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Velocity distribution and Dip phenomenon in a large amplitude meandering channel

Donatella TERMINI

Department of Civil, Environmental, Aerospace, Materials Engineering, Polytechnic School,
University of Palermo, Viale delle Scienze, 90128 Palermo, Italy
email: donatella.termini@unipa.it

ABSTRACT

The prediction of the velocity-dip, whereby the location of the maximum velocity occurs below the water surface, could be important to define the flow pattern and the momentum transport processes. As it is known, when the flow enters a bend the so-called helical motion, given by the combination of the transversal cross-sectional motion with the longitudinal motion (among others Yalin 1992) is produced. Literature studies (Blanckaert and Graf 2004; Termini 2015) have also demonstrated that the cross-sectional motion exerts an important role in the redistribution of the stream-wise velocity along the bend.

Still today, several aspects related to the influence of the cross-sectional motion on the velocity and fluid mass distributions are still poorly understood attracting the attention of the researchers. As an example, no systematic research has been conducted to analyze the vertical profile of the stream-wise flow velocity and the localization of the maximum value along a bend.

In this context, the present study analyzes the dip-phenomenon in a high-curvature meandering bend with the main objectives: 1) to explore the location of the maximum velocity along the bend for two values of the width-to-depth ratio; 2) to investigate the relationship between the velocity-dip, the channel's curvature parameters and the aspect ratio.

The analysis is conducted with the aid of data collected in a meandering laboratory flume which follows the sine-generated curve with a deflection angle at the inflection section θ_o=110°. The data used in the present work were collected, in the ambit of previous works (see in Termini 2009), during runs conducted in flat bed conditions both with a flow discharge of Q=0.019 m^3/s (aspect ratio B/h_{av}=9.09<10) and with a flow discharge Q=0.007 m^3/s (aspect ratio B/h_{av}=16.67>10).

The analyses conducted in the present work have shown that, for the aspect ratios examined, a dip forms in the velocity profiles and its position varies along the bend as a function of the channel's curvature and the aspect ratio. Generally, for B/h_{av}>10 the dip δ assumes values lower than those obtained for B/h_{av}<10. But, three different regions can be distinguished in each cross section along the bend: the outer-bank region for $r/B \leq 0.28$ (r=transversal abscissas), the central region for $0.28 < r/B \leq 0.61$, the inner-bank region for r/B>0.61. In the outer region, a different behavior between the two runs can be observed. Such a different behavior could be related both to the fact that, according to previous findings obtained by Termini (2009), the advective behavior of flow is more accentuated in the case of B/h_{av}>10 than in the case of B/h_{av}<10 and to the fact that, as described in Termini and Piraino (2011), for B/h_{av}<10 a counter-rotating circulation cell forms at the outer bank of the bend entrance maintaining the core of maximum velocity far from the bank. In the central and in the inner-bank regions, a similar behavior has been observed for the two runs. In particular, both in central and in the inner-bank regions the relative distance of the maximum velocity from the bed, Y_{max}/h, assumes a first high peak value close to the bend entrance and a second lower peak value close to the bend exit.

Thus, the position of the maximum velocity varies along the bend as a function of the distance from the outer bank, r/B, the channel's curvature and the width-to-depth ratio.

By parameterizing the channel's curvature by the deflection angle θ of each considered section, the relation between the dip-values, δ, and the parameters r/B, B/h_{av} and θ, has been explored. The application of the regression analysis of the δ–values by considering the aforementioned parameters as independent variables has yielded the following expression which directly relates the velocity-dip to the parameters θ and B/h_{av}

$$\delta = \left(a\frac{B}{h_{av}} + b \right) sin\theta + \left(c\frac{B}{h_{av}} + d \right) \tag{1}$$

The coefficients *a, b, c, d* have to be determined by using experimental data; for the considered case the following values of the coefficients have been obtained: a=-0.0536, b=0.8104, c=-0.1925, d=4.4003.

To verify the applicability of the aforementioned expression, the experimental δ-values obtained in the present work and those taken from literature have been plotted against the estimated ones by using the Eq.(1), as shown in Figure 1. Furthermore, in the same figure, the δ-values estimated by applying the expression suggested by Yang et al. (2004) have been also compared with the experimental ones.

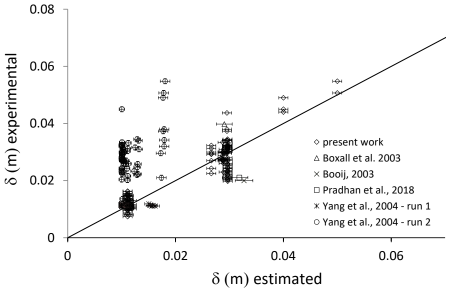

Fig. 1. Comparison between experimental and literature δ-values (m) and those estimated by using the proposed expression (the error bars are defined by the root mean squared error between the estimated and the experimental values).

From Fig. 1 it can be observed that, apart from some exception, the points thicken around the bisecting line, demonstrating the good agreement between the estimated and the experimental δ–values; the root mean squared error is quite low in comparison to the magnitude of the experimental values. The expression proposed by Yang et al. (2004) overestimate the values of the dip, especially in the case of run 2 (B/h_{av}<10).

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