ABSTRACT

Patterson, Timothy J. M.S.M.E., Purdue University, December 2014. Prediction of the Stress at the Inlet of the Nip Region in a Roll Compactor. Major Professor: Carl Wassgren School of Mechanical Engineering.

The stress at the inlet nip region of a roll compactor (i.e., feeder outlet stress) is a necessary input parameter for existing powder roll compaction models; however the nip region inlet stress is poorly understood and difficult to directly measure. The inability to specify the nip region inlet stress on a roll compactor limits comparisons between powder roll compaction models and experimental results. Therefore, this thesis investigates the application of a solid plug model to a powder feed screw of a roll compactor in order to predict the stress at the inlet nip region.

The feeder outlet stress predictions of the Solid Plug models developed by Tadmor et al. (1972), Campbell et al. (1995), and Hyun et al. (1997a) were compared to experimental results. Each of the Solid Plug models under-predicted the experimentally measured feeder outlet stress by orders of magnitude. Potential reasons why the Solid Plug models poorly predicted the experimental results are the accuracy of the friction coefficient measurements and the assumed values for the stress ratios. The friction coefficients could not be completely defined because the surface finish of the feed screw and barrel were unknown, and the stress ratios were assumed to equal one based on the kinetic theory of granular material (Lun, 1991).

The sensitivity of the Solid Plug models to the following input parameters: friction coefficients, stress ratio, and stress-density relationship are investigated. Adjusting the friction coefficients or stress ratios, such that the stress-density relationship predicts a density greater than the lower density limit, is shown to cause the Solid Plug models' feeder outlet stress predictions to rapidly increase and become more sensitive to the mass flow rate. In most cases, varying the friction coefficients or stress ratios by 10% caused the feeder outlet stress predictions to vary by a factor from two to ten.

The Solid Plug models' poor predictions of the experimental results are also likely due to assuming constant material parameters such as the friction coefficients and stress ratios. The sensitivity of the Solid Plug models to the material input parameters and the effects of the stress-density relationship show that small changes in the material parameters due to the variation in stress along the length of the feed screw could have a significant impact on the Solid Plug models' feeder outlet stress predictions.

The friction coefficients and stress ratios necessary for the Solid Plug models to accurately predict the experimental results were determined. The fitted parameters varied significantly from the initial values input because the initial feeder outlet stress predictions were orders of magnitude below the experimental results. Due to the sensitivity of the Solid Plug models to several input parameters and the poor comparisons between the Solid Plug models' feeder outlet stress predictions and experimental results, the Solid Plug models, as presented in the literature, do not lend themselves to predicting the nip region inlet stress applied to the powder roll compaction models.

In addition to applying the Solid Plug models to a powder feed screw, the Solid Plug models' derivations were extended to determine a relationship between the feeder torque and the feeder outlet stress. The derivations predict qualitatively the linear relationship between the feeder torque and feeder outlet stress observed experimentally, but quantitative predictions are orders of magnitude different. Although the Solid Plug models' predictions of feeder outlet stress are not applicable to powder roll compaction models, experimentally measuring the feeder torque-outlet stress relationship and measuring the feeder torque on a roll compactor would allow for the feeder outlet stress to be predicted. Determination of the feeder outlet stress allows for real time processing and complete comparisons between the powder roll compaction models and experimental results.