Experimental Study of Turbulence Kinetic Energy and Velocity Fluctuation Distributions in a 180 Degree Sharp Bend

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Abstract

The Reynolds shear stress and Turbulent Kinetic Energy are two of the important parameters when predicting the turbulent flow pattern in river bends, because such parameters indicate flow structures, especially the secondary flows. Since the product of the velocity components' fluctuations in various directions can be used to show the Reynolds shear stress, this paper first addressed velocity fluctuations, then the distribution of turbulence kinetic energy. The experiments were conducted in a 180 degree sharp bend channel with a central curvature radius of 2 meters and a width of 1 meter in the hydraulic laboratory of Persian Gulf University using Vectrino velocimeter. The results demonstrated that the maximum value of turbulence kinetic energy occurred at the 85 degree cross section and the minimum value at the 20 degree. Also, the maximum values of the longitudinal and transverse velocity fluctuations occurred at the 70 degree cross section near the inner wall.

Keywords: Reynolds Shear Stress, Turbulence Kinetic Energy, Flow Pattern, 180 Degree Sharp Bend, Vectrino Velocimeter.

1. INTRODUCTION

Due to the existence of secondary flow, flow characteristics in channel bends are much more complicated than those in straight channels [1]. Turbulence plays an important role in open-channel flows. It is to a large extent responsible for the spreading and mixing of heat and dissolved or suspended matter (sediments, pollutants, oxygen, etc.). It also has a strong interaction with the mean velocity field and the boundary shear stress. Turbulence plays an important role in the formation of cross-stream circulation cells, which in their turn influence the distribution of the velocity and the boundary shear stress. This interaction is reflected by the sensitivity of flow models to the turbulence closure. In spite of the relevance of both turbulence and bends, little is known about the turbulence characteristics in open channel bends [2].

Some researchers have carried out extensive studies on flow characteristics in channels with different bend angels by using the experimental and numerical models. Shukry (1949) [3] studied flow in river's bend, and introduced a criterion for strength of secondary flow. The criterion includes the ratio of kinetic energy of the lateral flow to that of the main flow. He also concluded that in a bend, the kinetic energy of the lateral flow is smaller than that of the longitudinal orientation. De Vriend & Geoldof (1983) [4] carried out a field investigation, and numerical simulation of flow in the Dommel, a river in the Netherlands, within a short period of time. The section includes two 90 degree bends located sequentially, and in the same direction, and there is a short, straight reach in between. The results indicated that maximum velocity is found at the entrance of the bend, close to the inner wall, and when close to the end of the bend, it is oriented towards the external bend. Lien et al. (1999) [5] investigated the flow pattern in a bend of 90 degrees and 180 degrees by using the depth averaged two-dimensional model. The effect of secondary flow in the model has been determined through calculation of the distributed tensor of the stress. In addition to spread stresses, the important forces existing in the flume have been compared, and the result indicates that the secondary flow in the 180 degree bend is stronger than that in the 90 degree bend. Blanckaert & Graf (2004) [6] studied velocity distribution, boundary shear stress, and the form and features of bed topography in bend flumes. They set out to determine bed topography dynamics in bend flumes considering a central zone as a cell which can twist, and using a semi 3D model. Vaghefi et al. (2008) [7] conducted an experimental study on 3D flow and scour pattern in a 90 degree mild bend. The results indicate the formation of a flow in the opposite direction of the primary secondary flow,