Variable Density Vortex Rings

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We numerically simulate the evolution of a variable density vortex ring resulting from the impulsive injection of a fluid into a quiescent surrounding of different temperature. We carefully investigate the influence of the jet-to-ambient temperature ratio $\alpha = T_j/T_a$ on the post-formation phase of the vortex ring. Two numerical codes using cylindrical [1] and, respectively, spherical coordinates [2] are considered to solve the Navier-Stokes equations for low-Mach flows. Figure 1 shows different vorticity evolutions for hot and cold jet injections. The baroclinic production term is responsible for the generation of a negative vorticity layer in the front of the vortex ring for the hot jet injection. The opposite effect is observed for cold jet injection. The ratio α is also found to considerably affect the integral characteristics of the vortex ring (circulation, impulse). We derive a simple model to describe these evolutions.

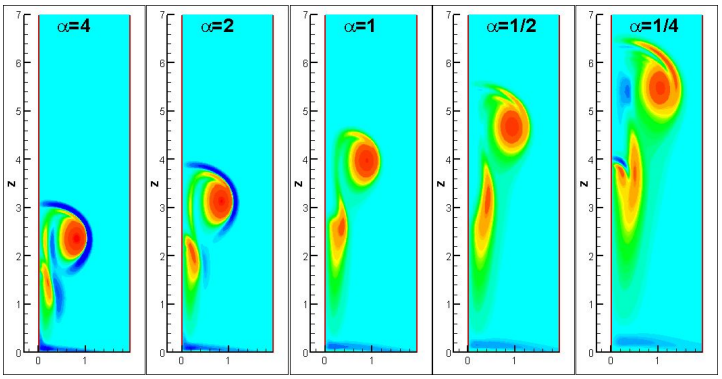

Fig. 1. Vorticity fields at $t = 10$ for different jet-to-ambient temperature ratios $\alpha = T_j/T_a$. The injection stops at $t = 6$.

References

1. S. Benteboula, PhD Thesis, Université Marne-la-Vallée (2006).
2. B. J. Boersma, In Ann. Research Briefs, Center for Turbulence Research (1999).