A Comparison Between Pulsed and Continuous Round Jets

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Pulsed jets can potentially be integrated into a diverse range of applications within aerospace, from stall suppression devices within aerodynamic active flow control systems to mixing aids in propulsion engines. Pulsed jets differ from continuous jets in that they have an integral periodic oscillatory component, characterized by the velocity amplitude of the imposed forcing. A continuous jet is a constant Reynolds number flow where the width of the jet increases in the axial flow direction. Previous studies conducted revealed higher levels of entrainment in pulsed jets compared to the equivalent continuous jet. These increasing levels of entrainment after an oscillation is imparted on to the flow carry with them the ability to mechanically enhance mixing within certain fluid streams. This property makes them particularly useful in vectored thrust applications like VTOL/STOL thrusters for which the length of the mixing zone needs to be minimized.

This paper presents some quantitative results describing the flow physics of both continuous and pulsed round jets in a quiescent flow. The focus of this study is to investigate, for both cases, the effect of varying the mean Reynolds Number and whilst keeping the frequency of oscillation (Strouhal number) constant. The results presented are acquired using both high spatial resolution 2C-2D multigrid cross-correlation digital particle image velocimetry (MCCDPIV) measurement in the near jet region up to $x/D_0 < 9$.

This paper will also address a number of pertinent aspects related to the turbulent nature of the jets at a Reynolds number based on diameter (D_0) and average velocity (U_0) at the orifice of 2000 and 4000. Issues of the optical arrangement for 2C-2D MCCDPIV and the spatial resolution from the perspective of turbulence statistics will also be discussed.

The experimental measurements of the continuous jets were carried out in an acrylic tank 1000 mm long, 500 mm wide and 500 mm deep, filled with filtered water. To remove the air/water interface within the facility, the tank has a riser tube with an inner diameter of 56.5 mm located on the perspex roof at the far end of the tank from the piston normal to the jet axis, and the facility was filled with water to the perspex roof. The riser tube alleviates the net mass injected during the continuous jet experiments. During the experiments the tank is filled to the ceiling with filtered water.

In each experiment continuous jets were formed by discharging water from a circular cylinder of inner diameter $D_p = 50$ mm through an orifice plate of diameter $D_0 = 10$ mm and thickness of 2 mm, positioned in the center of the end wall of the tank. The discharge is generated by long, constant-velocity or pulsing-velocity stroke of a piston driven by a computer-controlled stepper motor. The piston is located in a perspex cylinder, 700 mm long with a 50 mm diameter bore. At the end of each experiment the finishing position of the piston was $10D_0$ from the orifice, inside the cylinder cavity. The orifice plate obscured the optical path at the generator so that the flow behind the orifice could not be measured or easily visualized in this facility.

Prior to the PIV experiments, the flow was uniformly seeded with neutrally buoyant 11 μm diameter hollow glass spheres (Potters spherical, with a density of 1100 kg/m^3). These seed particles have been chosen because they faithfully reproduce the local water velocity having an estimated particle relaxation time of 7.4 μs.

The illumination source for the recording of PIV images is a New Wave Nd:YAG twin cavity laser system capable of producing 2 x 200 mJ pulses of 6 ns duration at a maximum frequency of 10 Hz. An articulated arm was employed to deliver the laser beam from the laser to the jet apparatus. A cylindrical lens was used at the exit of the articulated arm to expand the laser beam into a sheet of approximately 1 mm thickness. The laser sheet was aligned vertical including the jet axis.

The scattered light from the seed particles was recorded on a PCO pco.4000 14 bit digital CCD camera, which has an array size 4008 px x 2672 px. This digital camera can be operated in double shutter mode for single-exposed PIV image recording. A 105 mm Micro-Nikkor lens set at an aperture of f2.8 and a reproduction ratio of 2.4 was used for all experiments. With these settings the estimated aberration-free depth of field (Dof) for these experiments was 0.23 mm or 10.1 px and the diffraction limited particle image size was 6.91 μm (i.e. 0.8 px). The single exposed image pairs were analysed using the MCCDPIV algorithm described in Soria[1, 2].

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