Robust design optimization of a discharging hopper with DEM-based and experiment-based metamodels

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In design of bulk handling equipment such as hoppers, transfer chutes, and mixers Discrete Element Method (DEM) models are used to predict the dynamic performance of equipment designs. However, DEM simulations are computationally expensive and optimization with the DEM model in the loop is considered infeasible. Therefore a common approach is to construct a metamodel based on data from several DEM simulations. The metamodel is computationally efficient and can be used in an optimization loop to predict performance. In general, the design of bulk handling equipment is focussed on achieving a certain mean performance. However, bulk materials can have highly irregular particle shapes, sizes, and material packings. These aspects cause the geometry-dependent equipment performance to be stochastic and the performance distribution. This research focusses on including the variability of equipment performance in the design process through robust design optimization. The goal of the study is to identify how deterministic and robust optimization of bulk handling equipment design leads to different optima and to determine the reliability of these optima after validation. A hopper case study is considered for which the design is optimized such that specific mean discharge rates are reached in combination with minimum impact loads due to collapsing granular structures. The data used for the metamodels is based on experimental data for a discharging hopper as well as DEM results of an experiment equivalent DEM model. The optimization study shows that significantly different results are obtained with the different optimization strategies. The DEM-based optimisation shows good resemblence with the results for the experiment-based metamodel optimisation. However, the design solutions significantly differ for deterministic and robust optimization. Here, robust optimization leads to more clearly defined optima than the deterministic approach.