A Study of Granulation Methods for Lincoln Electric

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The senior design team working on the Lincoln Electric project is seeking to assist Lincoln Electric in developing improvements to the granulation processes of SAW granular fluxes to increase efficiency in production, specifically to reduce the mass fraction of particles that are too small (fines) or too large (overs), and thus fail to meet strict sizing criteria. Granulation processes such as high-shear mixing, Forberg paddle mixing, and fluidized bed granulation were tested to determine which process would result in prototype granules best matching the samples produced by Lincoln Electric.

Project Background

Lincoln Electric is considering an upgrade to its manufacturing process for its product family of bonded Submerged Arc Welding (SAW) fluxes and is seeking an analysis and prototype demonstration using various granulation methods available at Purdue’s Center for Particulate Products and Processes (CP3). Bonded SAW fluxes are typically a blend of powders (alumina, silicates, fluor spar, magnesia, and other minerals), bonded together with aqueous silicates in a granulation process.

The goal of this project is to determine the best granulation method to reduce out of size granules bonded together with aqueous silicates in a similar manner.

Results and Discussion

A Canty SolidSizer was used to collect size and shape data on the granules through image analysis, and a Flowdex was used to determine the angle of repose.

This plot is an example of the images collected by the SolidSizer. Here, the particles are plotted by their elliptical form factor and aspect ratio. The closer both variables are to 1, the more spherical and smooth the granules are; leading to increased flowability.

The Forberg mixer (above) was chosen for testing granulation processes due to its fluidization zone in the center of the mixer where binder could be injected, and the ease of installation in Lincoln Electric’s current facility.

Experimental Procedure

The five raw material powders used are weighed and added to the mixer. The materials are dry-mixed to ensure even distribution. A select fraction of the fifth powder material is left out and is used later to cap the granules due to its high surface area.

After dry-mixing, the sodium silicate binder is injected into the fluidization zone of the center of the mixer. The gel produced by the sodium silicate solution can be “set” with the addition of a weak acid. Acid is not a typical component and is mainly used in our prototype batches to expedite their preparation for characterization.

Lincoln Electric provided samples to use as a baseline to work towards.

As samples were created, they were characterized in a similar manner.

Since the granules need to be able to flow well and pile up over a weld joint, the drained angle of repose (Φd) needs to be between 40-45 degrees. This target was achieved in most prototype batches.

Contour plots derived from the model show the processing parameter values interacting with overs and geometric mean particle size. Reducing the “Binder / Powder, pre-capping” ratio can reduce the number of overs but is also correlated with a decrease in % of accepts. Increasing the “Capping, % of Total Mixture” allows for an increased “Binder / Powder, pre-capping” ratio without increasing overs while also increasing the % of accepts. An increased “Binder jet / tip speed” ratio correlates with increased % of accepts with little effect on overs. Overs could also be reduced by increased concentration of silicate in the binder solution.

Summary of Effects

The goal of this analysis is to determine which processing parameters will yield granulations with reduced overs without creating accepts that have too wide variations and too low average sizes.

This plot is an example of the images collected by the SolidSizer. Here, the particles are plotted by their elliptical form factor and aspect ratio. The closer both variables are to 1, the more spherical and smooth the granules are; leading to increased flowability.

Recommendations

Based on these findings, Lincoln Electric should seriously consider a modified Forberg mixer as a feasible candidate to replace their current granulation mixer. We believe this will increase production efficiency, reduce cost, and produce a product that falls within their ideal design criteria.