ME – PhD Thesis Colloquium

Interaction of a Vortex Ring with a Single Bubble/Rigid Buoyant Particle: Effect of Particle Shape and Vortex Curvature

Manoj N. Dixit, Department of Mechanical Engineering, IISc Bengaluru

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ABSTRACT

Multiphase turbulent flows are found in many natural and industrial flow settings like plankton and air bubbles in the upper ocean, formation of ice clouds, sediment-laden river flows, vapour bubbles in geysers, and industrial applications like ship hydrodynamics, paper industry, oil transportation, pollutants in the atmosphere, catalytic particles and bubble columns in process technology, to name a few. These flows involve complex and coupled interactions between particles/bubbles and the hairpin vortical structures present in the turbulent boundary layers. However, due to the high number density, multi-scale nature, and unsteadiness of the hairpin vortices, understanding vortex-particle/bubble interactions is challenging, and the dispersed phase makes them more formidable. While bubble deformability further adds to the complexity involved, particle anisotropy makes the problem more interesting. In this thesis, we experimentally study an idealisation of multiphase turbulent flow through the interaction of a vortex ring with a rigid buoyant particle/bubble, focusing on the effect of particle shape and the ring's initial aspect ratio on such interactions.

The thesis broadly comprises three main parts. In the first part, we study the interaction of a circular vortex ring with a rigid buoyant particle, focusing on the effect of particle shape on the dynamics of both the ring and the particle. The particle shape is quantified by the particle shape factor (χ), which provides us with a range of particle shapes, namely, disk, oblate spheroid, sphere, prolate spheroid and rod. An important aspect in multiphase turbulent flow is the vortex curvature, which influences the dynamics of the hairpin vortices. To better understand this, in the second part, we study the interaction of an elliptic vortex ring with a rigid buoyant spherical particle, focusing on the effect of the ring's initial aspect ratio (AR_0) on the ring and particle dynamics. In the third part, we are interested in exploring the effect of vortex curvature on the interaction between a vortex ring and a bubble by considering an elliptic vortex ring, with the vortex curvature varying along the elliptical vortex core axis. In this case, the finite surface tension at the two-phase interface introduces interesting physics. In addition to the ring's initial aspect ratio, the bubble capture angle (θ_c) is important in such interactions.

We use high-speed visualisations and Particle Image Velocimetry to measure the vortex ring trajectories, velocity and vorticity fields, and particle/bubble quantities such as angular velocity, azimuthal drift, and number of broken bubbles.

ABOUT THE SPEAKER

Manoj N. Dixit is a PhD scholar at the Flow Physics Lab, Department of Mechanical Engineering, Indian Institute of Science, Bengaluru, working with Prof. Raghuraman N. Govardhan. He completed his BTech in Mechanical Engineering in 2018 at PES University, Bengaluru, and thereafter joined IISc as a Direct PhD. His research is in the broad area of multiphase turbulent flow, focusing on the interaction of bubbles and particles with vortex rings.