Conjugate Heat Transfer of Cooling Channels

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Doctoral Presentation

Section Outline

Scientific Training

VKI Lecture Series on CFD

- Introductory course on CFD
- Basic discretization
- Basic turbulence modeling

VKI Lecture Series on LES

- Introduction to LES with theory and applications
- Interaction of numerical schemes with LES
- DES, ILES and Immersed Boundary for LES

Scientific Training

VKI Lecture Series on Optimization

- Introduction to Optimization for Engineering
- Discussion of single and multi-objective optimization
- Recent developments of optimization procedures
- Applications

Training through research

- As part of a research team

Technical and Complementary Training

Participated

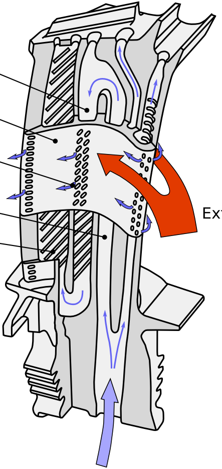
- VKI PhD Symposium: poster presentation
- Internal doctoral seminar at VKI: programming techniques

Planned training

- COPA-GT training sessions
- Language course
- Secondment -> suggestions ?

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

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

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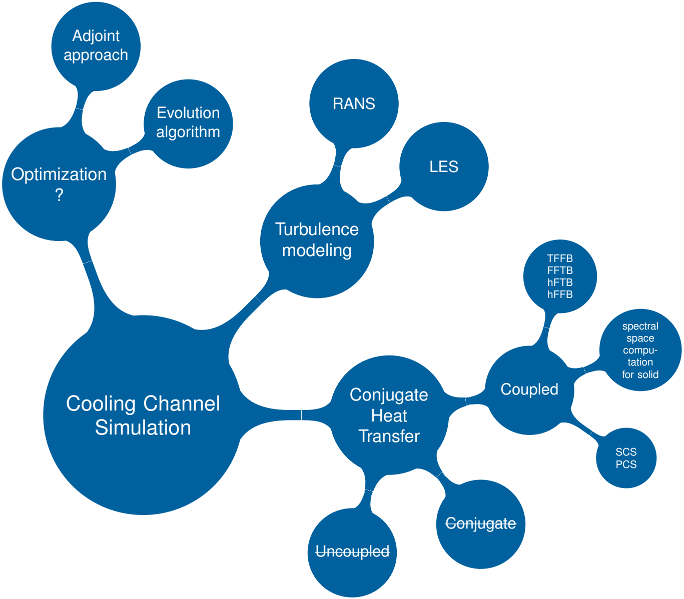
Section Outline

Objectives


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

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