LARGE EDDY SIMULATION OF HEAT TRANSFER IN RIBBED COOLING DUCTS

Máté Márton Lohász, Hungary
Supervisors: Prof. C. Benocci & Prof. P. Rambaud
Promoter: Assoc. Prof. G. Kristóf (Budapest University of Technology and Economics, Hungary)

The present research was about the Large-Eddy Simulation of the fully developed heat transfer in high blockage ribbed ducts. Two geometries were investigated: square sectioned ducts ribbed with perpendicularly and with 45 inclined square sectioned ribs respectively. The ribs - producing a 0:3 blockage of the duct - are placed successively at streamwise pitch distance of 10 rib height. The flow with the bulk Reynolds number of 40000 and Prandtl number of 0:7 was investigated applying uniform heat flux at each wall of the duct and using periodicity condition with a pitch length distance in the streamwise direction. The flow was investigated by four different sub grid scale stress modeling approaches by making use of approximately half million cells. The first and second order velocity statistics were validated to an extensive experimental database. The temperature distribution at the wall is compared to existing measurements as well.

These validations justified the applicability of the computational result for further analysis. The topology of the flows was described by various visualization techniques highlighting the differences appearing because of the different rib inclinations. It was found that the flow in the duct with perpendicular ribs was of the type of ribbed channel flow with the additional influence of the sidewalls of the duct, and that the inclined ribs were generating a secondary streamwise spiraling motion in the entire duct.

The heat transfer phenomenon was investigated by comparing the heat transfer enhancement maps with the flow reattachment/separation lines. Both correlation and deviation between these quantities were found and explained. Also the divergence of the different heat fluxes inside the two different ribbed ducts was highlighted clarifying the importance of turbulent and convective heat transfer. Finally a conditional averaging technique was proposed to quantify the behavior of the coherent structures in the flow. Probability of the vortices was shown highlighting the importance of vortices around the two differently aligned ribs. Conditional streamlines were applied at a particular position as an example to shed light on the different motion of vortices than average fluid. The concept of pressure and temperature deviation was introduced and used to show the importance of vortices in the production of pressure and temperature fluctuations. It was found that vortices mainly create negative pressure fluctuation, which is in agreement with the expectations and showed the usefulness of the methods. Furthermore positive temperature fluctuation of the vortices were found for the particular case of the inward heat flux investigated, which emphasize the importance the role of the vortices in turbulent heat transfer.

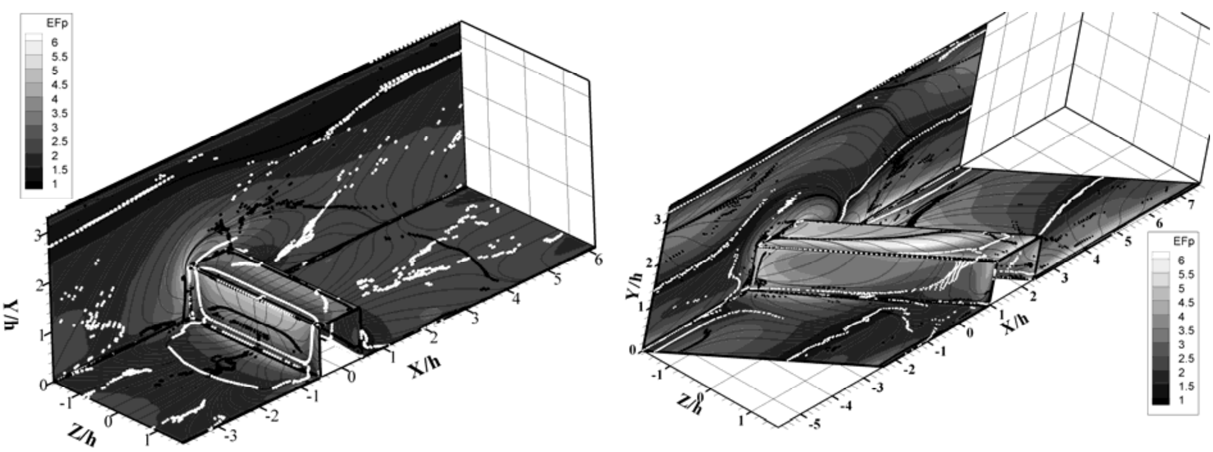

Figure 1: Heat transfer enhancement factor contour plots depicted together with bifurcation lines on the walls of two internal cooling duct geometries