Simulation strategies and grid dependence study in steady incompressible flow in ribbed channels with heat transfer

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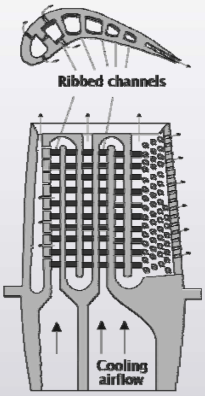
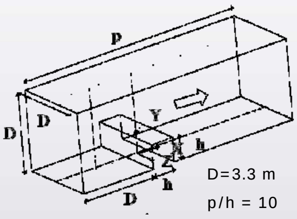


Turbulent momentum and heat over ribbed surfaces are of the great interest in the understanding of separated turbulent flow and in turbomachinery applications. The interest is motivated by the need to find the optimal geometry for the ribbed ducts which perform internal cooling of turbine blades.
Even if the flow is strongly three-dimensional, it is interesting, as a preliminary step, to make some simulations in 2D.
Several meshes have been studied and compared before present simulations. But in this work, the target is to find differences between results obtained on different kinds of meshes.
In present case the fine mesh is the result of adaption the coarse one. This adaption has been made with one of the Fluent options –Iso Value Adaption-.This method considers inserting maximum and minimum values for the temperature residuals.
In addition, a 3D mesh will be introduced using LES.



D=3.3 m
p/h = 10
h/D =0.3

NUMERICAL MODEL

To solve the steady incompressible flow within a ribbed channel with heat transfer next equations system has been used:

Reynolds-averaging equations:

$$\nabla \overline{U}_i = 0$$

$$\frac{\partial \overline{U}_i}{\partial t} + \overline{U}_j \cdot \frac{\partial \overline{U}_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial \overline{P}}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\frac{\mu}{\rho}\frac{\partial \overline{U}_i}{\partial x_j}\right) + \frac{\partial\left(-\overline{u_i' u_j'}\right)}{\partial x_j}$$

$$\frac{\partial \overline{T}}{\partial t} + \overline{U}_j \cdot \frac{\partial \overline{T}}{\partial x_j} = \frac{\partial}{\partial x_j}\left(\frac{\mu}{\Pr}\frac{\partial \overline{T}}{\partial x_j}\right) + \frac{\partial\left(-\overline{T' u_j'}\right)}{\partial x_j}$$

Transport equation standard k-ε model

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k \overline{U}_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M + S_k$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon \overline{U}_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon$$

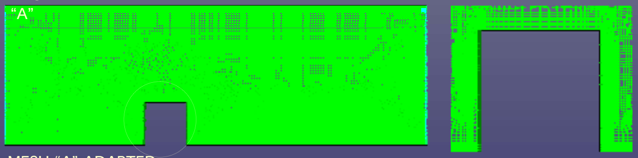
SIMULATION SETUP

Solver:	SEGREGATED 2-D dp
Formulation algorithm:	IMPLICIT
Modelo de turbulencia:	K–ε; Realizable; Enhanced Wall Treatment
Discretization models:	Presión → Second Order Pressure-Velocity Coupling → SIMPLE Momentum; Energy→ 2nd Orden Upwind Turbulent Kinetic Energy → 2nd Orden Upwind Turbulence Disipation Rate→ 2nd Orden Upwind
Fluid:	Air
Density:	Constant, 1 Kg/m3
Molecular viscosity:	Constant, 8.33e-5 Kg/m s
Material:	Plexiglas
Boundary Conditions:	Periodic Condition (mass flow rate= 3.33 Kg/s ; T_{bulk}=293
Heat flux:	10 w/m²
Reynolds Number:	40000
Prandtl Number:	0.8

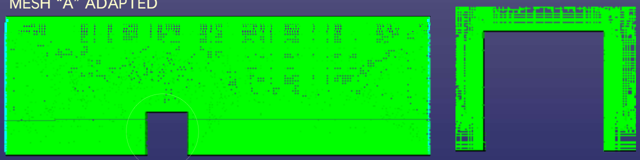
TESTED MESHES

Several different meshes has been simulated in 2D. But most outstandings are meshes A and B. In addition mesh A has been adapted through Iso-Value-Adaption using temperature residuals.

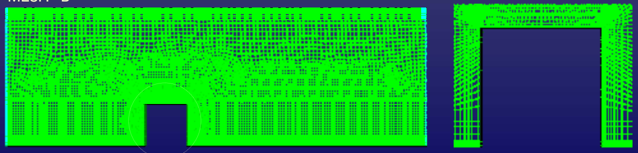
MESH "A"



MESH "A" ADAPTED



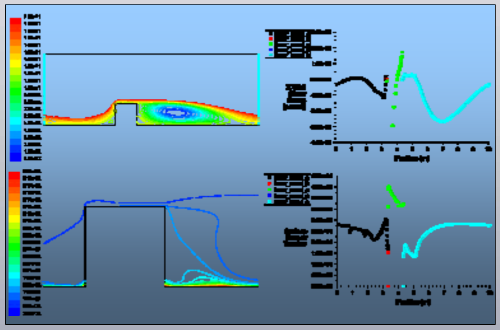
MESH "B"



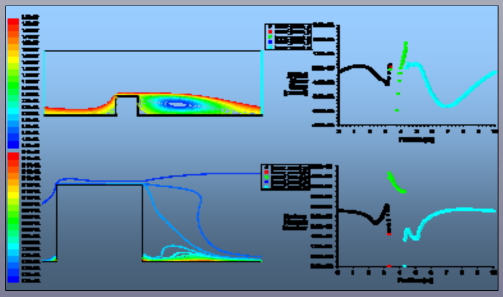
NUMERICAL RESULTS

Local Nusselt number and wall shear stress have been obtained close to the rib.
The simulation results for different meshes are presented.

MESH "A"



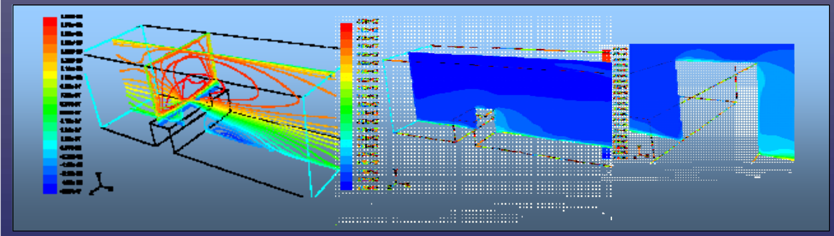
MESH "A" ADAPTED



Variations in the size of the recirculation zone has been detected. This size can be stablished using the wall shear stress downstream of the rib. The local Nusselt number is influenced by the size of recirculation

Actually, a 3-D geometry using Large Eddy Simulation (LES) is being simulated. The numerical results obtained up to now have been compared with experimental PIV data.
A good agreement have been obtained and differences lower than 10% in the recirculation size can be observed

3-D LES



In conclusion, for the cases analyzed, 3-D LES model provides a more detailed flow description.
However, a 2-D simulation allows to obtain global results with enough accuracy and lower computational cost.