Project Proposal

Identification of Real Gas Effects in Supercritical Turbines

General Information

Type:	Master Thesis (30 ECTS)
Laboratory:	Laboratory for Applied Mechanical Design (LAMD)
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Background

Supercritical power cycles are poised to play a pivotal role in the energy transition towards renewable sources, driven by their potential for higher efficiencies and greater energy density. In these cycles, fluids operate at pressures and temperatures beyond their critical points, where they exhibit non-ideal behavior, rendering the ideal gas law inapplicable. These supercritical fluids are subject to real gas effects and display complex, non-linear thermo-physical properties.
Friction and aerodynamic losses in turbines are traditionally estimated using empirical loss correlations, which have been developed and validated primarily under ideal gas conditions. Real gas effects at supercritical conditions alter the magnitude and behavior of loss mechanisms, raising concerns about the accuracy and applicability of existing empirical correlations. Therefore, further research is essential to understand how real gas effects influences loss mechanisms when using supercritical fluids within turbomachinery.

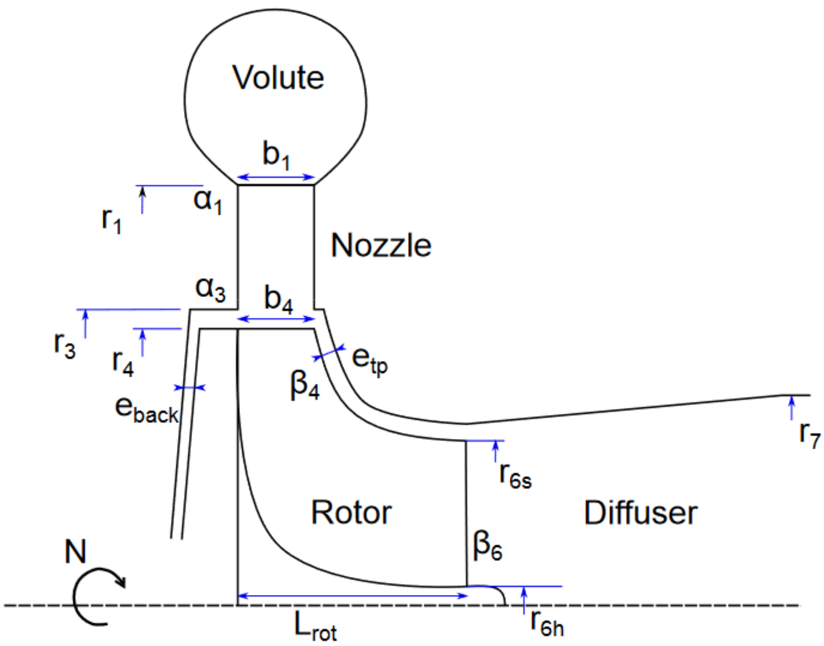

Figure 1: Radial Tubrine Geometry used in 1D Code

A typical radial turbine comprises an inducer, impeller, and diffuser. This study will leverage an in-house 1D code to design radial turbines and investigate how real gas effects influences various loss mechanisms under supercritical conditions.

Large variations of thermophysical properties can be found at the critical point, notably specific heat. These large changes in specific heat make the design of heat exchangers very difficult and complex. Additionally, large variations of thermophysical properties at the critical point have been observed between different fluids. An analysis of the different fluids, and their respective thermophysical properties will be provide understanding as to which fluids are best suited to operate in a recuperation cycle.

Objective

To identify and adapt loss mechanisms in radial turbines operating with supercritical fluids. Complete heat recuperation analysis for supercritical recuperation cycles.

Tasks

1. Literature review of supercritical turbine design and real gas effects.
2. Adaptation of 1D turbine model for supercritical operation (the 1D turbine model is already developed, and students are only required to apply the tool).
3. Identify loss mechanisms relevant to supercritical turbines.
4. Adapt existing loss models to account for supercritical conditions using computational fluid dynamics (CFD) simulations.
5. Design radial turbine for cycle power outputs of 2[MW], utilizing CO2 and Xenon as working fluids.
6. Heat transfer analysis focusing on heat load capabilities of different fluids.
7. Identification of fluids capable of recuperating large percentage of waste heat through the use of an extended corresponding states (ECS) model (the ECS model is already developed, and students are only required to apply the tool).

NB: adjustments may be required according to progress, results, and project duration.

Prerequisite knowledge

1. MATLAB
2. Fluid dynamics and CFD
3. Thermodynamics