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Modelling the Bubbling Bed State for Alumina Powders under Reduced Operating Pressure

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Extended Abstract

Fluidization under vacuum pressure has been a topic of growing research interest. Several industrial applications (such as drying, extractive metallurgy, and chemical vapour deposition) can potentially utilise vacuum pressure fluidization. Nevertheless, hydrodynamics of bubbling vacuum fluidized beds has not been numerically investigated in the literature. In our previous work, a correlation was developed to introduce the effects of slip flow into the well-known Ergun equation. This modified model was shown to improve the accuracy of pressure drop prediction and minimum fluidization velocity (Umf) for various alumina particle sizes and operating pressure. The work here aims to discuss the various implications of modelling the bubbling bed state with this new modified drag model and compare it against the well-known Gidaspow and Syamlal-O'Brien models. The 2D numerical models were set up on Ansys Fluent with the modified Ergun model introduced using Ansys Fluent User Defined Functions (UDF). Alumina particles with a constant diameter of 473 μm particle size were fluidized at 1.5, 2.0, 2.5, and 3.0Umf gas velocities at operating pressure of 1013, 498, 250, 102 and 31 mbar. The numerical model was validated using the minimum fluidization velocity, which showed excellent agreement with experimental data.

The modified Ergun model predicted bubbling at all four excess gas velocities. The average bubble size increased with the rise in gas velocity. However, the Gidaspow and Syamlal-O'Brien models did not predict any bubbling at and below $2.5U_{mf}$. Where they did (at $3U_{mf}$), the bubble size was considerably smaller than the modified Ergun model. The difference in the bubbling was due to the overestimation of the minimum fluidization velocity by these two drag models, resulting in a lower excess gas velocity. The underestimation of the excess gas, compared to the modified Ergun model, resulted in an underestimation of the bed expansion, bed voidage and solid flow velocity.

In the case of modelling the reduced pressure bubbling bed, a single gas flow velocity of $3U_{mf}$ was examined for a range of reduced pressures. Since the experimental minimum fluidization velocity increases with the reduction of operating pressure, each reduced pressure case modelled will have a different gas flow velocity. When the operating pressure of the bed was reduced, the modified Ergun model showed an increase in the average size of the bubbles as a direct result of the increase in the excess gas velocity and the reduction in gas density.

Interestingly but not unexpectedly, the Gidaspow model showed bubbling at the atmospheric and at the lowest pressure (3,112 pa). Between these two extremes, no bubbling was predicted. This behaviour was due to the turbulent term in the original Ergun equation changing when the density was reduced. The Syamlal-O'Brien model produced the smallest bubbles at atmospheric pressure due to the lowest excess gas predicted. The reduction in operating pressure led to a state where the minimum fluidization velocity was greater than the inlet gas velocity. This behaviour results in the lack of bubbling at low pressure. The flow-on effects of the lack of bubbling were also found to impact the average solid flow velocity of the bed and bed expansion. Overall, this work highlights the importance of the drag model and how its ability to predict the minimum fluidization velocity influences the bubbling bed and its properties.

***Keywords*:** Computational fluid dynamics, fluidized bed, gas-solid flow, vacuum pressure, slip flow, minimum fluidization velocity.