Measurement 94 (2016) 364–371

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Online monitoring of a pipe conveyor. Part I: Measurement and analysis of selected operational parameters

Vieroslav Molnár [a,*], Gabriel Fedorko [a], Miriam Andrejiová [b], Anna Grinčová [c], Peter Michalik [d]

[a] Technical University of Kosice, Park Komenskeho 14, 042 00 Kosice, Slovak Republic
[b] Faculty of Mechanical Engineering, Technical University of Kosice, Letna 9, 042 00 Kosice, Slovak Republic
[c] Faculty of Electrical Engineering and Informatics, Technical University of Kosice, Letna 9, 042 00 Kosice, Slovak Republic
[d] Faculty of Manufacturing Technologies of Technical University in Kosice with a seat in Presov, Bayerova 1, 080 01 Presov, Slovak Republic

ARTICLE INFO

Article history:
Received 23 July 2016
Received in revised form 12 August 2016
Accepted 13 August 2016
Available online 13 August 2016

Keywords:
Contact force
Rubber-textile conveyor belt
Idler roll
Regression models
Pipe conveyor

ABSTRACT

The need to maximize the performance and operational reliability of ecological continuous conveyor systems is increasing nowadays and their requirements are difficult to fulfil. One of the main reasons to this is the complexity of ecological continuous conveyor systems. Regular tracking and monitoring of systems selected parameters and indicators support their proper functioning and operational reliability. However, the process becomes useless if the parameters are not tracked and evaluated. The paper shall present the results of research aimed at determination of evaluation criteria for selected parameters. The research was carried out by a method of experimental measurement on an experimental rig the construction of which is similar to the construction of real pipe conveyors used in practice. Some of the convenient parameters to be tracked on a tube conveyor are a tension force and contact forces on hexagonal idler housing. The paper aims to track the course of contact forces and their mutual relations with intensity of tension forces. In order to create a comprehensive evaluation and analysis of the research, the experimental measurements were carried out for two cases, with and without material. The experimental tests are evaluated with the use of basic mathematical and statistics methods.

1. Introduction

Conveyor units represent a very important part within majority of logistic systems. Their role is to transport variety of materials and foster the functioning of individual technological processes. Their reliable operation, maintenance and execution of decision-making processes depend on operational parameters monitoring as well as their evaluation [1]. Due to this, various reports and reviews can be produced [2] or the operation can be controlled based on the obtained parameters [3].

The kind and extent of the tracked parameters depend on many factors. Every conveyor system has its specifications and requirements. The most complicated conveyor systems, with regard to tracked parameters, are the ones that contain conveyor belts.

Monitoring of conveyor belts' operation is the key condition for their effective and reliable functioning [4]. Because of this, the issue has been much researched along with the development in various fields of technologies suitable for monitoring purposes. The research of monitoring and controlling system for conveyor belts was conducted by Wang et al. [5]. They came to a conclusion that monitoring and controlling system can significantly contribute to reduction of physical work and reduction of number of accidents.

The importance of conveyor belts monitoring is also supported by its necessity in various fields of industry. One of them is the mining industry where conveyors play an important role.

The research of monitoring system for conveyor belts in coal mines had been carried out by Wang and Zhigang [6]. The main idea of the designed system is based on the monitoring of the drive unit operation. The other research on monitoring system design of conveyors in coal mines can be found in [7]. Designed and above mentioned monitoring systems allow tracking of a single or several parameters. One of these are the parameters of material handling as presented in his work by Li et al. [8].

One of the options of tracking the operation of conveyor belts is presented by Pang and Lodewijks [9]. They suggest the application of RFID technology and its implementation in supporting rollers. The other possible way of operational conditions monitoring is suggested by Min [10]. In his work, developing of security system for conveyor belt using the steel-cord type of conveyor is being described. Lee and Au [11] proposed a new conveyor system called

* Corresponding author.
E-mail address: vieroslav.molnar@tuke.sk (V. Molnár).

http://dx.doi.org/10.1016/j.measurement.2016.08.018
0263-2241/

mobile conveyor lines that can autonomously configure itself to move objects to a given destination. The above presented information shows that most attention is given to classical conveyor belts in the field of continuous conveyor systems monitoring. In practice, more often used are also different types of continuous conveyors typically derived from the construction of a classical one. These also include pipe conveyors.

Pipe conveyors, in spite of their 40 years of existence, started to be more significant in the industry in the last 15 years [12]. Their development was much stimulated by increased requirements for ecological aspects in material transport. Due to this, the research of their operational needs and issues increases, too. The initial assumption that all the knowledge about classical conveyors can be applied to pipe conveyors, too, is no longer true these days [13]. Several methods of information collecting for the research of pipe conveyors are being used nowadays. Abbaszadeh et al. [14] employed the use of ultrasonic metrotomography method to research the behaviour of steel-cord conveyor. The method was chosen due to its not destructive character of analysis and possibility to identify various unwanted conditions of a conveyor, e.g. voids. The other not destructive option of analysis of rubber-textile pipe conveyors is the use of computer metrotomography method [15]. Besides the research of conveyor behaviour, the other aspects of pipe conveyors are being questioned, too. To answer the questions, various special testing devices are employed. Their specs and use are subject to several works [16–18]. Guo et al. [19] researched the optimization and experimental study of transport section lateral pressure of pipe belt conveyor. Wang et al. [20] researched the magnetic model of low resistance permanent magnet pipe belt conveyor. Mathaba and Xia [21] presented a generic optimization model for the energy management of downhill conveyors.

From the information presented, pipe conveyors are widely used means of continuous material transport. Compared with the classical conveyors, the aspects of their operation are not that much researched nowadays. However, their further employment implies the need to do so. The article thus aims to depict the issues of safety system in the operation of pipe conveyors with more detailed principles and background. The issues have not been solved and published in such a complex way so far.

2. Material and methods

It is not easy to identify the adverse conditions and processes in the pipe conveyors' operation. The reason to this is their numerous occurrence in various places of the pipe conveyor track. From the point of view of absolute position, the place of their occurrence can be static, or it can eventually change depending on transport speed and time.

Adverse condition occurring in a static state is commonly attributed to static parts of a pipe conveyor such as hexagonal idler housing, guiding or supporting rollers, eventually, the overall construction of the track. In case of adverse condition occurrence its position does not change, however, its further progress can occur depending on the kind of adverse condition itself. The easiest way to identify the state like this is the use of visual method when failure is directly identified (Fig. 1), respectively the indirect acoustic method can be employed. Then the adverse condition is indicated by a various intensity sound and its location must be additionally specified.

In case of adverse condition with its location changing cyclically, the situation gets much more complicated since this type of adverse condition is connected with the conveyor itself, regardless to its type, either rubber-textile or steel-cord one.

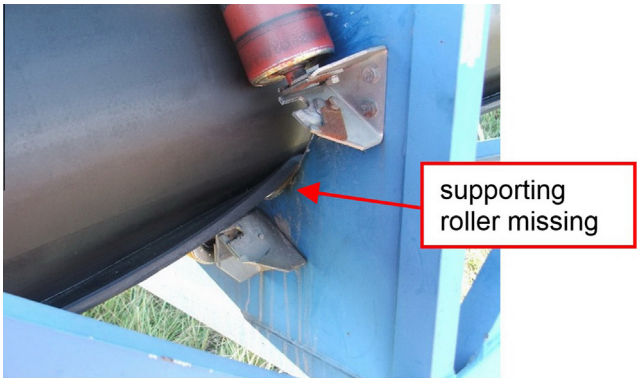

Fig. 1. The example of adverse operational condition – supporting roller missing.

Firstly, the existence of an adverse condition must be identified. In such a case, the use of visual methods has its limits for the conditions occurring in the upper layers of the conveyor belt. However, many defects occur in the inner structures of the conveyor belt where the visual methods of inspecting are not effective. At this point, further options arise but these might also have a few limits, e.g. acoustic method, thermal imaging method (Fig. 2) or a different type of non-destructive testing (NDT) method. The use of acoustic method does not seem to be effective. Although it signals the adverse condition, its location is problematic or even impossible. On the other hand, the use of thermal imagining is more effective. The most effective in such a case, however, seems to be the employment of NDT method with the possibility of conveyor's inner structure visualisation. Execution of such a method is still costly and demanding thus not economically justified for common operational conditions.

In the end, the application of the above mentioned methods is demanding and sometimes hard to execute in the course of real operation. The main reason to this is the need to record and evaluate the adverse condition at its initial stage. The sooner it happens, the faster the adequate measures can be taken to eliminate and prevent the threats to operational safety of the conveyor system.

The use of online monitoring of adverse conditions in the real operation of pipe conveyor seems to be much more effective with the employment of measuring of selected values. A wide variety of parameters can be tracked like this. e.g. Checking of conveyor belt rotation (Fig. 3) and preventing the material dumping.

The advantage of online monitoring is its continuous, resp. short intervals character. Thanks to this the adverse condition in the conveyor unit is reported immediately and the operator receives the info in no time. However, in order to perform the online monitoring, the parameters to be tracked and further evaluated need to be specified. The ones that will possibly be measured at minimum number of loci but will have the informative value about the adverse condition presence on the conveyor belt. The evaluation of these parameters will not only help to identify the adverse condition presence, but also decide whether it is serious one requiring a shutdown, respectively it is the one that signals the creation of an adverse condition without the need of shutdown. The parameters of such a value include tracking of tension force changes in the conveyor belt and contact force changes on the rolls of hexagonal idler housing.

3. Analysis of measurement points

Dependence between the tension force and size of contact forces on individual idler rolls needs to be researched for the