Measuring the velocity of gas and particles in and around a single bubble in a 3D fluidised bed

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Introduction: The flow of gas and particles in gas-solid fluidised beds determines the performance of the process, but is not yet well understood. In this paper, we investigate some of the classical models of fluidised beds using MRI measurements of the velocity of both the gas and solid phases.

Methods: Measurements were performed using a novel 11-interval phase encoded velocity imaging sequence [1]. In order to obtain sufficient signal from the gas phase, sulphur hexafluoride gas was used at a pressure of 7.5 barg; poppy seeds were used for the particulate phase. Even with this gas at pressure, MRI measurements of the velocity are still slow. Therefore, a system was developed to inject single, isolated bubbles reproducibly into an incipiently fluidised bed, analogous to a method previously used to study flow inside droplets [2]. Images of the flow of gas and solid are then obtained by averaging measurements from ~16 000 bubbles.

Results and discussion: Figure 1 shows an example of the velocity maps obtained for the gas phase (a) and the particle phase (b). The images clearly show a recirculation pattern in the gas phase that is consistent with the potential flow solution of Davidson and Harrison [3], for these group D particles. From the gas velocity field it is also possible to estimate the through-flow of gas through the bubble and show that this is consistent with the estimate of three times the minimum fluidisation velocity, U_{mf}., as expected. The velocity of the gas in the particulate phase is found to be less than expected in the classical theory owing to the net downward velocity of the particles relative to the rise velocity of the bubble. If the particle velocity is used to correct the expected gas velocity, it is in good agreement with the estimated interstitial velocity U_{mf}/ε_{mf}, where ε_{mf} is the voidage at minimum fluidisation.

Conclusions: This work presents the first measurements of the gas and particle velocity inside single bubbles in a gas-solid fluidised bed. The measurements have been used to investigate fundamental theories of gas-solid fluidisation. In the future, these measurements will be used to help develop new models of the fluid-particle interaction.

References: [1] Boyce, Rice, Sederman, Dennis, Holland, J. Magn. Reson. (2016). [2] Han, Stapf, Blümich, Phys. Rev. Lett. (2001) [3] Davidson, J.F., Harrison, D. Fluidised particles. (1963).

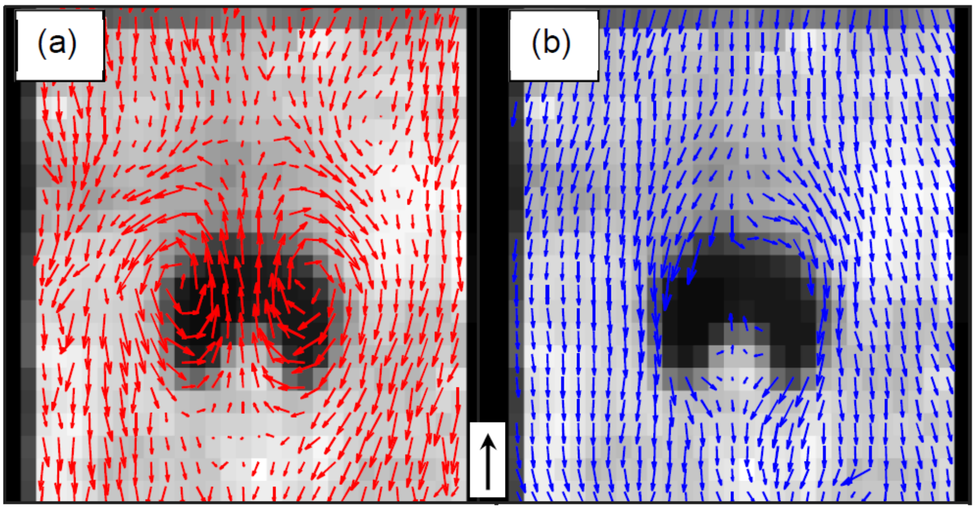

Fig. 1: Combined velocity vector fields shown for (a) the gas phase (in red vectors) and (b) the particle phase (in blue vectors) shown on an intensity image for the particle phase to illustrate the location of the bubble. The velocity fields are shown relative to the bubble reference frame. The scale of the vector field is shown in the arrow, which for the gas represents a velocity of 0.2 m s^{-1} and for the particles a velocity of 0.1 m s^{-1}. The field-of-view is 60 mm × 60 mm with a slice thickness of 2 mm.