MASS FLOW RATE OF NON-IDEAL CHOCKED FLOWS IN TURBINE STATORS

Marta Zocca* and Alberto Guardone

*Department of Aerospace Science & Technology
Politecnico di Milano,
Via La Masa 34, 20156 Milan
Italy

ABSTRACT

The maximum mass flow rate a supersonic turbine stator can discharge is limited by the occurrence of chocked flow conditions at the stator throat. When a turbine is operated away from the design point, the sonic conditions attained at the stator throat change accordingly, and deviations from the design mass flow rate are observed.

In this work, non-ideal chocked flows are studied and the dependence of sonic conditions on the total thermodynamic state is thoroughly discussed. Analytical correlations between the sonic and total thermodynamic variables are derived. The correlations highlight an explicit dependence of the sonic variables on the value attained by the fundamental derivative of gasdynamics Γ along the expansion from reservoir to sonic conditions. For a perfect gas, the value of Γ is constant and depends only on the fluid characteristics, regardless of process conditions. For non-ideal flows instead, Γ depends on the total thermodynamic state and shows a significant variation along the expansion. As a result, sonic and total thermodynamic properties are not in a relation of proportionality, contrary to the well-known behaviour of perfect gas flows.

The present findings are confirmed by state-of-the-art thermodynamic models applied to selected commercially available fluids for ORC applications. The sonic momentum density is computed for a wide range of operating conditions and maps are reported, which provide the sonic momentum density as function of the total pressure and temperature. Numerical simulations of supersonic expansions in exemplary converging-diverging geometries further confirm the predicted trends.