3D CFD Modelling of Dense Granular Flow Down an Inclined Rotating Kiln

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ABSTRACT

Rotary lime kilns are long, cylindrical heat exchangers, used in the pulp and paper industry, to supply enough heat to granular solids for decomposition of lime mud to lime to occur as part of the kraft chemical recovery process, while additionally providing efficient mixing to ensure a uniform product. The operating conditions in a kiln can have a significant impact on the flow dynamics of the solid material, which in turn impacts the product quality as well as lime nodule formation. Nodule size is correlated with the efficiency of a lime kiln, and therefore understanding the physics behind nodulation is of great importance. A dense granular flow model using Computational Fluid Dynamics (CFD) and the Kinetic Theory of Granul ar Flows (KTGF) is implemented to understand the physics and flow regimes within the kiln. A modified form of the frictional viscosity model is implemented to account for the constant frictional contact between particles. While previous work has been done on 3D CFD granular flow models for rotary drums, these models lack the axial flow of material, limiting the flow and energy analysis. Therefore, we present our progress towards a 3D CFD model for dense, granular flow down an inclined rotating kiln to analyze the impact of operating conditions on both the flow and energy field of solid material.

A 2D kiln model combined with a 1D bed model has already been developed, where bed effects are treated as heat and mass sources/sinks. This 3D model is an extension of the previous kiln model, with the 2D model providing inputs for the simulation. The 3D CFD model is generated in ANSYS Fluent 2022 R2. The physical model and geometry of the kiln is based on data given from a real industrial lime kiln. Due to computational expense, a slice of the kiln is modelled, where periodic boundary conditions are implemented to copy the flow field of the solid material. The KTGF model is implemented along with an additional modified frictional stress model to account for dense granular flow. The inlet velocity and temperature field, as well as fill ratio, are determined from the previous 2D kiln model for steady-state conditions. Axial velocities are solved by Fluent and scaled to match the expected steady-state mass flow rate from 1D model. Current work is being done to obtain and analyze the dynamic angle of repose, flow field, and energy field throughout the bed.