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Towards Accurate Velocity Profile Models in Turbulent Open-Channel Flows: Improved Eddy Viscosity Formulation

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Abstract : Velocity distribution in turbulent open-channel flows is organized in a complex manner. This is due to the large spatial and temporal variability of fluid motion resulting from the free-surface turbulent flow condition. This phenomenon is complicated further due to the complex geometry of channels and the presence of solids transported. Thus, several efforts were made to understand the phenomenon and obtain accurate mathematical models that are suitable for engineering applications. However, predictions are inaccurate because oversimplified assumptions are involved in modeling this complex phenomenon. Therefore, the aim of this work is to study velocity distribution profiles and obtain simple, more accurate, and predictive mathematical models. Particular focus will be made on the acceptable simplification of the general transport equations and an accurate representation of eddy viscosity. Wide rectangular open-channel seems suitable to begin the study; other assumptions are smooth-wall, and sediment-free flow under steady and uniform flow conditions. These assumptions will allow examining the effect of the bottom wall and the free surface only, which is a necessary step before dealing with more complex flow scenarios. For this flow condition, two ordinary differential equations are obtained for velocity profiles; from the Reynolds-averaged Navier-Stokes (RANS) equation and equilibrium consideration between turbulent kinetic energy (TKE) production and dissipation. Then different analytic models for eddy viscosity, TKE, and mixing length were assessed. Computation results for velocity profiles were compared to experimental data for different flow conditions and the well-known linear, log, and log-wake laws. Results show that the model based on the RANS equation provides more accurate velocity profiles. In the viscous sublayer and buffer layer, the method based on Prandtl's eddy viscosity model and Van Driest mixing length give a more precise result. For the log layer and outer region, a mixing length equation derived from Von Karman's similarity hypothesis provides the best agreement with measured data except near the free surface where an additional correction based on a damping function for eddy viscosity is used. This method allows more accurate velocity profiles with the same value of the damping coefficient that is valid under different flow conditions. This work continues with investigating narrow channels, complex geometries, and the effect of solids transported in sewers.

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