Review on the thermal stability of Accelerator Superconducting Magnets,

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Transfer from the coils to the helium heat sink

Rob van Weelderen (CERN), Maciej Chorowski and Slawomir Pietrowicz (WUT)

Outline

- Framework of the CERN/WUT collaboration
- Numerical Approach
- Status of experimental equipment

Framework of the CERN/WUT collaboration

Within the framework of K944/AT/LHC *Cooperation on operational safety for the LHC cryogenic system. Addendum No 2. Article 3: Part III Heat transfer flow from the magnet structure to the helium after resistive transition*, between CERN and Wroclaw University of Technology:

1. Analysis of heat extraction from the magnet is made. This effort has evolved into a direction which is more generally applicable than to resistive transitions only.
2. A cryostat for performing measurements of the heat transfer to and heat propagation in superfluid pressurized helium is designed and fabricated.

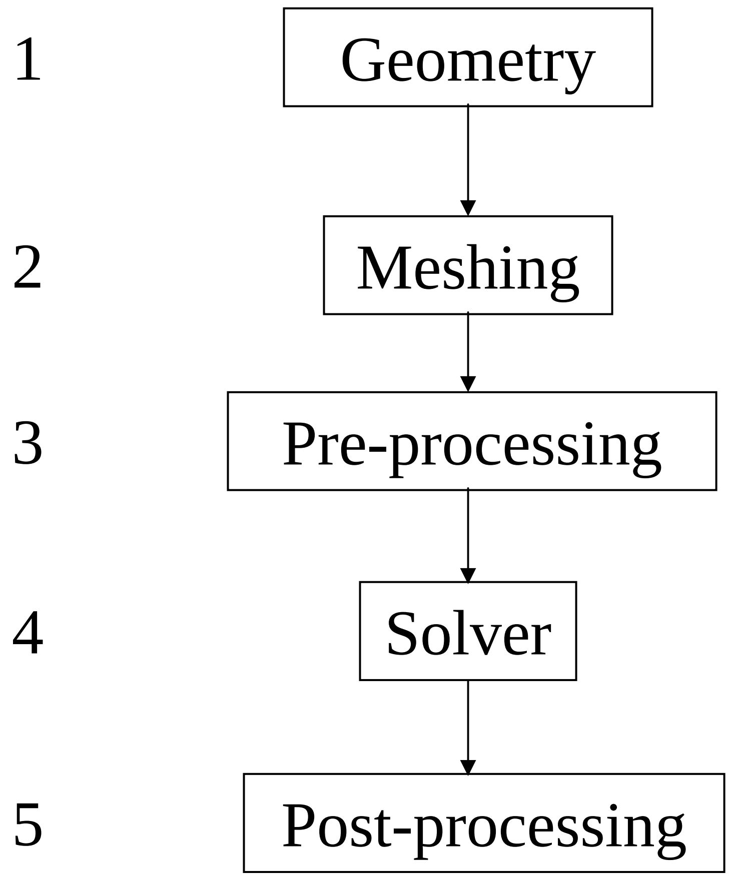
Numerical Approach: goals

The goals of the present work are to provide a numerical code which:

- Models the heat transfer throughout the whole magnet cold mass structure and the helium it contains with the exception of the heat transfer processes specific to the superconducting cable itself.
- Treats fluid hydro & thermodynamics in the same time as thermal conduction through solids.
- Can model magnets cooled in pool boiling-, supercritical- and pressurized superfluid helium.
- Can solve steady state and transients.
- Can use heat deposition data as function of geometry and time (i.e. Fluka results).
- Can use arbitrary heat transfer correlations specific to the accelerator magnet case.
- Is generic. I.e. in order to facilitate possibilities for long term use and development, the code should not be linked to a specific institute’s environment, and use as much as possible widely available software.

Numerical Approach: steps

The 5 steps of numerical solution



The whole processes can be solved in ANSYS Software

Numerical Approach: the CFD software

The software available at Wrocław University of Technology

Meshing:

– ANSYS ICEM v10.0;

Pre – processing, solver, post – processing:

– ANSYS CFX v10.0

CFD tool

CERN

The properties of Helium - Hepak

The possibility of creation the *.rgp (real gas properties) files which can be used in ANSYS CFX software

Properties of Helium

Numerical Approach: steps 1 & 2 Geometry and Meshing process

The geometry can be made with several CAD programs

Extension of file	Main Software
*.tin, *.x_t, *.x_b, *.sat, *.model, *.ipa, *.ipr, *.sur, *.idi, *stp, *.iges, *.step	IGES, ParaSolid, CATIA, ProEngineering, Unigraphics, Solid Edge, ACIS® Geometric Modeler
*dwg, *.dxf	AutoCAD

Numerical Approach: steps 3 pre-processing (1/2)

Importing mesh → Definition of simulation type → The domains which can be used during simulation →

Existing meshes generated with a wide range of analysis packages or ANSYS CFX products can be imported into ANSYS CFX-Pre. The volume mesh can contain *hexahedral*, *tetrahedral*, *prismatic* and *pyramidal* element types.

The Simulation Type form is used to specify the simulation as ***steady state*** or ***transient***

ANSYS CFX-Pre uses the concept of domains to define the type, properties and region of the ***fluid***, ***porous*** or ***solid***.

Domains are regions of space in which the equations of fluid flow or heat transfer are solved.

Numerical Approach: steps 3 pre-processing (2/2)

Boundary Conditions

Boundary Conditions must be applied to all the bounding regions of domain(s). Boundary Conditions can be ***inlets***, ***outlets***, ***openings***, ***walls*** and ***symmetry planes***; periodic interfaces are specified on the Domain Interfaces form.

- Normal Speed
- Cartesian Velocity
- Cylindrical Velocity
- Static Pressure
- Total Pressure
- Mass Flow Rate

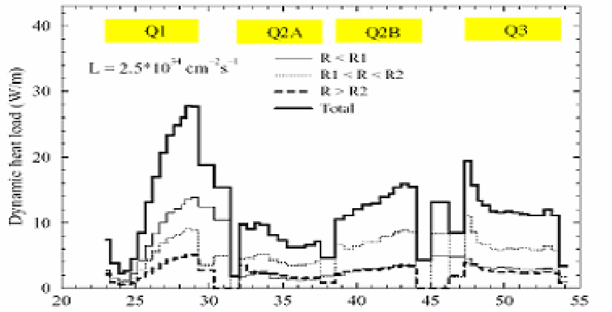
- Average Static Pressure
- Fluid Velocity (inhomogeneous)
- Normal Speed (homogeneous)
- Cart. Vel. Components (homogeneous)
- Cyl. Vel. Components (homogeneous)
- Bulk Mass Flow Rate
- Static Pressure
- Degassing Condition (inhomogeneous)
- Supercritical

Wall

If heat transfer is modelled, the following options are available for wall modelling:

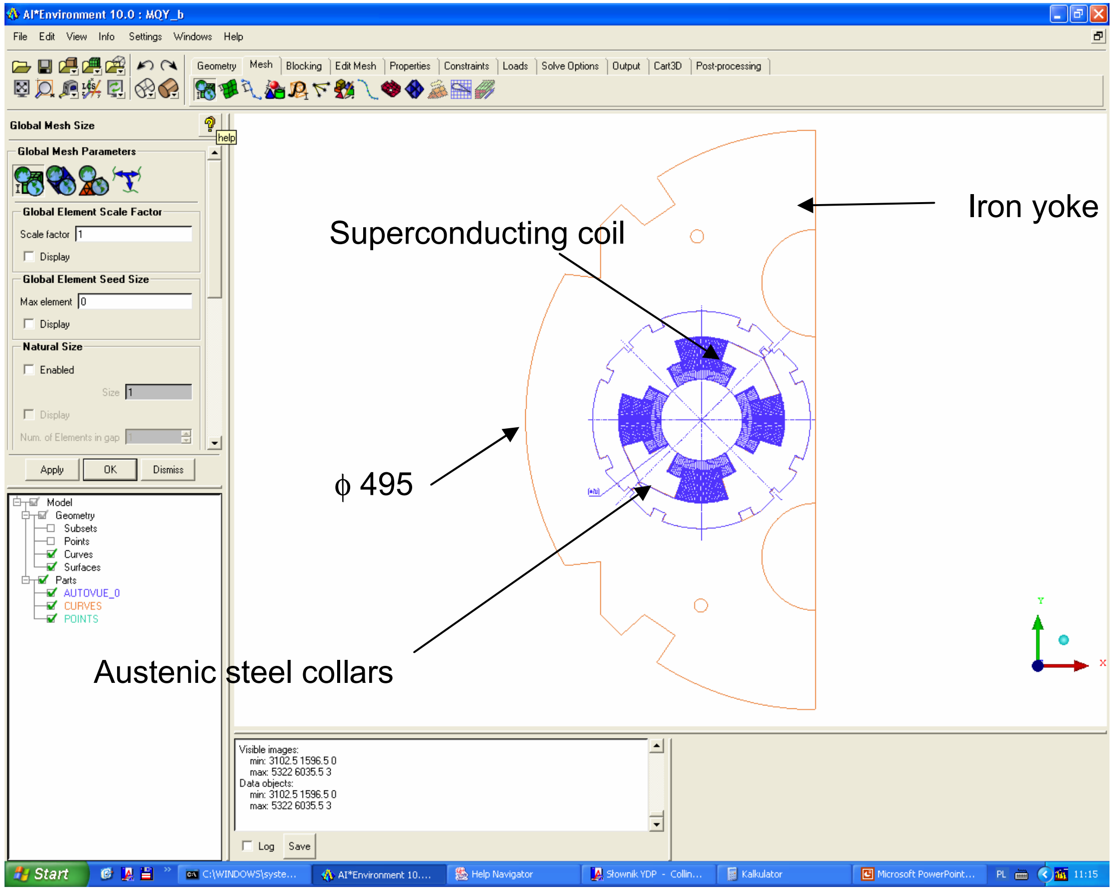
- Adiabatic Fixed Temperature
- Heat Flux ←
- Heat Transfer Coefficient
- Fluid Dependent (when using the Inhomogeneous model)

Energy decomposition



This boundry condition could, for example be applied in selectected areas of magnets

Numerical Approach: trial example MQY magnet



Cross-section of MQY magnet (central part)

Main parameters of the MQY magnet

Coil inner diameter	70
Magnetic lenght	3.4 m
Operating temperature	4.5 K
Nominal gradient	160 T/m

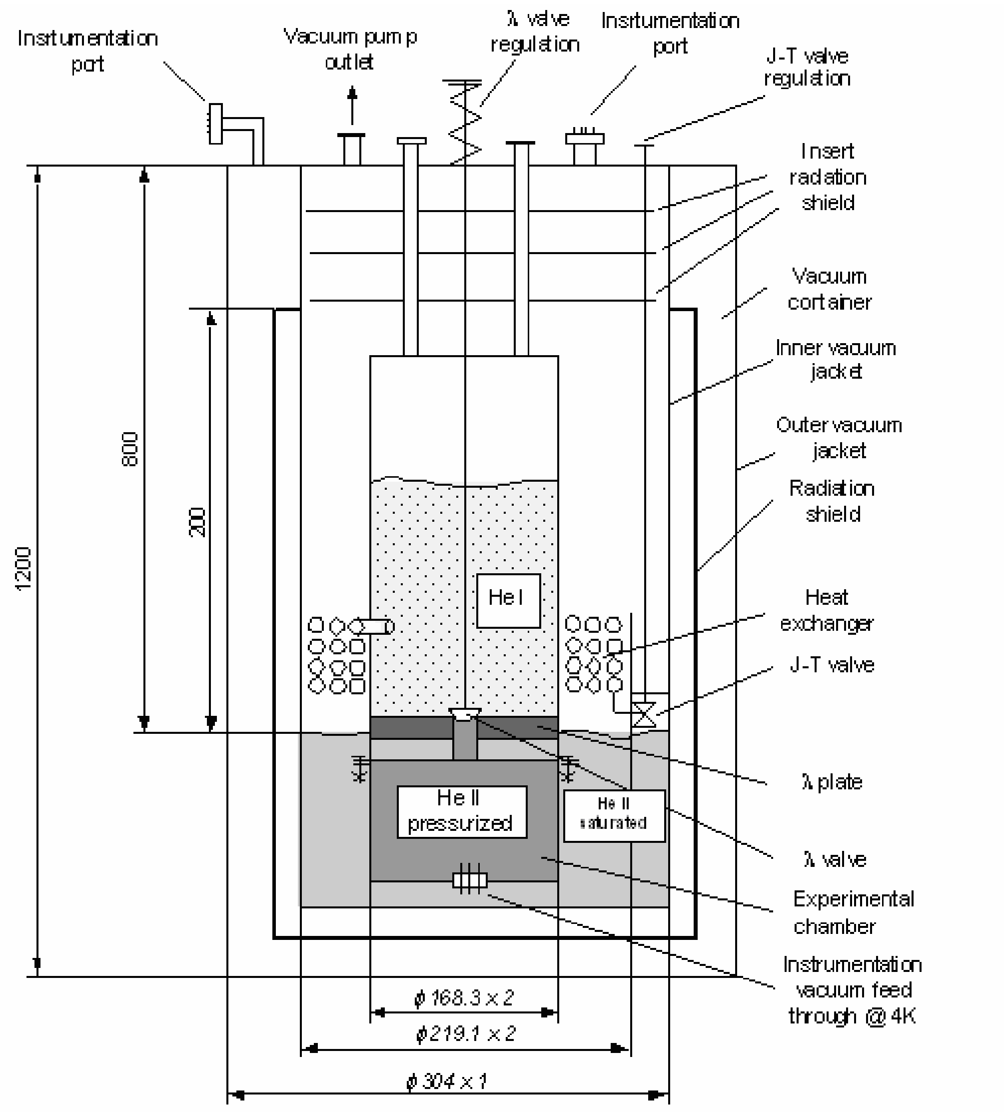
The thermal phenomena in MQY magnet (the tasks)

- Conduction in solid materials (coil, collar, yoke) with respect to the changes of properties as a function of temperature;
- Thermal contact conductance between superconducting coil and collars, or collars and yoke
- The thermal – hydraulic processes in helium (heat transfer between the solid elements and helium (He I, He II))
- The dissipation energy in beam pipe and superconducting coils

Numerical Approach: status

- Helium properties have been integrated
- Superfluid helium conduction module under development
- code comparison with analytical & literature data has started
- Trial examples, like the MQY magnet, are being explored

Experimental equipment: status (1/2)



A cryostat for performing measurements of the heat transfer to and heat propagation in superfluid pressurized helium is designed and fabricated.

The design is based on the so-called Claudet bath principle.

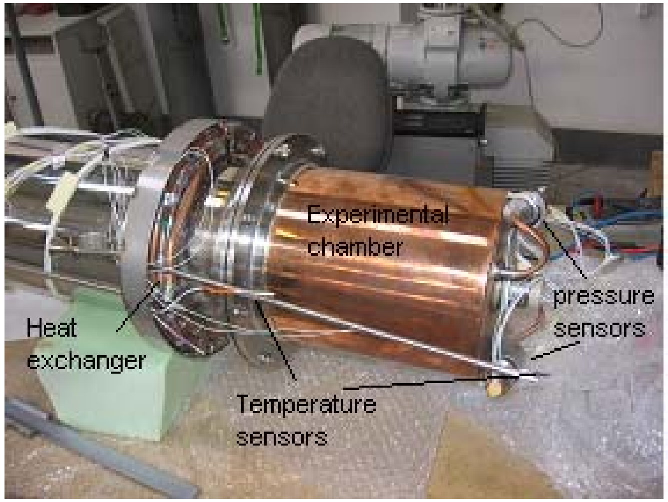
Experimental equipment: status (2/2)

The vacuum container was assembled and leak tested in May 2006.

The insert was assembled and leak tested in June 2006.

The instrumentation was verified August 2006

The functional performance of the complete system was done August 2006.



Conclusions

Numerical code:

•Helium properties have been integrated.

•Superfluid helium conduction module under development.

•code comparison with analytical & literature data has started.

•Trial examples, like the MQY magnet, are being explored.

•Follow-up by CERN specialists required. Proposed stay of WUT collaborator for some months at CERN beginning of 2007.

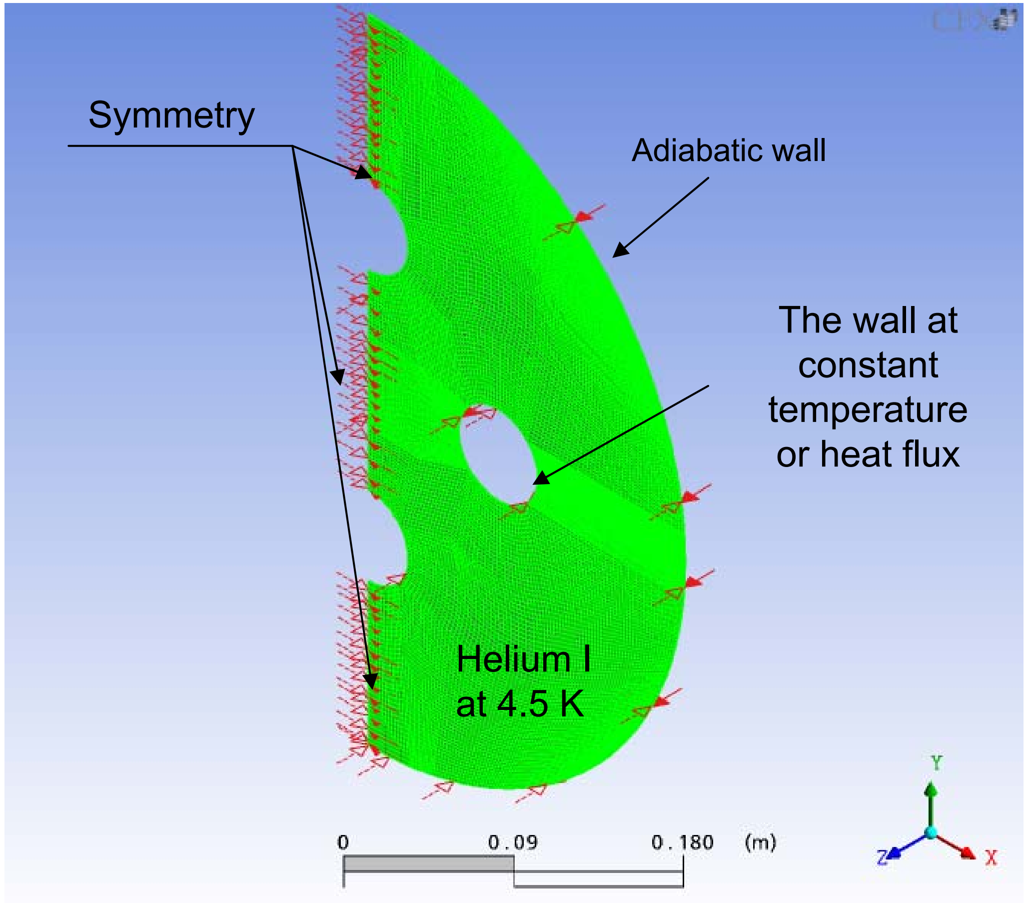
Heat transfer measurements cryostat:

•Cryostat ready.

•Initial measurement program will aim at validation.

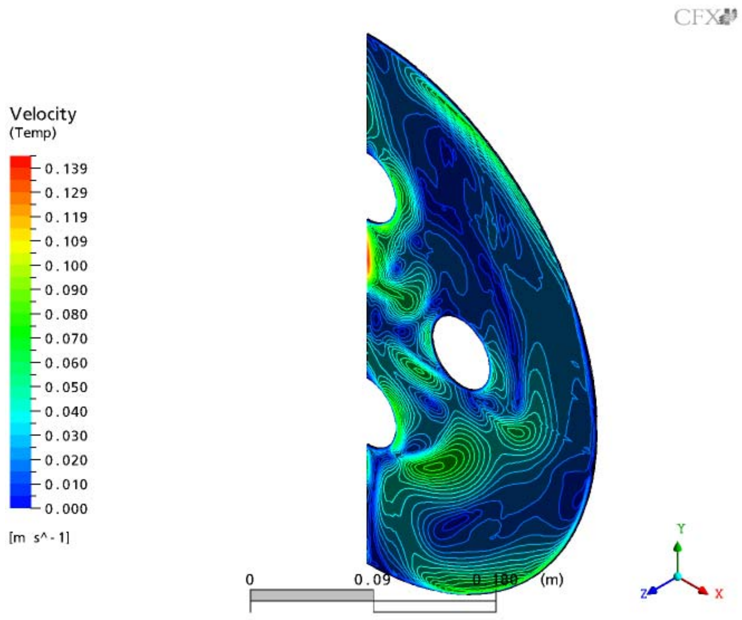
•Infrastructure in WUT needs upgrade not to work with He loss.

Extra slides-Numerical Approach: trial example MQY magnet

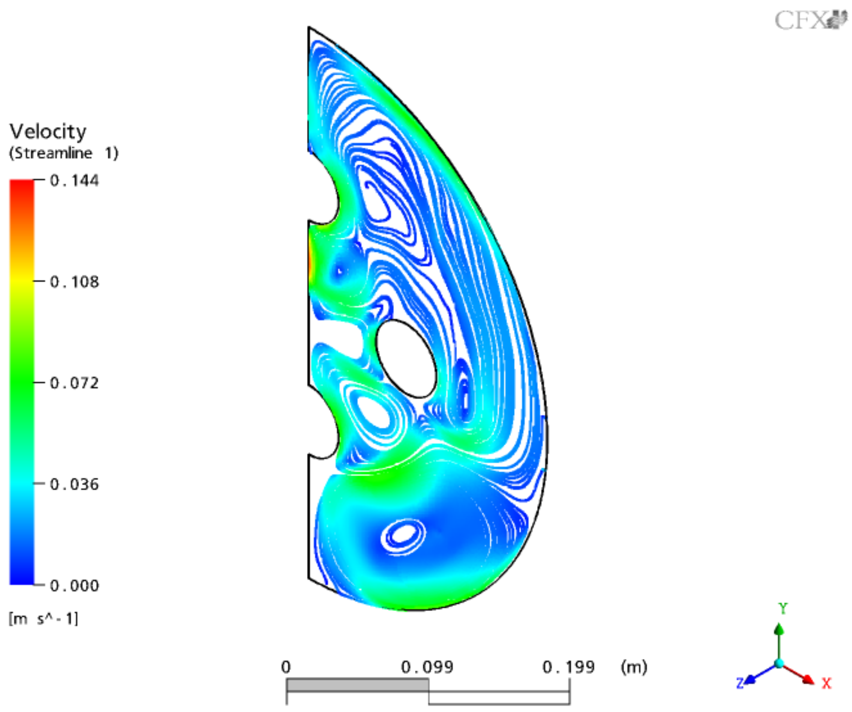


The geometry, boundary conditions and mesh applied during numerical calculations of MQY magnet

Extra slides-Numerical Approach: trial example MQY magnet



The velocity in Helium I



The streamlines in Helium I