NUMERICAL SIMULATION ON VERTICAL, TURBULENT, PLANAR BUOYANT JETS WITH RIGID HORIZONTAL BOTTOM BOUNDARY

WENXIN HUAI[1] and ZHONGHUA YANG[2]

[1]Professor, State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan Hubei 430072, China
(Tel: +86-27-68772206, Fax: +86-27-68772310, e-mail: wxhuai@whu.edu.cn)
[2]Researcher, State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan Hubei 430072, China
(Tel: +86-27-68772211, Fax: +86-27-68772310, e-mail: y_z_hua@sohu.com.cn)

In the present study, attention is directed at an aspect of the behavior of turbulent buoyant jets -namely, their impingement with a solid boundary- that has received relatively little attention. Thought the problem has some general relevance to the phenomenon of microburst and downdraughts in the Earth's atmosphere, the principal motivation for the study is the need for modeling information on the seafloor impact and bottom spreading of so-called produced water discharges from marine petroleum exploration platforms. Produced water contains a wide variety of dissolved inorganic salts and organic compounds, contributing in some circumstances to a fluid density excess up to ten times that of the receiving seawater into which it is discharged. In the present study, the produced water discharge has been modeled by a plane, buoyant, turbulent jet discharging vertically downwards into static, homogeneous, receiving water. Previous experimental and theoretical investigations have studied free, turbulent, planar, buoyant jets (see, for example, Kotsovinos, 1975; Kotsovinos and List, 1977; Yannopoulos and Noutsopoulos, 1990) and these investigations provide key reference data with which the impinging buoyant jet simulation can be compared. Saved for the microburst modeling studies cited above, the impingement of buoyant thermals (rather than steady, continuous buoyant discharges) was investigated. Solid boundary effects have been studied for maintained steady discharges having source momentum and buoyancy by Cavalletti and Davies (2003; henceforth named the CD study).

The purpose of the present investigation has been to simulate the flow and density field. The results are given by k-ε model and hybrid finite analytic method. Wall functions are used to relate the value at the first grid points outside the viscous sub-layers to the boundary conditions. Fig.1 shows a vertical, turbulent, planar buoyant jet with rigid horizontal bottom boundary. The jet exit width is denoted by B, the exit velocity v_0, the exit jet density ρ_0, ambient density ρ_a ($\rho_0 > \rho_a$).

For comparisons between the numerical results and the experimental data, the calculations were made for the same range of the parameters used by the CD Study. The calculated axial velocity distributions are compared with the experimental data of Alessandra and Davies (2003) and data calculated by Yannopoulos (1990) for the reference configurations of a free turbulent buoyant jet and a free turbulent pure jet respectively.

A typical example of velocity distribution in cross section is compared with the experimental data of the CD study. It is found that the velocity distribution far from the boundary (y=0) is taken as Gaussian assumption. This conclusion is same as the CD study, while the value of velocity is smaller than that of the CD's study.

The centerline velocity, density and turbulent kinetic energy were calculated for F=10.9, 12, 13.6, 18.2 and 20. The predicted results show that the whole field of the jets studied in this paper can be divided into three regions, namely issuing region, entrainment region and impingement region. The centerline velocity decreases gradually in the issuing region and impingement region.

It is found that the axial density decays gradually along the axis of buoyant jet. At the impinging region, the density becomes approximately constant.

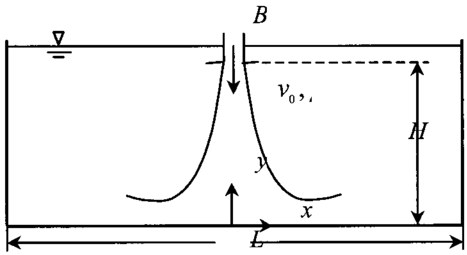

Fig. 1 Sketch of physical system

REFERENCE

Alessandra Cavalletti and Davies Peter A. (2003). Impact of vertical turbulent planar negatively buoyant jet with rigid horizontal bottom boundary. *J. Hydraulic. Eng.*, ASCE 219, 1, pp. 53-62.

Davies, P.A. and Valente Neves, M.J. eds. (1994). Recent research advances in turbulent jets and plumes. Kluwer Academic, Dordrecht, The Netherlands.

Fischer, H.B., List, E.J. Koh, R.C.Y., Imberger, J. and Brooks, N.H. (1979). Maxing in inland and coastal waters. Academic, New York.

Kotsovinos, N.E. (1975). A study of the entrainment and turbulence in a plane buoyant jet. PHD thesis, Rep. No. R-064641, E & P Division, Norsk Hydro, Bergen, Norway.

Kotsovinos, N.E. and List, E.J. (1977). Plane turbulent buoyant jets. I: Integral properties. *J. Fluid Mech.*, 18, pp. 25-44.

Rodi,W.(1979). Turbulence model and their application in hydraulics. IAHR, Delft.

Wei Li and Wenxin Huai, (1995). Calculation of whole field for vertical round buoyant jets in static linearly stratified environment. *J. of Hydraulic Research*, 33, 6, pp. 865-876.

Wei Li and Wenxin Huai (1997). Buoyant jet theory and its application. Science Press(In Chinese).

Yannopoulos, P. and Noutsopoulos, G. (1990). The plane vertical turbulent buoyant jet. *J. Hydraulic. Res.*, 28, 5, pp. 565-580.

Chen,C.J. and Rodi,W. (1978) A review of experimental data of vertical turbulent buoyant jets. *Pergamon Press*.