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The Behaviour of a Turbulent Buoyant Jet into Flowing Environment

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Abstract

In this study the mean axial velocity at the centreline of a buoyant jet which is discharged vertically upwards from a source, into flowing environment inside a denser ambient fluid (water), in an open channel, is investigated. The presence of a buoyant jet is studied experimentally using a 2DParticle Image Velocimetry (PIV).
For this reason individual experiments were conducted. Salt water is used as the ambient fluid and fresh water as the jet fluid. Experiments were made for flowing ambient fluid. For the flow visualization of the buoyant jet, the water, was dyed with either rhodamin (red color) or fluorescein (green color), aiming to the best appearance of the buoyant jet field.The velocity fields of the buoyant jet were determined analysing 200 pairs of photographs in each experiment. These fields were used to quantify the different behaviour of the buoyant jet into flowing environment.
Results show that the presence of salt water can affect the flow dynamics with different way into flowing environment. The present findings are discussed and compared with other experimental data in similar conditions reported in the literature. These findings from experimental data analysis should be useful for the verification of numerical models.

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1. Introduction

Flows of buoyant jets are very common.Turbulent buoyant jets and plumes have been studied theoretically and experimentally by using both fresh and salt water ([1], [2]). [3] describes in detail the use of the integral method in buoyant-jet flows and its applicability limits; he and his co-workers have formulated and validated the Corjet integral model, which has been incorporated in the Cormix model [4]. In the study of [5] the integral momentum and tracer equations for the mean motion with the turbulence contribution in momentum and tracer fluxes are integrated on the centreline of either plane or round buoyant jets, using suitable assumptions for the spreading coefficients and a closing function, and unified first- and second-order solutions are derived in the entire buoyancy range for mean axial velocities and mean concentrations. Comparisons to experimental data in the literature validate the model and show that second-order solutions deviate less than first-order solutions.

[6]proposean integral model predicting the mean flow and mixing properties of inclined plane and round turbulent buoyant jets in a motionless environment of uniform density. The results predicted are compared with experimental data available in the literature, and the accuracy obtained is more than satisfactory.

There are many experimental data available in the literature regarding buoyant jets in a quiescent ambient environment, but there aren't many experimental data available in the literature regarding buoyant jets into flowing ambient environment. In the study of [7] the turbulence of vertical round buoyant jets in a cross flow was investigated. For this reason experiments were conducted for the calculation of velocity distribution, shear stresses and temperature field. Measurements were taken for the horizontal channel using an Acoustic Doppler Velocimeter (ADV) and they are analyzed with the help of software ExploreV. Results show that the velocity vectors around the buoyant jet have a rapid and turbulence behaviour. Also the behaviour of buoyant jet isn't a result only from different density between buoyant jet and environment but it is related with parameters such as wave length λ and wave widthε. [8] based on experimental observations on gas-phase horizontal laminar jets with positive and negative buoyancy, when the Froude number was less than 1, have challenged this seemingly sound proposition.

For the experimental investigation of buoyant jets and plumes recent efforts have introduced the Particle Image Velocimetry (PIV) technology. [9]investigated experimentally the turbulent characteristics of open-channel flow using a PIV.[10]performed experiments to study the turbulent characteristics of the flow in an open channel with horizontal and inclined impermeable beds using a two-dimensional (2D) Particle Image Velocimetry (PIV). Also,[11]) were carried out experiments to investigate the influence of transition from vegetation to gravel bed and vice versa in open channels. For the simulation of the two porous beds (grass-like vegetation and gravel bed) were used to represent the permeable bed. Finally,[12] assessed the effects of turbulent flow on the velocity distribution in an open channel in a half-separated (impermeable and permeable) bed using a 2-D PIV.

In this study, the mean axial velocity at the centreline of a buoyant jet which is discharged vertically upwards from a source, into flowing environment inside a denser ambient fluid (water), in an open channel, is investigated experimentally using a PIV. Salt water is used as the ambient fluid and fresh water as the jet fluid. Results show that the presence of salt water can affect the flow dynamics with different way into flowing environment in comparison with buoyant jets in a quiescent environment.

2. Experimental Procedure-Measurements

In total, twelve (12) experiments were carried out in an open channel of the Hydraulics Lab. The channel was 6.5m long, 7.5cm wide and 25cm deep.The buoyant jet was discharged vertically upwards from a tank with fresh water in salt water. The velocity of the buoyant jet was measured at 7130 points of the jet centerline for a horizontal channel bed. These fields were used to quantify the behaviour of the buoyant jet with fresh water of density $\rho_0 = 1.000$ gr/cm^3 and with different salt water densities (ρ_a=1.010, 1.015, 1.020 gr/cm^3). The initial velocity of the buoyant jet was kept constant and equal to 0.07m/s. Also, the water depth of the open channel was kept constant and equal to 0.10m. The velocity of the open channel ranged between 0.059 and 0.122m/s.The source, which supplies the buoyant jet with fresh water, was fixed at 5cm over the channel bottom.For the flow visualization of the buoyant jet, the water, was dyed with either rhodamin (red color) or fluorescein (green color), aiming to the best appearance of the buoyant jet field.The experimental set-up is showed in figure 1. The characteristics of the experiments are presented in Table 1.