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Generation and maturation of a vortex ring in non-Newtonian fluids

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Abstract :

Vortex rings are coherent structures that dominate the dynamics of many flows. They are present in a wide range of situations : in industrial mixing systems (in the vicinity of the agitation moving blades), but also in nature during the ejection of volcanic gas or in the wakes behind insects, birds and fishes, where a periodic release of vortex rings is observed.

In this work we study the formation and maturation of a vortex ring in non-Newtonian fluids, with a special focus on shear-thinning fluids and yield stress fluids. The experimental system consists of a cylindrical tube-piston device whose lower part is immersed in a tank containing the fluid. Particle Image Velocimetry (PIV) is used to analyze the flow. A preliminary study is realized with Newtonian fluids to validate the device the device. It allows exploration of low Reynolds numbers configurations, showing the existence of a vortex ring for Reynolds numbers as low as 10. This work is then extended to non-Newtonian fluids, using shear-thinning Xanthane solutions (behavior index between 0.6 and 1) and two yield stress fluids (Carbopol) with yield stress between 1 and 3 Pa. The results are analyzed in terms of vorticity fields and of characteristics of the ring (velocity and geometry). T, the time evolution of these variables as a function of the characteristics of the fluid is reported. Then we focus on the rolling up and detachment mechanisms for the larger Reynolds numbers while, at low Reynolds numbers, the investigation is focused on the more complicated dynamical mechanisms involved, taking into account the influence of the nature of the fluid on this dynamics.