ABSTRACT

Easo, Liza A. Ph.D., Purdue University, Jan 2017. Liquid dispersion in sheared particulate material. Major Professor: Carl Wassgren, School of Mechanical Engineering.

Wet granulation and coating are critical steps in a number of industrial processes used in the chemical and pharmaceutical industry. In these processes, liquid is added to powder and mechanically mixed to uniformly disperse the liquid in the system. The liquids typically form capillary bridges in between particles which significantly changes the physical behavior and dynamic strength of these powders. It is crucial for final product formulations and design to determine the dynamic strength of these wet granular material as well as quantitatively understand the liquid dispersion rate. Currently, most processes involving the dispersion of liquids in particulate beds are designed by trial and error resulting in a significant loss of materials, not to mention time, potential profits, and product effectiveness. At present, there are few models predicting the mixing rate of these powder-liquid mixtures. The objective of this thesis was to develop and validate better predictive models for the dispersion of liquids in granular material. It is vital to understand the microscopic liquid transfer process in order to develop better macroscopic predictive models using the Discrete Element Method (DEM), typically used for analyzing particulate systems. For the microscopic model, a Computational Fluid Dynamic (CFD) model and VOF method was utilized to numerically investigate the filling of a liquid bridge when two spherical particles with uniform films touch. A constitutive model for pendular bridge regime was developed to predict the liquid filling rate of a capillary bridge.

A macroscopic model was then developed using the open source DEM code, LIGGGHTS. The dynamics of wet granular material differ significantly from dry granular material due to the cohesive effects of the liquid bridges. The cohesive ef-

fects of the liquid bridges and liquid transfer was incorporated in the DEM code. The existing liquid transfer models was compared with a new model that spatially tracks the liquid drops on the particle surface. The liquid transfer models were also compared to a population balance model to show an exponential decaying mixing rate. The results show a high dependence of mixing rate on the liquid bridge participation models. Additionally it was shown that the effects of orientation and roughness affect the liquid transfer rates.

Finally, a non destructive method to experimentally study the liquid transfer rates using X-Ray computed tomography (XRCT) was developed. A shear cell setup was devised to fit inside the XRCT machine and the liquid was tracked using a MATLAB image processing algorithm. The experiment showed qualitatively the liquid transfer from shearing the particulate system. The experiment also showed that cohesion is an integral part of such systems and cannot be ignored in DEM simulations.