ABSTRACT

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Title: Developing a Validated Model for Predicting Grain Damage Using DEM
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Grain kernel damage during harvesting and handling continues to be a challenge in grain postharvest operations. The damage causes physical and physiological changes to grain, which reduces the grain quality and leads to significant yield loss. During harvesting and handling, grain kernels are subject to complex loading conditions consisting of a combination of impact, shear, and compression forces that can result in mechanical damage. Although there is considerable empirical data focused on kernel damage, there is a lack of generalizable mechanics-based predictive models. Mechanics-based models are desirable since they would be useful for providing guidance on designing and operating grain handling processes to minimize kernel damage and, thus, improve grain quality. The objective of the current study is to develop a mechanics-based model for predicting damage of corn and wheat kernels using the discrete element method (DEM).

The first step in DEM modeling is to determine the model input parameter values. This step is critical since the accuracy of the DEM simulations model is greatly affected by these parameters. The input parameters for the model developed in this current study are the physical and mechanical properties of corn and wheat kernels. These properties were determined by either direct measurement or calibration tests and validated with bulk material tests. X-ray micro-CT scanning method was used to acquire the grain kernel particle shape representation. The coefficient of friction (COF) was measured using a reciprocating pin tribometer. The coefficient of restitution (COR) was measured using the calibration method with a box containing multiple bins. The measured model parameter values were used to simulate common bulk material tests, i.e. bulk density and angle of repose. A comparison was made between the simulated results and the experimental measurements. The low percent error between experimental and simulated values indicate the accurate model parameter values estimation.

The damage resistance of corn and wheat kernels to compression, friction, and repeated impacts were measured using the universal testing machine, pin-on-disk tribometer, and Wisconsin

breakage tester, respectively. Lognormal distribution was used to model the compression test data, and three-parameter Weibull distribution was used to model the single and repeated impact test data. The statistical models were able accurately predict the damage probability based on the loading force or input energy. The wear damage was insignificant for corn-acrylic, corn-steel, and wheat-acrylic wear tests. For wheat-steel wear test, the average work done by the friction force to cause pericarp damage was 3.85 ± 1.50 J. The test results showed that the corn kernels were more susceptible to impact loading, while wheat kernels were more susceptible to compression loading. Both corn and wheat kernels had high resistance to wear damage.

The statistical model that predicts the impact damage probability based on impact energy was implemented in DEM. Stein breakage tester was used to validate the developed model. The damage level of the samples was then evaluated and compared with the predicted damage level output by the DEM simulation using the measured input parameters. However, it was found that the DEM simulation prediction error of damage level was high when the input parameters characterized by the Wisconsin breakage tester were used. The parameters were then recalibrated using Stein breakage tester. The model was able to give a good prediction on the damage fraction at different sample size and time levels when the recalibrated parameter values were used.