DISCRETE ELEMENT MODELING OF PARTICLE FLOW IN A CRYOGENIC GRINDER AND DEVELOPMENT OF A VERTICALLY ALIGNED PRE-COOLER

ABSTRACT

Cryogenic grinding of spices improves the quality of the ground powder by reducing the loss of volatile compounds which would have otherwise evaporated due to high temperatures that develop inside the grinder. Screw conveyor is used in this work as a pre- cooler to reduce the temperatures of the spices before they are fed in to the grinder. Understanding of the flow and residence time distribution inside the pre-cooler is important for improving and scaling up the cryo grinding process. The Discrete element Method (DEM) is widely used for understanding flow behaviour of the particles in different process applications. Black pepper is modelled with the DEM to investigate the mass flow and residence time distribution in a screw conveyor used as a pre-cooler in the cryogenic grinder and the results are compared with the experiments. A Rotating drum apparatus was used to analyze the angle of repose and flow characteristics of black pepper to select the DEM input parameters. The Coefficient of static friction for particle to particle contact and the Coefficient of rolling friction for particle to wall contact have the highest impact on the results. The simulations that best matched the experimental results have values of coefficient of static friction for both particle to particle and particle to wall contact as 0.4 and Coefficient of rolling friction between particle to particle contacts of 0.03. The validation of the parameters to model the particle flow was carried out on a screw conveyor at rotational speeds of 5, 10, & 20 rpm and mass input of 25g and 50 g. The mass flow rates and residence times predicted using DEM are in agreement with the experimental results. The residence times obtained using EDEM (API) are comparable with the pulse input tracer methods confirming that DEM can be applied for accurate prediction of residence times in screw conveyors. Optimization of the screw dimensional parameters was then carried out with the validated parameters. The optimized screw conveyor had screw flight of 66mm, screw shaft of 42mm and pitch to diameter ratio of 0.42. The mass flow rate from the screw conveyor was 6.67 kg/h and a residence time of 401s for 1.87 m length. A vertically aligned pre-cooler was developed to replace the horizontal screw conveying pre-cooler. The mass flow rate in the vertically aligned pre-cooler was dependent on paddle height, baffle diameter and rotational speed. On the other hand, the residence time was found to be a function of rotational speed of the paddles and angle of baffle cut section only. Particle breakage in the hammer mill was modeled using the particle replacement method of DEM. It was found that the particle replacement method with four numbers of progenies and a size ratio of 0.33 can be used to qualitatively model the breakage to understand mill material interaction.

Keywords: Cryogenic grinding, Discrete Element Method, pre-cooler, screw conveyor, modeling, validation, optimization, vertically aligned pre-cooler, particle breakage, particle replacement method, mill material interaction, hammer mill, shape of hammer