Code_Saturne/SYRTHES coupling validation on a RIBS exchanger

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Introduction

- Heat exchangers **optimization** using *Code_Saturne* [1] and SYRTHES open sources codes developed by EDF R&D
- Validation of *Code_Saturne*/SYRTHES **coupling**, important in the optimization chain

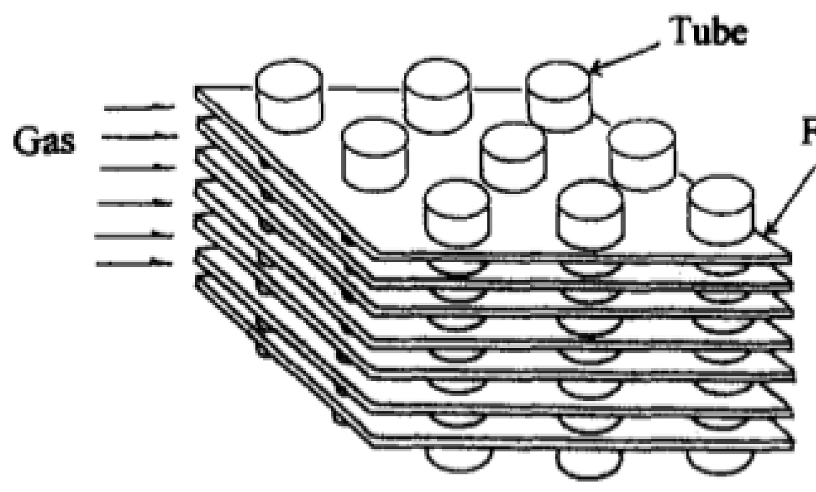


Figure 1: Schematic plate-fin tube heat exchanger (from Jang et al. [2])

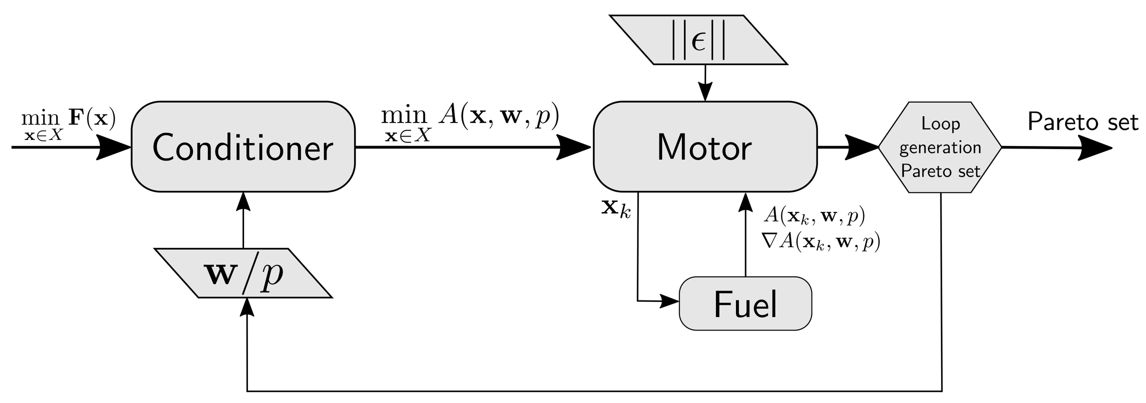


Figure 2: Optimization chain: Code_Saturne and SYRTHES included into Fuel *module.*

Case study: 2D ribs

- Experimental data from Wang and Sunden [3, 4]
- Effect of **periodic squared ribs** on the heat transfer trough heated squared canal

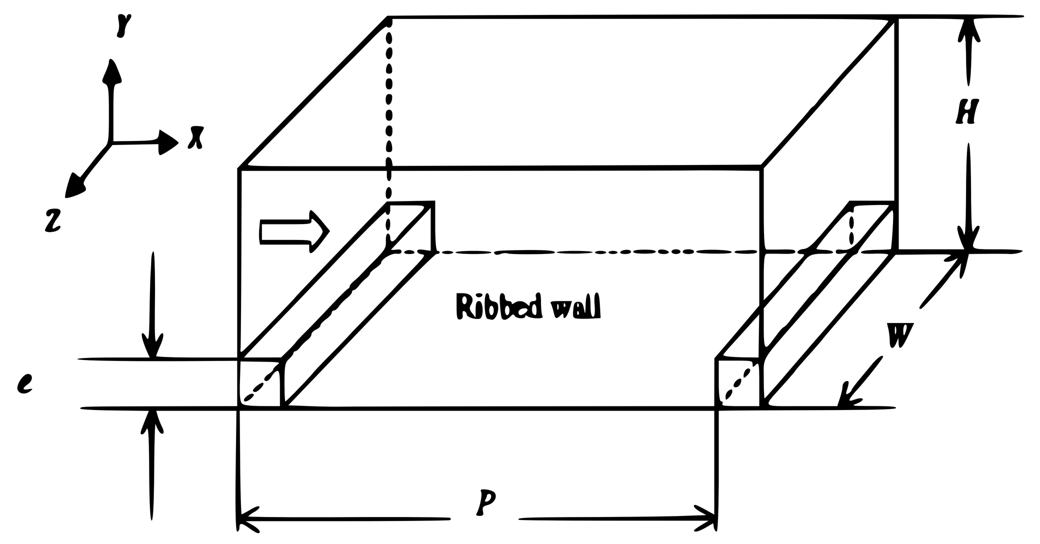
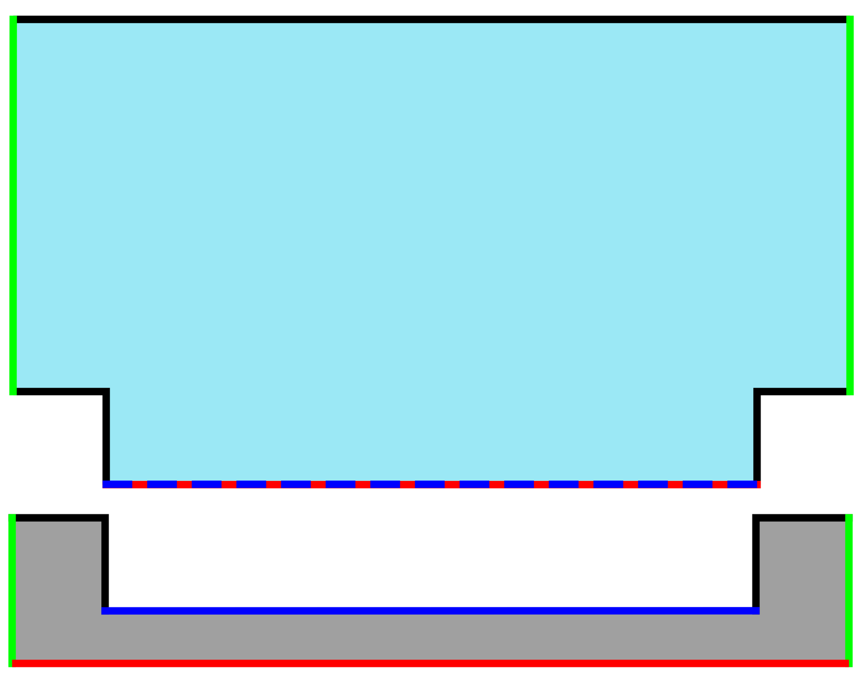


Figure 3: Case dimension: $H = 50$ mm, $W = 50$ mm, $e = 7,5$ mm et $p = 12e = 90$ mm.

Data formatting

- Only one pattern: **geometrical periodicity**
- **2D ribs**: one *fluid-only* case and one *fluid-solid* case



Color	Type
Black	Wall, $\phi = 0$
Red	Heated Wall
Green	Periodicity
Blue	Coupling

Figure 5: Boundary conditions.

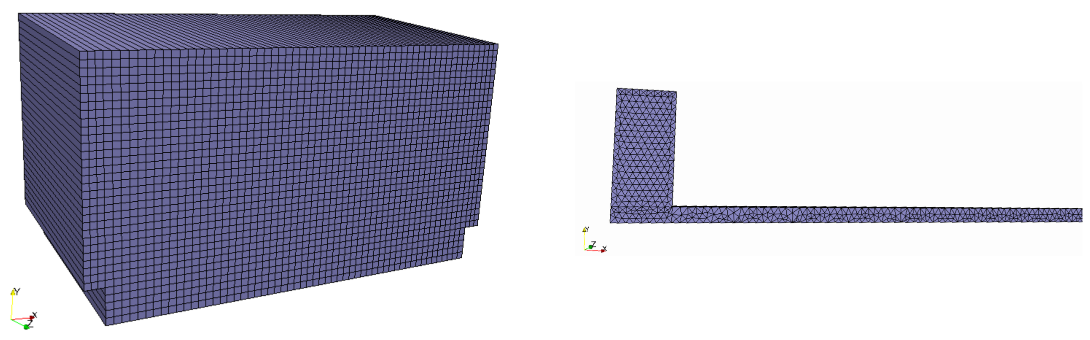


Figure 4: Structured mesh for the fluid domain and unstructured for the solid domain.

On the case *without* coupling, the fluid domain is heated with a constant flux. For the coupling case, the constant flux is replaced by the face by face coupling between fluid and solid. To be coherent to the experiment, the ribs and the top wall are adiabatic. The periodicity boundary involves physical and geometrical periodicity.

Source term

- The **physical periodicity** involves: $\widetilde{T}_{inlet} = \widetilde{T}_{outlet}$ and $\widetilde{p}_{inlet} = \widetilde{p}_{outlet}$
- Variable change (for T) through a source term adding in *Code_Saturne*:

$$div(\rho \mathbf{u} c_p \widetilde{T}) = -div(\mathbf{Q}_{\widetilde{T}}) - \rho c_p a_T u_x$$

with

$$a_T = \frac{\dot{q}(L-2l)}{\rho c_p \sum_i u_{x,i}\Omega_i}$$

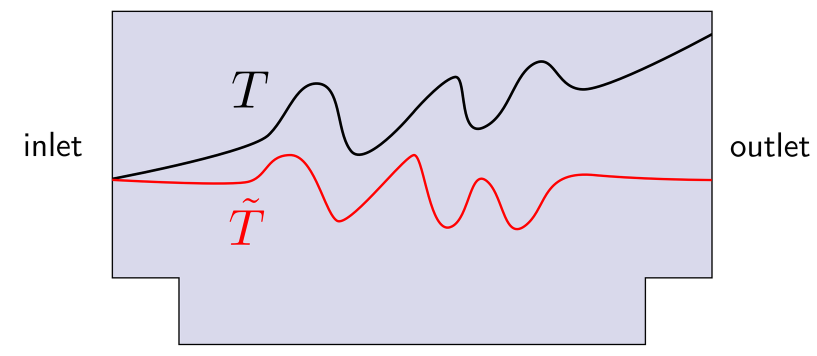


Figure 6: Sketch of the variable change: the shifted temperature $\widetilde{T}$ is solved instead of T.

Results

- **Fluid-only simulations**: turbulence model sensitivity is carried out available in *Code_Saturne*
- **Fluid-solid simulations**: EBRSM turbulence model is compared to fluid-only and experimental data

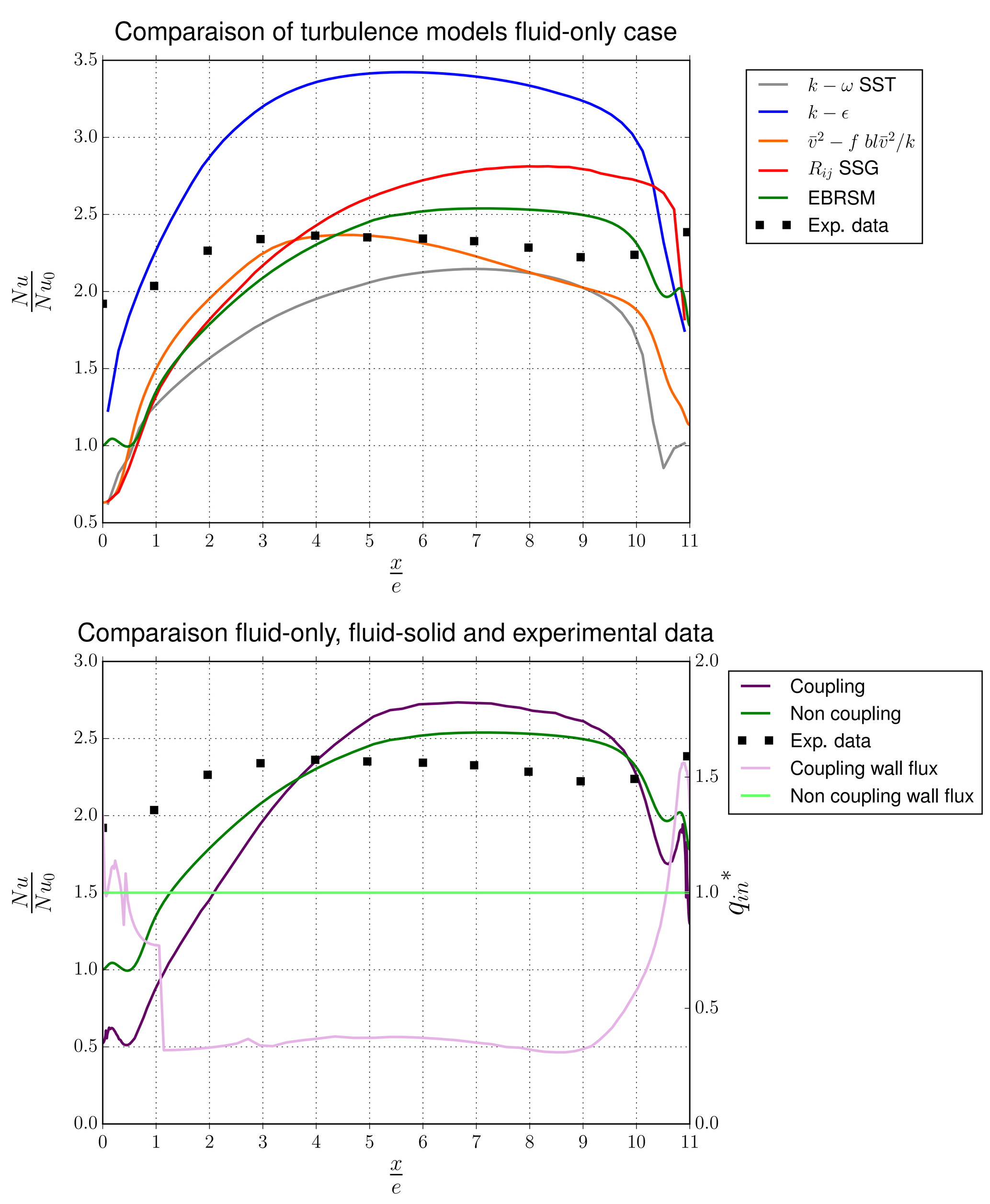


Figure 7: Dimensionless Nusselt number against $\frac{x}{e}$ ratio.

Using *Code_Saturne* user define functions, local Nusselt number is computed:

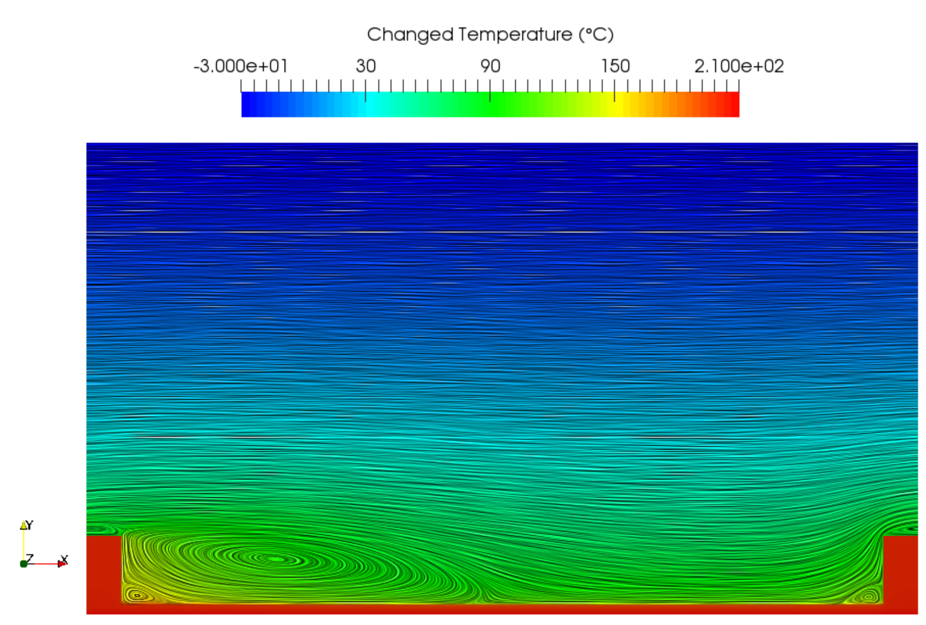


Figure 8: Streamlines coloured by the temperature.

$$Nu_x = \frac{\dot{q}_{fac,x} D_H}{(\widetilde{T}_{fac,x} - \widetilde{T}_{bulk,x})\lambda}$$

with

$$\widetilde{T}_{bulk,x} = \frac{\int_{S_x} \widetilde{T}_x \rho \mathbf{u} \cdot \mathbf{dS}}{\int_{S_x} \rho \mathbf{u} \cdot \mathbf{dS}}$$

and, gived by the wall condition $\widetilde{T}_{fac,x} = a_P + b_P \widetilde{T}_x$ and $\dot{q}_{fac,x} = a_P^f + b_P^f \widetilde{T}_x$.
The Nusselt number is dimensionless by the Nusslet number for a plane plate $Nu_0 = 0.023 Re^{0.8} Pr^{0.4}$.

Regards to the complexity of the physics, the results are in good agreement with the experimental data, EBRSM model being the best.

References

[1] EDF R&D. 2015. URL: http://www.code-saturne.org.

[2] Jiin-Yuh Jang, Mu-Cheng Wu, and Wen-Jeng Chang. "Numerical and experimental studies of threedimensional plate-fin and tube heat exchangers." In: *International Journal of Heat and Mass Transfer* 39.14 (1996), pp. 3057–3066.

[3] L. Wang and B. Sunden. "Experimental investigation of local heat transfer in a square duct with continuous and truncated ribs." In: *Experimental Heat Transfer* 18 (2005), pp. 179–197.

[4] L. Wang and B. Sunden. "Experimental investigation of local heat transfer in a square duct with various-shaped ribs." In: *Heat and Mass Transfer* 43 (2007), pp. 759–766.

Acknowledgement

Thanks to the EDF R&D team, who helped me using the codes.