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3D Magnetic Resonance Velocimetry Measurements of Turbulent Gas-Liquid Flow

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Extended Abstract

Multiphase computational fluid dynamics (CFD) analysis is commonly employed in various industrial applications, such as power plants and chemical engineering. It is imperative to thoroughly validate the applied turbulence models to ensure the accuracy and reliability of the CFD simulations [1]. Obtaining experimental data in such flows is challenging with optical methods, which necessitates the development of non-optical experimental techniques [2]. This study presents the application of Magnetic Resonance Velocimetry (MRV) for a turbulent gas-liquid multiphase flow.

In this study, the MRV technique is applied to provide experimental benchmark data for a backward-facing step (BFS), in which a turbulent horizontal water flow interacts with a vertical gas jet in the wake of the step. The BFS case is selected due to its combination of inhomogeneous and anisotropic turbulence with strong phase interactions, which poses a challenge for turbulence models. The experiment provides accurate 3D data, including the mean velocity vector, mean void fraction and Reynolds stress tensor. All applied MRV methods have been rigorously validated against conventional measurement techniques [3-6].

The benchmark experiment has been designed to provide high quality measurement data with well controlled boundary conditions. Only MR-compatible materials were used for the channel construction, with dimensions optimized to match the capabilities of the magnetic resonance imaging system. All measurements were executed using a large bore 3 Tesla clinical whole-body scanner at the DFG-core facility MRI flow lab in Rostock.

The step height is h=30mm and the channel height upstream of the step is 1/2h. The channel has a constant width of 5h and a flow development length of 23.5h. Upstream of the channel section is a settling chamber, a smooth nozzle and a trip ring. The bulk velocity upstream of the step is 1 m/s, resulting in an inlet Reynolds number of 14,920 based on the channel height. Downstream of the step, at a distance of 3h, an air jet enters the channel through a 1mm hole with a mass flow rate of 0.036 g/s. This position was chosen to be in the middle of the reattachment zone to promote turbulent mixing between the two phases. The water pressure and temperature inside the channel at the point of air injection is 23.8 °T and 144000 Pa, resulting in a crossflow-to-jet volumetric flow rate ratio of 100.

MRV measurements of the 3D mean velocity, 3D mean void fraction, and 3D Reynold Stress tensor were conducted at an isotropic resolution of 1.5mm. For comparison, a single-phase water flow with the same Reynolds number was measured in the same setup. Shadowgraphy measurements were performed to provide additional information on the bubble size distribution. This study demonstrates the ability of MRV to accurately measure 3D fluid mechanics parameters in complex turbulent multiphase flows and provide comprehensive validation data for the development of CFD models in this context.

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