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# Proposal of the methodology for noise sources identification and analysis of continuous transport systems using an acoustic camera

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ABSTRACT

Reliable, trouble-free operation of continuous transport systems requires regular monitoring and evaluation of each operational indicator. Various methodologies and technologies can be used to record them. Particularly advantageous evaluation technologies are those which allow the transport system to be monitored to the widest extent, in the easiest way to identify adverse parameters or locations of occurrence of undesired operational conditions. Such methodologies include acoustic visualisation techniques. Despite their undeniable advantages and great potential in the field of belt conveyance, they have been used only minimally. The paper presents a research that examines possibilities of using acoustic visualisation techniques in belt conveyance with focus on selected functional parts.

## 1. Introduction

Belt conveyors are widely used to transport variety of materials nowadays. Their employment can be seen in various industries and they are inevitable part of various complex logistic systems. That is why their reliable operation is a key factor to efficient operation of company logistics. Thus, their operation needs to be monitored and evaluated constantly [1].

Several ways of belt conveyors monitoring exist. One of them is described by Wang et al. [2]. The other contribution to the topic of belt conveyors monitoring is presented by Lu et al. [3].

Monitoring, from the point of view of its execution, is quite a difficult process. The difficulty lies in the need of monitoring several parameters which can be really complicated due to the length of transport route and volume of monitored data [4]. A lot of information obtained by various methods is required to monitor belt conveyors [5]. The methods include the one of computer simulation which is in details discussed in [6]. Lodewijks et al. [7] present the use of Internet of Things (IoT) to monitor belt conveyors. This is a very progressive way in accordance with Industry 4.0 applying in wide variety of industries. The issue is even more detailed in [8].

Automatization of maintenance and operation process of belt conveyors employs various ways to collect data for monitoring of operation [9]. Its essence is simple and based on the collection of data [10]. Such a collection can be done with the use of RFID technology [11], thermography or application of various physical laws [12]. The use of thermography in belt conveyors is also discussed by Michalik and Zajac [13]. The same issues are discussed by other authors, too [14,15]. The issues of online monitoring of belt conveyor is also described by Molnár et al. [16]. Within their research, benchmarking and evaluation standards were considered which support decision making processes in online monitoring. The method of experimental measurements is proposed to obtain the data. Similar issues are being dealt with in [17]. Monitoring of belt conveyors is performed for several reasons including the process

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of predictive maintenance [18].

The process of monitoring can be done in a complex way with consideration of the whole transport system or eventually it can focus on the volume of transported material or individual structural parts of the belt conveyor.

Tracking of transported material on a belt conveyor should be one of priorities of the belt conveyor operators. It should be carried out for maintenance reasons or as a background for various economic analyses. Tracking itself, however, significantly depends on the kind of transported material. Zhang and Yang [19] dealt with the issues of monitoring of coal ash content on a moving belt conveyor. The other option to monitor transported material is the use of experimental measurements and computer simulation [20,21].

The other category to which attention is paid in online monitoring of belt conveyors is its structural parts or additional equipment such as crusher of transported material. Structural parts of belt conveyor include the belt itself, carcass or idler rolls and drums of a belt conveyor. Idler rolls and drums are very difficult to monitor. It is due to their amount (rolls) and also due to the fact they contain many moving but closed components which are difficult to see and monitor. This issue was discussed by Moni et al. [22].

Other important structural part of a belt conveyor is bearings inside the idler rolls as well as drums or the above mentioned additional equipment – crushers. There is no special method to analyse these since no information can be obtained without a direct intervention into structural parts of the belt conveyor. However, the methods already exist which fully comply with the condition but are not applied in belt conveyors. These methods include acoustic visualisation techniques.

## 2. Material and methods

Belt conveyors are used to transport various kinds of loose and solid materials which makes them highly effective and practical transport equipment. However, their operation requires much safety, simple operation and maintenance. Additional equipment is often used in the operation of belt conveyors, making their operation and maintenance easier. These include equipment for material fraction adjustment such as crushers, sieves, grates and the like. The crushers of transported material can be positioned on the filling or return end of the belt conveyor. Their primary task is the adjustment of material fraction either for transportation purpose or for further processing of transported raw material. Crushing of material can be done in several ways, e.g. the use of counter-rotating rolls, so called middle crushing, eventually crushing is done between apart rotating rolls and cutting boards on the outside of crushing area. Crushers can further be modified in order to let solid pieces of material in.

Since crushing of transported material is typically achieved by cutting and high pressure triggered by a high twisting force on crushing rolls, the process is connected with load to individual structural parts of the crusher. Thus these structural parts need to be monitored at regular intervals within overall monitoring of the whole transportation system. Acoustic visualisation techniques can be used for such a purpose as described in Fig. 1.

The draft in Fig. 1 consists of the follow-on steps:

a. Preliminary analysis of noise sources and acoustic background.

In case of identified noise, the following should be spotted and found out prior to measurement:

- Individual noisy parts of machine or the system and their location,
- Operational parameters and machine or system load,
- Preliminary shortcomings and faults of the machine such as bad placement, insufficient connections, placement, seams and gaps in covers and the like.

b. Selection of measuring points and operating modes.

During the measurements of these machines, equipment and systems, measuring points are chosen in accordance with principles applying to selected measuring equipment, machine placement and safety of the technician performing the work.

When measuring with an acoustic camera, it is necessary to take into account the parameters of the measuring device itself, that is to say, the range of the smallest and largest sensor distance from the source at which measurement can be made without major deficiencies or errors. In most cases, the measuring site is selected perpendicularly to the source of noise from the sites where the largest emission of noise sources is predicted. If necessary and possible, measurements are performed at different sites of the crusher. In some cases, it is advisable to use microphone array to measure sound sources over longer distances (e.g. up to 300 m). After evaluation of the first acoustic pictures and defining critical locations, a more detailed analysis of the microphone array elements (sound sources) can be done, intended to measure the distance of up to 10 m.

Measurements can be made using different types of acoustic cameras from different manufacturers. With regard to general requirements on the measuring equipment it is advised to picture low frequencies correctly (e.g. up to 300 Hz), with dynamic range of microphones from 30 ÷ 130 dB (A-weighted) and resistance to high relative humidity (eg up to 80%).

c. Creating of sound recording.

In this step, a sound recording or several recordings are created depending on whether the equipment works in a single operating mode or several ones. In belt conveyors, for comparison and better analysis the following modes are typically chosen: