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Numerical Study of Channel Convergence Effects on Flow Pattern in 90 Degree Bends

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Abstract

As a result of topography changes along the open channels, designing the right bend is an essential. Channel width limits, such as existence of culverts beneath the roads and sharp changes in topographies, usually impel engineers to design non-prismatic or converging bends along the open channels. In this research the flow pattern in a 90^o curved converging rectangular open channel is numerically investigated. A three-dimensional simulation was carried out using the commercial CFD package ANSYS-FLUENT. To obtain the most accurate pattern, five different turbulence models: standard k-ε, realizable k-ε, RNG k-ε, k-ω and RSM, along with the VOF free surface model were utilized to solve the 3D Navier-Stokes equations. The accuracy of the model was analyzed with observed data from experimental study of an ordinary 90^o open channel curvature as a qualitative reference and the computed results of the present study were validated. The predicted results for the flow characteristics are in reasonable agreement with the experiment data. As extent of the work, a converging open channel bend was simulated and the velocity profiles and the flow separation after the bend are evaluated. It has been concluded that unlike the ordinary open channel bend, the minimum velocity in a converging channel occurs in different locations along the bend while the separation zone is eliminated. Concerning how it can affect the conveyance capacity and channel width, the issue could be attention-getting in the study of sedimentary processes of meandering rivers.

Keywords: open channel bend, converging bend, volume of fluid, turbulence modeling, flow separation.

1. INTRODUCTION

Rivers have fascinated engineers and scientists for decades while providing water supply for domestic, irrigation, and industrial consumption or transportation and recreation use. However, the design and organizing these systems require a full perception of mechanics of the flow and sediment in rivers. River channels do not remain straight for any appreciable distance, as noticed by Leopold and Wolman (1960) it is very unlikely to find a straight stream with the length longer than ten channel section width [1]. One of the significant characteristic attributes of flow in an open-channel bend is its secondary flow and therefore the helical motion that is the main reason of the winding river morphology and the tendency to create a succession of shoals and deeps along its way, that the physical explanation of the phenomenon has been identified as the attenuation of current velocities by secondary flows. Secondary currents are formed due to disequilibrium in pressure gradient and centrifugal force at an arbitrary section. Super-elevation, secondary flows and their tending to redistribute the mean velocity, permuting the boundary shear stress, bank erosion and shifting, flow separation (that its presence coming together with vortex bar formation decreases the channel width and conveyance capacity), and bed migration in mobile boundary channels have made the study of the meandering open channels of a high interest in the field of river engineering.

Meandering was defined by Yalin (1992) as “a self induced plan deformation of a stream, under ideal conditions, is periodic and anti-symmetrical with respect to an axis x, say” [2]. Many experimental and numerical investigations have been carried out to give an attempt to gain a clear understanding of flow characteristics in meandering open-channels and river bends. Thompson (1876) published one of the first reports dealing with flow pattern in an open-channel bend. He described the development of a helicoidal flow approach and described the phenomenon as being the result of the variation in velocity of fluid segments along the water depth [3]. Rozovskii (1957) conducted a series of experiments on a tight 180^o bend of rectangular cross section with straight inlet and outlet reaches [4]. As a result, strong secondary currents were observed. He measured velocity profiles near the walls and noticed that the utmost velocities occur below the water surface. Accordingly, as a recent experimental investigation, A.A Akhtari (2009) has carried out