Validity range of linear kinetic modeling in rarefied pressure driven single gas flows through circular capillaries

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Abstract

The range of validity of various linear kinetic modelling approaches simulating rarefied pressure driven gas flow through circular tubes is computationally investigated by comparing the flowrates obtained by the linear approaches with the corresponding nonlinear ones. The applicability margins of the linear theories in terms of the parameters determining the flow (gas rarefaction, pressure ratio, tube aspect ratio) are specified, provided that the introduced deviation norm is smaller than a specific value. The work is motivated by the fact that computational effort is significantly reduced when linear, instead of nonlinear, kinetic modelling is implemented. It is found that the range of validity of the linear solutions is much wider than the expected one, as defined by their formal mathematical constrains and it remains valid in a range of parameters, where the DSMC method and nonlinear kinetic modeling become computationally inefficient, resulting in great computational savings.

Keywords: kinetic theory, kinetic modeling, rarefied capillary flows, DSMC