Experimental Study of Submersible Jet on Flow Hydraulic Parameters

Mohsen Solimani Babarsad and Habib Musavi Jahromi

***Abstract*—**Behavior of turbulent jet is relying on jet parameters, environmental and geometric parameters. In this research, it has attempt to Study effect of jet parameters of internal angle on maximum effective length and velocity on centerline from nozzle experimentally. Toward this end, four internal angles 30, 45, 60 and 90-degree are considered for this study in a flume with 600cm as long, 100cm as high and 150cm in width. Various discharges were used to evaluate effective length for a wide range of densimetric Froude numbers F_0, from 17.9 to 39.4 that is defined at the nozzle. As a result, It is revealed that both velocity on centerline and effective length decreases when nozzle angle decreased from 90° to 30°. The results show that, for all range of Fr_0 the U_m/U_0 ratio for nozzle with α=90° on centerline increases 20% - 27% than nozzle with α=30° that has lowest velocity on centerline than other nozzle.

***Keywords*—**Turbulent jet, velocity, effective length, Froude number.

I. Introduction

JET can be used to dilute pollutants to ambient flow. Thus, when a pollutant is pumped into receiving water, there is usually a legal or administrative requirement that significant dilution be achieved as rapidly as possible [4]. One of the many techniques for achieving rapid dilution is the turbulent jet, which entrains and mixes large volumes of receiving water with the pollutant discharge [3]. By this definition, the simple jet is a turbulent flow pattern generated by a continuous source of momentum. A closely related phenomenon is the plume; however, the plume has no initial momentum and is generally considered a buoyancy drive phenomenon [7].

The fluid mechanics community has investigated turbulent buoyant jets intensively for many. As an example of this research, in the context of waste disposal and contaminant dispersal, arrays of turbulent buoyant jets are generated in the marine environment when wastewater is discharged from the diffuser sections of sea outfalls [1], the achievement of prescribed dilution limits on the concentrations of contaminants contained in the wastewater depends crucially on the behavior of the turbulent buoyant jets within the receiving water column [5], and the impact of heated buoyant jets released into the atmosphere from urban incinerator plants which is a key determining factor for ambient air quality [8]. Study on disruption of the spatial and temporal development of a round, turbulent, buoyant jet by a localized patch of turbulence of horizontally homogeneous turbulence generated at a location remote from the jet source [6]. Investigated effective parameters of the buoyant jets have been evaluated in the stagnant ambient fluid and to precede the goals of the study, the positive mixing length and trajectory characteristics from a buoyant jet and the maximum length of upper and inferior limits of trajectory have been considered [2]. In the present study, by changing in the geometric parameter of jet like the internal angles of nozzle, the turbulence level and effective length of the jet was investigated.

In Fig. 1, an elementary jet is schematically defined. Due to this figure, the distance L_0 is the length of the zone of flow establishment or the core length. Within the distance L_0, the jet centerline velocity U_0 is constant. For distance $x>L_0$, the centerline velocity U_m is more less than U_0 and is reduced oscillatory.

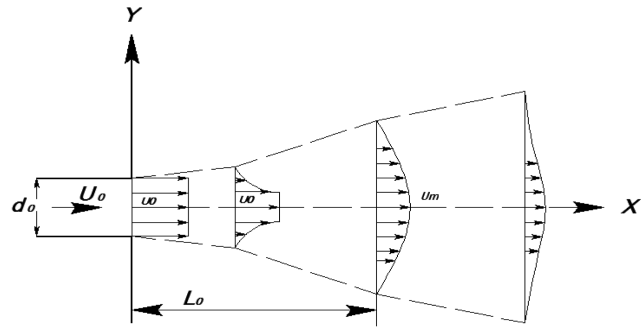

Fig. 1 Schematic for a plane jet

According to the Fig. 1 the densimetric Froude number, Fr_0 and Reynolds number Re are written as:

$$F_r = \frac{U_0}{\sqrt{gd_0}} \quad (1)$$

and,

$$Re = \frac{U_0 d_0}{\nu} \quad (2)$$

where d_0, ν are the jet diameter and viscosity of water respectively, U_m is maximum velocity in longitudinal x direction.

II. Material and Methods

In order to investigate the research purpose, the researchers built a flume with 600cm length, 100cm high and 150cm wide, that sidewalls were made of glass and the bed was made

M. Solimani Babarsad is with Dep. Of Water science, Shoushtar branch, Islamic Azad University, Shoushtar, Iran (phone: +98-916-9099784; e-mail: Mohsen_solimani@yahoo.com).
H. Musavi Jahromi is professor of Dep. Of Water science, Shahid Chamran university, Ahwaz, Iran (e-mail: dr_musavi@yahoo.com).

of iron metal (see Fig. 3). Two centrifugal pumps supply pressure and discharge for jets header from reservoir. Discharges were measured by a Rotameter flow meter that installed on inlet pipe with DN=2" inches and Velocities on centerline are measured by Electromagnetic flow meter (E.M. Flow meter) that is located on a 3D chariot. The nozzle element is made of aluminum (see Fig. 2) that installed on a common header that located on 20cm above the bed, to create a fixed water level on jets; a morning glory spillway was placed at the end of flume. Flow is circulated between outlets of morning glory spillway; reservoir, pump station and flume (see Fig. 4). Values of U_0 were selected to achieve a range of the densimetric Froude number, from 17.9 to 39.4 and Reynolds number Re was in the range of 56000 to 123000.

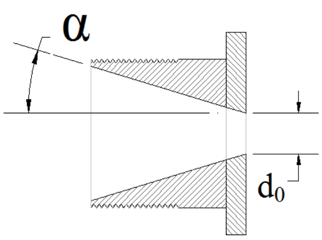

Fig. 2 Longitudinal nozzle's section

Fig. 3 Flume Perspective

III. Results and Discussion

For submersible jets with inner convergence angle can be shown to be function of

$$f_1 = (U_0, H, \nu, U_m, g, X, d_0, \rho, \alpha) \qquad (3)$$

In which ρ, g are the mass density and acceleration of gravity respectively, H is the water level over jet, α is the jet internal angle and other variables have been defined previously. Using Buckingham's theory, the following dimensionless relationship is finally obtained

$$\frac{x}{d_0} = f_2(F_r = \frac{U_0}{\sqrt{gd_0}}, Re = \frac{U_0 d_0}{\nu}, \frac{H}{d_0}, \frac{U_m}{U_0}, \alpha) \qquad (4)$$

In this equation Fr_0 and Re are, respectively the Froude and Reynolds values at the jet nozzle. The value of the Reynolds number in these experiments was quite high. It means that viscosity has no effect and thus Reynolds number can be eliminated from analysis. As a result, (4) would change to (5).

$$\frac{x}{d_0} = f_3(F_r = \frac{U_0}{\sqrt{gd_0}}, \frac{H}{d_0}, \frac{U_m}{U_0}, \alpha) \qquad (5)$$

During experiments, the intensity (H/d_0) was kept constant equal to 50, this ratio obtained with increasing gradually Insofar as jets flow have not effect on water level, so (5) for submersible jet can be written as:

$$\frac{x}{d_0} = f_4(F_r = \frac{U_0}{\sqrt{gd_0}}, \frac{U_m}{U_0}, \alpha) \qquad (6)$$

With using the results, the relation between dimensionless parameters of (6) was plotted which shown in Fig. 5 to Fig. 9. These figures show the dimensionless parameter X/d_0 against U_m/U_0 for a constant densimetric Froude number for each nozzle. As illustrated in this figures jet with α=90° has highest velocity on effective length in compare with the other jets. The results also show that, for all range of Fr_0 the U_m/U_0 ratio for nozzle with α=90° on Effective length increases 20% -27% than nozzle with α=30° that has lowest velocity on centerline than other nozzle. These differences for nozzles with α=45° and α=60° are 10% -15% and 6% - 12% respectively.

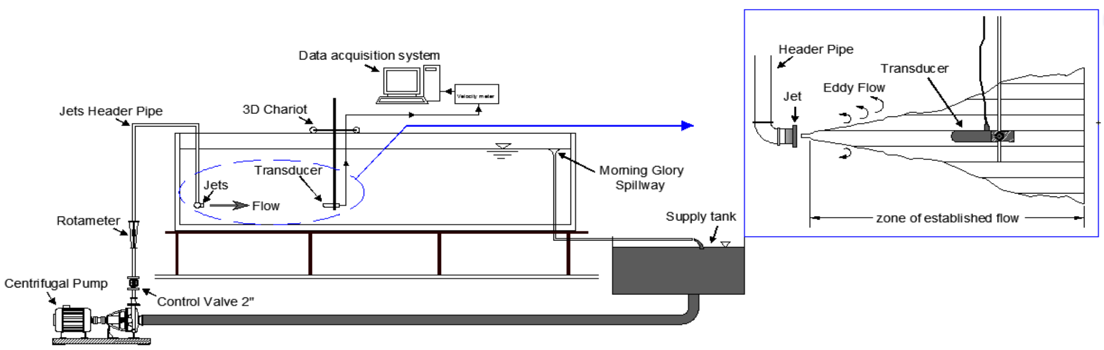

Fig. 4 Schematic view of the experimental setup

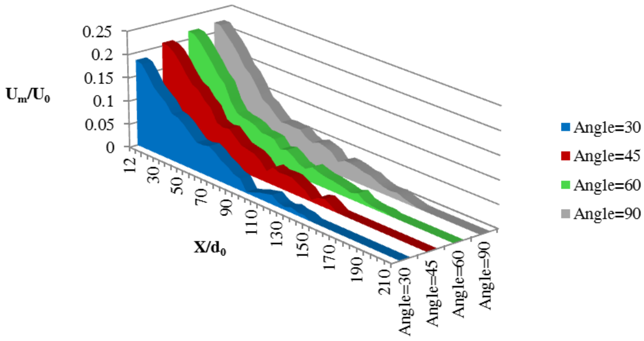

Fig. 5 Relationship between U_m/U_0 and x/d_0 in Fr_0=17.9

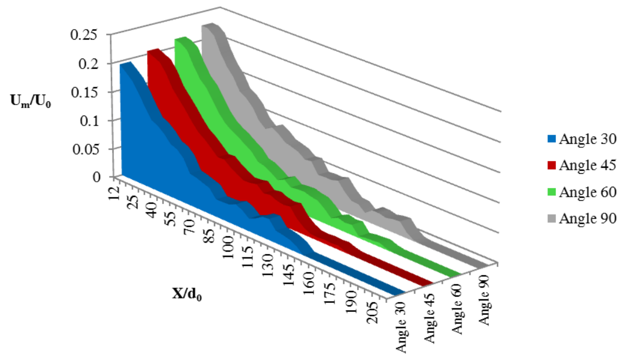

Fig. 6 Relationship between U_m/U_0 and x/d_0 in Fr_0=22.4

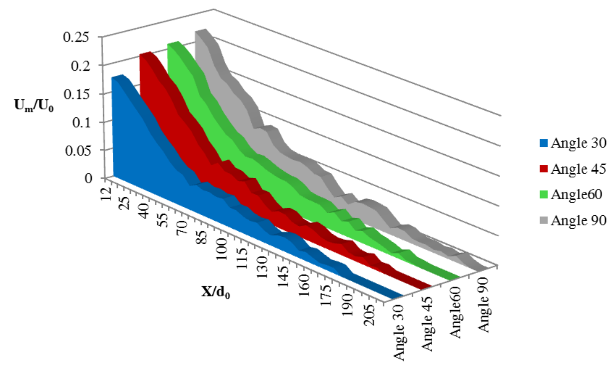

Fig. 7 Relationship between U_m/U_0 and x/d_0 in Fr_0=28.2

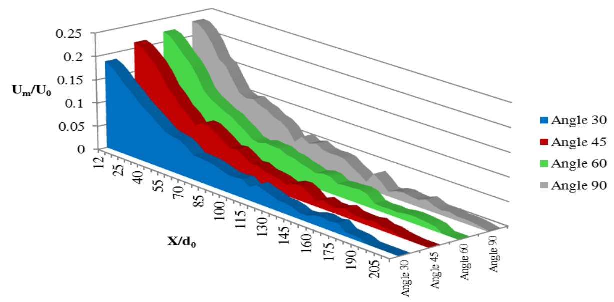

Fig. 8 Relationship between U_m/U_0 and x/d_0 in Fr_0=33.7

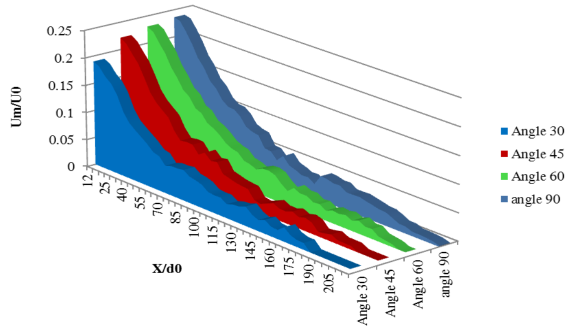

Fig. 9 Relationship between U_m/U_0 and x/d_0 in Fr_0=39.4

Fig. 10 shows that the ratio of U_m/U_0 against $X/d_0$for jet with inner angle 90°. According to this figure, Effective Length can be divided into two regions, (a) Near Field and (b) Far Field.

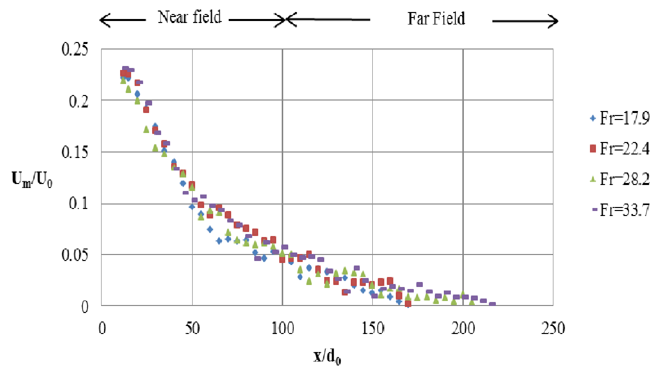

Fig. 10 Velocity on centerline for jet with α = 90°

In near field, flow pattern is affected by initial jet's momentum and velocity on centerline is reduced with steep slope by constant gradient. For this region, Upstream boundary is approximately limited in X/d_0=100. For X/d_0>100, the rate of decreasing U_m/U_0 has a mild slope. In this zone the jet's flow momentum are very low and eddies that generated between jet's flow and ambient resource are stronger than eddies flow in near field. Thus, the velocity on centerline has an Oscillating gradient. For finding relationship between X/d_0, U_m/U_0 and Froude number according to experimental data of jet nozzle with α = 90° by using SPSS.ver.19 software, (7) are generated.

$$\left(\frac{U_m}{U_0}\right) = 0.45 - 0.086 \, \mathrm{Ln} \left(\frac{x}{d_0}\right)^{-0.025} R^2 = 0.970 \qquad (7)$$

IV. Conclusion

The present study was carried out with the purpose of identifying the effect of inner Convergence Angle on Maximum effective length in Submersible jet. Twelve tests were conducted and the results were analyzed. From these results, the following conclusions can be found.

A. Velocity on Effective Length decreases when nozzle inner angle decreased from 90° to 30°.

B. For all range of Fr_0 the U_m/U_0 ratio for nozzle with α =90° on centerline increases 6%-27% than nozzles with α=30°, 45° and 60°.

C. Flow on centerline is divided into two zones (a) Near Field and (b) Far Field. In Near Field flow in Zone (a) is affected by jet's momentum and ratio of U_m/U_0 has a constant gradient but in zone (b) eddies flow is stronger and velocity on centerline has an Oscillating gradient

REFERENCES

[1] Aderibigbe, O. Rajaratnam, N. (1998). Effect of sediment gradation on erosion by plane turbulent wall jets. Journal of hydraulic engineering, ASCE, 124(10), 1034-1042.

[2] Ahadiyan, J., &MusaviJahromi, H., (2009). Effect of jet hydraulic properties on geometry of trajectory in circular boyantjet in the static ambient flow. Journal of applied sciences, Vol.9, no.21, pp3843-3849.

[3] Stefano, P. Dipankar, R. (2009).Effect of jet air content on 3D plunge pool scour. 33rd IAHR Congress: Water Engineering for a Sustainable Environment.

[4] Octavio, E. Yarko, N. Marcelo, H. (2009).Sedimentation Management by Jet and turbidity current with application to a reservoir for flood and pollution control in Chicago Illinois. Journal of hydraulic research Vol.47, No.3.

[5] Wood, I.R., Bell, R.G.,Wilkinson, D.L., (1993). Ocean Disposal of Wastewater. Advanced Series on Ocean Engineering, vol. 8.World Scientific, Singapore.

[6] Mehraein, M. Ghodsian, M. SalehiNeyshaboury, S.A.A (2009) 33rd IAHR Congress: Water Engineering For a Sustainable Environment.

[7] Guo,Y., Malcangio, D., Davies, P.A., Fernando, H.J.S., (2005). A laboratory investigation into the influence of a localised region of turbulence on the evolution of a round turbulent jet. Fluid Dyn. Res. 36, 75–89.

[8] Wygnanski, I., Fiedler, H. (1969). Some measurements in the self-preserving jet. Journal of Fluid Mech. 38, 577–612.