MEAN FLOW CHARACTERISTICS OF THREE DIMENSIONAL WALL JETS IN A CROSS-FLOW

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The flow in the vicinity of tidal inlet, effluents discharging from the banks of rivers and a tributary joining the main course of flow can be modeled as turbulent jets in cross-flow. Further, if the lateral flow discharges horizontally very near the bed of the main channel, a wall jet type of flow results. For a deeply submerged outlet, the free surface effects can be ignored. The efflux velocity of the jet being generally large, local scour in the vicinity of the lateral flow could take place. Prediction of the flow and temperature field of heated jets is often necessary to mitigate the adverse impacts on the receiving water body.

Information on the mean flow characteristics of wall jets in a cross-stream is scanty. In the past Ozsoy(1977) studied the behavior of a tidal inlet in the presence of long-shore currents based on certain assumptions, which are difficult to find in practice. Hence in the present investigation experiments were conducted to find the mean flow characteristics of such a shear flow.

Three shapes of nozzles, viz., square, rectangular and circular, having the same cross-sectional area of 108 mm^2 were used to generate the wall jet. The ratio of the jet efflux velocity and that of the free stream was in the range of 1.5 to 3.15. The jet Reynolds number was close to $5x10^4$. As the free surface effect was negligible, all the experiments were conducted in a suction-type open loop wind tunnel. Three different excess-temperatures, ΔT_0, of 8, 11, 15^0C at the efflux section of the nozzle were adopted. Various combinations of aspect ratio of the nozzle and ΔT_0 were experimented to determine the jet trajectory, velocity and the mean temperature field of the shear flow.

An empirical expression to describe the trajectory of the jet, which accounts for the velocity ratio and the aspect ratio of the outlet, has been proposed. Mean velocities were measured at different cross-sections normal to the trajectory and isovels were drawn by interpolation. The isovels were used to find the mass flux at specified locations of the trajectory. The coefficient of entrainment α_e was evaluated based on the rate of change in the mass flux along the jet trajectory. This coefficient included entrainment both from a mechanism similar to that of the free jet as well as the flow entrainment due to the component of the free stream normal to the trajectory. The latter component was found to be higher in the zone of maximum deflection of the jet.

The thickness of the wall jet normal to the bottom boundary as well as in the transverse planes are linear functions of the distance measured along the trajectory of the jet. The velocity-excess on the jet axis decays rapidly in the region of maximum deflection. A single relationship was developed, for the range of test conditions, by incorporating square root of the velocity ratio, R, in normalizing the axial distance from the nozzle.

The local skin friction coefficient, c_f, attains higher values in the proximity of the outlet section and then drops to take up a constant value of 0.0046 in the far field. This is quite different from the behavior of the three dimensional wall jet in a stagnant ambient, Rajaratnam and Pani (1974).

As a consequence of using two different length scales, because of asymmetry, the temperature excess measured parallel to the bottom boundary exhibited similarity and followed the Gaussian distribution. Further, the normalized centerline temperature-excess decays in proportion to $(\frac{S}{\sqrt{A}})^{-0.634}$ regardless of the velocity ratio values covered in the present experiments.

KEYWORDS: Shear flows; Wall jets; Flow entrainment; Wall shear; Jet trajectory

REFERENCES

Ozsoy,E., 1977. Flow and mass transport in the vicinity of tidal inlets. Tech.Report No.0636, Coastal and Oceanographic Engg. Lab., Univ. of Florida, Gainsville, Florida.

Rajaratnam, N. and Pani, B.S., 1974. Three dimensional turbulent wall jets, Jr. of Hyd. Division, ASCE, Vol. 100, HY 1