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A Vertical Jet's Turbulent Characteristics in Wave Environment: Experimental Study

Yifei Zhang[1], *Feng Zhou*[2], *Zhaochen Sun*[2], *Li Li*[3]
[1] Second Institute of Oceanography,State Ocean Administration
Hangzhou, China
[2] State Key Lab of Coastal and Offshore Engineering
Dalian University of Technology
Dalian, China
[3]Digilink, Dalian, China

ABSTRACT

This paper presents experimental results of a turbulent jet vertically discharged into a flow field of regular waves, in the intermediate between deep and shallow water. The instantaneous velocity field of the turbulent jet was measured using the particle image velocimetry (PIV) technique. Phase average method was used to extract the turbulent velocity from the PIV measurements. Four different wave heights were used to show the effects of wave heights on jet. The results suggest that the influence of wave height on the turbulent characteristics of jets is significant. The convection term is more sensitive than the turbulent diffusion term for the change of wave heights, and the value of the turbulent diffusion term is about $1/8 \sim 1/3$ of the value of the convection term, which shows that the effect of the turbulent diffusion term can't be ignored in time-average N-S equations.

KEY WORDS: jet; PIV; wave height; turbulent.

INTRODUCTION

In the treatment project of wastewater discharged into sea, the wastewater is mixed with the ambient water by jets. Wave is the most familiar phenomena in coastal waters, so the interaction of a turbulent jet flow and waves has been an important problem. Although studies on jets in a stagnant environment and a cross flow have been intensively performed by experimental works and numerical models in the last several decades (e.g., Rajaratnam, 1976; Fischer et al, 1979; Li and Huai, 2002; Park et al, 2006), the understanding of interaction between jet and wave hasn't been enough. An early study on diffusion of effluence in a wave environment was performed by Shouto and Ti (1974). They found that the diffusion of the plume increases significantly with the existence of the waves. Chin (1987) investigated the influence of surface waves on a buoyant jet experimentally. He suggested that the primary influence of waves is in the region of the source. Subsequently some researchers studied jets in a wave environment and achieved some valuable results and conclusions (e.g., Chyan and Hwung, 1993; Koole and Swan, 1994; Mori and Chang, 2003; Ryu et al, 2005). However for the complexity of the jet turbulence and the limitation of experimental facilities, the experimental study of the jet was usually focused on the time-averaged component, Mossa (2004) experimentally studied the turbulent component of the jet in three periodic regular waves. This paper is to investigate the influence of wave heights on the turbulent behavior of a non-buoyant vertical round jet experimentally. The PIV technique was employed to measure the velocity field. The phase average method was used to analyze the experimental data. A range of wave heights were used to test the effect of waves on the turbulent characteristics of the jet.

EXPERIMENTAL METHODS

The experiments were carried out in a two-dimensional glass-walled wave flume at the State Key Lab. of Coastal and Offshore Eng., Dalian Univ. of Technology of China. In this study the origin of coordinates is located at the source of the vertical round jet with x being the horizontal axis and z the vertical axis. A schematic sketch of the problem (side view) is shown in Fig. 1. In Fig. 1, *H* is the wave height, *D* is the inner diameter of the jet outlet, h_j is the vertical distance of the outlet from the bottom, and *h* is the water depth.

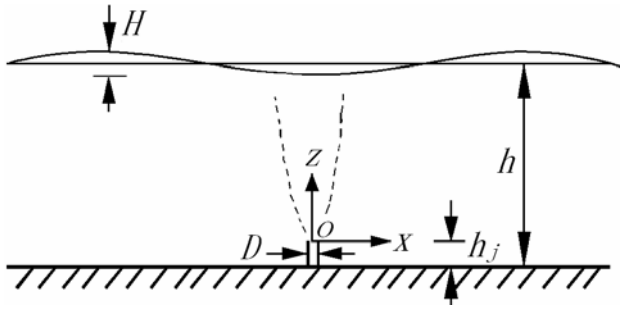

Fig. 1. Schematic sketch of experimental geometry and parameters

The wave flume is 24 m long, 0.45 m wide and 0.6m deep. The flume was filled with tap water and the water depth *h* was kept constant at 0.40m throughout the experiments. A piston-type wave maker is located at one end while a wave absorber is at the other end. A round orifice with an inner diameter (*D*) of 4 mm was introduced about 12 m from the wave maker and 6cm from the tank bottom ($h_j = 6cm$). A constant head tank with water located above the wave flume was connected to the jet to provide a constant velocity. A double-wire