A Methodology for Optimizing Turbines powered by Rotating Detonation Combustors

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1. INTRODUCTION

• Design optimization can be defined as the process of determining the most desirable design given a set of constraints.
• The objective function is any sign of interest that must be minimized or maximized.
• This methodology utilizes a robust unsteady 1D Euler equations solver, a meanline performance analysis, and an optimization algorithm.

2. 1D EULER MODEL

The unsteady 3D-CFD simulations have very high computational cost and time. Therefore, reducing the order of the simulation can be highly beneficial. The compressible 1D-Euler equations are as follows.

\[
\frac{\partial}{\partial x} \left( \rho A \right) + \frac{\partial}{\partial x} \left( \rho V A + \rho V A \left( \rho E + P \right) \right) = \frac{\partial}{\partial x} \left( \frac{m_b}{W} \left( F_x + PA \right) + \Delta (\text{m}V_x) \right)
\]

\[

\Sigma F_x = \Delta (\text{m} V_x)
\]

\[

\Sigma F_i = F_{in} - F_{endwall} + F_{endwall} + F_x
\]

\[

F_x = F_{in} + F_{endwall} + \Delta (\text{m} V_x)
\]

\[

W = (\text{m} V_x)_{out} - (\text{m} V_x)_{in}
\]

The meanline method is executed to compute the source terms for a range of steady-state operating points. The boundary conditions include total pressure and total temperature at the inlet and the static pressure at the outlet.

The baseline design for the current work is the high pressure turbine of the Energy Efficient Engine project by NASA.

3. OPTIMIZATION METHODOLOGY

3.1 Objective Function and Variables

The non-dimensional entropy is used as the objective function to be minimized. Non-dimensional entropy generation is computed by subtracting the corresponding values at the turbine outlet from the inlet. \( P_{\text{ref}} = 1 \text{Pa}, \ T_{\text{ref}} = 1 \text{K} \).

\[
S = \left[ \frac{T}{T_{\text{ref}}} \right]^{\gamma/(\gamma-1)} \left[ \frac{P}{P_{\text{ref}}} \right]^{-1}
\]

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<th>( \Delta S )</th>
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4. RESULTS AND CONCLUSION

4.1 Optimization Results

Optimization variables

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5. FUTURE WORK

• Perform 3D-CFD simulation for both original and optimized design.
• Introduce the bleed flow into the 1D Euler model, in order to simulate the flow with the turbine blade cooling.

6. REFERENCE