Difference Between Ribbed or Dimpled Systems

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Abstract

The purpose of this design project is to compare the heat transfer and system efficiency. The project was carried out with two different models, that is, a channel with ribs and another with dimples with numerical data at different Reynolds Numbers. The numerical study was carried out with the Flow simulation method. The result shows that for both channels with ribs and dimples there were no significant changes due to the geometry selected in this project. However, the friction factor is comparatively higher for both geometries with the lower Reynold numbers used.

Introduction

The component called turbine, as seen in Figure [1], is placed after the combustion chamber and is subjected to high temperatures.

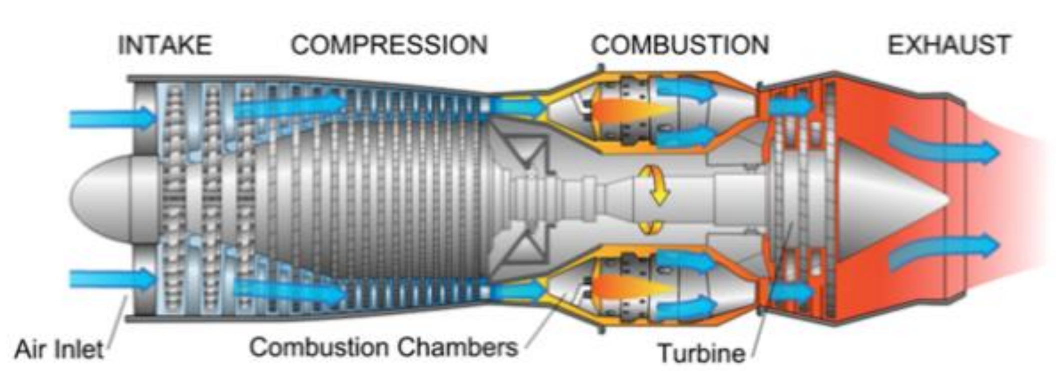

Figure 1. Gas Turbine Engine

The requirements for gas turbine engines have required Significant advances in the cooling of turbine blades.

There are many cooling techniques used in gas turbine blades, as seen in Figure 2, which consist of internal convection cooling, film cooling and external cooling. Continuous work is being done to improve cooling technology to increase gas turbine efficiency.

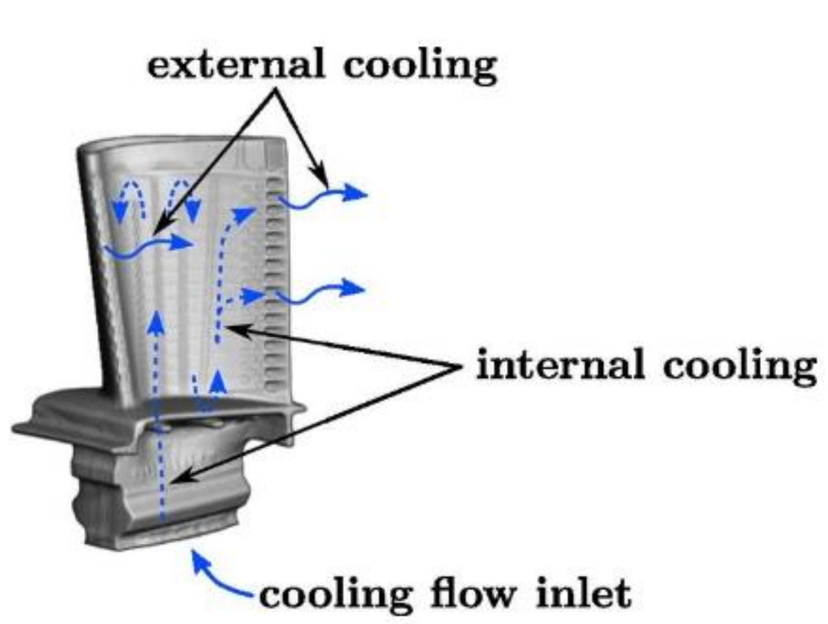

Figure 2. Gas Turbine Internal Cooling Passage

To improve the thermal efficiency of a gas turbine engine, the turbine inlet temperature is increases steadily until it produces high temperature loads on the turbine blades.

Problem

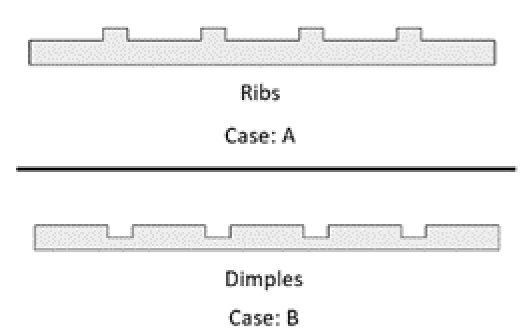

Figure 3. Rib and Dimple Configurations

Table 1:
Assumption Parameter

Re"1"=	5000	
Re"2"=	10000	
T "Solid:	1500	k
T "Inlet"=	295	K
Q=	2000	W/m^2

Design

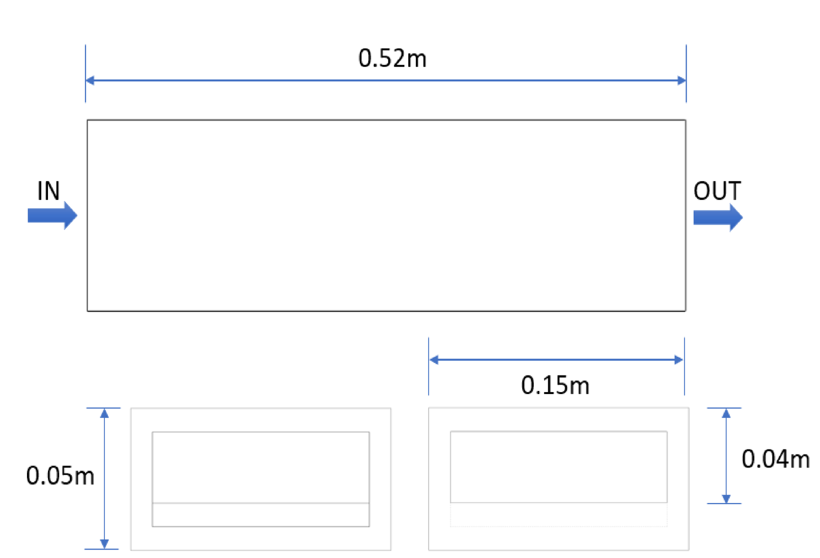

Figure 4. Dimensions of the Cooling Channel (Dimensions are in Meters)

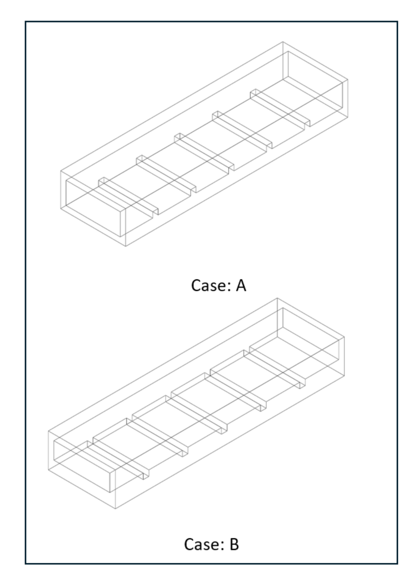

Figure 5. (Case A) Ribs, (Case B) Dimples

Methodology

- The Reynolds number is defined as:
  $$Re=\rho VDh\mu= 4\dot{m}\mu Pe$$
- Th energy input, **Q"**, and the heat transfer area, **A**.
  $$Q''=QA$$
- The local heat transfer coefficient **(h)** is defined as:
  $$h=QTS-T\infty$$
- The local Nusselt number :
  $$Nu=h\ Dhk$$
- The Nusselt number **(Nu_o)** for fully developed turbulent flow:
  $$Nuo=0.023\ Re0.8\ Pr0.4$$
- The Fanning friction factor in the ribbed canals is defined as:
  $$f=\Delta PD(LDh)(12\rho u2)$$
- The friction factor obtained for a fully developed flow in a smooth tube is expressed as:
  $$fo=0.316Re-0.25$$
- The thermal performance factor (g) is defined as:
  $$\eta=((Nu/Nuo)/(f/fo))1/3$$

Simulation

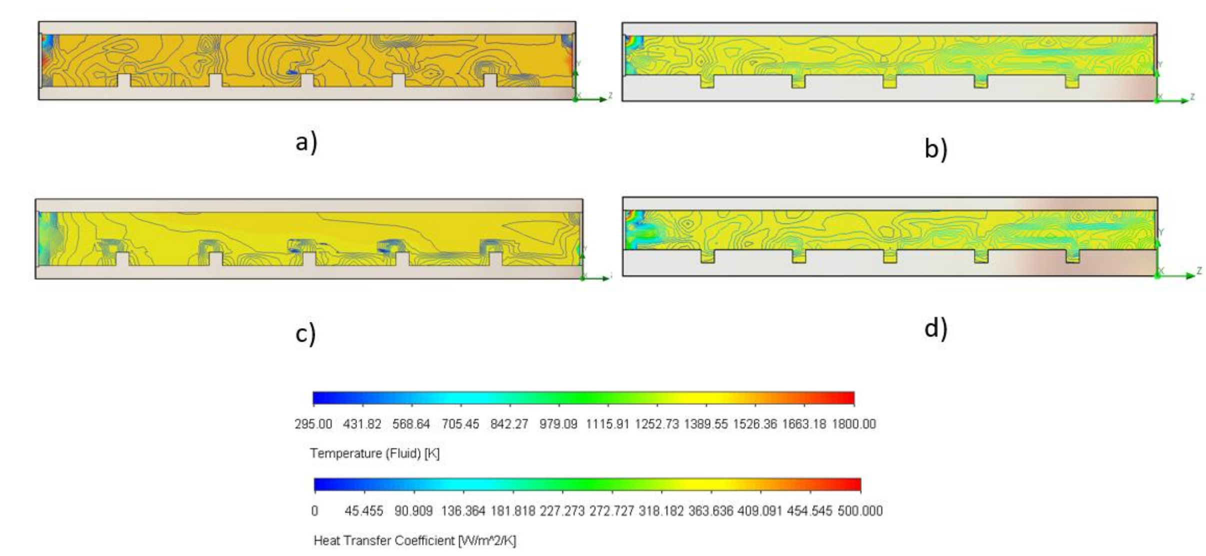

Figure 6. Temperature and Heat Transfer Coefficient Distribution along the Cooling Channels at Re=5,000 for Case A), Case B) and Re=10,000 at Case C), Case D)

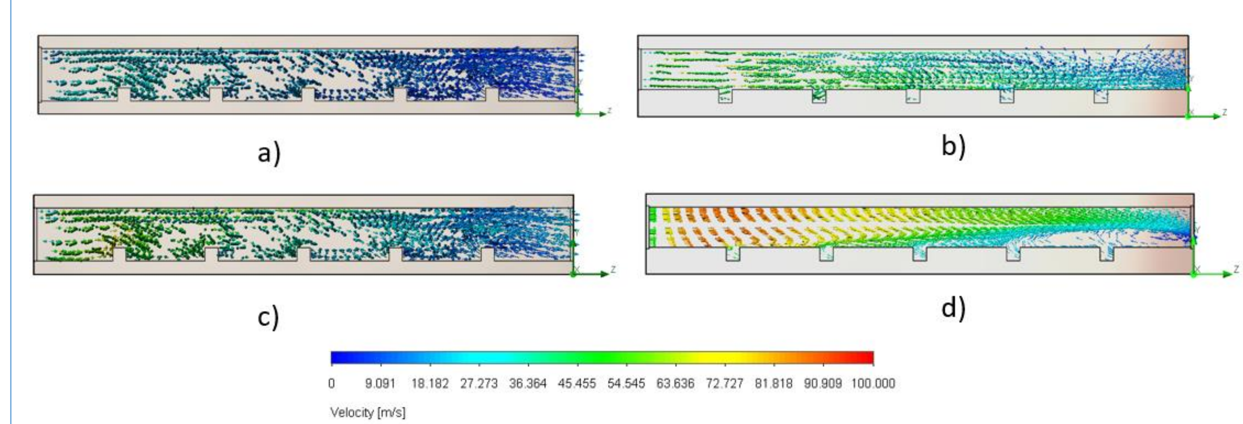

Figure 7. Velocity Distribution along the Cooling Channels at Re=5,000 for Case A), Case B) and Re=10,000 at Case C), Case D)

Conclusions

In this project we analyze the comparison of cooling channels with ribs and dimples. However, in the project it was possible to observe and analyze that there is not much difference in the channels of the different cases. In the project, two different models with two different orientations were demonstrated. The goal was to compare two channels with different internal models to analyze heat transfer and see which is more efficient when creating a design from scratch.

In the present study, the following conclusions were reached:

- With the ribbed cooling channel, we were able to see more changes in the system because it is more efficient when creating a design from scratch.
- It can be concluded that the increase in heat transfer and decrease in pressure drop depend on the geometry and aerodynamic design.
- In general, for our study, no significant change in heat transfer was observed because the geometry dimensions were very small, so the efficiency was almost the same for the different cases.

Results and Discussion

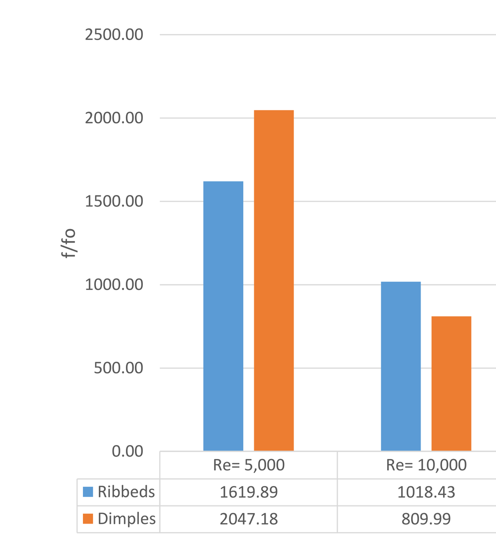

Figure 8.
Normalized Friction Factor

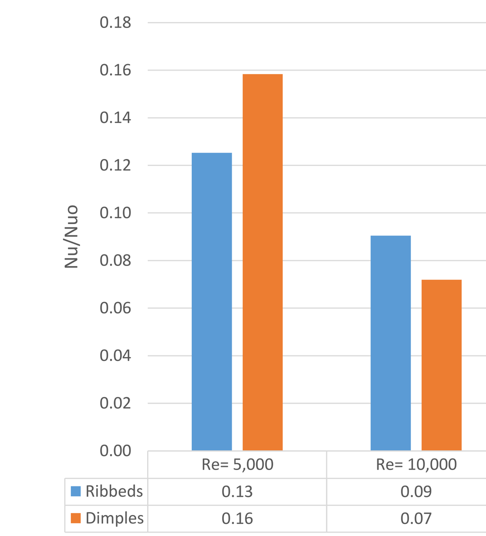

Figure 9.
Normalized Nusselt Number

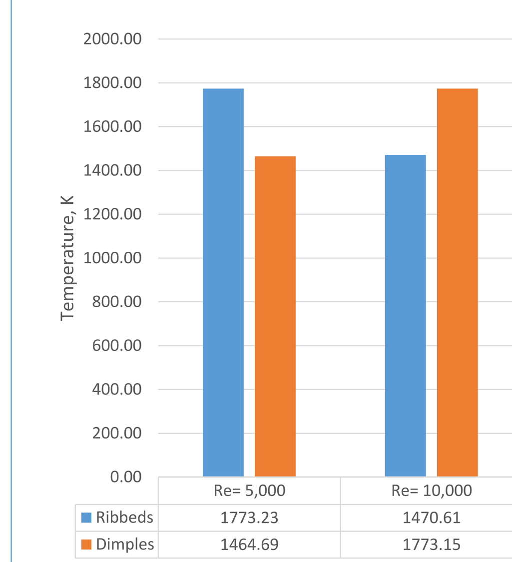

Figure 10.
Different Temperatures

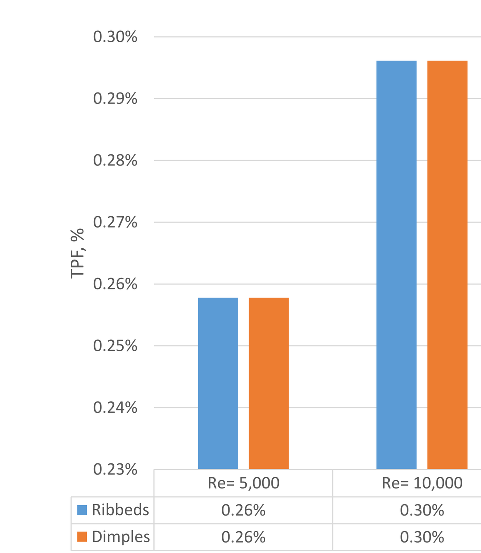

Figure 11.
Thermal Performance Factor

Future Work

- For future work I would study the two models again but with larger dimensions.
- The system will be analyzed with higher temperatures to observe if there are changes in pressure drop and efficiency.

Acknowledgements

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References

[1] Tamunobere, O. (2015). Cooling of Gas Turbine Blade and Heat Transfer and Film Cooling on a Gas Turbine Blade and Shroud. 1.
[2] Saravani, M. S., Amano, R. S., DiPasquale, N. J., & Halmo, J. W. (2020). Turning guide vane effect on internal cooling of two-passage channel with parallel ribs. Journal of Energy Resources Technology, 142(9). [Online] Available: https://doi.org/10.1115/1.4046731