Abstract

The thesis presents the application of information-theoretic approach together with the maximum entropy principle to various kinds of open channel flow problems. The proposed works are based on the well-known Shannon entropy as well as a generalized entropy, namely, Rényi entropy. Each of the mathematical models derived in the thesis is validated with the laboratory and/or field data available in literature. Chapter 1 of the thesis is the introductory chapter.

In Chapter 2 and 3, spatial distribution of streamwise flow velocity is derived through two different studies: one is by extending the existing work incorporating additional constraints based on conservation of momentum and energy and another is by exploring the concept of relative entropy theory. The non-linear governing differential equations for velocity are solved using a non-perturbation approach, and the convergency of the solutions is shown both theoretically and graphically. Instead of solving a system of non-linear equations, in Chapter 2, the Lagrange multipliers are determined by minimizing a convex potential using quasi-Newton method along with BFGS scheme. Effects of additional constraints on two dimensional distribution of velocity are analyzed, and it is found that the energy and momentum coefficients significantly affect the velocity profile in a channel cross-section. On the other hand, in Chapter 3, four types of prior PDFs are proposed in support of the relative entropy theory. In comparison with the existing and other prior-based velocity profiles, normal- and gamma-type prior-based equations have shown significant improvement, especially near the channel bed.

In Chapter 4, the classical Rouse equation for suspended sediment concentration is derived using Shannon entropy together with the logarithmic constraint. The connection between the deterministic and the probabilistic approach is made through the hypothesization of a non-linear CDF in the space domain. The proposed approach allows to relate the physical parameter Rouse number to the Lagrange multiplier.

Chapter 5 and 6 derive the analytical expressions for two important flow parameters in sediment-laden flow, namely, hindered settling velocity of sediment and bed-load layer thickness. A non-linear CDF is hypothesized to relate the exponent of settling velocity with the particle Reynolds number, volumetric concentration of sediment, and submerged specific gravity. The applicability of the derived model is tested through the assessment of hindered settling velocity formula for different sets of data. On the other hand, in Chapter 6, the bed-load layer thickness is related to the dimensionless shear stress through the hypothesization of a non-linear CDF. Apart from the algebraic method, method of maximum likelihood estimation (MLE) is applied to calculate the values of the Lagrange multipliers. The physical interpretation is provided through the proposed regression equations of several empirical parameters present in the model.

In Chapter 7 and 8, a generalized entropy, namely, Rényi entropy is applied for deriving one and two dimensional distribution of streamwise flow velocity in open channel. The derived equation for two dimensional distribution is made easy-to-use by defining an entropy parameter and writing the equation in terms of it only. The effects of entropy index and entropy parameter for assessing the velocity profile are discussed in details. Satisfactory agreement of both the models with a wide range of experimental and field data shows the potential of the Rényi entropy in the context of application to velocity in open channel flow.

Keywords: Open channel flow; Sediment transport; Shannon entropy; Rényi entropy; Principle of maximum entropy; Lagrange multipliers; Analytical solution; Bed-load layer thickness; Settling velocity; Rouse equation; Streamwise velocity; Maximum likelihood estimation; Homotopy analysis method; Padé approximation; Quasi-Newton method.