Numerical Simulations of Transonic Nozzle Flows of Ideal and Non-ideal Fluids

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Abstract

The invisicid transonic flows at the nozzle throat of converging-diverging nozzles is investigated numerically using the open source CFD solver SU2. Numerical simulations are carried out in both the ideal, dilute-gas regime and in the non-ideal compressible flow regime in the close proximity of the liquid-vapour saturation curve and critical point. A grid dependence study is carried out to determine the suitable discretization to capture the nozzle maximum mass flow rate, which is proportional to the curvature of the sonic line at the nozzle throat. Two families of contours for the divergent section are analysed. Profiles of the first family are 5^{th} order polynomials realizing a smooth transition from the inlet to the throat section. In the second family of contours, the throat region is represented by a circular arc, which is joined smoothly to the inlet section through a 5^{th} order polynomial. The mass flow rate is computed at the throat section of different nozzles designed at varying fluid molecular complexity, reservoir thermodynamic conditions and radius of curvature at the throat. Grid convergence is evaluated on the basis of the calculated discharge coefficient. The sonic line for ideal and non-ideal gases is assessed against the linearized theory of Sauer. The shape of the sonic lines associated to the converging portions of the first family are found to deviate significantly from those predicted by the linearised theory and a very large number of elements is found to be required for grid convergence both in ideal and non-ideal conditions. For converging portions of the second family instead, results are in good agreement with the theoretical model and a lower grid refinement is required to correctly estimate the nozzle discharge coefficient.

References

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