

Portfolio Paper

Visualization of Circular Subsonic Jet Flow by DNS⁽¹⁾

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Received 7 June 2009 and Revised 29 June

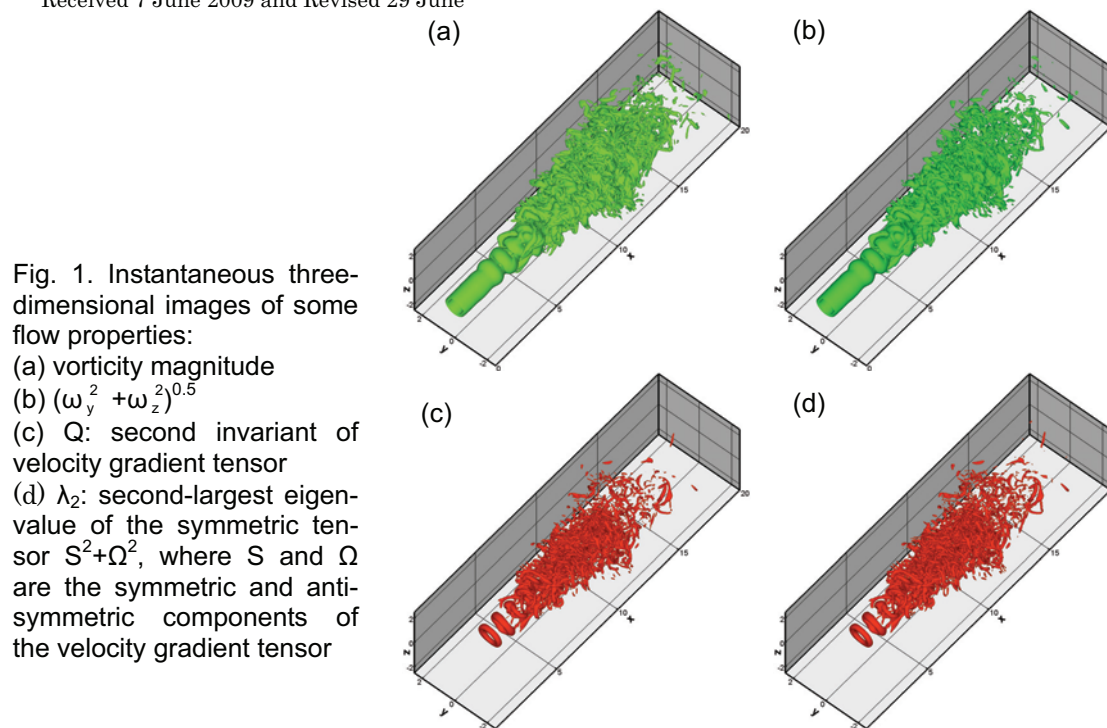


Fig. 1 shows the simulation results of direct numerical simulation of a circular jet, which issuing into large environment from a round nozzle with laminar coflow. The jet velocity is $U_1 = 180\text{m/s}$, coflow velocity is $U_2 = 3.5\text{m/s}$. The Reynolds number is 4700 based on the jet diameter, velocity $U_c = U_1 + U_2$ and air properties at 1atm and 300K. The physical domain size of the simulation is $L_x/d = 20$, $L_y/d = 14$, $L_z/d = 14$, where d is the jet diameter. These reference quantities are used to normalize all the flow variables: length scale $l_r = d$; velocity $u_r = U_c$; density ρ_r , ambient air density at 1atm and 300K. Fully compressibly three-dimensional Navier-Stokes equations are solved using eighth-order explicit difference scheme and fourth-order explicit Runge-Kutta scheme. Characteristic non-reflecting boundary conditions are used at all boundaries along with buffer zone method at outflow and sidewall boundaries of the jet. Over 20 million grid points are used here. Fig. 1(a) and fig. 1(b) show the three-dimensional instantaneous image of vorticity magnitude and $(\omega_y^2 + \omega_z^2)^{0.5}$ respectively, where ω_y and ω_z are the vorticity in y and z direction. It is clear that the contours are tubular near the jet exit and become more and more wrinkled after 2d downstream of the jet nozzle. And finally break up to many small vortex tubes further downstream. Fig. 1(c) shows the profile of velocity gradient tensor invariant Q, defined as $Q = -\frac{1}{2} \frac{\partial u_i}{\partial x_j} \frac{\partial u_j}{\partial x_i}$. Fig. 1(d) shows the λ_2 -criterion to

illustrate the vortex structure. The rolling up of coherent vortex rings due to Kelvin-Helmholtz instability and its breaking up to small vortexes is clear. It is also found that the image of Q and λ_2 are almost the same. This demonstrated that the flow structure in circular jet flow can be extracted using either Q or λ_2 , with no significance difference. Furthermore, it is simpler to calculate Q than λ_2 , then we can make a conclusion that Q will be enough to capture the vortex structure in circular jet flow.

⁽¹⁾ Supported by National Natural Science Foundation (50736006, 50806066) and National Science Foundation for Distinguished Young Scholars (50525620)