IAF SPACE PROPULSION SYMPOSIUM (C4)
Liquid Propulsion (2) (2)

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A PARAMETRIC BLADE DESIGN STUDY IN THE BALJÉ-DIAGRAM: APPLICATION TO SUPERSONIC IMPULSE TURBINES

Abstract

Turbopump fed liquid propellant rocket engines come in two basic configurations: closed cycle and open cycle. In the former case, the full turbine mass flow rate is injected into the main combustion chamber. The required enthalpy for the expansion is provided either through the regenerative cooling circuit (expander cycle) or through pre-combustion of the propellants (staged-combustion). The closed cycle is characterized by a high turbine mass flow rate and a low expansion ratio. On the contrary, for the open cycle, the turbine mass flow rate is not expanded through the main combustion chamber and the pressure ratio is supercritical. Supersonic turbines are hence the preferred choice. Due to the bleed mass flow rate, a major part of the engine performance is governed by the turbopump losses. It is therefore imperative to maximize the utilization of the available adiabatic specific work. This motivates the optimization of turbine efficiency for the required operating conditions during its design phase. Previous work has focused on a closed expander cycle applications with a full admission subsonic turbine. A parametric study has been performed in the Baljé-Diagram. The efficiencies obtained with several blade design methodologies have been characterized by means of CFD simulations over a wide range of conditions. The current study aims to extend this approach to open cycle supersonic turbines. Starting point and reference case for the work is a partial admission turbine designed using a modified Ovsyannikov-Deych approach. This method has been successfully applied for the LUMEN Demonstrator engine and it has been numerically validated. The approach will be compared with results obtained based on the Baljé-Diagram. The motivation for this work is to evaluate both design methods (Baljé and modified Ovsyannikov-Deych) applied to supersonic impulse turbines over a wider range of operating conditions. This will be done, using geometrical and Mach similarity for the blade profile generation, including CFD simulations to parametrically investigate the blade efficiency as input for turbine design optimization.