CHARACTERISTICS OF CONCENTRATION FIELD IN THE INITIAL REGION OF A JET IN COFLOW

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Mean and fluctuating characteristics of the scalar concentration field within the initial region of a submerged round jet in stagnant ambient and in a coflow are investigated quantitatively with the non-intrusive flow measurement and visualization technique of laser-induced fluorescence (LIF).

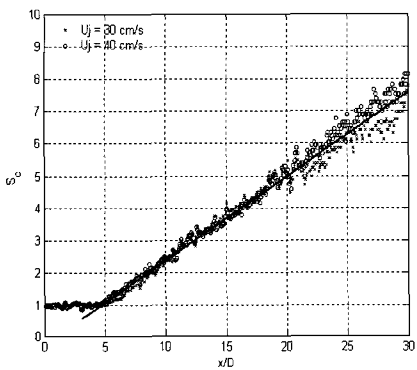
For the mean concentration field, the emphasis is to obtain confident data of the length of the zone of flow establishment (ZFE) of the jet in stagnant ambient and in different ambient flow situations. The development of the concentration half width of the jet is another issue to be addressed. Dynamic characteristics of the concentration field are analyzed on a time sequence of LIF images using the proper orthogonal decomposition (POD) technique.

Experiments were carried out in a 5 m long and 1.2 m wide section built inside a shallow water basin. For the coflow situation, a uniform ambient flow at velocity U_0 was produced inside the section. A submerged round jet was formed by discharging water from a circular nozzle fed from a constant overhead tank. The water depth was about 0.45 m and the jet nozzle was placed in 0.2 m above the flume bottom. The nozzle used has an exit diameter D = 4.8 mm. The jet exit velocity was adjusted with a valve and a calibrated rotameter. Experiments on a simple jet in stagnant ambient ($U_0 = 0$) were performed with two values of jet exit velocity U_j at 30 and 40 cm/s, corresponding to Reynolds number 1310, 1750, respectively. Experiments on jet in coflow were made with $U_j = 30$ and 40 cm/s and $U_0 = 2, 3.5, 4, 6, 9$ cm/s. The ambient-to-jet velocity ratio had values $R = U_0/U_j = 0.05, 0.0875, 0.1, 0.2$ and 0.3.

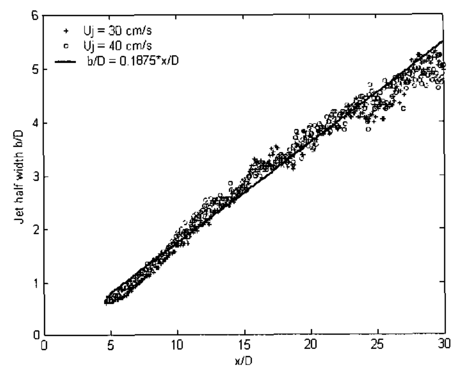
To make LIF measurement, Rhodamine 6G, a fluorescent dye, at a constant concentration was added to the jet discharging fluid. A laser light beam, produced from a 4W argon-ion laser crossed through the horizontal central longitudinal section of the jet. A high-speed CCD camera, PCO-1200hs, was mounted at the top of the water flume to record the LIF images at a rate of 50 image/s for a length of 10 s, that is a sample size of 500 images. The flow images covered a physical size of 37 cm × 24 cm on the measurement plane which corresponded to 77D × 50D. In pixels, the image size was 1028 pixel × 672 pixel, thus the spatial resolution was 0.36 mm per pixel or about 0.075D per pixel.

For the mean LIF image of the simple jet, it is found that the centerline dilution $Sc = C0/Cc$ ($C0$ being the concentration at jet exit and Cc the mean concentration at centerline) remains unity within $x/D < 4.7$. Thereafter, Sc increases linearly with downstream distance x/D. This suggests that the length of the potential core (ZFE) is approximately $lx = 4.7D$. This value is close to the value of $5D$ in previous literature. The concentration half-width is also found from an analysis of the mean concentration profiles $C(r)$ along the radial direction. It is defined as the radial location r at which the concentration drops to $C(r) = e$-

1*Cc*. The results on the two simple jets show a good linearly relationship between *b* and *x* with a slope 0.1875. downstream of the ZFE. Characteristics of the concentration fluctuations are also analyzed from the ensemble of instantaneous LIF images. The results show that the highest standard deviation of concentration fluctuations are found near the end of the ZFE and that the radial profiles of the standard deviation had a widely-separated double-peak distribution inside the ZFE and a less pronounced double-peak distribution farther downstream.



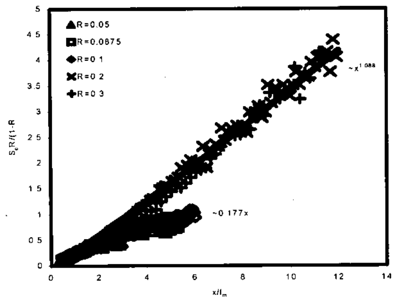
Centerline dilution of simple jet



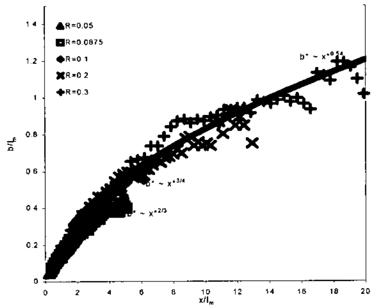
Concentration half width.

For the jets in coflow, it is found that the length of the ZFE is shortened and that the velocity ratio affects the mean characteristics of the concentration field. For different values of *R* being studied, the centerline concentrations begin to decay at axial locations between *x/D* = 3 and 4 with an average value of $lx \approx 3.4D$. The shorter length *lx* for a jet in coflow has been suggested in the literature and argued as the effect of stronger entrainment in the case of a non-zero ambient flow. For the centerline dilution *Sc,* it is found that a better description of its development with downstream distance can be obtained using the excess momentum length scale which is defined as $l_m = M_e^{1/2} / U_0$, where *Me* is the initial excess momentum flux at exit. The development of centerline dilution is better presented in the form of *Sc R/*(1 – *R*) against *x/lm*. At *R* = 0.05, 0.085 and 0.1, the dilution *Sc R/*(1 – *R)* varies with *x/lm* in a roughly linearly manner with a slope of 0.177. At larger velocity ratios, *R* = 0.2, 0.3, the best fitted curve is *Sc R/*(1– *R*) = 0.28 (*x/lm*)1.088. Complex relationships are also found for the increase of the concentration half width with downstream distance.

POD analysis of the time-varying concentration field suggests that a relatively large numbers of eigenfunctions or modes are require to represent the dynamic characteristics. The first 18 modes contain about 50% of the total energy while the first 65 modes account for 80% of the total energy. A reasonably accurate reconstruction of the instantaneous concentration field is made using the first 65 modes.



Centerline dilution of jet in coflow



Concentration half-width of jet in coflow.

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