Simulation of Turbulent Flow in Channel Using Generalized Hydrodynamic Equations

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Abstract : This study explores Generalized Hydrodynamic Equations (GHE) for the simulation of turbulent flows. The GHE was derived from the Generalized Boltzmann Equation (GBE) by Alexeev (1994). GBE was obtained by first principles from the chain of Bogolubov kinetic equations and considered particles of finite dimensions, Alexeev (1994). The GHE has new terms, temporal and spatial fluctuations compared to the Navier-Stokes equations (NSE). These new terms have a timescale multiplier τ, and the GHE becomes the NSE when τ is zero. The nondimensional τ is a product of the Reynolds number and the squared length scale ratio, $\tau=Re*(l/L)^2$, where l is the apparent Kolmogorov length scale, and L is a hydrodynamic length scale. The turbulence phenomenon is not well understood and is not described by NSE. An additional one or two equations are required for the turbulence model, which may have to be tuned for specific problems. We show that, in the case of the GHE, no additional turbulence model is needed, and the turbulent velocity profile is obtained from the GHE. The 2D turbulent channel and circular pipe flows were investigated using a numerical solution of the GHE for several cases. The solutions are compared with the experimental data in the circular pipes and 2D channels by Nicuradse (1932, Prandtl Lab), Hussain and Reynolds (1975), Wei and Willmarth (1989), Van Doorne (2007), theory by Wosnik, Castillo and George (2000), and the relevant experiments on Superpipe setup at Princeton, data by Zagarola (1996) and Zagarola and Smits (1998), the Reynolds number is from Re=7200 to Re=960000. The numerical solution data compared well with the experimental data, as well as with the approximate analytical solution for turbulent flow in channel Fedoseyev (2023). The obtained results confirm that the Alexeev generalized hydrodynamic theory (GHE) is in good agreement with the experiments for turbulent flows. The proposed approach is limited to 2D and 3D axisymmetric channel geometries. Further work will extend this approach by including channels with square and rectangular cross-sections.

Keywords : comparison with experimental data. generalized hydrodynamic equations, numerical solution, turbulent boundary layer, turbulent flow in channel
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