the belt itself, and force relations in the belt, particularly in the section where the point force is developed.

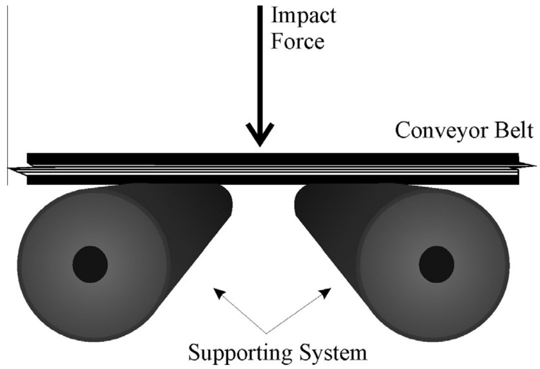

Fig. 1. Representation of the impact force and the supporting system.

2. Material and methods

2.1. Problem formulation

Belt conveyors represent a highly efficient transportation system with a simple structure [23]. They are used in plenty of industries. They are widely used in the coal mining, chemical industry, ports, and power plants [24]. They represent the most productive and thus also the most cost-efficient means of transport, high labour productivity, and ecological wholesomeness. An important part of a belt conveyor is the carrying and driving component – a conveyor belt. Operational experience indicates that the consumption of conveyor belts is remarkably affected particularly by the wear of conveyor belts and their damage caused by belt rip or lengthwise tear. Damage to a conveyor belt has far-reaching consequences. Therefore, it is necessary to know the relations existing in the damaging process. One of the possible methods of collecting the information about the damaging process is the testing in laboratory conditions. Testing of rubber-textile conveyor belts consists of testing methods, specified by standards, aimed at identification of their use properties [25]. The paper is focused on the examination of the conditions affecting the damage of a rubber-textile conveyor belt at the place where the material falls down at the transfer point. The objective is to compare the results obtained in experiments with and without the supporting system. The comparison will be carried out using the created regression models.

2.2. Testing equipment description

Laboratory experiment is an appropriate means of identification of critical values of impact and tension forces during the material's impact onto the conveyor belt when idle, i.e. determination, or verification, of the conveyor belt impact resistance in terms of the belt support (Fig. 1).

Experimental tests were focused primarily on identification of dynamic effects and reactions in the system consisting of a conveyor belt – idlers and a conveyor belt without idlers. Laboratory experiments were carried out with the test samples supported at the impact site by a set of impact idlers or without the belt support. In each test sample, impact and tension force measurements were carried out. The experiment was performed using the testing equipment constructed in the Logistics Institute of Industry and Transport in the Technical University of Kosice.

The testing equipment simulates the vertical impact of the material onto the conveyor belt with a pyramid-shaped impactor (Fig. 2). The testing equipment (Fig. 3) is described in more details in the paper [26]. The main parts of the equipment are: a tower and a frame table.

The tower is equipped with a hoisting winch of a drop hammer with the load capacity of 300 kg. The winch lifts the drop hammer up to the maximum height of 2.6 m, which is determined by the height of the tower structure. The drop hammer weight can be adjusted from the minimum value of 40 kg (drop hammer structure weight) up to the maximum value of 300 kg. The weight can be adjusted by adding the calibrated loads weighing 5, 10, and 20 kg. The drop hammer is dropped on a testing object in a free fall. Impactors simulating the properties of the falling material are attached to the end of the drop hammer.

The frame table has a steel structure. The table is equipped with movable hydraulic jaws for the testing object fixation and tensioning. The table is designed to enable performance of tests with and without the supporting system.

2.3. Test specimens

Collection of samples from the conveyor belt and preparation of testing objects are subject to general conditions that must be respected in individual tests. A detailed description is shown in the paper [27]. Testing objects used in the experiment are extracted from the rubber-textile conveyor belt of P 2500/5 + 2 type.

2.4. Test fundamentals and procedure

A selected impactor is attached to the drop hammer. The impactor simulates the properties of the material falling onto the conveyor belt. Input parameters are set on the drop hammer: the weight and the drop height. The weight of the impacting drop hammer was ranging between 50 kg and 100 kg with the 10 kg difference. The drop height was