Master thesis 2 – Internship proposal
Comparing Advanced RANS Models to LES and Experiments in Ribbed Passage Heat Transfer Analysis

Background:

The utilization of artificial surface roughness, specifically in the form of ribs to enhance heat transfer, is a common practice in various engineering applications, including gas turbines and heat exchangers. These turbulence-inducing elements disrupt the flow, leading to improved convective heat transfer. There is a prevailing trend in the industry to elevate turbine inlet temperatures as a means to enhance the performance of modern gas turbine engines. This places the components of a gas turbine engine, particularly the initial moving stage blades, under exposure to gas temperatures that significantly exceed permissible metal temperature limits. Consequently, cooling techniques have been adopted to uphold acceptable airfoil temperatures and safety standards for blade longevity. Figure 1 depicts a method for cooling contemporary gas turbine blades. These blades incorporate cooling passages lined with rib turbulators, which constitute the focal point of our current project. It's worth noting that the downside of introducing such surface roughness is an increase in pressure loss. Despite extensive research on heat transfer, turbulence, and turbulent boundary layers in rough surface scenarios, the intricate physics underlying these flow phenomena continue to be a subject of ongoing investigation.

Aim:

In the past few decades there have been several experimental and numerical studies of the rib-roughened surfaces. However, the most widespread techniques adopted were based on solution of the Reynolds-Averaged Navier-Stokes (RANS) equations, where the choice of turbulence model plays a critical role in determining the accuracy of the simulations. This project aims to carry out detailed flow and heat transfer measurements and evaluate the performance of few advanced RANS models against a Large Eddy Simulation and experimental results for a rib-roughened channel flow using OpenFOAM.

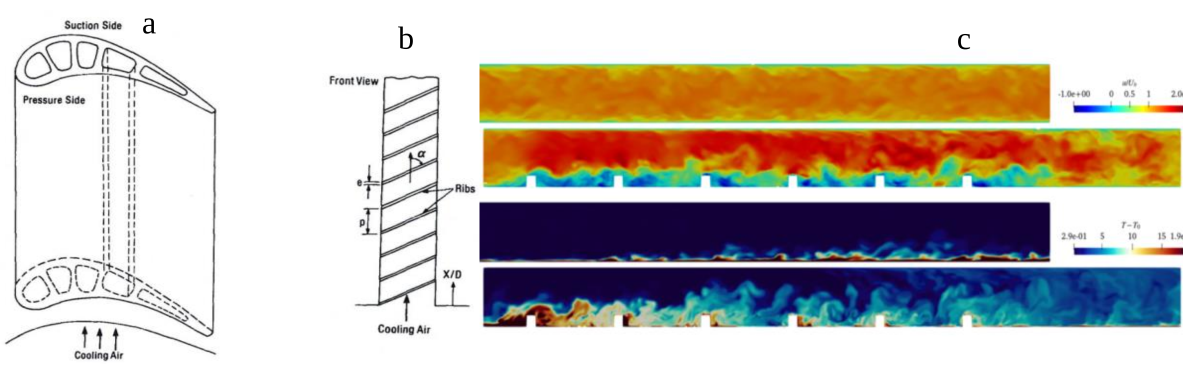

Figure 1. (a) sketch of an internally cooled turbine airfoil, (b) rectangular channel with a pair of opposite ribbed walls, (c) streamwise velocity and temperature variations through ribbed channel.

The project includes:

It involves the creation of simulation geometries for 2D/3D ribbed channels, which represent a shorter domain compared to experiments. You will conduct and investigate simulations of the flow and heat transfer in a 2D/3D rib-roughened passage using several advanced RANS turbulence models, including Eddy-Viscosity Models (EVM) and a Reynolds Stress Model (RSM). Additionally, Large Eddy Simulation (LES) will be conducted, and the results will be compared against experimental measurements. Furthermore, the effects of the rib thermal boundary condition on heat transfer will be investigated. All computations will be performed using the open-source CFD code OpenFOAM.

References:

- L. Wang, M. Salewski and B. Sunden. Turbulent flow in a ribbed channel: Flow structures in the vicinity of a rib. Exp. Therm. Fluid Sci., 34: 165-176, 2010.
- V. Baruskov, V. V. Terekhov and V. I. Terekov. Numerical simulation of a separated flow in a ribbed channel by the RANS and LES methods. J. Phys., 2039:pp. 012003, 2021.
- J. Ahn, H. Choi, and J. S. Lee. Large eddy simulation of flow and heat transfer in a rotating ribbed channel, Int. J. Heat Mass Transf., Vol. 50, pp. 4937-4947, 2007.

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