Abstract

The objective of this doctoral dissertation is to propose mechanisms that support the maintenance of large belt conveyors used for transporting bulk materials over long distances. This work aims to identify and develop solutions that enhance the efficiency and reliability of the conveyors while minimizing the risk of failures that could lead to costly downtime.

Extensive literature reviews were conducted to gain a comprehensive understanding of the current state of knowledge and technology in the field of belt conveyors. This analysis included market needs assessment and a detailed evaluation of available solutions. Based on this analysis, monitoring the behavior of the belt and rollers along the conveyor route was identified as a critical area needing improvement. The primary focus was placed on the ability to predict failures, which is crucial for avoiding downtimes and ensuring operational continuity.

This work aligns with the Industry 4.0 concept, which involves integrating modern digital technologies into industrial processes. The research utilizes machine learning techniques, the Internet of Things (IoT), advanced analytical algorithms, and decision-making mechanisms.

As part of the research, an original model of the belt conveyor was developed along with innovative CAD tools for creating and designing conveyor models. Proprietary tools were also created to parameterize the models and perform analytical calculations to determine the forces, resistances, and stresses occurring on the conveyor. These calculations are based on scientific literature, research, and the knowledge and experience of BEUMER in understanding the behavior of individual conveyor components.

The research and simulations presented in this work were conducted on an existing belt conveyor installation located in China. This conveyor has a total length of 12,461 meters and allows for the transport of 2,400 tons of limestone per hour. Due to its location in mountainous terrain, the conveyor has a complex geometry with numerous elevations and curves, making it an ideal test object.

This dissertation also includes the development of methods and tools for adapting the created models to real conveyor installations. To accurately fit the model, machine learning techniques were employed. Additionally, a combination of data collection and processing methods was proposed along with developed tools to implement the concept of a digital twin, enabling precise monitoring and analysis of conveyor operation in real time.

Furthermore, the dissertation proposes methods for addressing real-world problems that may arise during conveyor operation. All proposed methods are aimed at predicting the risk of future failures rather than merely detecting their occurrence, as event detection is typically handled by sensors installed on the conveyor and is not the focus of this work. Based on analytical calculations, machine learning, and measurements, a method for detecting the

risk of belt misalignment was proposed first. Subsequently, a method for detecting excessive belt slippage was developed, also based on similar data processing techniques. Lastly, an innovative enhancement of a method for detecting rollers that require replacement was proposed, which was suggested in the scientific literature but could not be implemented due to its limitations.

The analyses and research confirmed the thesis that it is possible to create tools supporting the maintenance of belt conveyors based on measurements, machine learning techniques, and analytical calculations.