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PhD dissertation abstract

Designing of storage bunkers used in the continuous conveyor system of the Rudna Mine using modern numerical methods

Storage bunkers are a crucial component of the ore transportation system in copper ore mines, ensuring its continuity. In the currently used bunkers, several operational problems can be observed that are related to changes in the receiving bins design, blockages in the receiving bin and reciprocating plate feeder, and the wear damage (abrasion) of steel linings. An essential issue in this context is determining the impact of the ore masses on the bunker structure and its optimization while maintaining their operational efficiency. At present, the only possible solution is to use integrated methods of discrete elements and finite elements (DEM and FEM, respectively) to conduct advanced stress state analyses resulting from the interaction of the ore masses.

In the first part of the study, using the DEM method, a digital ore model was prepared to define the correct physico-mechanical parameters of copper ore. The modeled ore was then used in the process of creating its flow model in the bunker-receiving bin system, whose results were consistent with real observations. In the next stage, studies were conducted on the vertical load generated by the ore mass on the receiving bin structural elements. The results of the initial numerical simulations using the DEM environment and force measurements by strain gauge provided previously unknown information about the actual load on the receiving bin structure. The obtained load values served to validate the ore flow model in the bunker-receiving bin system, which was later used for model research aimed at determining changes in the receiving bin's structure.

Model studies allowing for the determination of the optimal operating point of the analyzed bunker-receiving bin system were carried out in three stages. The first stage was oriented on the assessment of the currently used design and identification of a possible range of changes that would enhance it. As a result of the simulations, it was decided that the new receiving bin design should be shortened by 1 m, and the entire bin moved 1 m away from the bin's back wall. Various simulation variants were conducted for the newly defined structure, characterized by different technical parameters of the reciprocating plate feeder. Using the PCA method, it was found that the most significant impact on particle speed in the reciprocating plate feeder, the pressing force of the ore on the reciprocating plate feeder, and reciprocating plate feeder efficiency are the feeder's length, frequency, and offset from the receiving bin's axis. An optimization procedure was carried out for these parameters using a gradient optimization algorithm with constraints. The results obtained for the optimal operating point were verified with simulation results and found to be consistent. The comparison of simulation load values on the reciprocating plate feeder and particle movement speed obtained for the current and proposed solution allowed to indicate the expected range of geometric changes in structural features. In the last stage, simulations were conducted in an integrated DEM and FEM environments, resulting in stress and displacement distribution in the structure under the influence of forces caused by accumulated and moving ore masses. The analyses showed that the newly proposed structure exhibits better strength properties than the structure used so far. Analyses conducted for both the

current and new structure showed that for the proposed design, the areas of maximum stress were reduced.

As a result of the research, guidelines and recommendations were developed for designing underground ore storage bunkers to enhance their operational safety, reliability, and utilization rate. These guidelines, already at the design stage, allow for minimizing previously observed problems with receiving bins structures, thereby reducing the number of repairs and replacements of operational parts of the bunkers. The research results form the basis for introducing actions to streamline the process of filling and emptying strage bunkers used in KGHM Polska Miedź S.A. mines, and the proposed range of optimization actions should be used already at the stage of designing new technical solutions for the bunker-receiving bin system, tailored to specific locations and defined transportation tasks.

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