ABSTRACT

Biorefineries which seek to convert biomass into ethanol face many different challenges, and among them, mechanical failure of equipment is common. Unfortunately, the resulting downtime can significantly reduce the profitability and the viability of bioethanol plants. One important piece of mechanical equipment in this setting is the compression screw feeder, which is used both to convey and compress biomass into pressurized chemical reactors. However, due to the variability of feedstock properties, this feeding operation is challenging. An analytical model for predicting the operational steady-state torque of a compression screw feeder can assist the identification of optimal processing conditions, as well as predict and prevent equipment failure.

Since these models have not yet been proposed, this thesis restricts attention to milled corn stover and investigates the application of the discrete element method (DEM) and analytical techniques to develop predictive models for the stresses and torques developed inside a compression screw feeder. Specifically, DEM simulations are used to identify and study the stresses within the different sections of a representative compression screw feeder for three backpressures, three screw pitches, and three internal friction angles. Using these numerical results, a suite of analytical models is then developed to predict the operational torque required to drive the screw feeder. In this thesis, the DEM results are also used in lieu of experimental data to provide a point of comparison for the models.

The analytical models predict stresses on the correct order of magnitude and are not prohibitively sensitive to input properties, but the operational steady-state torque is overpredicted by the model in all cases. The mispredictions of the model are likely due to the assumption of constant material properties along the densification process, and the assumption

of hydrostatic conditions throughout the compression screw feeder (especially near the boundaries). Despite these limiting assumptions, the proposed procedure for calculating the torque provides a first-order estimate of the required screw torque, demonstrates the sensitivity of the screw feeder to different inputs, and outlines the necessary steps to improve the model. The DEM simulations proved an invaluable tool in analyzing the behavior of bulk material within a compression screw feeder, but more experiments and simulations (possibly using the finite element method) are needed to further understand the biomass feeding operation.