Heat exchanger multi-scale modelling using *Code_Saturne*

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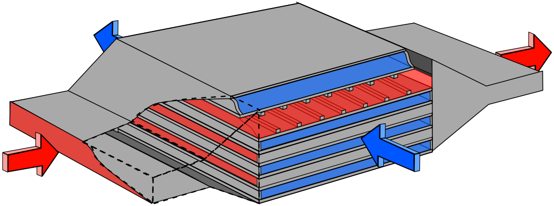
Plan

Heat exchanger is multiscale



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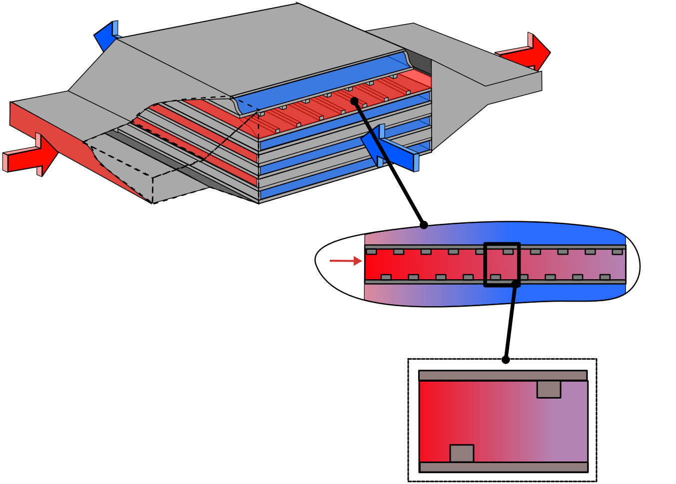

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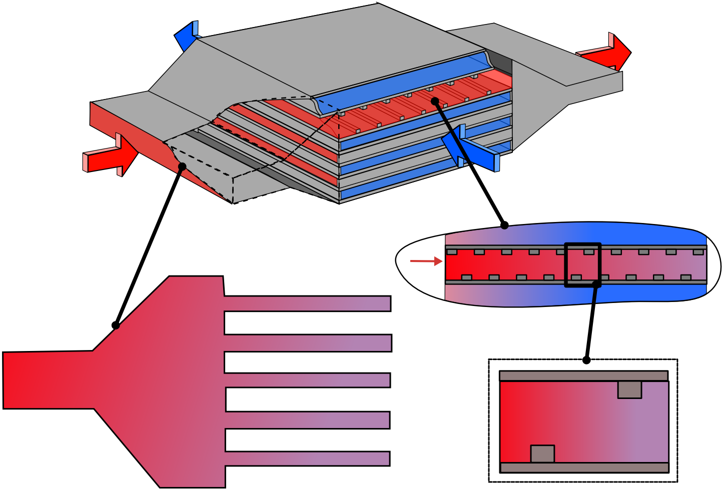

How to model it ?

- **Full CFD**
  - Difficult and expensive
- **CFD pattern and Integral method (NTU)**
  - Cheaper but too many hypothesis
- **CFD pattern and CFD distribution**
  - Can handle thermal transfer and distribution issue
  - Called **multi-level approach**

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HEX multi-scale using *Code_Saturne*

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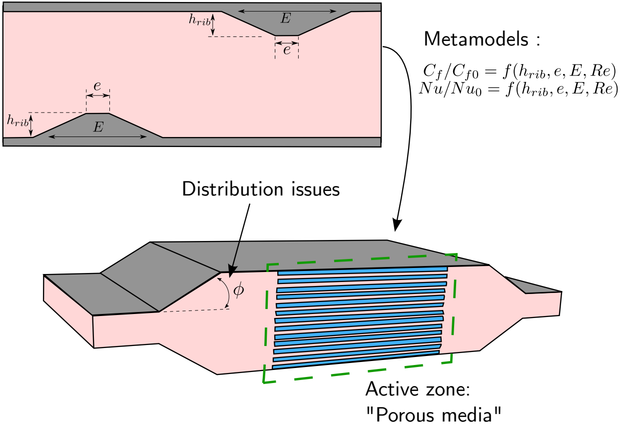
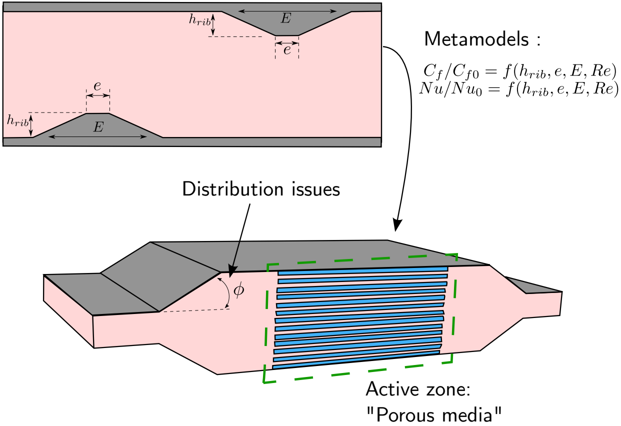
Multi-level approach



Nu and C_f in each channel depend on the mass flow rate (*Re*)



Nu and C_f in each channel depend on the mass flow rate (*Re*)

How to do this with *Code_Saturne* ?

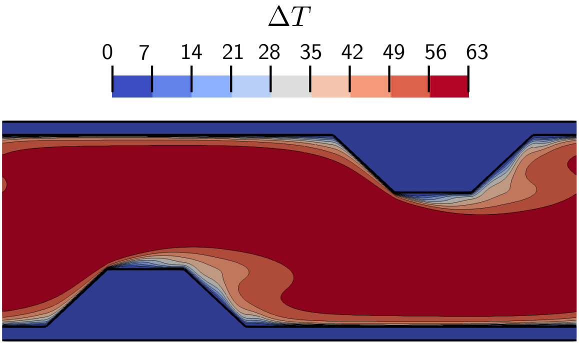
Internal Coupling and metamodelling

Plan

Pattern modelling

HEX multi-scale using *Code_Saturne*

Motivation
Metamodel
Multi-level
Results
Conclusions

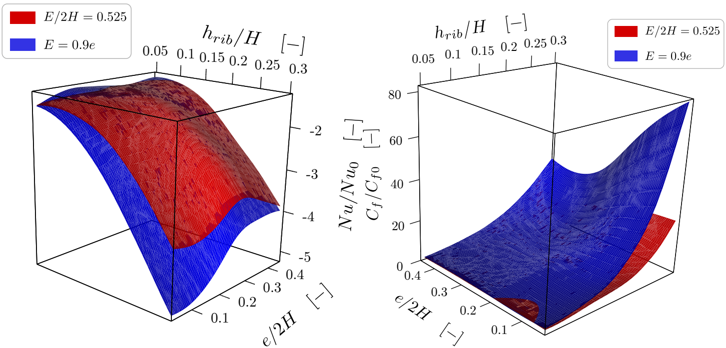


- Periodic conditions
- Internal coupling
- $BL - \bar{v}^2/k$ model
- 2 dimensional

$$Nu = \frac{\dot{q}\ D_H}{\lambda(T_{wall} - 0.5(T_{in} + T_{out}))}$$

$$C_f = \frac{\Delta P_{in,out}}{0.5 \rho {U_{deb}}^2} \frac{D_H}{L}$$

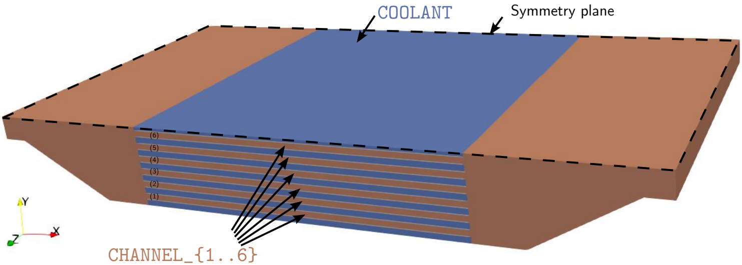
Interpolation by kriging using a design of experiments with 48 observations for *Nu* and 139 observations for C_f



Response surfaces for Re = 8000

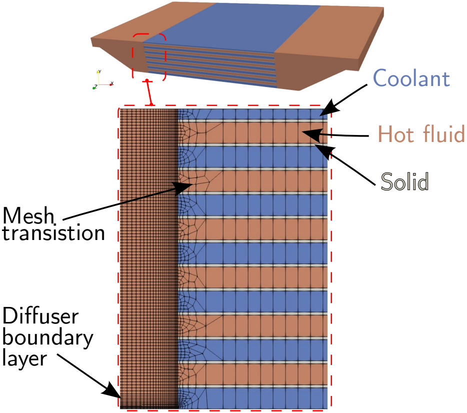
Plan

Heat exchanger geometry



- **Air/Water crossflow**
- Symmetry
- 6 hot channels
- 6.5 cold channels
- 12 solid plates
- Crossflow :
  - Coolant $(-\vec{Z})$
  - Hot $(\vec{X})$

Mesh



$\simeq$ 3 000 000 cells

Heat transfer and pressure loss coefficient overloaded on active part:
only one cell on the channel width to have mean quantities

Metamodels plugging

Code_Saturne user files to change

Pressure losses

- `cs_user_zone.c`
- `cs_user_head_losses.c`

Heat transfer coefficient

- `cs_user_source_terms.f90`
- `cs_user_extra_operations.c`

Pressure losses

`cs_user_zone.c`

Define the zones where apply the head losses

- `CHANNEL_1` to `CHANNEL_6`
- `COOLANT`

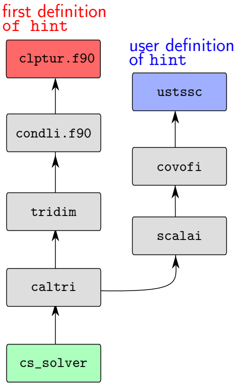
`cs_user_head_losses.c`

$$cku[iel] = 0.5\frac{C_f}{D_H}||\vec{V}[iel]||$$

with C_f given by the **metamodel** and Dittus-Boelter

Heat transfer coefficient - hint

How is it calculated ?



cs_user_source_terms.f90: ustssc

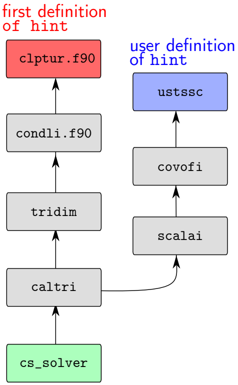
For each CHANNEL_{1..6}

- Compute *Re* at the outlet
- Call the **metamodel** $\rightarrow$ *Nu*
- Compute hint
- getfbr to select interface faces
- Overload hint using cs_ic_set_exchcoeff

cs_user_extra_operations.c

Define a syscall function used cs_user_source_terms.f90 to call the metamodel

How is it calculated ?



`cs_user_source_terms.f90: ustssc`

For each `CHANNEL_{1..6}`

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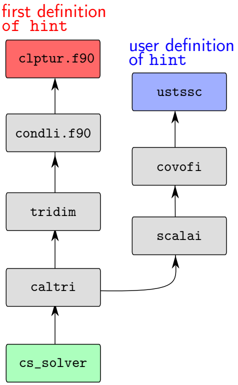

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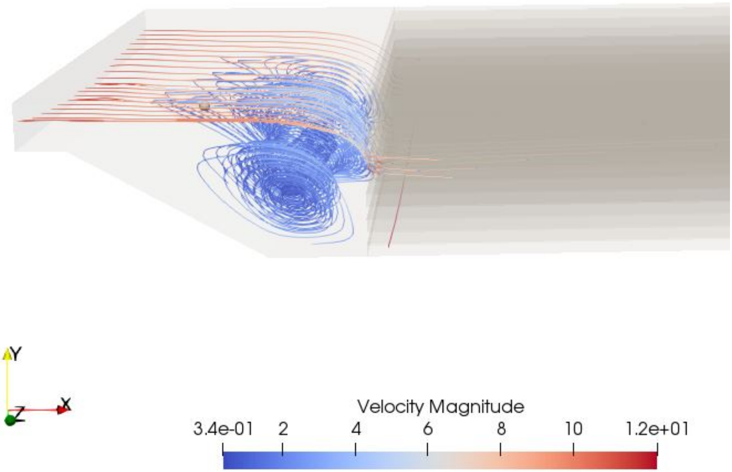
Velocity and pressure fields

HEX
multi-scale
using *Code_Saturne*



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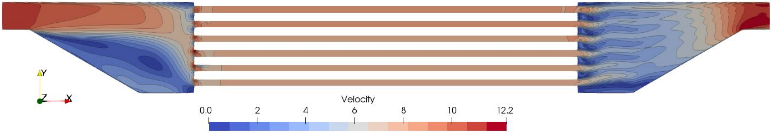
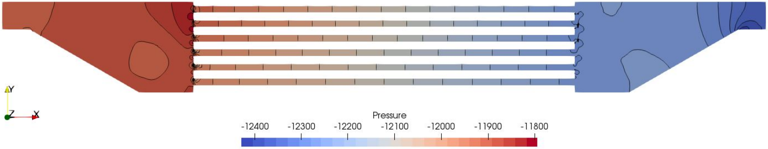
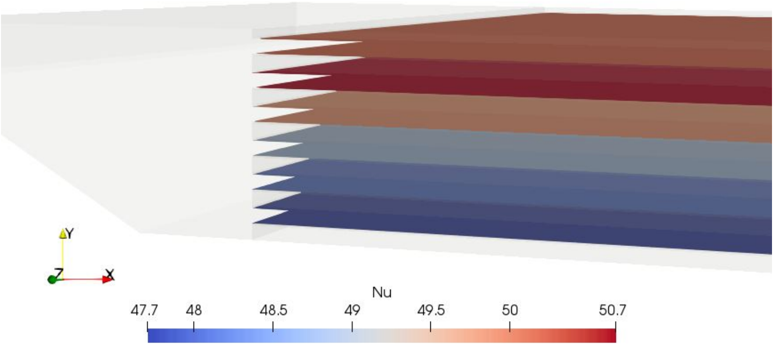




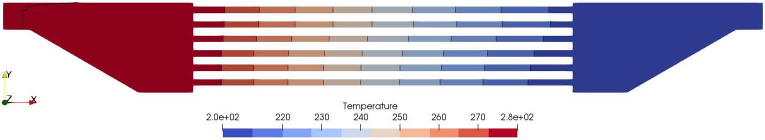
CHANNEL	1	2	3	4	5	6
$U\ [m.s^{-1}]$	7.46	7.56	7.74	8.0	8.31	8.2
$Re\ [-]$	6800	6900	7000	7400	7580	7470
$Nu\ [-]$	47.7	48.0	48.7	49.9	50.7	50.2
$C_f.10^2\ [-]$	19.47	19.50	19.53	19.61	19.66	19.63

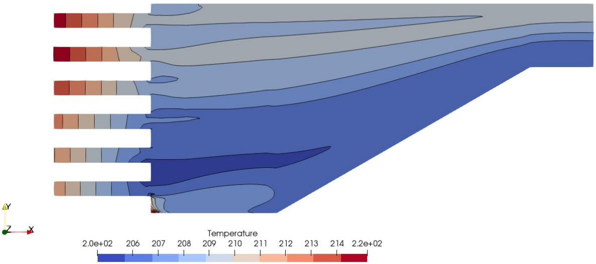
Settings verifications

CHANNEL	1	2	3	4	5	6
Nu [−]	47.7	48.0	48.7	49.9	50.7	50.2



Temperature field





Heat exchanger performances

	Effec. [−]	ΔP_{tot} [Pa]
NTU method	0.588	311
Multi-level CFD	0.40	347

- CFD-ΔP_{tot} higher due to the diffuser
- NTU-Effectiveness higher due to homogeneous behaviour hypothesis

Plan

Conclusions

Conclusions

- Can predict the performances
- Deal with distribution issues

Work in progress

- Optimization based on this multi-level approach
- Extend the `hint` trip to model fouling by adding a thermal resistance at each face

Thanks for your attention

Questions?