ME – PhD Thesis Defense

Interaction of bubble(s) and buoyant rigid particles with vortical structures: Towards understanding turbulence modulation in bubbly-turbulent flows

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Offline mode: Conference Room, ME @ IISc

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ABSTRACT

Bubbly turbulent flows occur in many places, such as in chemical reactors and geophysical applications, besides interest from the drag reduction perspective using injected bubbles in a (water) boundary layer. In these flows, an important aspect is the interaction of bubbles with vortical structures, where bubble deformability is generally thought to play a crucial role. We experimentally investigate an idealization of these flows, namely, the interaction of a vortex ring in water with air bubble(s) and rigid equivalents of the air bubble, namely, buoyant rigid particles. In these idealized cases, the bubble / rigid buoyant particles are captured by the vortex ring, due to the low pressure within its core, leading to significant coupled interaction between the bubble/buoyant particle and the vortex ring.

The thesis comprises four main parts. In the first part, the interaction between a single vortex ring with a single deforming bubble is studied, with the focus being on the relative size of the bubble to the vortex ring quantified through a bubble to ring core diameter ratio or a volume ratio of the bubble to the vortex core. We are interested in the coupled dynamics of the bubble and the vortex ring, and hence measure the time evolution of both the bubble dynamics and the vorticity using high-speed shadowgraphy and time-resolved PIV, respectively. The results show the importance of the bubble to vortex core size ratio in determining the evolution of both the bubble and vorticity dynamics, which can be of importance in understanding flow modulation in bubbly-turbulent flow. An important aspect in these interactions is the deformability of the bubble. To better understand this aspect, we have studied in the second part of the thesis, the interaction between a rigid buoyant particle and a vortex ring. The results show large differences in some aspects of the interaction with the ring, while they remain qualitatively similar in others, and these differences and similarities are highlighted. In the third part of the thesis, we go one step closer to bubbly-turbulent flows, by investigating the interaction of a vortex ring with a number of bubbles or a bubble swarm, with the capture of the bubbles by the ring being a continuous process here. This is followed by a study of an application of bubbly-turbulent flow, namely, drag reduction (DR) in a water boundary layer by injection of air bubbles into a fully developed turbulent channel flow. As most of the practical applications related to DR takes place in seawater, we have investigated the effect of salt concentration on the bubble dynamics and hence DR. In these cases, the salt plays a crucial role as it prevents bubble coalescence and hence significantly alters the bubble sizes and therefore the drag. Overall, the above studies help better understand bubble interaction with vortical structures in bubbly turbulent flows.

ABOUT THE SPEAKER

Subhajit Biswas is a PhD candidate in the Department of Mechanical Engineering at Indian Institute of Science, Bengaluru, working under Prof. Raghuraman N. Govardhan. He graduated with a bachelor's degree in Mechanical Engineering from Jalpaiguri Govt. Engineering college, West Bengal and obtained his master's degree in Mechanical Engineering from Indian Institute of Science, Bengaluru, in 2015. His research broadly focuses on multiphase turbulent flows.