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EXTENDED ABSTRACT

Estimation of Radial Spreading Coefficient of Convergent and Inclined Surface Jet Flow over the Horizontal Bed of a Stagnant Ambient

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Introduction

Desalination plants dispose with the wastewater feed via channels and pipelines. The behavior of dense flows discharged into receiving water body is very important, thus prompting researchers to conducted numerous studies on the behavior of flows from surface and submerged dischargers. Among the scholars focusing on submerged dischargers, Zeitoun *et al*. (1972), Cipollina *et al*. (2005), and Bleninger and Jirka (2008) investigated submerged negatively buoyant jets in horizontal, vertical, and oblique discharge conditions and obtained results on flow trajectory and dilution rate. Furthermore, Researchers have also delved into surface dischargers. Using numerical modeling, Kassem *et al*. (2003) inquired into the effects of different parameters of an outflow, a bed, and receiving ambient water on the properties of dense flows discharged through inclined and divergent channels. Kotsovinos (2000), Papakonstantis and Christodoulou (2010), Kaye and Hunt (2004) experimentally examined the spreading of dense flows caused by the impingement of submerged jets on a horizontal plane. Papakonstantis and Christodoulou (2010) concentrated on negatively buoyant circular jets and vertical and horizontal positively buoyant jets, reporting that the dense flow in negatively buoyant jets and vertical positively buoyant jets has a circular outer boundary. The authors also observed that radial distance from the impingement point to the outer boundary of flow is related to time by a power of 0.5.

As previously stated, understanding the behavior of dense flows discharged into receiving ambient water is highly important. Correspondingly, this study explored the spreading of dense horizontal flow over the bed of deep and stagnant ambient water.

Material and Methods

Experiment method

The experimental model used was a 3.2 × 0.6 × 0.9 m^3 flume with walls and a floor made of Plexiglas. The jet fluid was a salt water solution with a concentration of 45 g/L. To ensure the visibility of the fluid's movement path, the prepared solution was colored using a substance that exerts no effect on density changes. The flow rate of the jet fluid was adjusted using an electromagnetic flow meter with an accuracy of 0.01 L/s. The jet fluid was injected into the ambient water using Plexiglas rectangular channels with a width of 0.06 m and convergence angles of 12.5°, 25°, 45°, and 90°.Given that the discharge channels were intended to inject the jet fluid tangentially to the surface of the ambient water, they were installed and adjusted on a base at a certain slope and convergence angle. The water depth in the flume was adjusted to a constant value of 0.7 m in all the experiments. The ambient fluid was allowed to settle before jet fluid injection. During this interval, the temperatures of the jet fluid and the ambient fluid were measured using a thermometer, and their densities were measured using a hydrometer. For each experiment, the movement path of the jet fluid across the receiving ambient water was recorded using two digital camcorders with frequencies of 40 and 50 FPS. Camera 1 was placed on a 0.7 m base and perpendicular to the central horizontal plane of jet flow to record images of the flow's plan, and camera 2 was placed in front of the flume's wall and perpendicular to the central vertical plane of jet flow to record images of the flow's section. The images captured by camera 2 were used to determine the exact location of jet flow impingement on the flume's bed. The data were analyzed via image routing from the bed mesh of the flume and rulers mounted on the wall of the flume (Figure 1).

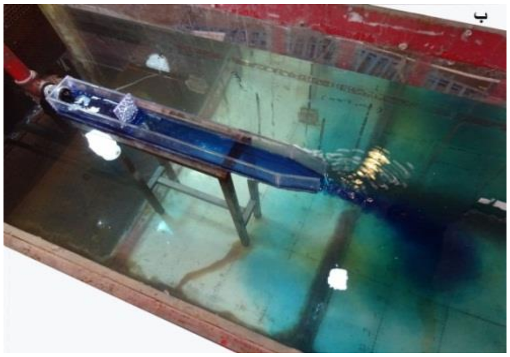

Fig. 1- Convergent surface jet in an experimental run

Results and Discussion

Relationship between spreading radius and time

surface dischargers release jet fluid onto a bed across a curvilinear path. Two-dimensional coordinates of the outer boundary points were extracted by image routing from the bed mesh. The relationship between radial distance and time was determined via power regression. The power of *n* in relation to t^n was estimated in each experiment, and the results indicated that no significant change occurs in the power of *n* for each of the variables R, A, and B. Therefore, an average value of *n* was defined for each condition. The obtained averages are expressed as Equations. (9a), (9b), and (9c).

$$n_{ave} = 0.45, \quad R \sim t^{0.45} \tag{9a}$$
$$n_{ave} = 0.57, \quad A \sim t^{0.57} \tag{9b}$$
$$n_{ave} = 0.42, \quad B \sim t^{0.42} \tag{9c}$$

In the equations above, R, A, and B are the average, major, and minor radial distances, respectively.

Spreading coefficient

The normalized average, major, and minor radial distances were determined with respect to the results of dimensional analysis and the determined power levels. The spatial variables and the initial jet parameters have a linear relationship—a result that was determined with acceptable accuracy. In the other words, the spreading coefficient of surface jet flow is the ratio of each spatial variable to its corresponding initial parameter. Spreading coefficients were determined in all the experiments. Because the ranges of variations in the spreading coefficients of the jets at average, major, and minor radial distances are limited, an average spreading coefficient was defined for each condition. The obtained average values of C_r, C_a, and C_b are shown in Eqs. (10a), (10b), and (10c).

$$C_r = 4, \quad R = 4\left(d^{0.55}{U_{0_j}}^{0.45}t^{0.45}\right) \tag{10a}$$

$$C_a = 2, \quad A = 2\left(d^{0.43}{U_{0_j}}^{0.57}t^{0.57}\right) \tag{10b}$$

$$C_b = 4.5, \quad B = 4.5\left(d^{0.58}{U_{0_j}}^{0.42}t^{0.42}\right) \tag{10c}$$

In the equations above, C_r, C_a, and C_b are the spreading coefficients of the jets at average, major, and minor radial distances, respectively.

Conclusion

In this study, horizontal jet flow spreading over the bed of stagnant ambient water was experimentally evaluated. Jets were superficially discharged from convergent rectangular channels, after which the relationship between radial distance and time, and spreading coefficients were examined. Data were analyzed using image routing, and the results were compared with those of previous studies. The best relationship between radial distance and time was evaluated via power regression. The relationship between spreading radius and time was $t^{0.45}$ for surface jets without a longitudinal slope, $t^{0.57}$ for inclined surface jets flowing along an ellipse's major axis, and $t^{0.42}$ for inclined surface jets traversing an ellipse's minor axis. The changes of resultant powers from zero to 8 percent caused an increase of 27 percent and the changes of resultant powers from zero to 4 percent caused a decrease of 7 percent. After the linear regression of radial distances and initial jet flow parameters, the spreading coefficients of jets at average, major, and minor radial distances were estimated at 4, 2, and 4.5, respectively.

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