OpenFOAM for turbomachinery applications

Olivier Petit and Håkan Nilsson
Chalmers University of Technology

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Aim of the project

- Develop and validate useful tools for turbomachinery applications.
- Contribute to the community by releasing case-studies through the Turbomachinery working group.
- Gather all the experience and use the different tools available to compute the U9 Kaplan turbine from the inlet pipe until the draft-tube.
About the OpenFOAM Turbo Wg

• Initiated at the Second OpenFOAM Workshop in Zagreb, June 2007.

• Steering committee: Maryse Page, Martin Beaudoin (Hydro-Québec) and Håkan Nilsson (Chalmers)

• Homepage: OpenFOAM Wiki: http://openfoamwiki.net/index.php/Sig_Turbomachinery

• Code sharing: A branch of the OpenFOAM-extend project on SourceForge.net: http://openfoam-extend.svn.sourceforge.net/viewvc/openfoam-extend/trunk/Breeder_1.5/OSIG/TurboMachinery/

• Contact: openfoam-extend-turbowg@lists.sourceforge.net

• Portal: http://extend-project.de/user-groups/11/viewgroup/groups
Contributions to OpenFOAM Wiki

• Developments
  • Descriptions of contributed solvers, utilities and libraries
• Tutorials
  • How to implement (new application, boundary condition, turbulence model)
  • Cylindrical coordinate systems
  • turboPerformance functionObject
• Howtos: mergeMeshes, GGI, MRFSimpleFoam, etc..
• Validation test cases
  • ERCOFTAC conical diffuser
  • Dellenback Abrupt Expansion (in turbulenceWG wiki)
  • ERCOFTAC centrifugal pump
  • Single-channel pump
  • Timisoara swirling flow test rig
• List of Publications
The ERCOFTAC centrifugal pump case-study

- The centrifugal pump has 7 impeller blades, 12 diffuser vanes and 6% vaneless radial gap. The pump operates on air, and at constant rotational speed of 2000 rpm.

How to get the cases

- Need OpenFOAM-1.5-dev + developments available in Breeder branch on OpenFOAM-extend

- [http://openfoamwiki.net/index.php/Sig_Turbomachinery_/_/ERCOFTAC_centrifugal_pump_with_a_vaned_diffuser](http://openfoamwiki.net/index.php/Sig_Turbomachinery_/_/ERCOFTAC_centrifugal_pump_with_a_vaned_diffuser)

- How to do a full check-out of all the ERCOFTAC centrifugal pump files:
  
  `svn checkout`  

- How to update: `svn update`

- How to commit: `svn commit`
Meshes

- The mesh was generated with ICEM-HEXA and exported in the Fluent mesh format. The rotor and stator were meshed separately.
- 93886 hexa cells, Average Y+ value is around 40.
- 2D model and 3D model are available
ECPMixerGgiFvMesh2D Case study

- 2D test case
- The transientSimpleDyMFoam solver is used and GGI interface couples the rotor and stators
- Physical rigid motion of the mesh

<table>
<thead>
<tr>
<th>OpenFOAM version</th>
<th>1.5-dev</th>
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<tr>
<td>Solver</td>
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<td>kEpsilon</td>
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<td>Boundary conditions</td>
<td>Inlet U, k, ε profile1DFixedValue</td>
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<td>Outlet k, ε zeroGradient</td>
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• The physical motion of the mesh allows unsteady visualisation of the wakes by generating a movie.
ECPMixerGgiFvMesh2D Case study - results

radial relative velocity

radial velocity

angle

0 0.5 1 1.5 2

0.5

0.25

0.2

0.15

0.1

0.05

0

-0.2

-0.4

-0.6

-0.8

-1

tangential relative velocity

angle

0 0.5 1 1.5 2

-0.2

-0.4

-0.6

-0.8

-1
The Timisoara Swirl Generator case-study

• Designed to create the draft tube flow features of a Francis turbine operating at part load

• Create a detailed measurement database to understand and better control the precessing vortex rope in the draft tube

• Develop OpenFOAM as the future first choice for industrial CFD in water turbine applications (create tutorials, validate new implementations useful for Turbomachinery applications)
The Timisoara Swirl Generator case-study

• Need OpenFOAM-1.5-dev + developments available in Breeder branch on OpenFOAM-extend. Available as well for OpenFOAM 1.6-ext.

• [http://openfoamwiki.net/index.php/Sig_Turbomachinery_/_Timisoara_Swirl_Generator](http://openfoamwiki.net/index.php/Sig_Turbomachinery_/_Timisoara_Swirl_Generator)

• How to do a full check-out of all the Timisoara Swirl Generator files:
  
svn checkout

• How to update: svn update

• How to commit: svn commit
The Timisoara Swirl Generator case-study

- Four leaned strouts
- 13 guide vanes
- Free runner with 10 blades
- Convergent divergent draft tube
- Free spinning runner (torque=0), 920 rpm
Computational domain and OpenFOAM setup

- 2.8 Millions cells, block-structured hexahedral mesh
- Boundary condition at the inlet: plug-flow with nominal discharge 30 l/s
- 920 rpm (for which the runner spins freely in OpenFOAM)
- Unsteady simulation using k-ε turbulence model
Comparison between designed and computed velocity profiles

Section 1

Section 2
Comparison between experimental and computed velocity profiles

Axis 0

Axis 1

Axis 2
Visualisation of the vortex rope
The U9 Kaplan turbine

- Prototype located in Porjus, consist in a Kaplan turbine.
- Designed to be able to perform detailed measurements on a real scale turbine/generator unit.
- 1:3.1 scale model of the U9 turbine is set up at Vattenfall Research and Development in Älvkarleby.

U9 unit, Porjus, Sweden

U9 scale model, Älvkarleby, Sweden
Goals of the U9 project

• Create a detailed measurements database that can be used to validate future numerical simulations. Berhanu Mulu and Pontus Jonsson (Luleå, Sweden) are responsible of this side of the project.

• Investigate the impact on the flow of the curved pipe at the inlet of the spiral casing.
Impact of the inlet pipe on the flow
On-going simulations

22 M block-structured hexahedral mesh with six GGI interfaces, generated with ICEM
Thank you very much for your attention!

The ERCOFTAC Centrifugal pump case-study, developed for the 4th OpenFOAM workshop, can be found at: http://openfoamwiki.net/index.php/Sig_Turbomachinery/ERCOFTAC_centrifugal_pump_with_a_vaned_diffuser

The Timisoara Swirl Generator case-study, developed for the 5th OpenFOAM Workshop, can be found at: http://openfoamwiki.net/index.php/Sig_Turbomachinery_/Timisoara_Swirl_Generator

The Turbomachinery working group website is located at: http://openfoamwiki.net/index.php/Sig_Turbomachinery