Abstract

The dissertation is devoted to the real-time monitoring of the close transportation devices, namely, belt conveyors. It presents a novel measurement system based on the linear strain gauges placed on the tail pulley surface. These gauges enabled monitoring and continuous collection and processing of data related to the process. Also the initial assessment of the artificial intelligence application to the load identification was made. In further perspective, implementation of such a system can improve safety of the work and reduce the reparation expenses, leading to the application of the greener solutions. The abovementioned features of the innovative measurement system meet the high requirements of *Industry 4.0* concept.

After the introduction and formulation of the objectives, in Chapter 3, a review of existing solution is presented. Particular attention was paid to different types of the belts applied in the conveyors, and to the maintenance issues, including economical questions and safety. A wide range of the proposed monitoring systems is described, based on the recently published works.

In Chapter 4, research methodology and the examined object are presented. To perform experimental works, a test rig was built, making possible to simulate the work of a conveyor belt in laboratory conditions. Three strain gauges were placed on the surface of the tail pulley, so that they may sense the varying pressure of the belt during conveyor's work. Application of the linear strain gauges is an innovative solution, because they collect continuous signal around the entire circumference of the pulley. This way the dynamical errors generated by the strikes of the belt on the point strain gauges were eliminated. Additionally, a dedicated calibration set was built for the strain gauges fixed to the pulley surface, and the metrological characteristics were determined. In particular, it was found that the strain gauge indications were dependent on the angle position of the pulley and on the load. The expanded uncertainty $U0.99 = 3.6$ ADU was estimated, being less than 1% of the measured value. Repeatability calculated as equipment variation was $\%EV = 3.8\%$ for different loads and $\%EV = 5.8\%$ for different declination angles.

During the experimental research in dynamic conditions, the strain gauge signal was registered while the following parameters were altered: belt velocity, load on the belt, and certain damages were made in the belt. This way, the points in the registered graphs were identified related to the loads, $P_c = f(t)$, and the ones related to the damages $P_u = f(t)$. The experiments were performed in several stages for two belts with different input parameters, obtaining 953 graphs of the registered strain gauge signals.

Chapter 5 consists of discussion of the results and their comparative analysis. In addition, the tests of strength were made using the samples made out of the tested belt material. At the end of the chapter, initial analysis was made on feasibility of the artificial intelligence application for the analysis of the received signals. Among five tested algorithms, Transformer Neural Network (TNN) and Long Short-Term Memory (LSTM) reached the classification accuracy $A_c = 100\%$ when identifying the load placed on the moving belt.

In Chapter 6, the summary of the performed research works and analyses is given. It was demonstrated that the results obtained from the innovative strain gauge measurement system proved the formulated scientific theses. Moreover, main advantageous characteristics of the monitoring system were described with possibilities and directions of further research. The feasibility of the system for conveyor belt real-time monitoring was confirmed, especially in terms of the *predictive maintenance*, in agreement with main concepts of *Industry 4.0*.

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