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Original Research Article

Application of selected Levy processes for degradation modelling of long range mine belt using real-time data

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ABSTRACT

When analysing *big data* generated by a typical diagnostic system, the maintenance operator has to deal with several problems, including a substantial number of data appearing every second. Maintenance systems, especially those in mining industry additionally require the operator to make reliable predictions and decisions under uncertainty. All this create so called information overload problem, which can be solved in data mining with the use of existing data reduction techniques. Unfortunately, with complex mining machinery operating under diverse conditions more advanced approaches are needed. Effective solutions can be found among non-trivial degradation assessment techniques provided which shall be properly applied. This work proposes new methods to modelling specific system degradation and prognosis for system failure occurrence. The approach presented here does not rely on typical statistical assumptions. This paper relates to mathematical modelling of real diagnostic data with the use of selected stochastic processes – types of Wiener process and Ornstein–Uhlenbeck process. The main novelty and contribution is in the specific forms of above mentioned processes, in the ways how the process parameters were estimated and also in realistic correlation of proposed models to the studied system. Simulated and real case results show that the proposed robust functional analysis reduces bias and provides more accurate false fault detection rates, as compared to the previous method. We hope the outcomes provide applicable inputs for more effective principles of system operation, predictive maintenance policy and risk assessment.

1. Introduction

In recent years, industrial firms have implemented many new technological solutions aimed at improving the quality of manufactured goods or limiting losses. As a consequence, machines have become increasingly complex, imposing growing demands on their users, especially in terms of maintenance. This, among other things, creates a need for the use of appropriate methods and techniques to ensure the

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durability and reliability of entire, often very complex and sophisticated production systems.

System operation data are an invaluable source of information which, when properly used in operational decision-making, can bring significant and tangible financial benefits at a negligible cost. The so-called information overload and difficulties with effective analysis and processing of collected data due to the need of using sophisticated tools, extensive knowledge and experience pose a challenge to almost every company. These problems are therefore addressed by innovation-supporting activities in engineering [1–6].

One of the information overload solutions used in data mining is data dimensionality reduction – utilization of the most relevant data portions both for inference and also predictions. Time series analysis, principal component analysis and factor analysis methods are amongst the most popular techniques of reducing the number of variables to avoid the curse of dimensionality [7,8]. According to Choi et al. [9], intelligent data reduction techniques and partitioning methodology are needed for effective fault diagnosis in automotive systems. Some aspects of data reduction were also used for several years in chromatographic measurements. These methods are rooted in tools such as multivariate analysis and neural networks analysis [10]. Data reduction techniques are used as an effective and adequate predictive maintenance (PM) tools [11,12]. Such tools are becoming more and more important, as reflected by a considerable increase in the number of publications devoted to this problem [6,13–20]. The positive effect of PM approaches in the improvement of operation and maintenance processes may be mitigated by different factors. According to Goodman [21], statistical features can sometimes provide sufficient information for basic troubleshooting and failure indication as a result of effective data analysis.

With complex machinery operating under a wide variety of conditions, however, more advanced approaches are needed. Recent advances in monitoring and data real-time industrial data collection have also led to information overload due to the increased number of measurements and increased number of variables associated with every observation.

The item analyzed in this study is a system affected by many factors. As we study long range mine transportation belt and look both for the system condition and prediction of potential failure occurrence another field of our interest is the way of elaboration of indirect diagnostic data for system condition assessment. We possess segment of diagnostic system data obtained with a computerized measuring system installed in the belt conveyor (Fig. 1). Inspirational examples of interesting approaches how indirect diagnostic signals can be elaborated in order to obtain system condition information can be found in works by Glowacz [22–24] and Mazurkiewicz [25–27]. However these approaches lack stochastic point of view which we try to animate in context of the studied system here in this article. Some issues of processes modelling related to condition based maintenance and risk-cost assessment have been recently published. Applicable and inspirational outcomes have been discussed by Baji et al. [28], Dijoux et al. [29] and Jin et al. [30].

As the statistical analyses are not the best for our case we apply stochastic processes for system condition and degradation modelling. Our approaches are based on specific forms of stochastic processes – Wiener process with drift and Ornstein–Uhlenbeck process. The theoretical forms of the processes are described further but here we can state that specific forms of these processes are given mainly by way how the parameters were estimated. The suitability of these processes utilization lies in the way how well they interfere with the real studied system. The fact that we study also negative increments of system degradation excludes other traditionally applied tools. The objective is to find and to study the first hitting time distribution when the applied degradation processes reach a critical threshold. These outcomes can provide very valuable inputs for further system operation, maintenance policy and life cycle costing.

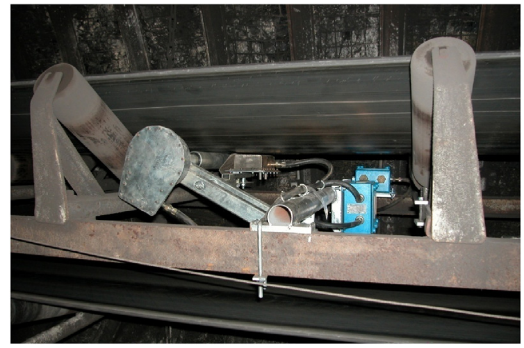

Fig. 1 – Arrangement of the measuring system on the belt conveyor route [26].

2. Diagnostic field data origin and form

System measuring instalation enables the following: continuous monitoring of the condition of all connections and belt sections between them; signalling of the exceeding of alert thresholds; evaluation of the belt conveyor's operating conditions; identification of a single connection at any moment of the belt conveyor's operation; assessment of the efficiency of performed maintenance works such as the reinforcing of the connection by the application of mechanical elements [26]. It is important here to allow for a long-term analysis of historical data for each single belt connection making part of the conveyor belt route, from the manufacturing of the connection until the end of its service life. However, the main task of the measuring system is to enable continual monitoring of the condition of the belt connections, as they are critical elements of the entire structure. A decreased strength of the connection and, subsequently, its failure caused by successive wear are amongst the main causes of failure of belt conveyor systems.

Conveyor belt failure usually has the form of a rupture which in nearly 100% of cases occurs at the point of belt connections. To ensure belt condition control, it is therefore vital to monitor all belt connections on the entire route of every belt conveyor that makes part of a transport system. The data obtained with the measurement system described in the previous section of this paper can be effectively used to model