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Enhanced transport phenomena in the Navier-Stokes shell-like slip layer

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Summary

Due to last mass flow rate measurements in gas micro and nano-channels several discrepancies in the mathematical modeling have been arise. The most important one, is the "flow enhancement" related with the wall slip phenomena. Thus, in the literature, there is opinion that the Navier-Stokes slip condition is correct only in certain restricted circumstances, particularly those restricted to the first order boundary conditions. A one possible way for solving of the above discrepancies, used recently in the literature, is developing a variety of so-called "second order boundary conditions". This way is incorrect since it always leads to an inconsistency between a bulk stress tensor and its boundary representation known as "wall stress".

In the paper we propose to remove the classical Navier slip condition and replace it by a new generalized Navier-Stokes slip boundary conditions. These conditions are postulated to be ones following from the mass and momentum balance within a thin, shell-like moving boundary layer. Owing to this, the problem of consistency between the internal and external friction in a viscous fluid is solved within the framework of a proper form of the layer balances, and a proper form of constitutive relations for appropriate friction forces. Finally, the common features of the Navier, Stokes, Maxwell and Reynolds concepts of a boundary slip layer are compared and revalorized. Classifications of different mobility mechanisms, important for flows in micro- nano- channels, are discussed.