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Portfolio Paper

Flow Images of a Low Reynolds Number Annular Swirling Jet

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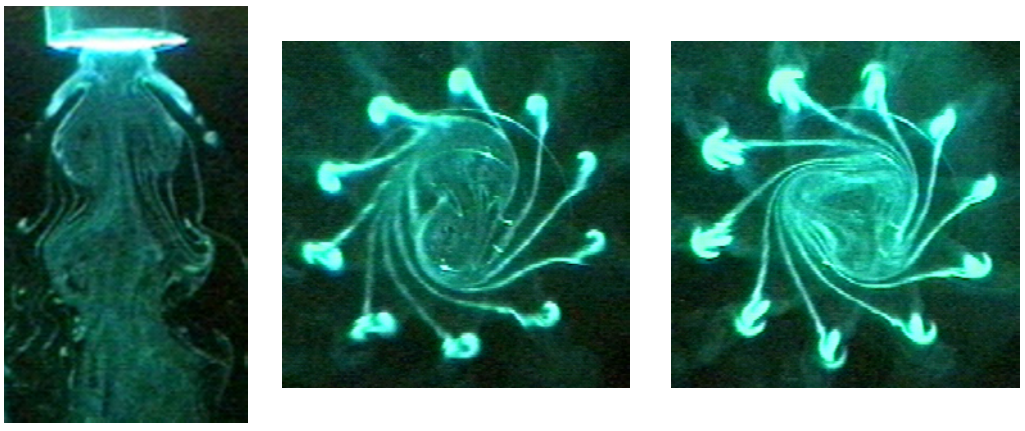

(a) longitudinal plane (b) horizontal plane, S type (c) horizontal plane, Delta type

Fig. 1. Visualization images of the annular swirling jet at Re = 350 and S = 1.41.

In this portfolio, the flow field behind an asymmetric, cylindrical center-body of an annular swirling jet flow is investigated. The key parameters in this experiment include the Reynolds number, Re ($=UD_h/\nu$), and the swirl number, S ($=G_\theta/RG_x$), where U is the volumetric mean axial velocity, D_h is the hydrodynamic diameter, R is the outer diameter of the annulus, G_θ is the axial flux of the tangential momentum, and G_x is the axial flux of the axial moment[1,2]. A flow visualization technique using seeding particles and laser light sheet was applied to allow comprehensive imaging of the swirling flow structures. Two flow patterns, S and Delta type, in the cross-section of the asymmetric cone behind the center-body were observed at Re = 350 and S = 1.41.

Figure 1(a) shows flow pattern in the longitudinal planes through the exit of the annular swirling jet. The pressure downstream of the exit was lower than that of the centre-body; which caused a rapid expansion of flow. It is evident from the results obtained that a vortex has been shed from the annular vortex in a form similar to a succession of vortex loops that were symmetric about the central axis. Flow visualization was made available on a horizontal cross-section to study the flow structure in the asymmetric cone behind the centre-body as shown in Figs. 1(b) and (c). These flow patterns are similar to the experimental results reported by Billant et al.[3]; the S type shows the spiral mode and the Delta type displays the bubble mode. These images were taken at a distance downstream of the jet exit at $x/D = 2.14$, where D is the outer diameter of the annular flow region. These flow patterns, S and Delta type, are formed by interactions of two and three vortices on the horizontal plane with a rotating period of are 1.2 s and 0.83 s, respectively. For a given Reynolds number, the rotation frequency is different for each flow pattern. It is interesting to note that the frequency of the spiral mode is a reciprocal of that of the bubble mode. Moreover, the flow patterns of these two types are interchangeable between themselves on the same horizontal plane, but the change over time is random and unpredictable.

References : (1) Sheen, H.J., Chen, W.J., and Wu, J.S., Journal of Fluid Mechanics, 350 (1997), 177-188. (2) Sheen, H.J., Chen, W.J., Jeng, S.Y. and Huang, T.L., Experimental Thermal and Fluid Science, 12-4 (1996), 441-451. (3) Billant, P., Chomaz, J.M. and Huerre, P., Journal of Fluid Mechanics, 376 (1998), 183-219.