Conjugate Heat Transfer of Cooling Channels

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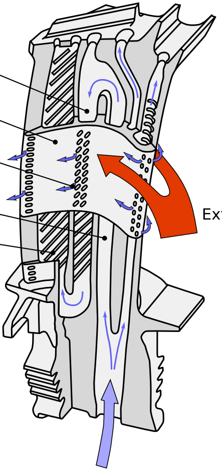
COPA-GT project meeting, January 7, 2012
Doctoral Presentation

Section Outline

Turbomachinery Cooling



Goal of the PhD project

- Conjugate Heat Transfer of cooling channels in a turbine blade using LES
- Why Conjugate Heat Transfer ?
- Why LES ?

Conjugate Heat Transfer

HT Modes

- Conduction
- Convection
- Radiation

Dealing with CHT

- Uncoupled
- Conjugate
- Coupled

!

Time scales vary by orders of magnitude

Coupling methods

$$\boxed{\mathit{fluid}} \underset{T}{\overset{q_{wall}}{\rightleftarrows}} \boxed{\mathit{solid}} \qquad \boxed{\mathit{fluid}} \underset{T}{\overset{h,\, T_{fluid}}{\rightleftarrows}} \boxed{\mathit{solid}}$$

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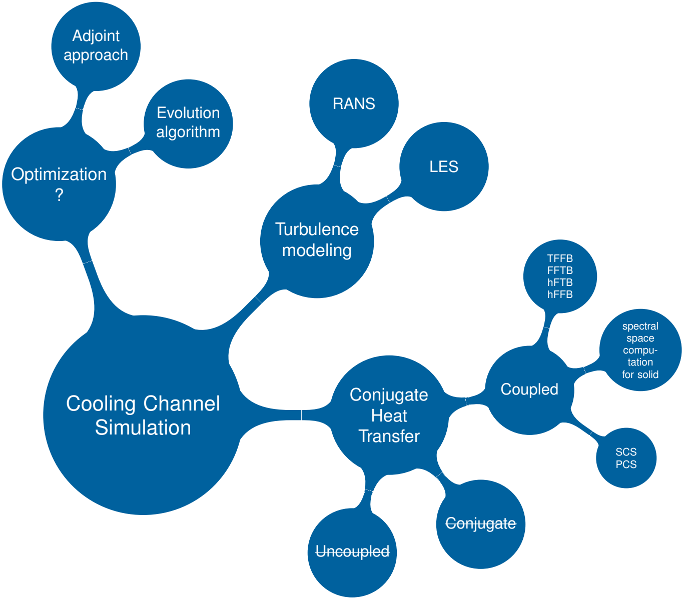
Section Outline

Objectives


Adjoint approach
Evolution algorithm
Optimization ?
RANS
LES
Turbulence modeling
TFFB
FFTB
hFTB
hFFB
spectral space compu-tation for solid
Coupled
SCS
PCS
Cooling Channel Simulation
Conjugate Heat Transfer
~~Conjugate~~
~~Uncoupled~~

COOLFluiD 3

Kernel

- Simulation environment focused on complex multi physics
- Component-based architecture, object oriented, generic
- https://coolfluid.github.com (LGPLv3 license)

Discretization

- UFEM, RDM, Spectral-FDM
- Compr. Euler and NS, incompr. NS, Conduction

Component for the Cooling Channel Simulation

- Further techniques: expression templates to build a Domain Specific Language (DSL)
- This DSL was developed by using the library Boost::Proto

Continuity equation

$$A_{pu_i} = \int_{\Omega_k} \left(\mathbf{N}^T \left(\nabla \mathbf{N} \right)_i \right) \mathrm{d}\Omega_k$$

DSL code example

```
_A(p,u[_i]) += transpose(N(p)) * nabla(u)[_i]
```

Achievements

What did we do ?

- Introduction to COOLFluiD 3
- In order to make coupling possible: restructuring both the component we are working with and the DSL

What are the next steps ?

- Implementing stable coupling procedures for LES
- Perform simulations of CHT with RANS and LES
- Comparison of the results with existing VKI experiments

References

- T. Banyai et. al. *A Fast Fully-Coupled Solution Algorithm For The Unsteady Incompressible Navier-Stokes Equations.* CMFF, 2006
- B. Janssens et. al. *Discretization of the Incompressible Navier-Stokes Equations using a Domain Specific Embedded Language.* 9th National Congress on Theoretical and Applied Mechanics, 2012
- T. Verstraete. *Multidisciplinary Turbomachinery Component Optimization Considering Performance, Stress, and Internal Heat Transfer.* Universiteit Gent, PhD Thesis, 2008

Section Outline

Training Sessions

- VKI-LS: Introduction to CFD
- VKI-LS: Introduction to LES
- VKI-LS: Optimization
- VKI-RM: 2D Boundary Layers
- VKI: Internal Seminar and PhD Symposium
- Turbomeca: Maintenance Course on Helicopter Engines
- Chalmers University: Hybrid LES techniques
- Udacity: Introduction to Computer Science
- Udacity: Programming Languages
- Coursera: Heterogeneous Parallel Programming
- Stanford University - Coursera: Scientific English
- French Course, Level B1 (09/2012 - 06/2013)

01-06/2012

- VKI-LS: CFD
- VKI-LS: LES
- VKI-LS: Optimization
- VKI-PhD: Symposium
- Seminar: Programming in CF3
- Maintenance Course MAKILA 2

07-12/2012

- VKI-RM: 2D Boundary Layers
- Chalmers Univ.: LES
- Udemy: Advanced C++
- Udacity: Intro to CS
- Udacity: Programming Languages
- Udacity: Debugging
- Coursera: Parallel Programming
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- French, Level B1