Intensification of phosphate fertilizers granulator using CFD: transition phenomenon investigation FuturE work & perspectives

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GENERAL CONTEXT

The granulation, using rotary drums technology, is an essential operation unit to form granules with good quality in many industries such as food processing, pharmaceutical, and mineral processing. The main objective of this work is to evaluate the effects of the key operation parameters of this process, especially the rotational speed on the behaviour of multiphase flow within an inclined rotary drum granulator by the use of computational fluid dynamics (CFD).

MATHEMATICAL MODEL

The Eulerian model that we used allows to simulate fluid-fluid and fluid-solid multiphase flows. Navier Stokes equations are presented by Euler-Euler approach and coupled to the Kinetic Theory of Granular Flow model.

The continuity equations for gas-solid mass conservation are:

$$\frac{\partial(\alpha_g)}{\partial t} + \nabla.(\alpha_g \overrightarrow{v_g}) = 0 \quad \& \quad \frac{\partial(\alpha_s)}{\partial t} + \nabla.(\alpha_s \overrightarrow{v_s}) = 0$$

$\overrightarrow{v_g}$ and $\overrightarrow{v_s}$ are the velocities of air and fertilizer particles.

The gas volume V_f, f is defined by : $V_g = \int_V \alpha_g \, dV$.

The conservation of the gas and solid momentum is given by the following equations:

$$\frac{\partial}{\partial t}(\alpha_g \rho_g \overrightarrow{v_g}) + \nabla.(\alpha_g \rho_g \overrightarrow{v_g}\,\overrightarrow{v_g}) = -\alpha_g \nabla p + \nabla.\overline{\overline{\tau_g}} + \alpha_g \rho_g \vec{g} + \alpha_g \rho_g (\vec{F}_{q,g} + \vec{F}_{lift,g} + \vec{F}_{vm,g}) + (K_{gs}(\overrightarrow{v_g} - \overrightarrow{v_s}))$$

$$\frac{\partial}{\partial t}(\alpha_s \rho_s \overrightarrow{v_s}) + \nabla.(\alpha_s \rho_s \overrightarrow{v_s}\,\overrightarrow{v_s}) = -\alpha_s \nabla p - \nabla p_s + \nabla.\overline{\overline{\tau_s}} + \alpha_s \rho_s \vec{g} + \alpha_s \rho_s (\vec{F}_q + \vec{F}_{lift,s} + \vec{F}_{vm,s}) + (K_{gs}(\overrightarrow{v_g} - \overrightarrow{v_s}))$$

Where $\vec{F}_q$, $\vec{F}_{lift,s}$, and $\vec{F}_{vm}$ are external body force, a lift force and a virtual mass force, respectively and K_{sg} is the momentum exchange coefficient

CAD MODEL AND MESHING

The reliability of each simulation results is based on the generated mesh performance. Using Design Modeler 19.1 we developed the granulator geometry and we meshed it under ANSYS Mesher. A coarser, medium and refined meshes had been generated, respectively (Fig.1).

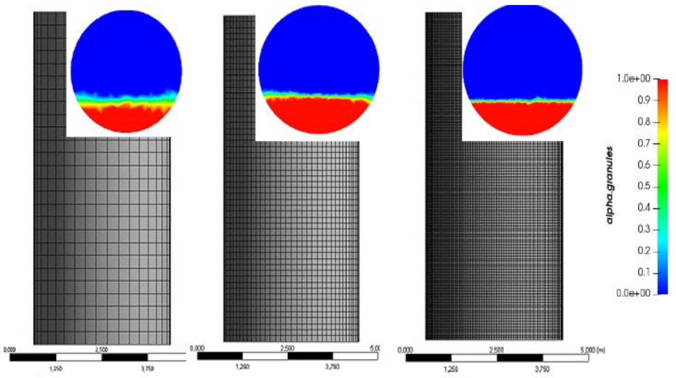

Fig. 1: Meshes for mesh convergence study

The model is discretised using finite volume method, and The First-Order-Upwind-method was used for interpolating the cell centre values to the cell boundaries

RESULTS AND DISCUSSION

The rotary granulator was set to different rotational speeds (8, 16, 24 and 32 rpm) in order to analyze the different regimes of solid motion. The results in Fig. 2 show the transition between the known typical transverse bed motions (rolling, cascading, and cataracting) during rotation. When the speed increase the arch of the kidney-shaped bed increase.

The simulation results are compared with published experiment and simulated data (Santos et al 2013) for model validation.

The hydrodynamic of the solid phase present a transition inside the vessel at different levels, depending on the inclination angle degree. This shows the importance of the rotational speed in optimizing the granulation process. Each efficiency in monitoring the granulator key parameters will control the hydrodynamic flow that govern the chemical reaction progress.

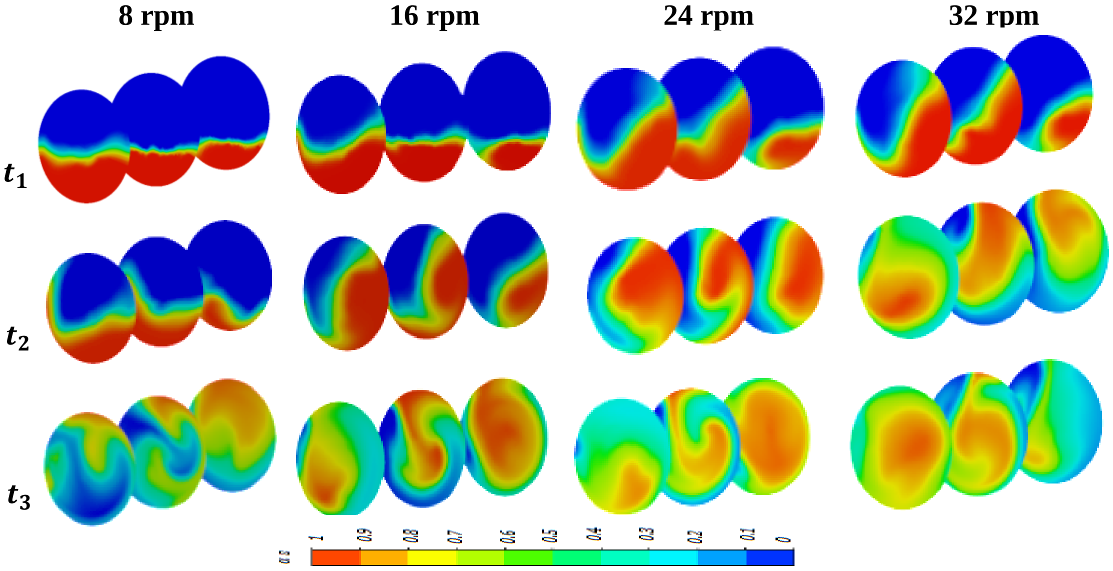

Fig. 2: The distribution of fertilizer particles in different rotational speeds, and instants

FUTURE WORK & PERSPECTIVES

Our research work is open to different directions. Many studies will be carried to evaluate the effect of the key operating parameters on the hydrodynamic flow within the rotary drum granulator and the evolution of fertilizer particles distribution as a function of time, for different granulator rotation speeds. Also the geometry characteristics impact (inclination angle) will be investigated. The chemical reaction will be added to correlate the physical to chemical aspects of the process. Hence, the CFD simulation can be the efficient tool for an intensified granulation process, respecting the physicochemical properties of the product.

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INNOVATION AND DISRUPTIVE TECHNOLOGIES FOR A SUSTAINABLE PHOSPHATE INDUSTRY