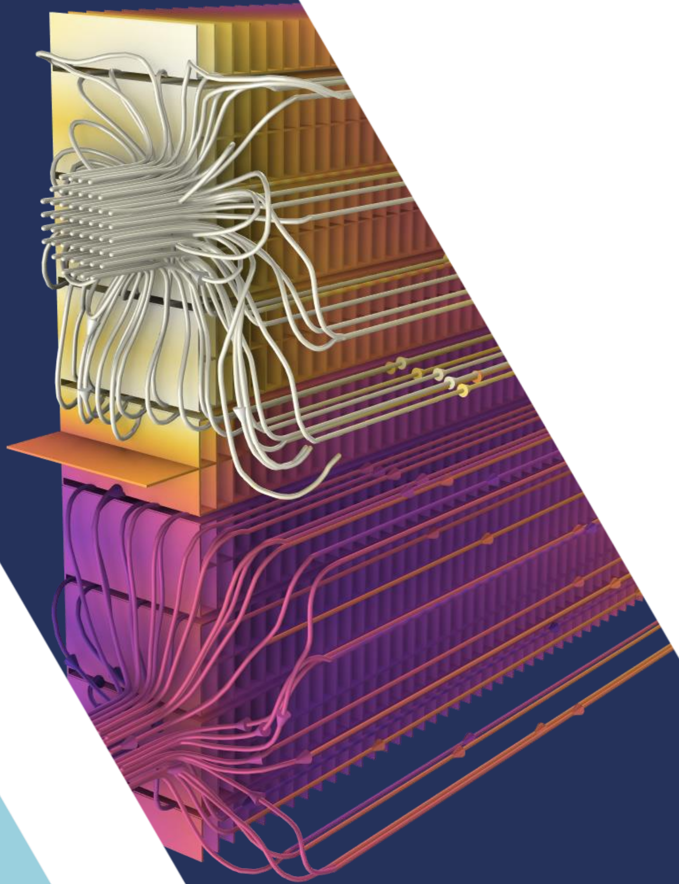

Modeling of Heating or Cooling System

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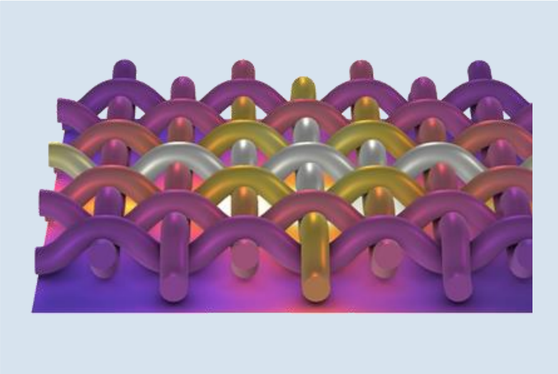
+284 011 745

Agenda

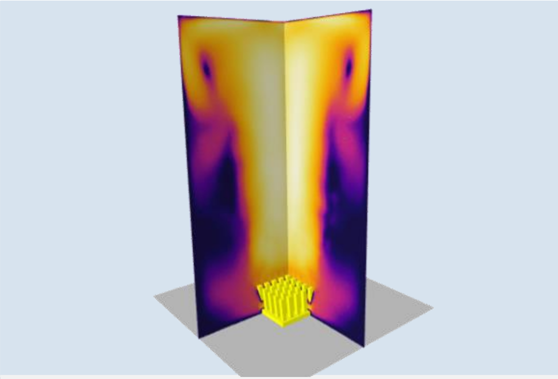
- Heat Transfer Module
- Pipe Flow Module
- DEMO: Adding the heat transfer into „*our new product*“ simulation
- DEMO: What if your R&D Manager wants internal cooling of coil wires

Heat Transfer Module



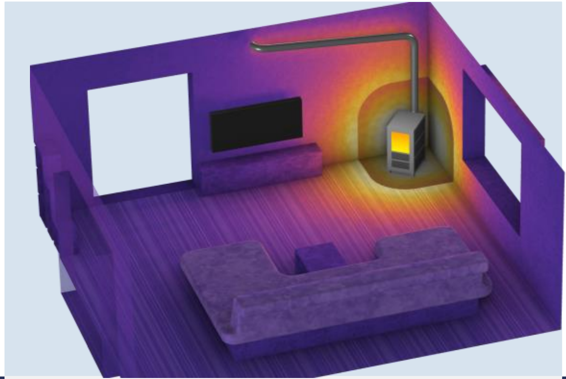
Conduction

- Isotropic, anisotropic, linear, and nonlinear thermal conductivity
- Thermal contact
- Thin layers



Convection

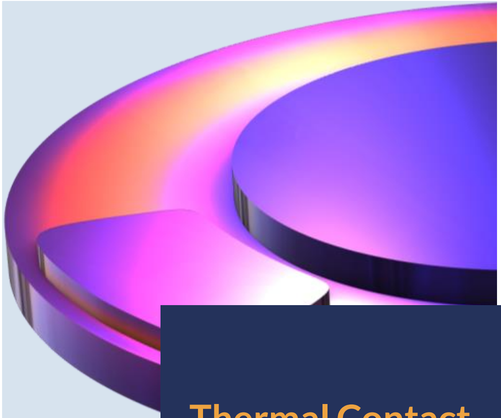
- Free and forced convection
- Laminar and turbulent flow
- Effective material properties



Radiation

- Surface-to-ambient and surface-to-surface radiation
- External radiation sources
- Radiation in participating media

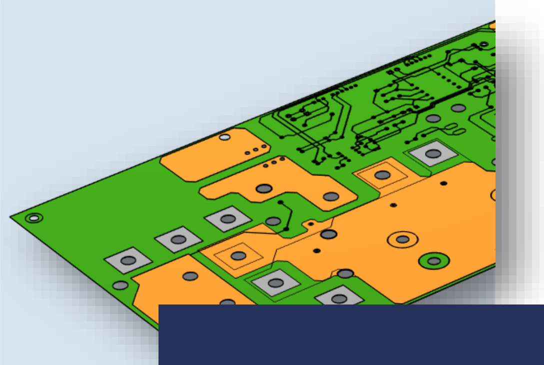
3 less-known but powerful features in Heat Transfer Module



Thermal Contact

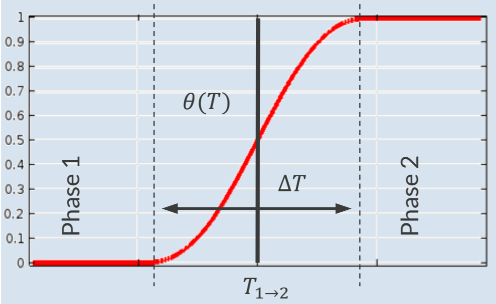
Computes effective heat conduction respecting real contact:

conduction in points, radiation through gap and convection in gap.



Thin Structures

Computes virtual thickness with 2D elements to achieve the best accuracy vs. cost compromise.



Phase Change

Supports up to 5 phase transitions including chemical irreversible transformations driven by Arrhenius kinetics.

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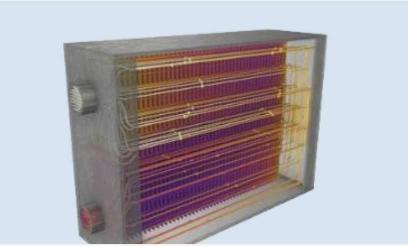
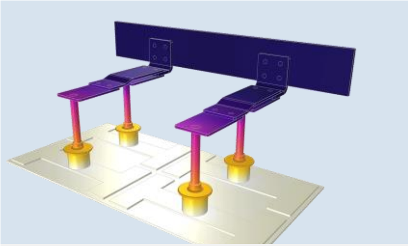
Heat Transfer Module – Selected Application Areas



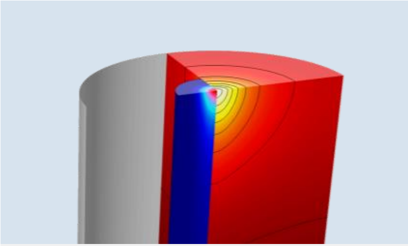
Heat Exchangers

- Heat Transfer in Solids and Fluids



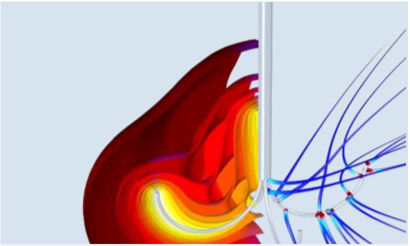
Electromagnetic Heating

- Joule Heating,
- Induction Heating (ACDC Module)
- Microwave Heating (RF Module)



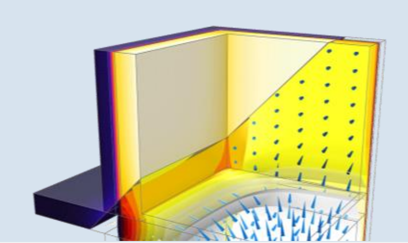
Laser Heating

- Radiative Beam in Absorbing Media
- Laser Heating (Wave Optics Mod.)
- Ray Heating (Ray Optics Module)



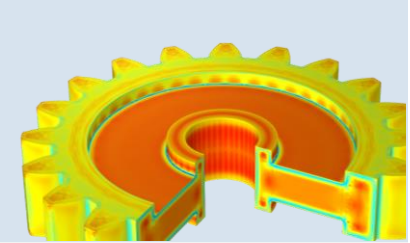
Bioheat Transfer

- Pennes' Equation for modeling biological tissues
- Laser, Ultrasound, Microwave…



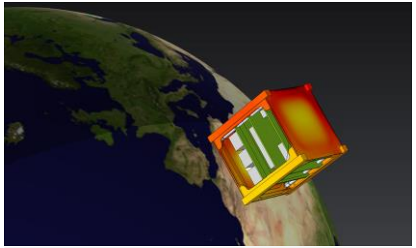
Thermal Management in Buildings

- Heat and Moisture Transport in Building Materials
- Meteorological data ASHRAE
- Sun position based on GPS and time



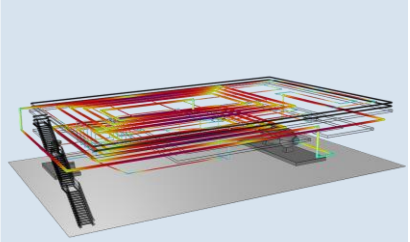
Phase Change Application

- Freezing, Melting, Evaporating…
- Ireversible transformations in chemistry (e.g. resin solidification)
- Metal Processing Module



Spacecraft Thermal Analyses

- Respecting solar radiation, albedo, planet infrared flux and heating from electronic spacecraft parts



Large or complicated systems

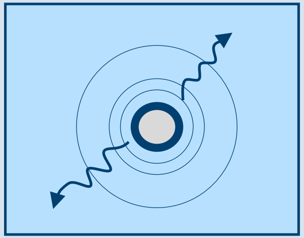
- Nonisothermal Pipe Flow
- Very effective tool modeling pipes using 1D elements and correlations

Pipe Flow Module

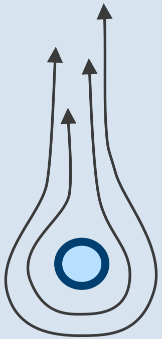
- Friction factor correlations
- Pipe cross sections, fittings, valves, pumps, etc.
- Automatic handling of laminar and turbulent flow

Heat Transfer in Pipes

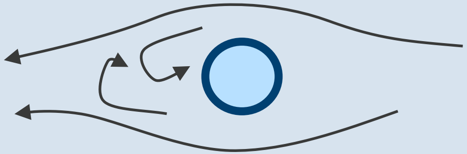
Surrounding Media and Inside Pipes



Conduction in solids.



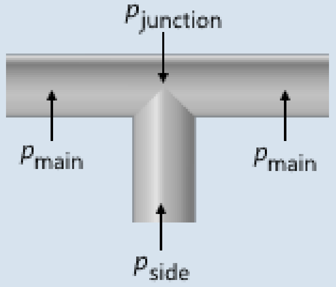
Free convection.



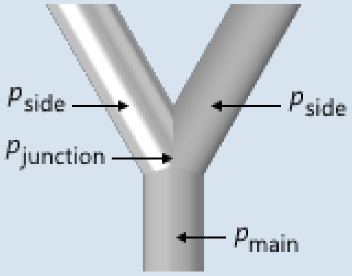
Forced convection.

- Heat transfer coupling with surrounding volumes:
  - Automatic calculation of heat transfer coefficients for internal, wall layer resistance, and external heat transfer
- Nusselt correlations for heat transfer at pipe walls
- Viscous heating of high-shear fluids
- *Nonisothermal Pipe Flow* interface combines *Pipe Flow* interface and *Heat Transfer in Pipes* interface

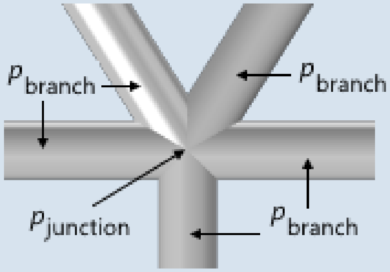
Valves, Bends and Pumps included



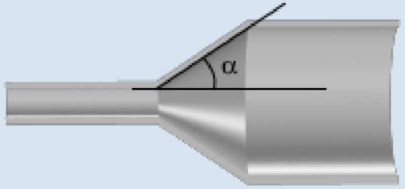
T-junction



Y-junction



N-way junction



Contraction and expansion

- Correlations for sudden pressure change for several common building blocks
- Included correlations for loss coefficients, K_i, where $\Delta p = \frac{1}{2}\rho K_i u^2$
- 90° or 45° bends, T-junction, Y-junction, N-way junction, Contraction and expansion, valves and pumps

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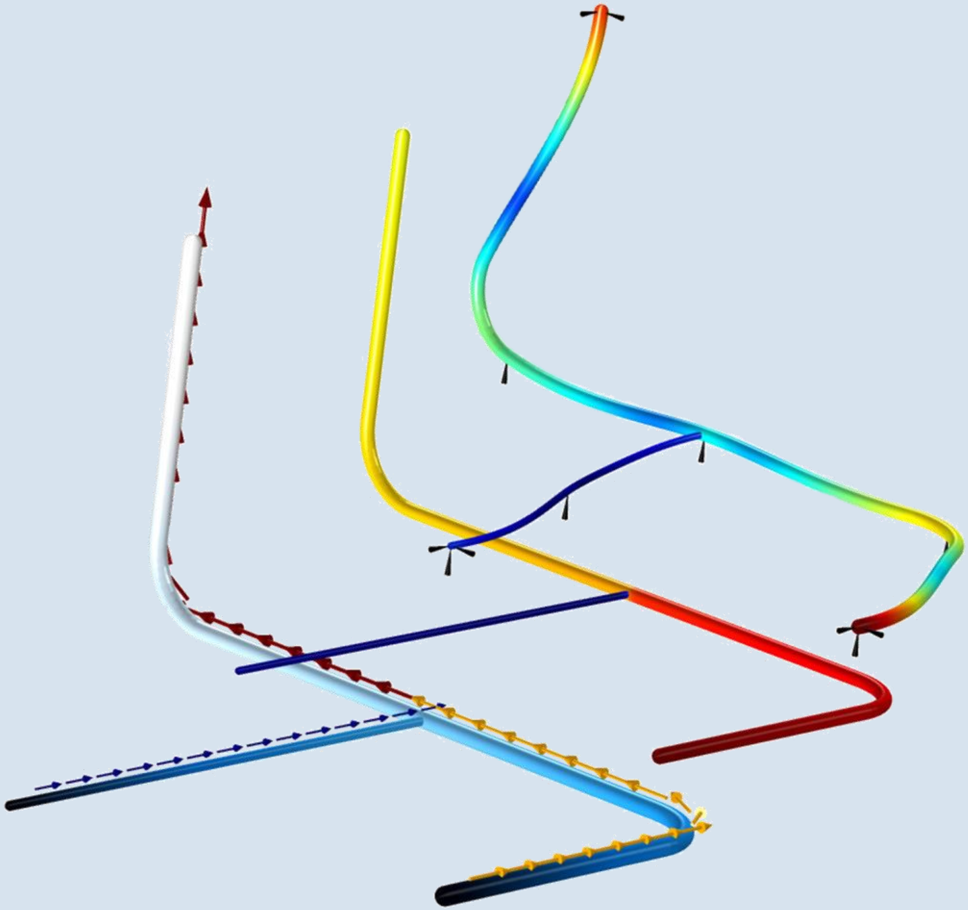
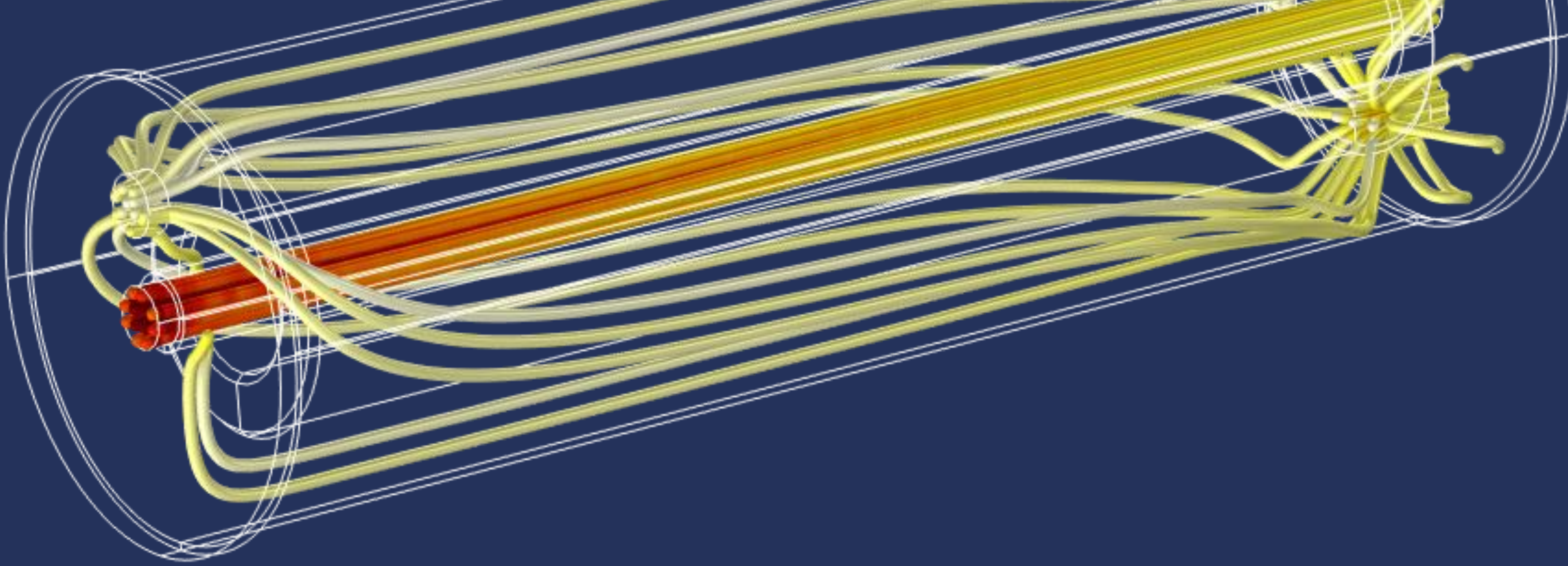
Pipe Mechanics

- Beam-type elements for analysis of pipes
- Correction factors for flexibility and stresses in pipe bends
- Multiphysics coupling for loads from the *Pipe Flow* interface:
  - Pressure
  - Drag force
  - Bend forces
  - Junction forces



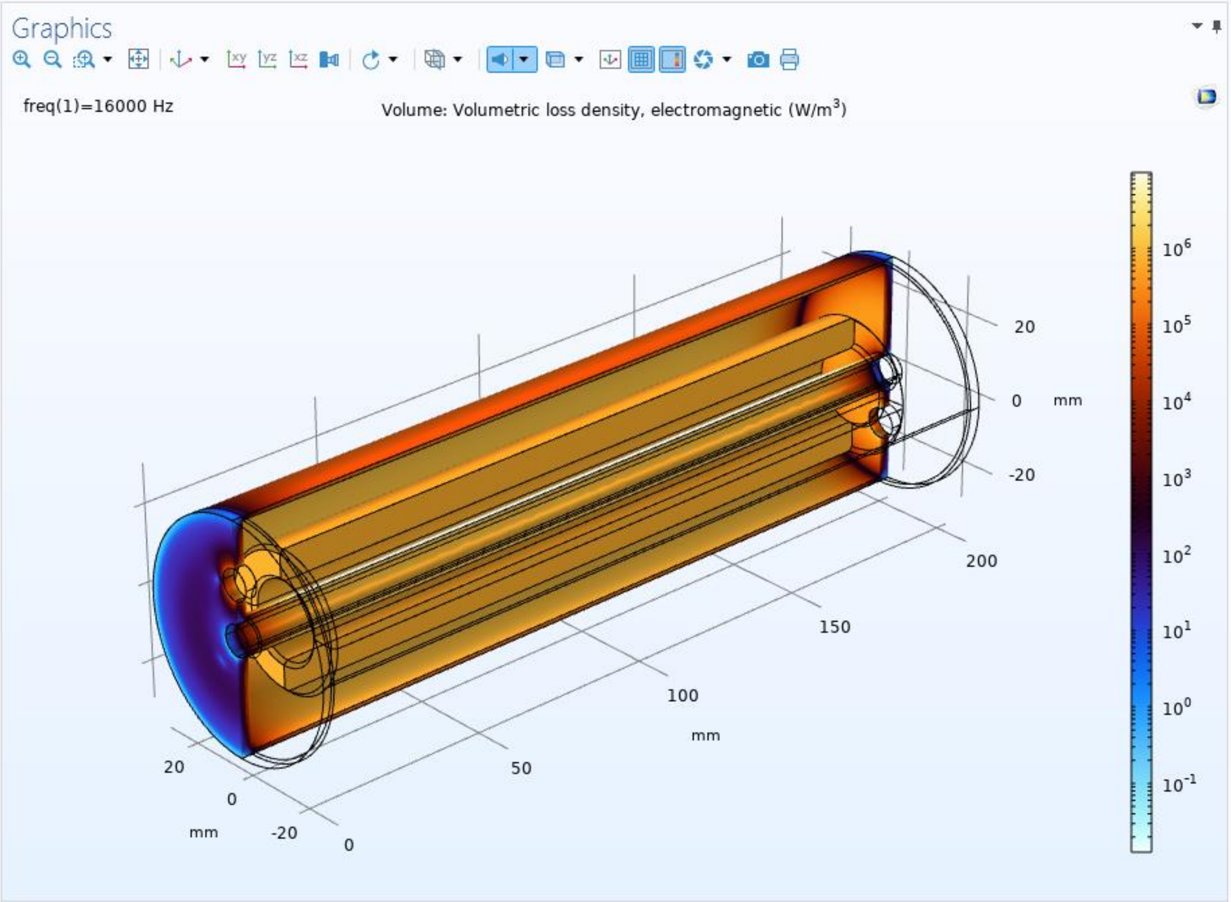
Results from a coupled flow, heat transfer, and mechanical analysis in a piping system: pressure and velocity (left), temperature (middle), and stress with exaggerated deformation (right).



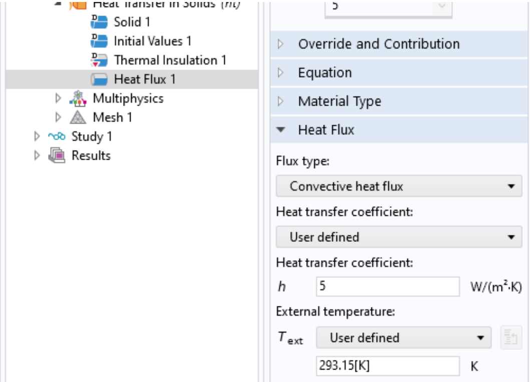
DEMO: Adding the Heat Transfer into *„Our New Product“* Simulation

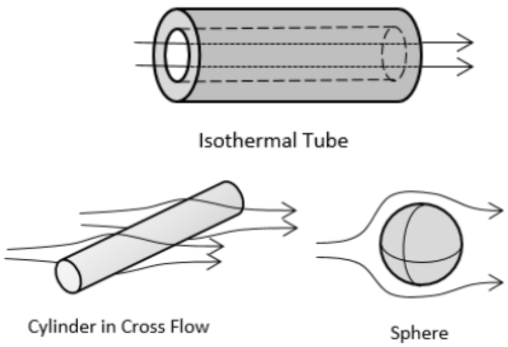
What Matouš has done

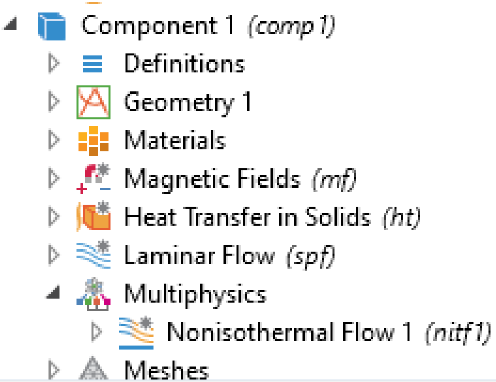
- Induction heating of metal parts inside the heater.
- He gives me distribution of electromagnetic loss.
- We will use this to heat the water.



3 Ways How To Simulate Forced Convection







Heat flux with estimated htc

Estimation of the heat transfer coefficient in the relation:

$$q = htc \cdot (T_{ext} - T)$$

htc using a convective correlation

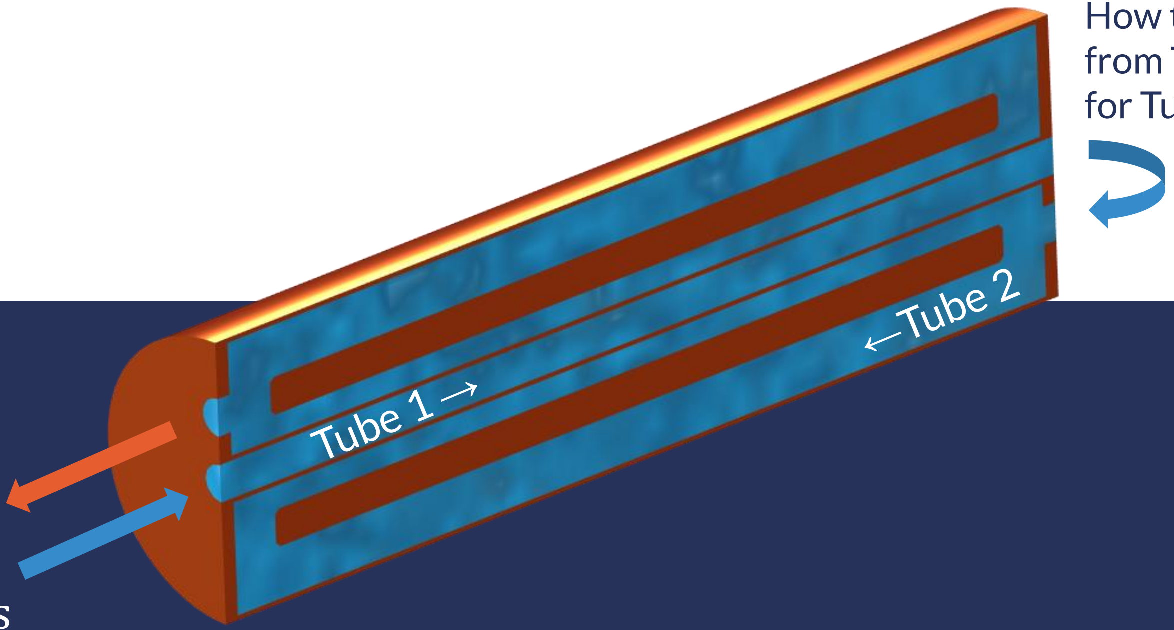
Built-in empirical external/internal natural or forced convection htc for given shapes can easily spare time.

Modeling fluid flow explicitly

The most general but time expensive approach can be done with either HT or CFD Module.

https://www.comsol.com/blogs/modeling-natural-and-forced-convection-in-comsol-multiphysics/

Boundary Conditions for the nonisothermal fluid flow



How to use outlet from Tube 1 as inlet for Tube 2?

$p_{out} = 1$ [atm]
$T_{out} = ?$ °C

$u_{in} = 0.01$ m/s
$T_{in} = 10$°C

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Modeling proces step-by-step

1. Parameters
2. Physics interface „*Laminar Flow*“
   - *Be aware of compressibility!*
3. Coupling of „*Heat Transfer in Solids*“ with „*Laminar Flow*“

Settings

Parameters

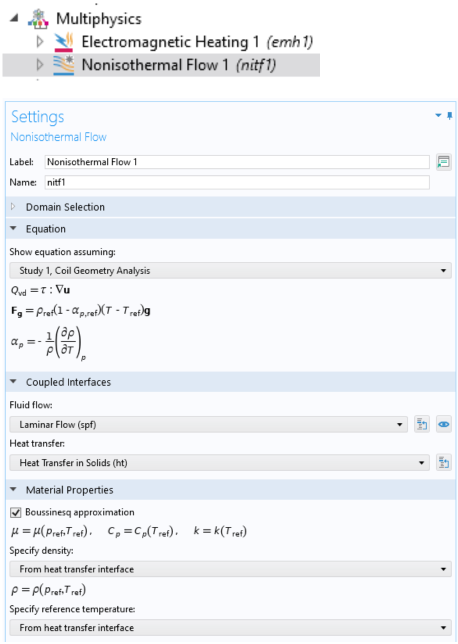
Label: Parameters 2 - Martin

Parameters

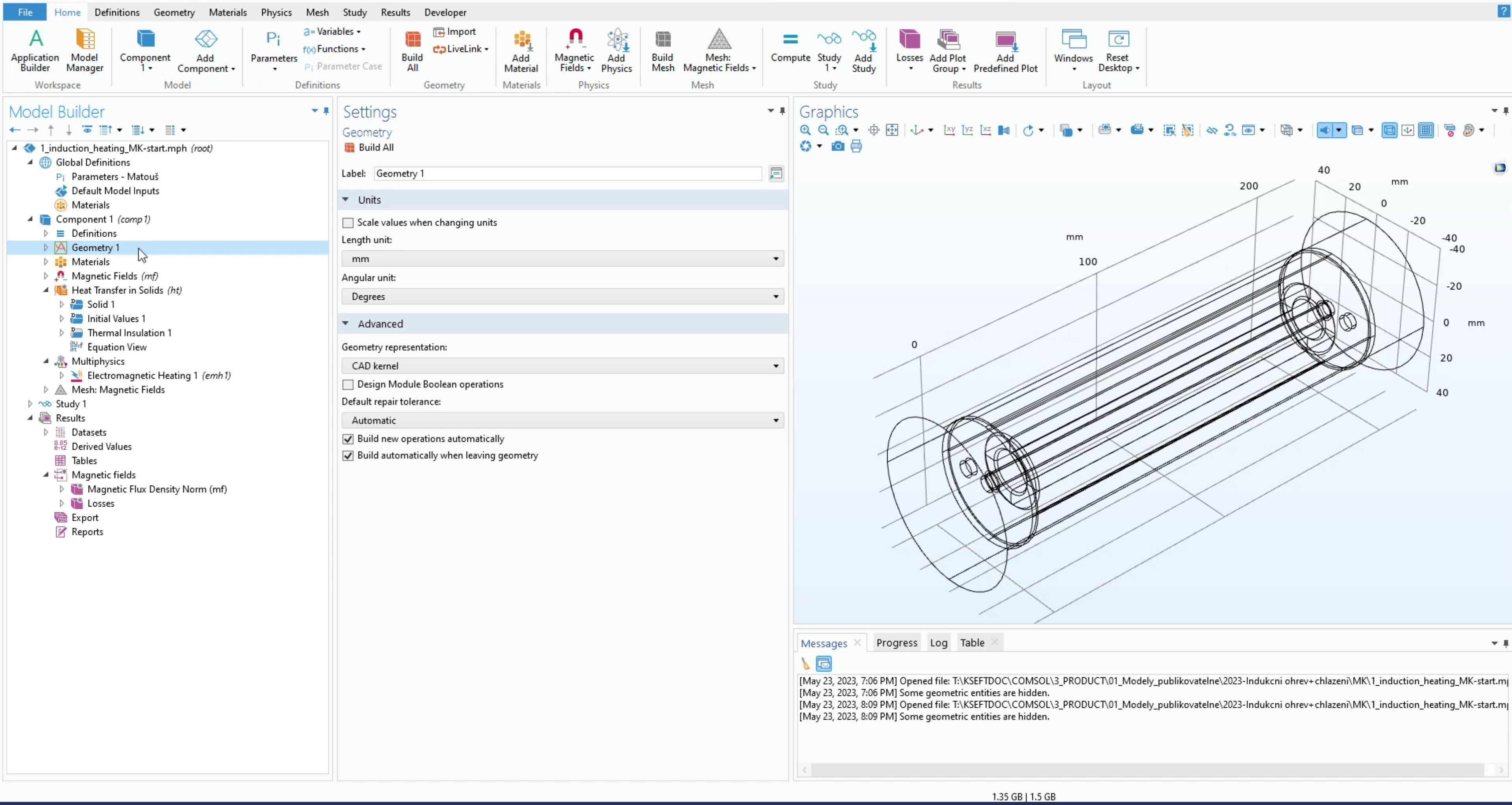
Name	Expression	Value	Description
d_ci	20 [mm]	0.02 m	Coil inner diameter
d_ce	d_ci+2*w_c	0.036 m	Coil external diameter
d_t	2*(r_t-th_bw)	0.008 m	Boiler cooling tube inner...
rho_w	1000 [kg/m^3]	1000 kg/m³	Water density
eta_w	1e-3 [Pa*s]	0.001 Pa·s	Water dynamic viscosity
u_in	0.01 [m/s]	0.01 m/s	Inlet velocity
Re_t	u_in*d_t*rho_w/eta_w	80	Reynolds number inner t...
T_in	10 [degC]	283.15 K	Inlet temperature

Compressibility levels

- Incompressible $\rho = \rho(p_{ref}, T_{ref})$
  - or with Boussinesq approximation $F_g = \rho_{ref} - \rho_{ref}\alpha_p(T - T_{ref})$
- Weakly compressible $\rho = \rho(p_{ref}, T\ )$
- Compressible $\rho = \rho(p, T\ )$



Boussinesq approximation for incompressible flow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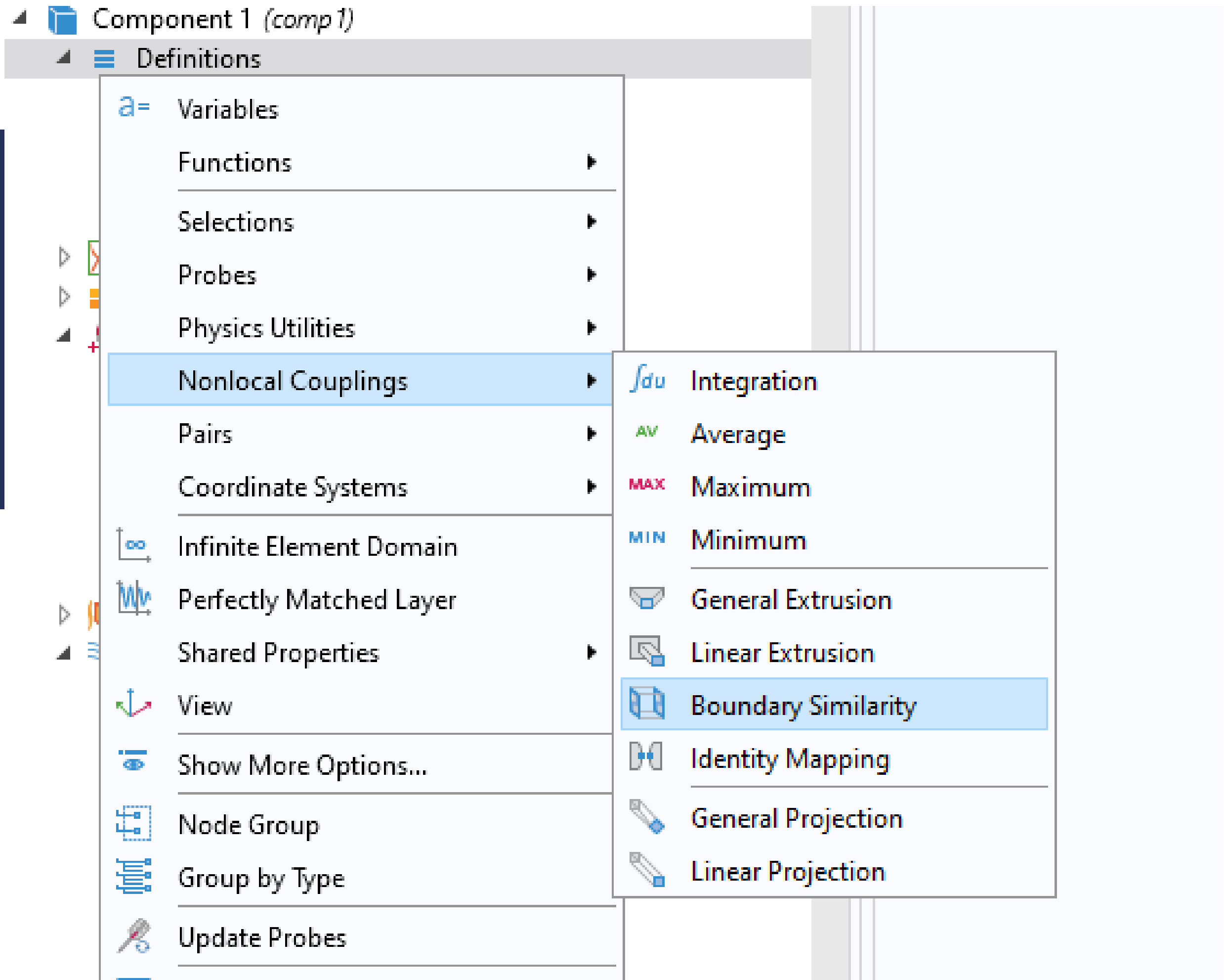
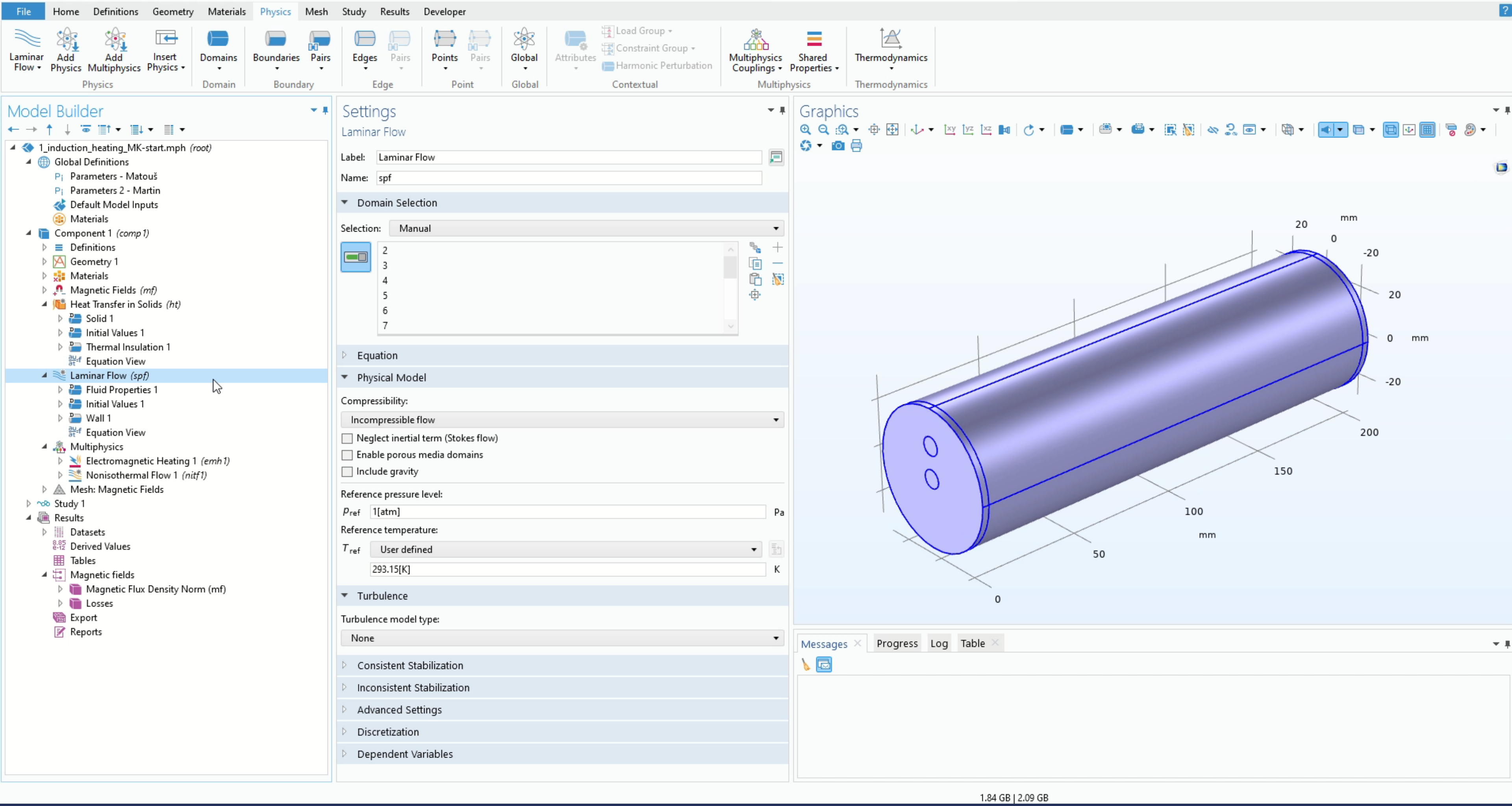
Modeling proces step-by-step

4. CFD boundary conditions for tube 1
5. Definition of „*Boundary Similarity*“ mapping operator
6. CFD boundary conditions for tube 2

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Name: spf
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Selection: Manual
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Equation
Physical Model
Compressibility:
Incompressible flow
Neglect inertial term (Stokes flow)
Enable porous media domains
Include gravity
Reference pressure level:
pref 1[atm] Pa
Reference temperature:
Tref User defined
293.15[K] K
Turbulence
Turbulence model type:
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Consistent Stabilization
Inconsistent Stabilization
Advanced Settings
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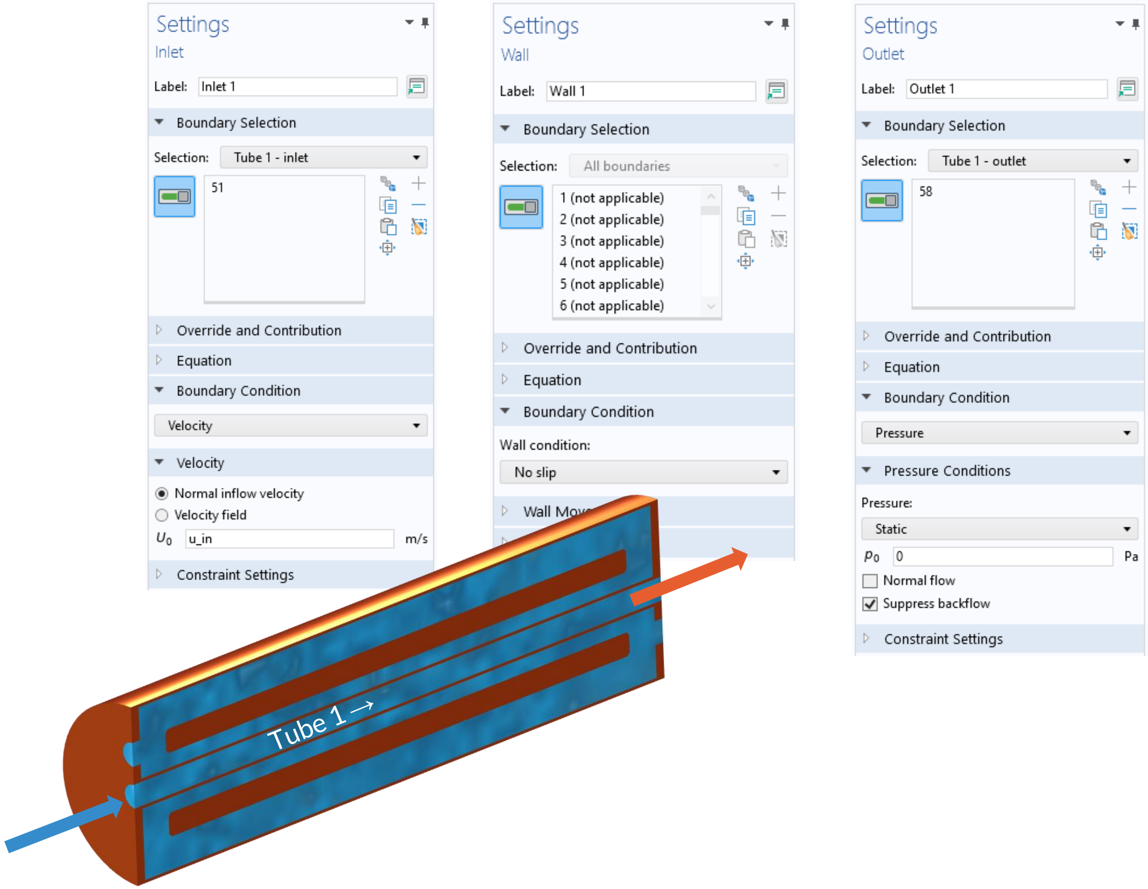
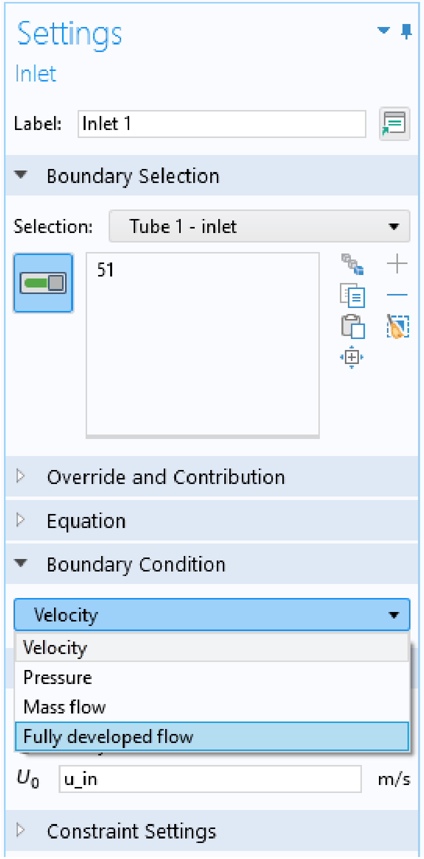
Quiz: What we could improve?

- Look at the conditions, there is one inconsistency in boundary conditions, which can lead to convergence issues.



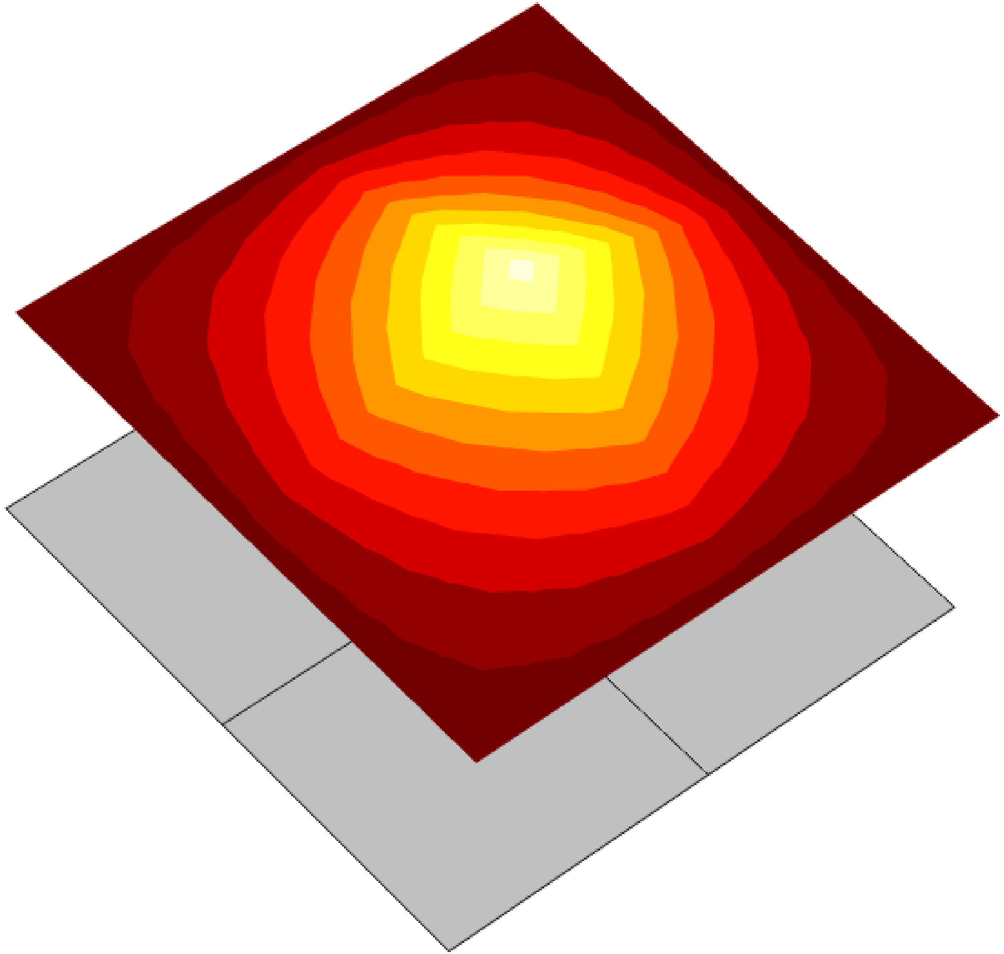
Quiz: What we could improve?

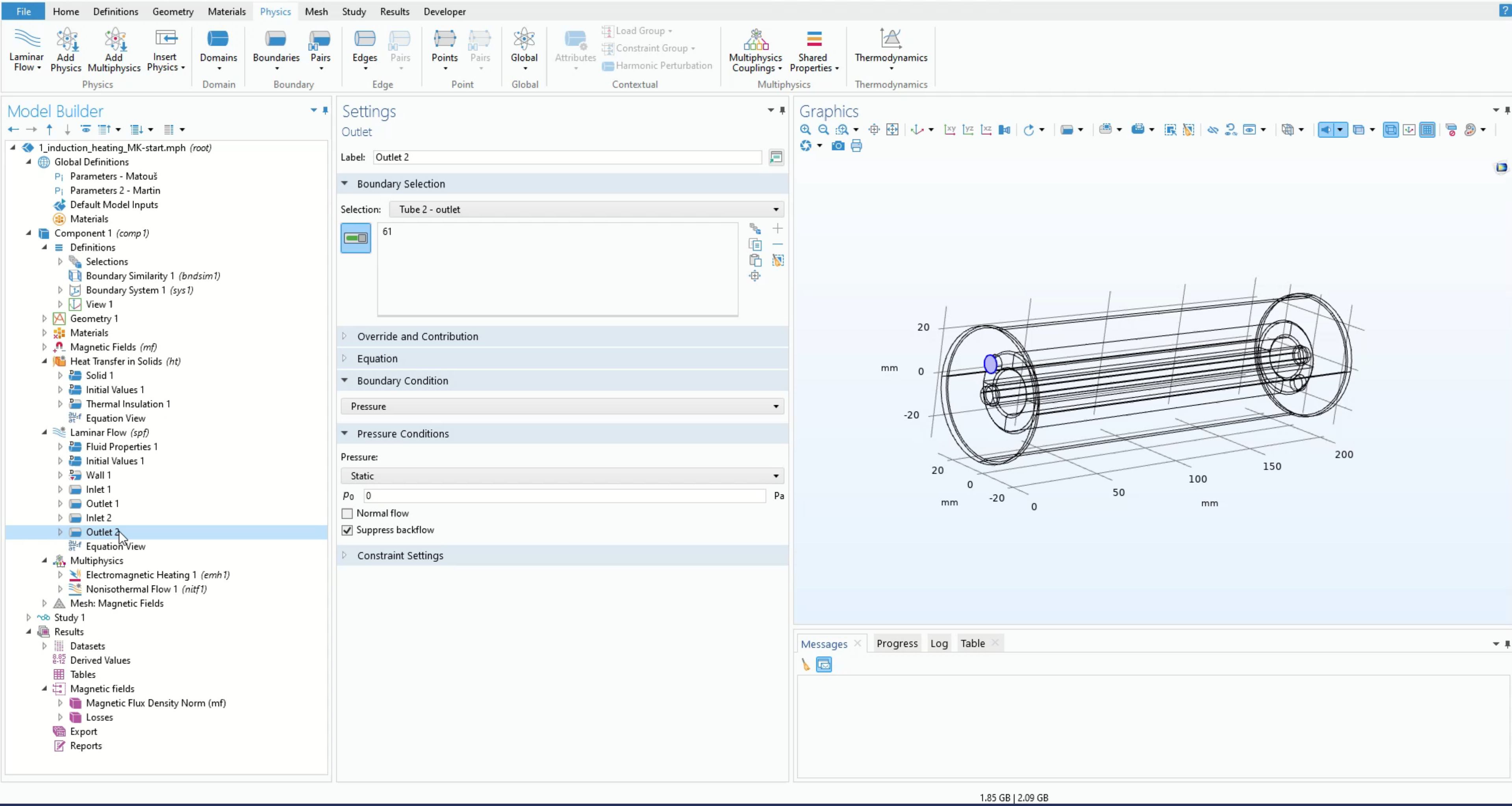
- Look at the conditions, there is one inconsistency in boundary conditions, which can lead to convergence issues.
- We can improve convergence by setting the Fully Developed Flow condition on the Inlet 1. This condition respects No slip condition on walls.



Modeling proces step-by-step

7. Heat Transfer in Solids: fluid domain and boundary conditions
8. Automatic CFD Mesh with extra boundary layers for skin effect resolution

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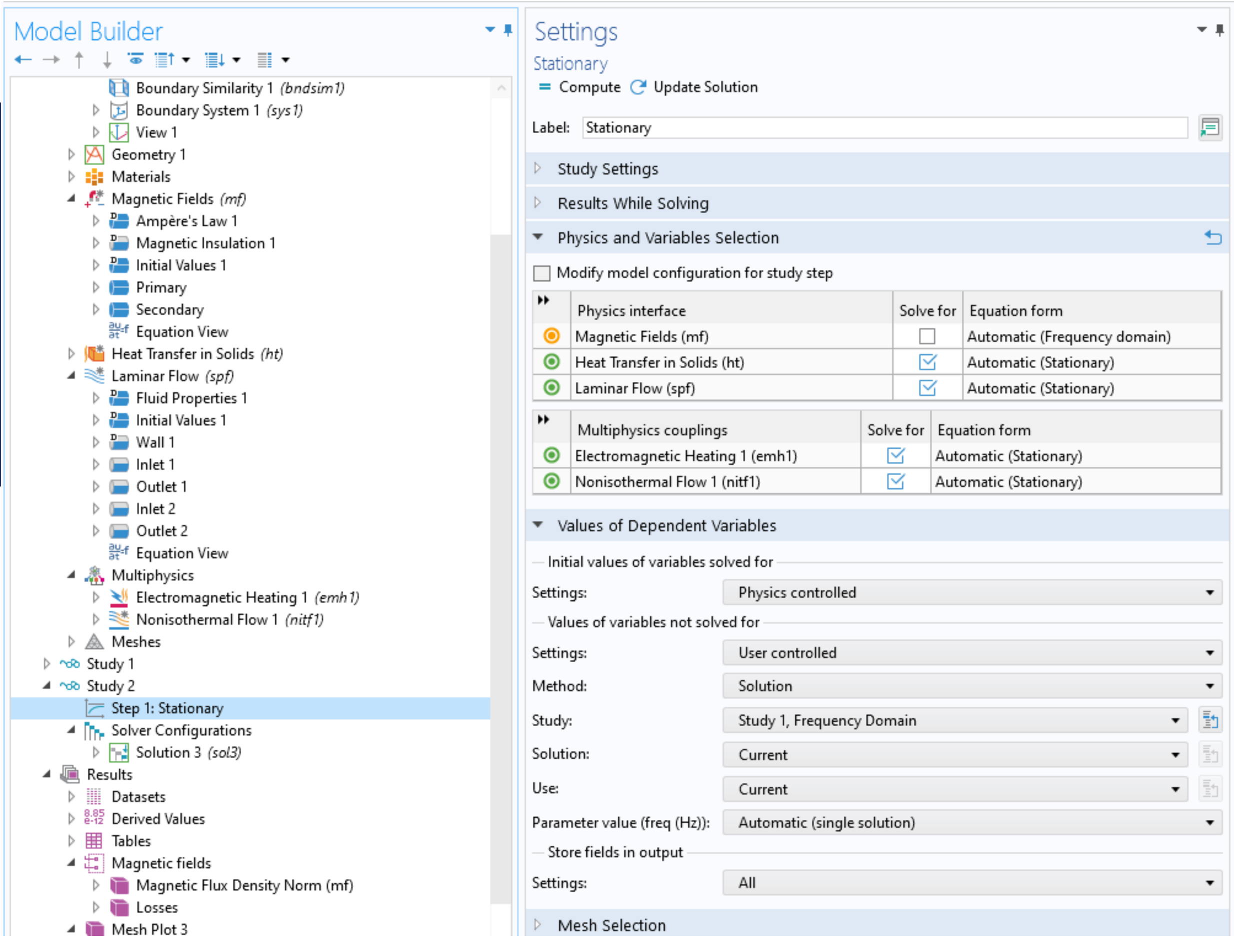
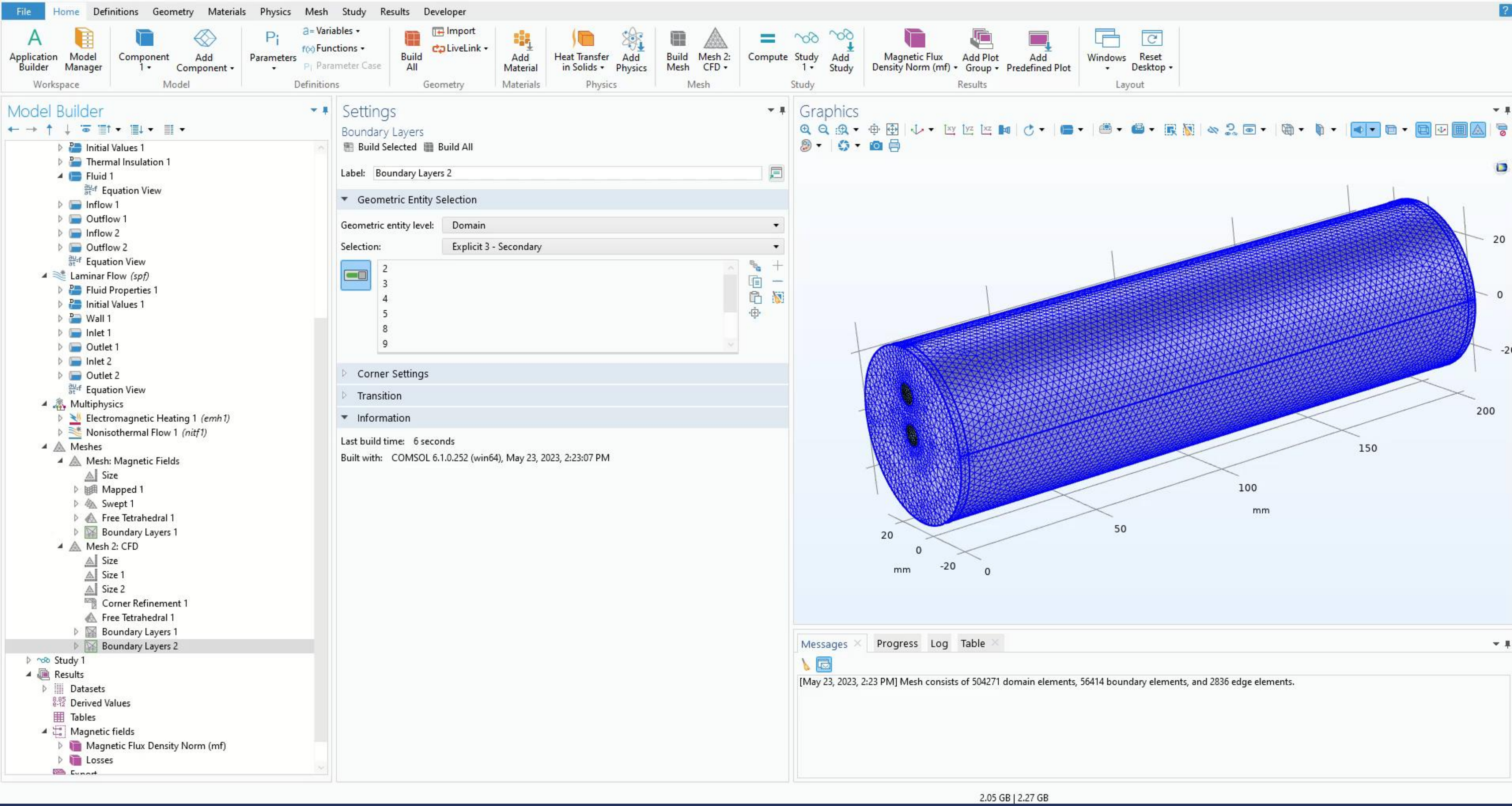
Modeling proces step-by-step

9. Study 2 takes results from Study 1
   - Initial values of variables solved for (T, u, v, w, p)
   - Initial values of variables not solved for (elmag loss)

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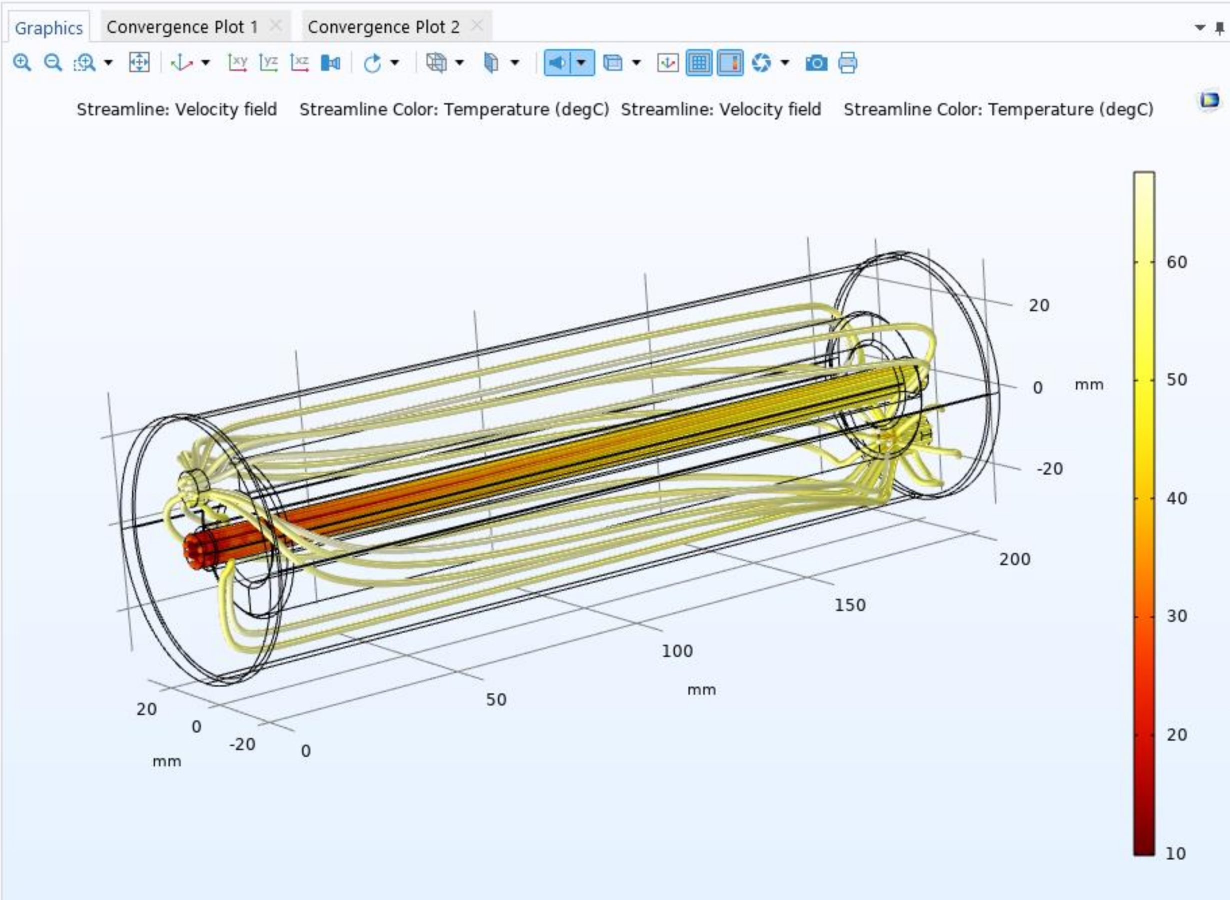
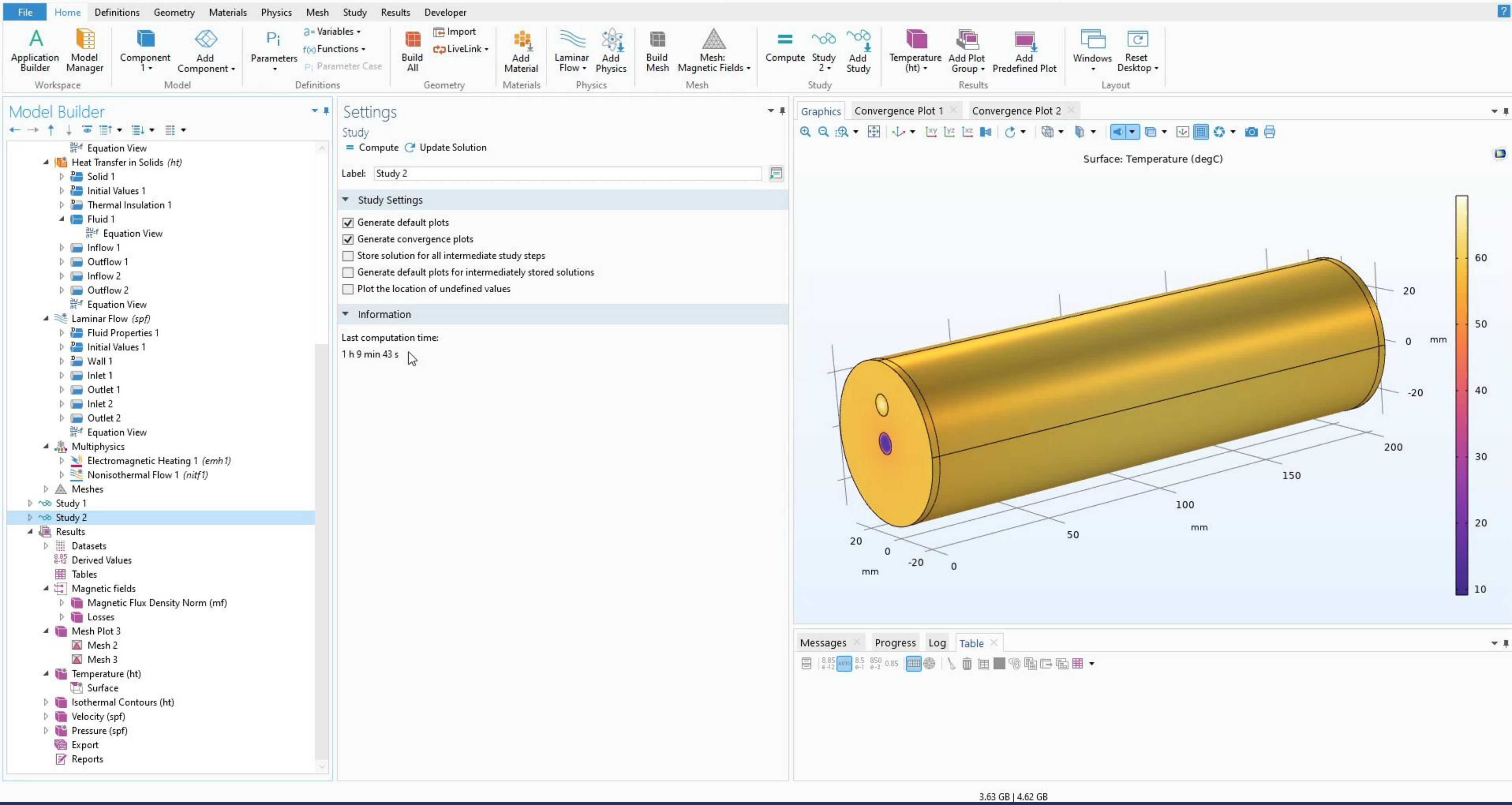
Geometric Entity Selection
Geometric entity level: Domain
Selection: Explicit 3 - Secondary
2
3
4
5
8
9
Corner Settings
Transition
Information
Last build time: 6 seconds
Built with: COMSOL 6.1.0.252 (win64), May 23, 2023, 2:23:07 PM
Graphics
20
0
200
150
100
mm
50
20
0
-20
mm
0
Messages
Progress
Log
Table
[May 23, 2023, 2:23 PM] Mesh consists of 504271 domain elements, 56414 boundary elements, and 2836 edge elements.
2.05 GB | 2.27 GB

COMSOL

Modeling proces step-by-step

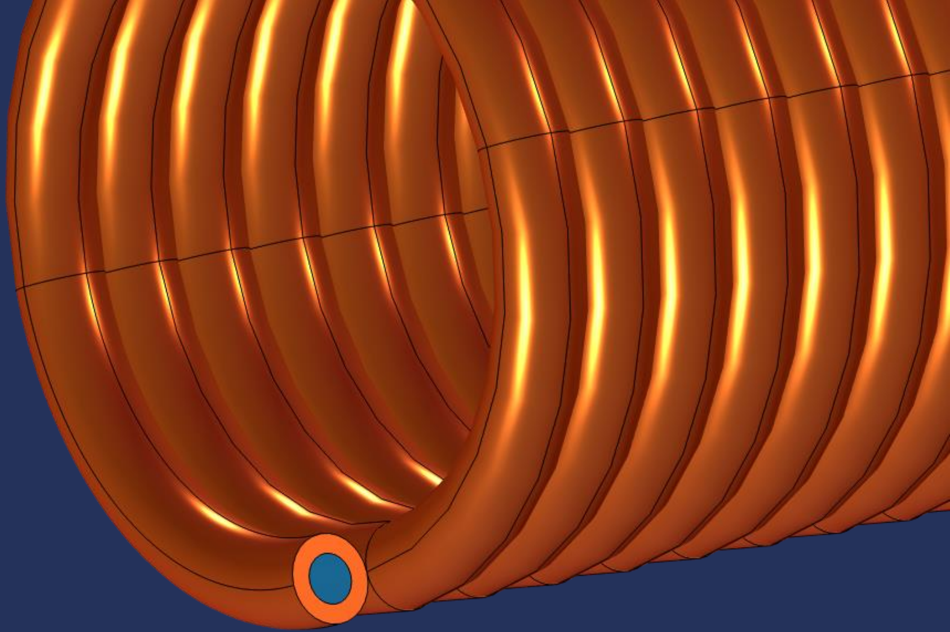
10. Postprocessing
    - Velocity slice
    - Velocity streamlines colored by temperature
    - Max Temperature in Volume
    - Averaged Temperature on output boundary




File
Home
Definitions
Geometry
Materials
Physics
Mesh
Study
Results
Developer
Application Builder
Model Manager
Workspace
Component 1
Add Component
Model
Parameters
Variables
Functions
Parameter Case
Definitions
Build All
Import
LiveLink
Geometry
Add Material
Materials
Laminar Flow
Add Physics
Physics
Build Mesh
Mesh: Magnetic Fields
Mesh
Compute
Study 2
Add Study
Study
Temperature (ht)
Add Plot Group
Add Predefined Plot
Results
Windows
Reset Desktop
Layout
Model Builder
Equation View
Heat Transfer in Solids (ht)
Solid 1
Initial Values 1
Thermal Insulation 1
Fluid 1
Equation View
Inflow 1
Outflow 1
Inflow 2
Outflow 2
Equation View
Laminar Flow (spf)
Fluid Properties 1
Initial Values 1
Wall 1
Inlet 1
Outlet 1
Inlet 2
Outlet 2
Equation View
Multiphysics
Electromagnetic Heating 1 (emh1)
Nonisothermal Flow 1 (nitf1)
Meshes
Study 1
Study 2
Results
Datasets
Derived Values
Tables
Magnetic fields
Magnetic Flux Density Norm (mf)
Losses
Mesh Plot 3
Mesh 2
Mesh 3
Temperature (ht)
Surface
Isothermal Contours (ht)
Velocity (spf)
Pressure (spf)
Export
Reports
Settings
Study
Compute
Update Solution
Label: Study 2
Study Settings
Generate default plots
Generate convergence plots
Store solution for all intermediate study steps
Generate default plots for intermediately stored solutions
Plot the location of undefined values
Information
Last computation time:
1 h 9 min 43 s
Graphics
Convergence Plot 1
Convergence Plot 2
Surface: Temperature (degC)
60
50
40
30
20
10
20
0
-20
mm
200
150
100
50
0
mm
20
0
-20
mm
Messages
Progress
Log
Table
3.63 GB | 4.62 GB

Modeling proces overview

1. Parameters
2. Physics interface „*Laminar Flow*“
3. Coupling of „*Heat Transfer in Solids*“ with „*Laminar Flow*“
4. CFD boundary conditions for tube 1
5. Definition of „*Boundary Similarity*“ mapping operator
6. CFD boundary conditions for tube 2
7. Heat Transfer in Solids: fluid domain and boundary conditions
8. Automatic CFD Mesh with extra boundary layers for skin effect resolution
9. Study 2 takes results from Study 1
10. Postprocessing

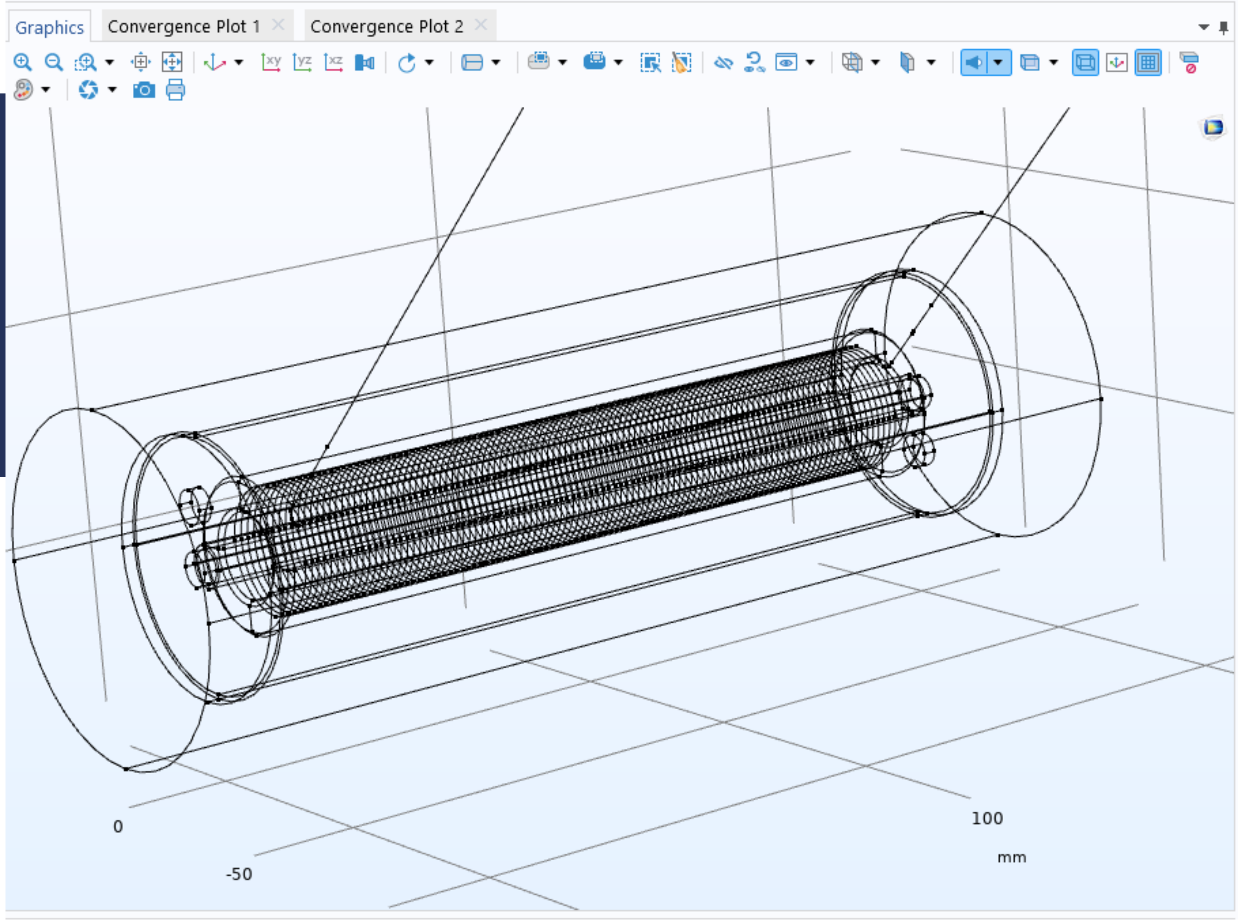


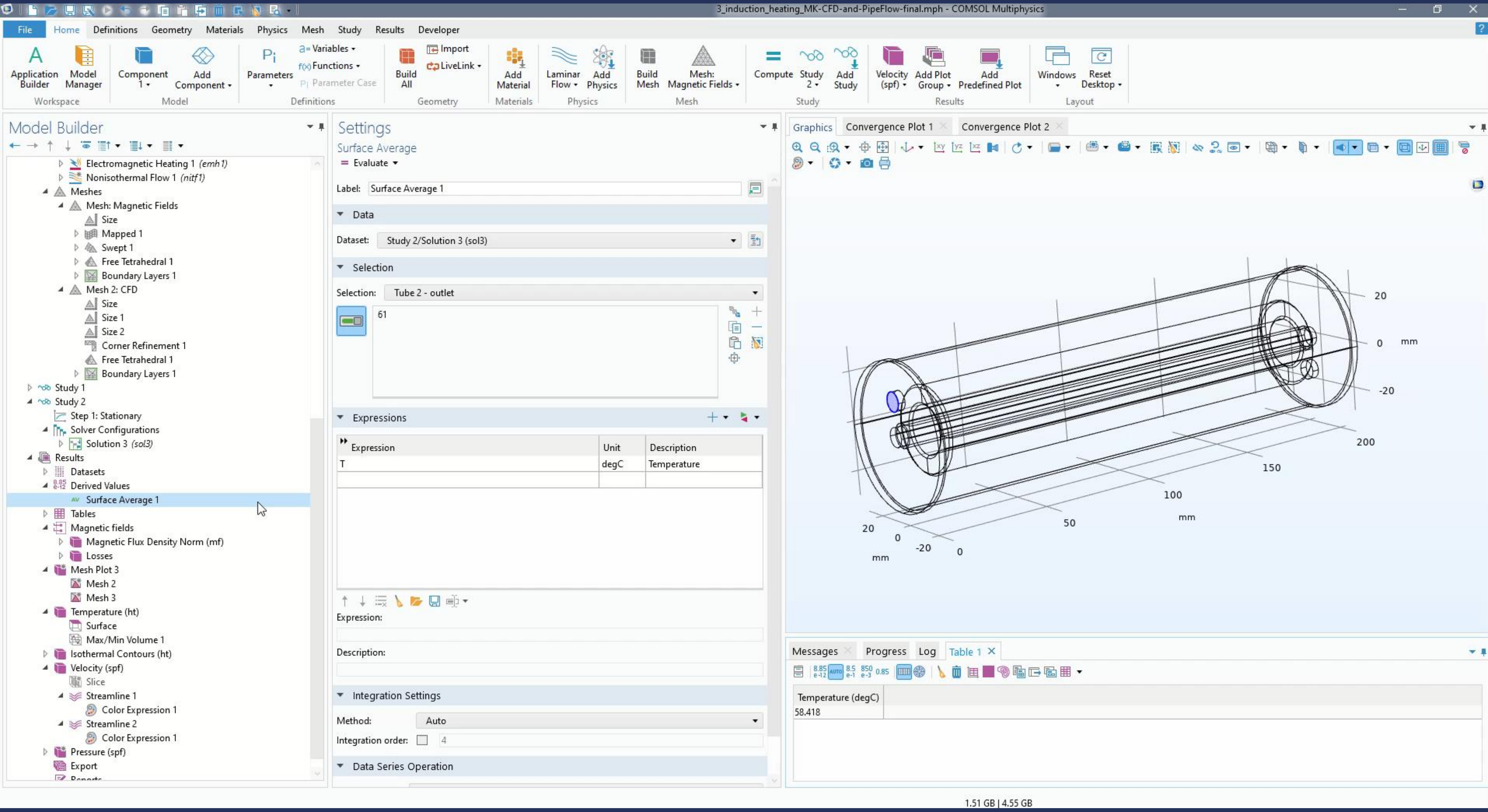
DEMO: What if R&D Manager wants internal cooling of coil wires

COMSOL

Modeling proces step-by-step

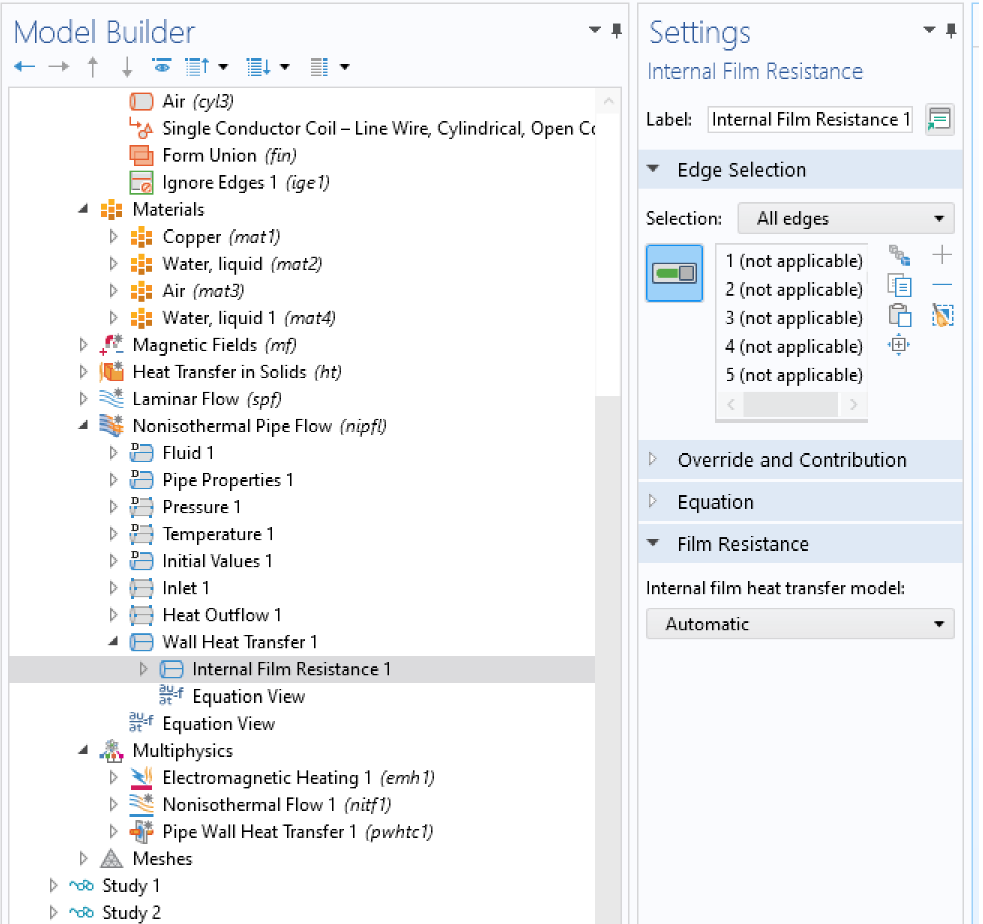
1. New parameters
2. New geometry part from library

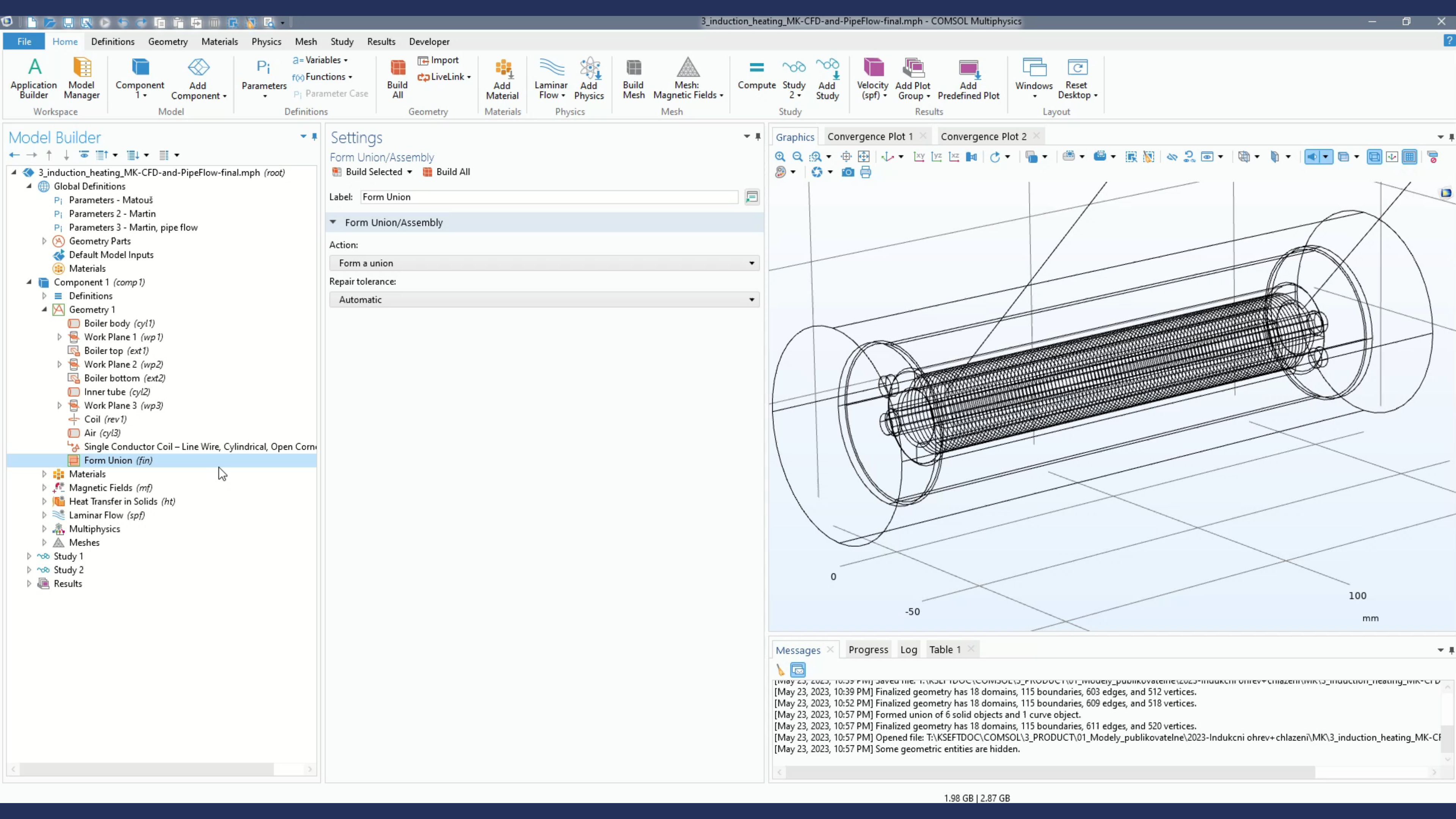



3_induction_heating_MK-CFD-and-PipeFlow-final.mph - COMSOL Multiphysics
File
Home
Definitions
Geometry
Materials
Physics
Mesh
Study
Results
Developer
Application Builder
Model Manager
Workspace
Component 1
Add Component
Model
Parameters
Variables
Functions
Parameter Case
Definitions
Build All
Import
LiveLink
Geometry
Add Material
Materials
Laminar Flow
Add Physics
Physics
Build Mesh
Mesh: Magnetic Fields
Mesh
Compute
Study 2
Add Study
Study
Velocity (spf)
Add Plot Group
Add Predefined Plot
Results
Windows
Reset Desktop
Layout
Model Builder
Electromagnetic Heating 1 (emh1)
Nonisothermal Flow 1 (nitf1)
Meshes
Mesh: Magnetic Fields
Size
Mapped 1
Swept 1
Free Tetrahedral 1
Boundary Layers 1
Mesh 2: CFD
Size
Size 1
Size 2
Corner Refinement 1
Free Tetrahedral 1
Boundary Layers 1
Study 1
Study 2
Step 1: Stationary
Solver Configurations
Solution 3 (sol3)
Results
Datasets
Derived Values
Surface Average 1
Tables
Magnetic fields
Magnetic Flux Density Norm (mf)
Losses
Mesh Plot 3
Mesh 2
Mesh 3
Temperature (ht)
Surface
Max/Min Volume 1
Isothermal Contours (ht)
Velocity (spf)
Slice
Streamline 1
Color Expression 1
Streamline 2
Color Expression 1
Pressure (spf)
Export
Settings
Surface Average
Evaluate
Label: Surface Average 1
Data
Dataset: Study 2/Solution 3 (sol3)
Selection
Selection: Tube 2 - outlet
61
Expressions
Expression
Unit
Description
T
degC
Temperature
Expression:
Description:
Integration Settings
Method: Auto
Integration order: 4
Data Series Operation
Graphics
Convergence Plot 1
Convergence Plot 2
20
0
-20
mm
200
150
100
50
0
mm
20
0
-20
mm
Messages
Progress
Log
Table 1
Temperature (degC)
58.418
1.51 GB | 4.55 GB

Modeling proces step-by-step

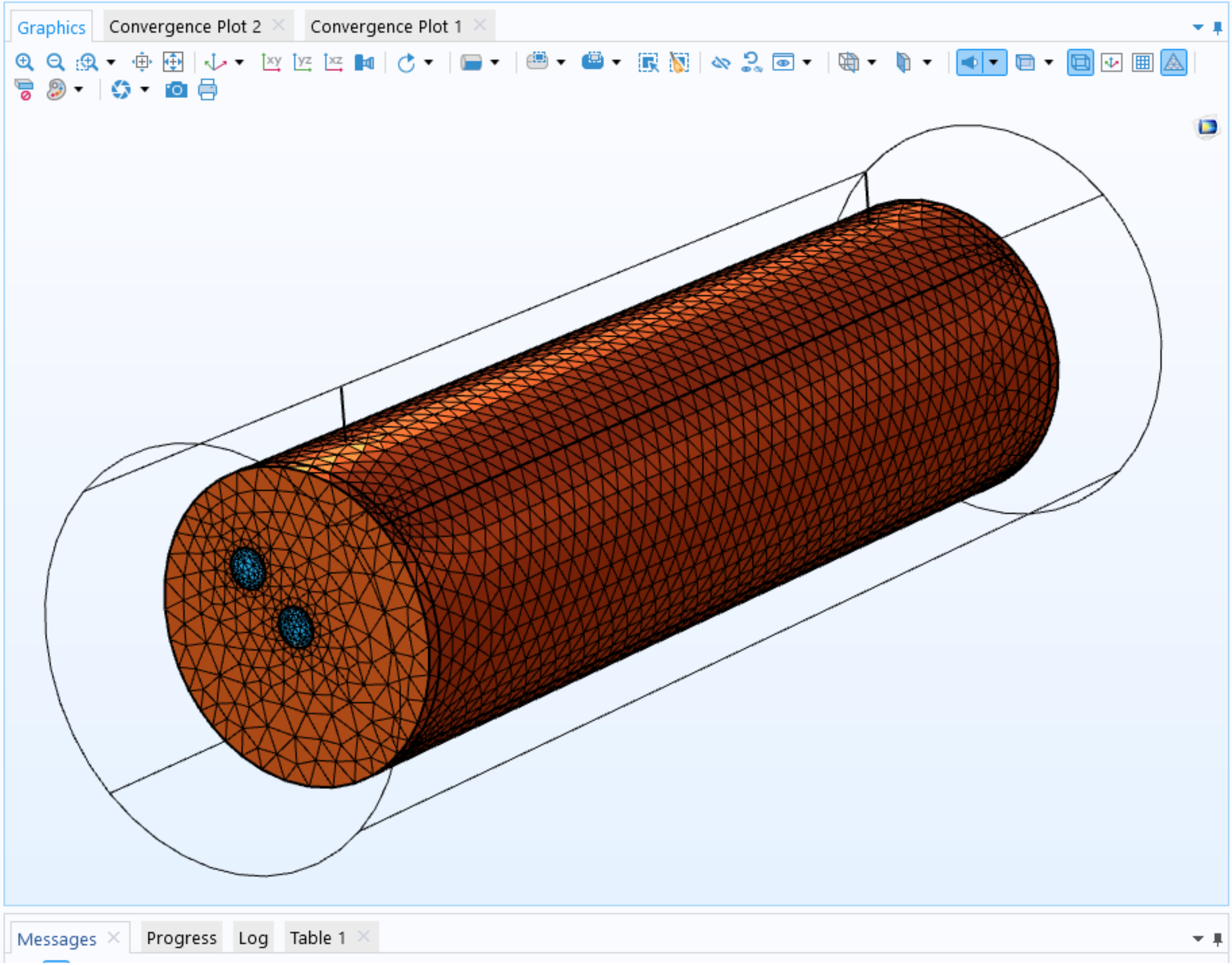
2. Material for pipe fluid
3. Physics interface *„Nonisothermal Pipe Flow“*
   - *Pipe shape and size needed!*
4. Boundary conditions
   - Wall Heat Transfer with Internal Film Resistance needed!
5. Coupling *with „Heat Transfer in Solids“*

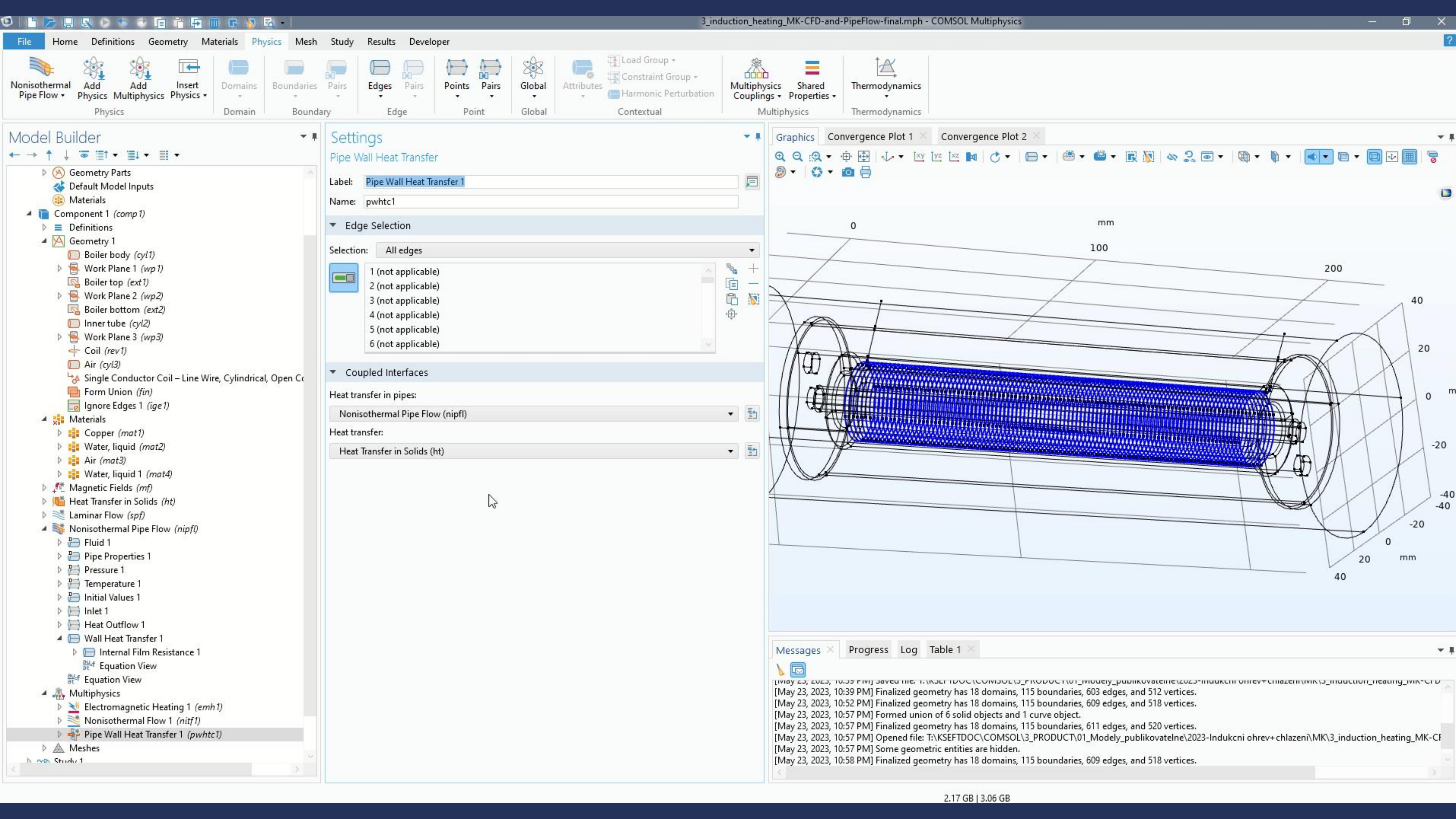



3_induction_heating_MK-CFD-and-PipeFlow-final.mph - COMSOL Multiphysics
File
Home
Definitions
Geometry
Materials
Physics
Mesh
Study
Results
Developer
Application Builder
Model Manager
Component 1
Add Component
Parameters
Variables
Functions
Parameter Case
Build All
Import
LiveLink
Add Material
Laminar Flow
Add Physics
Build Mesh
Mesh: Magnetic Fields
Compute
Study 2
Add Study
Velocity (spf)
Add Plot Group
Add Predefined Plot
Windows
Reset Desktop
Workspace
Model
Definitions
Geometry
Materials
Physics
Mesh
Study
Results
Layout
Model Builder
3_induction_heating_MK-CFD-and-PipeFlow-final.mph (root)
Global Definitions
Parameters - Matouš
Parameters 2 - Martin
Parameters 3 - Martin, pipe flow
Geometry Parts
Default Model Inputs
Materials
Component 1 (comp1)
Definitions
Geometry 1
Boiler body (cyl1)
Work Plane 1 (wp1)
Boiler top (ext1)
Work Plane 2 (wp2)
Boiler bottom (ext2)
Inner tube (cyl2)
Work Plane 3 (wp3)
Coil (rev1)
Air (cyl3)
Single Conductor Coil – Line Wire, Cylindrical, Open Corn
Form Union (fin)
Materials
Magnetic Fields (mf)
Heat Transfer in Solids (ht)
Laminar Flow (spf)
Multiphysics
Meshes
Study 1
Study 2
Results
Settings
Form Union/Assembly
Build Selected
Build All
Label: Form Union
Form Union/Assembly
Action:
Form a union
Repair tolerance:
Automatic
Graphics
Convergence Plot 1
Convergence Plot 2
0
-50
100
mm
Messages
Progress
Log
Table 1
[May 23, 2023, 10:39 PM] Finalized geometry has 18 domains, 115 boundaries, 603 edges, and 512 vertices.
[May 23, 2023, 10:52 PM] Finalized geometry has 18 domains, 115 boundaries, 609 edges, and 518 vertices.
[May 23, 2023, 10:57 PM] Formed union of 6 solid objects and 1 curve object.
[May 23, 2023, 10:57 PM] Finalized geometry has 18 domains, 115 boundaries, 611 edges, and 520 vertices.
[May 23, 2023, 10:57 PM] Opened file: T:\KSEFTDOC\COMSOL\3_PRODUCT\01_Modely_publikovatelne\2023-Indukcni ohrev+chlazeni\MK\3_induction_heating_MK-CF
[May 23, 2023, 10:57 PM] Some geometric entities are hidden.
1.98 GB | 2.87 GB

Modeling proces step-by-step

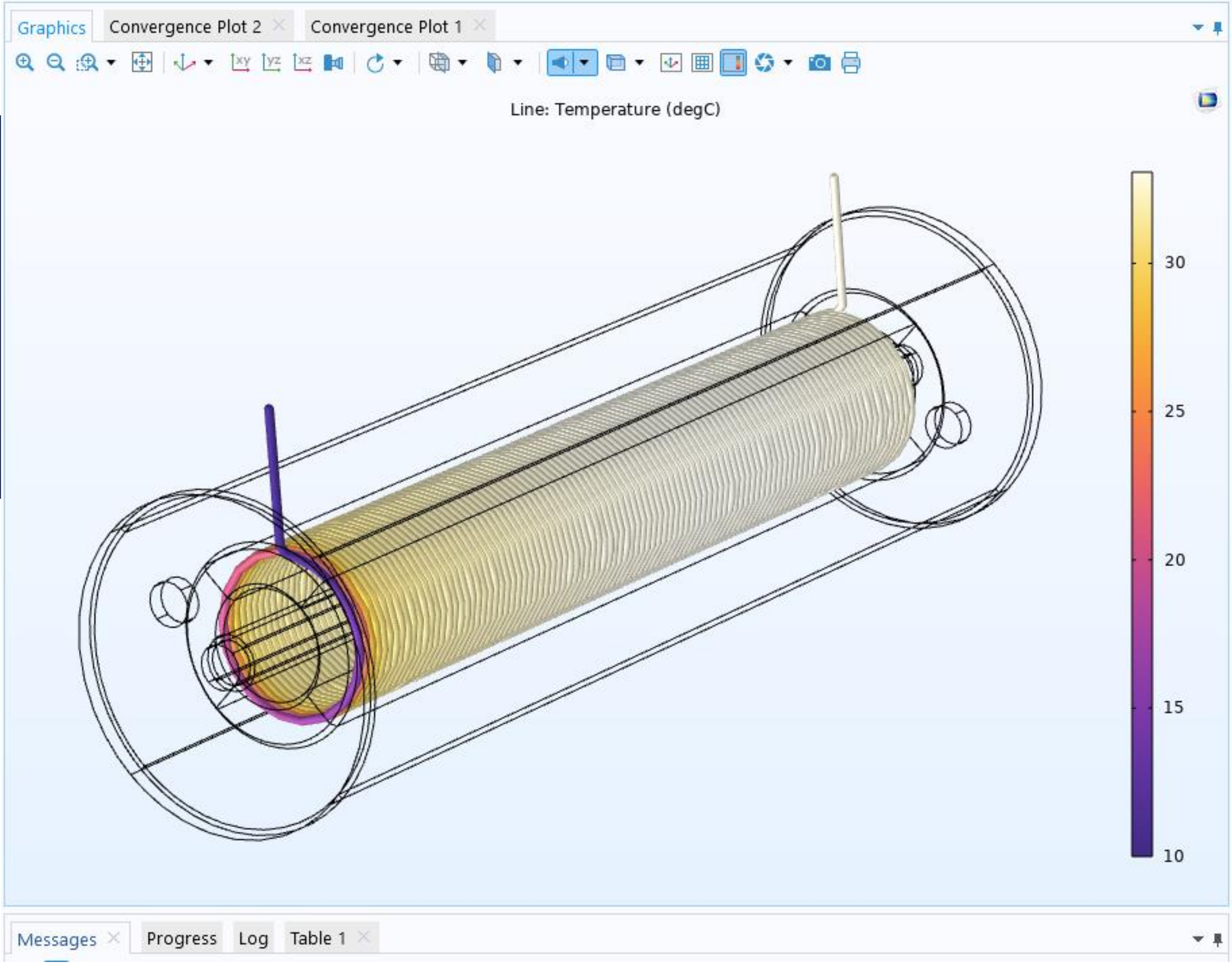
6. Building mesh (COMSOL would build it instead)
7. Study 3 takes results from Study 1

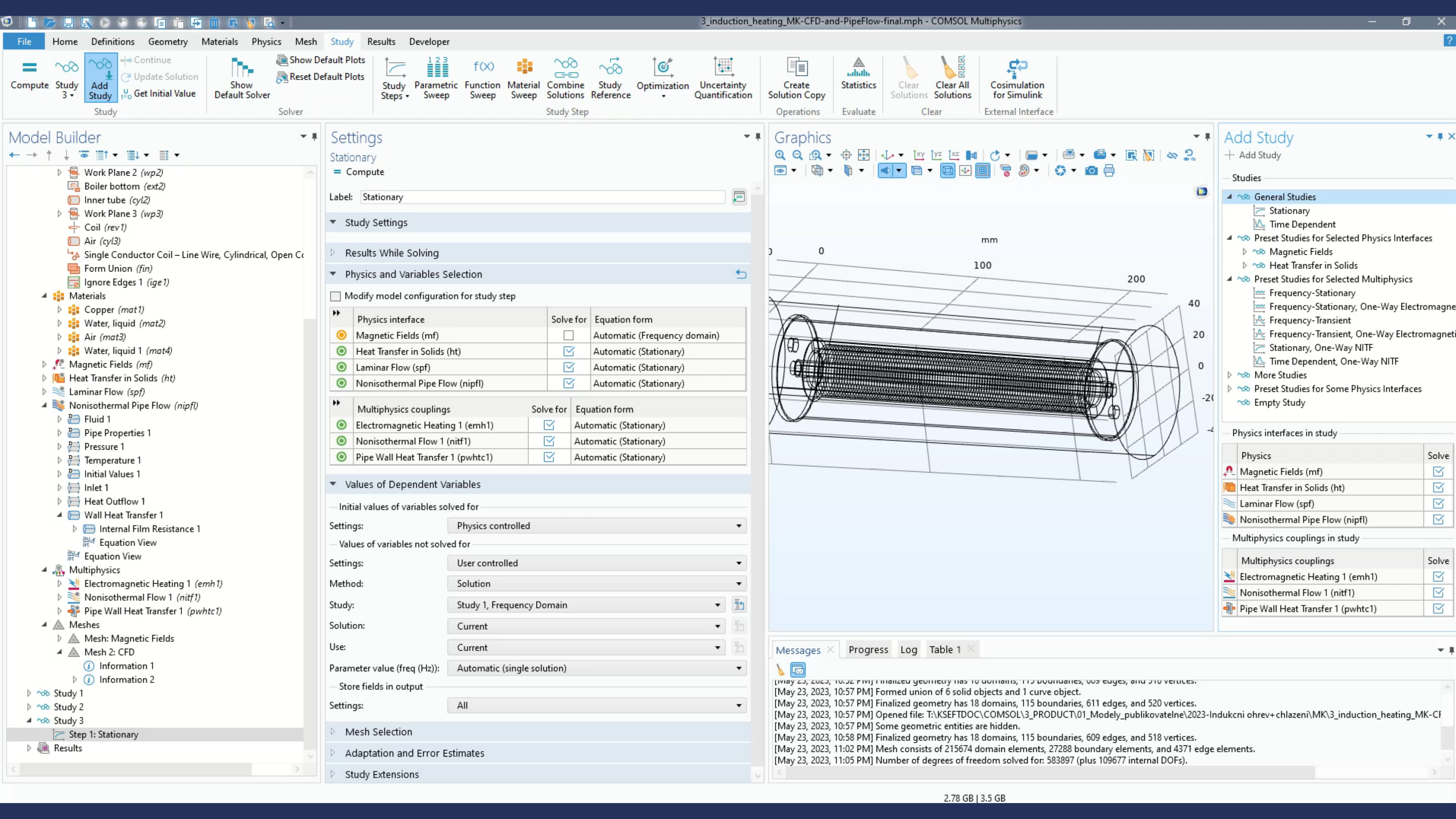


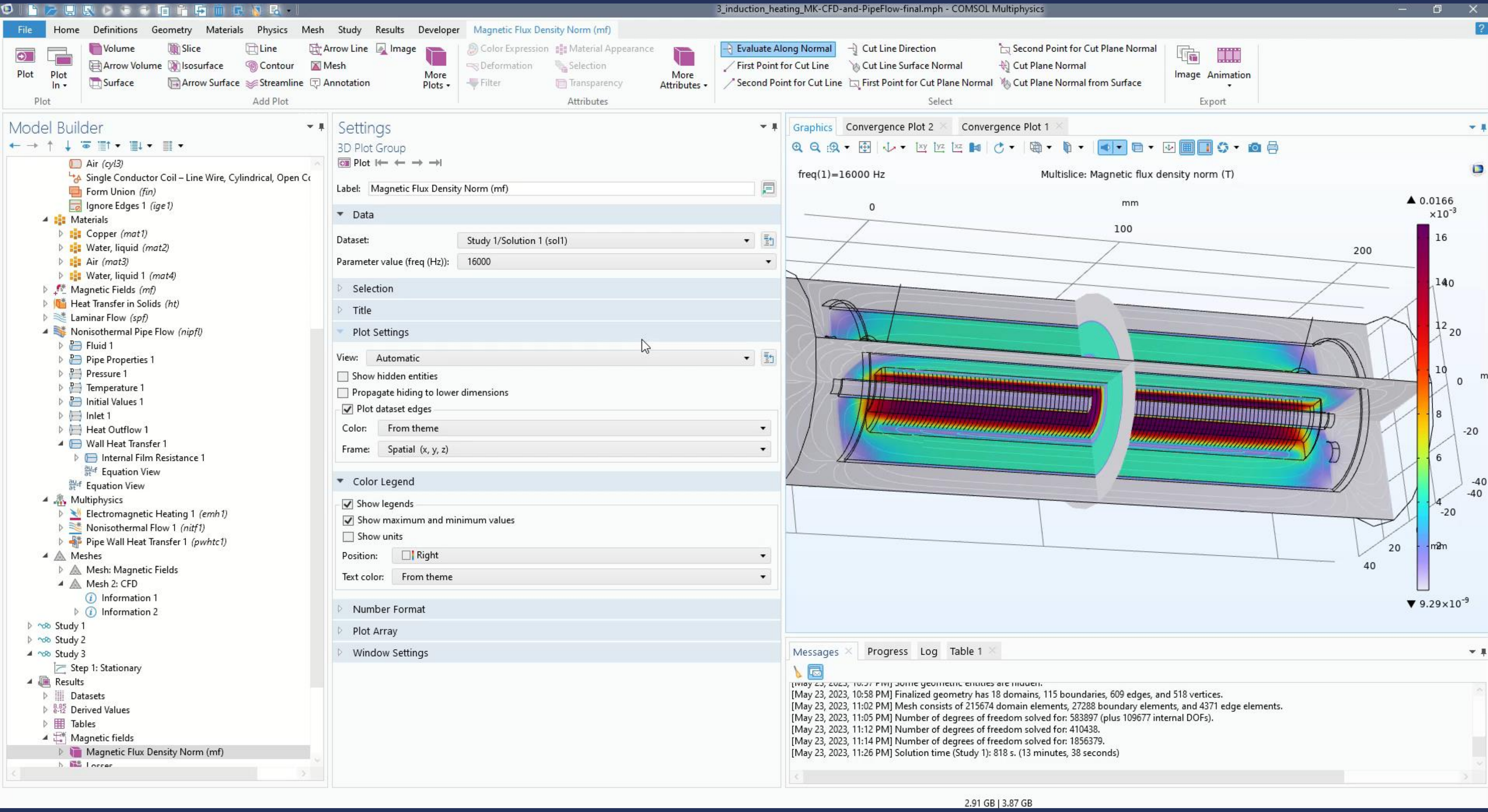

3_induction_heating_MK-CFD-and-PipeFlow-final.mph - COMSOL Multiphysics
File
Home
Definitions
Geometry
Materials
Physics
Mesh
Study
Results
Developer
Nonisothermal Pipe Flow
Add Physics
Add Multiphysics
Insert Physics
Physics
Domains
Domain
Boundaries
Pairs
Boundary
Edges
Pairs
Edge
Points
Pairs
Point
Global
Global
Attributes
Load Group
Constraint Group
Harmonic Perturbation
Contextual
Multiphysics Couplings
Shared Properties
Multiphysics
Thermodynamics
Thermodynamics
Model Builder
Geometry Parts
Default Model Inputs
Materials
Component 1 (comp1)
Definitions
Geometry 1
Boiler body (cyl1)
Work Plane 1 (wp1)
Boiler top (ext1)
Work Plane 2 (wp2)
Boiler bottom (ext2)
Inner tube (cyl2)
Work Plane 3 (wp3)
Coil (rev1)
Air (cyl3)
Single Conductor Coil – Line Wire, Cylindrical, Open Co
Form Union (fin)
Ignore Edges 1 (ige1)
Materials
Copper (mat1)
Water, liquid (mat2)
Air (mat3)
Water, liquid 1 (mat4)
Magnetic Fields (mf)
Heat Transfer in Solids (ht)
Laminar Flow (spf)
Nonisothermal Pipe Flow (nipfl)
Fluid 1
Pipe Properties 1
Pressure 1
Temperature 1
Initial Values 1
Inlet 1
Heat Outflow 1
Wall Heat Transfer 1
Internal Film Resistance 1
Equation View
Equation View
Multiphysics
Electromagnetic Heating 1 (emh1)
Nonisothermal Flow 1 (nitf1)
Pipe Wall Heat Transfer 1 (pwhtc1)
Meshes
Study 1
Settings
Pipe Wall Heat Transfer
Label: Pipe Wall Heat Transfer 1
Name: pwhtc1
Edge Selection
Selection: All edges
1 (not applicable)
2 (not applicable)
3 (not applicable)
4 (not applicable)
5 (not applicable)
6 (not applicable)
Coupled Interfaces
Heat transfer in pipes:
Nonisothermal Pipe Flow (nipfl)
Heat transfer:
Heat Transfer in Solids (ht)
Graphics
Convergence Plot 1
Convergence Plot 2
mm
0
100
200
40
20
0
-20
-40
-40
-20
0
20
40
mm
Messages
Progress
Log
Table 1
[May 23, 2023, 10:39 PM] Finalized geometry has 18 domains, 115 boundaries, 603 edges, and 512 vertices.
[May 23, 2023, 10:52 PM] Finalized geometry has 18 domains, 115 boundaries, 609 edges, and 518 vertices.
[May 23, 2023, 10:57 PM] Formed union of 6 solid objects and 1 curve object.
[May 23, 2023, 10:57 PM] Finalized geometry has 18 domains, 115 boundaries, 611 edges, and 520 vertices.
[May 23, 2023, 10:57 PM] Opened file: T:\KSEFTDOC\COMSOL\3_PRODUCT\01_Modely_publikovatelne\2023-Indukcni ohrev+chlazeni\MK\3_induction_heating_MK-CF
[May 23, 2023, 10:57 PM] Some geometric entities are hidden.
[May 23, 2023, 10:58 PM] Finalized geometry has 18 domains, 115 boundaries, 609 edges, and 518 vertices.
2.17 GB | 3.06 GB

Modeling proces step-by-step

7. Recomputing Study 1. Geometry changed!
8. Computing Study 3
9. Postprocessing




3_induction_heating_MK-CFD-and-PipeFlow-final.mph - COMSOL Multiphysics
File
Home
Definitions
Geometry
Materials
Physics
Mesh
Study
Results
Developer
Compute
Study 3
Add Study
Continue
Update Solution
Get Initial Value
Study
Show Default Solver
Show Default Plots
Reset Default Plots
Solver
Study Steps
Parametric Sweep
Function Sweep
Material Sweep
Combine Solutions
Study Reference
Optimization
Uncertainty Quantification
Study Step
Create Solution Copy
Operations
Statistics
Evaluate
Clear Solutions
Clear All Solutions
Clear
Cosimulation for Simulink
External Interface
Model Builder
Work Plane 2 (wp2)
Boiler bottom (ext2)
Inner tube (cyl2)
Work Plane 3 (wp3)
Coil (rev1)
Air (cyl3)
Single Conductor Coil – Line Wire, Cylindrical, Open Co
Form Union (fin)
Ignore Edges 1 (ige1)
Materials
Copper (mat1)
Water, liquid (mat2)
Air (mat3)
Water, liquid 1 (mat4)
Magnetic Fields (mf)
Heat Transfer in Solids (ht)
Laminar Flow (spf)
Nonisothermal Pipe Flow (nipfl)
Fluid 1
Pipe Properties 1
Pressure 1
Temperature 1
Initial Values 1
Inlet 1
Heat Outflow 1
Wall Heat Transfer 1
Internal Film Resistance 1
Equation View
Equation View
Multiphysics
Electromagnetic Heating 1 (emh1)
Nonisothermal Flow 1 (nitf1)
Pipe Wall Heat Transfer 1 (pwhtc1)
Meshes
Mesh: Magnetic Fields
Mesh 2: CFD
Information 1
Information 2
Study 1
Study 2
Study 3
Step 1: Stationary
Results
Settings
Stationary
Compute
Label: Stationary
Study Settings
Results While Solving
Physics and Variables Selection
Modify model configuration for study step
Physics interface | Solve for | Equation form
Magnetic Fields (mf) | Automatic (Frequency domain)
Heat Transfer in Solids (ht) | Automatic (Stationary)
Laminar Flow (spf) | Automatic (Stationary)
Nonisothermal Pipe Flow (nipfl) | Automatic (Stationary)
Multiphysics couplings | Solve for | Equation form
Electromagnetic Heating 1 (emh1) | Automatic (Stationary)
Nonisothermal Flow 1 (nitf1) | Automatic (Stationary)
Pipe Wall Heat Transfer 1 (pwhtc1) | Automatic (Stationary)
Values of Dependent Variables
Initial values of variables solved for
Settings: Physics controlled
Values of variables not solved for
Settings: User controlled
Method: Solution
Study: Study 1, Frequency Domain
Solution: Current
Use: Current
Parameter value (freq (Hz)): Automatic (single solution)
Store fields in output
Settings: All
Mesh Selection
Adaptation and Error Estimates
Study Extensions
Graphics
mm
0
100
200
40
20
0
Add Study
Add Study
Studies
General Studies
Stationary
Time Dependent
Preset Studies for Selected Physics Interfaces
Magnetic Fields
Heat Transfer in Solids
Preset Studies for Selected Multiphysics
Frequency-Stationary
Frequency-Stationary, One-Way Electromagne
Frequency-Transient
Frequency-Transient, One-Way Electromagneti
Stationary, One-Way NITF
Time Dependent, One-Way NITF
More Studies
Preset Studies for Some Physics Interfaces
Empty Study
Physics interfaces in study
Physics | Solve
Magnetic Fields (mf)
Heat Transfer in Solids (ht)
Laminar Flow (spf)
Nonisothermal Pipe Flow (nipfl)
Multiphysics couplings in study
Multiphysics couplings | Solve
Electromagnetic Heating 1 (emh1)
Nonisothermal Flow 1 (nitf1)
Pipe Wall Heat Transfer 1 (pwhtc1)
Messages
Progress
Log
Table 1
[May 23, 2023, 10:57 PM] Formed union of 6 solid objects and 1 curve object.
[May 23, 2023, 10:57 PM] Finalized geometry has 18 domains, 115 boundaries, 611 edges, and 520 vertices.
[May 23, 2023, 10:57 PM] Opened file: T:\KSEFTDOC\COMSOL\3_PRODUCT\01_Modely_publikovatelne\2023-Indukcni ohrev+chlazeni\MK\3_induction_heating_MK-CF
[May 23, 2023, 10:57 PM] Some geometric entities are hidden.
[May 23, 2023, 10:58 PM] Finalized geometry has 18 domains, 115 boundaries, 609 edges, and 518 vertices.
[May 23, 2023, 11:02 PM] Mesh consists of 215674 domain elements, 27288 boundary elements, and 4371 edge elements.
[May 23, 2023, 11:05 PM] Number of degrees of freedom solved for: 583897 (plus 109677 internal DOFs).
2.78 GB | 3.5 GB

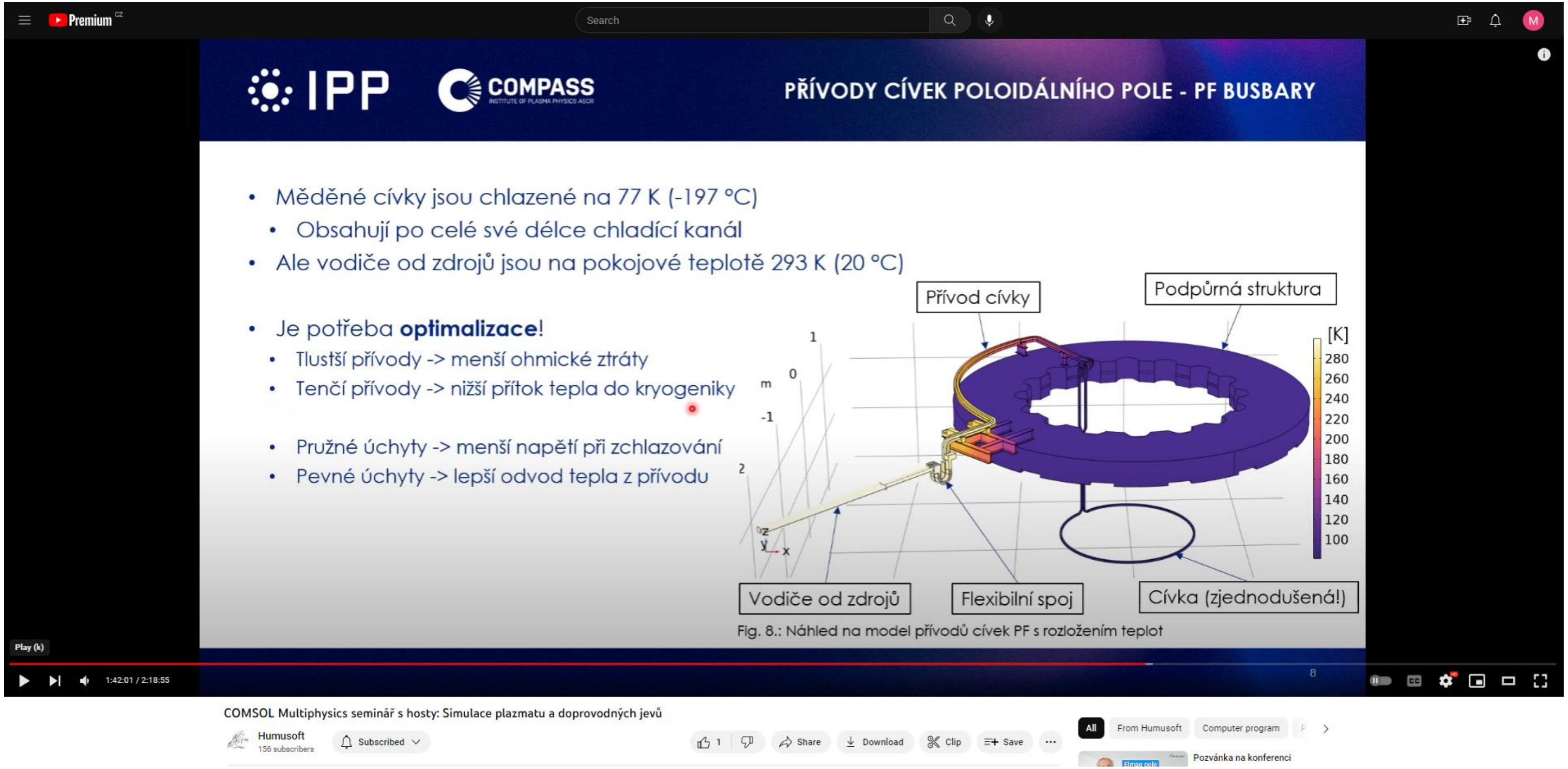


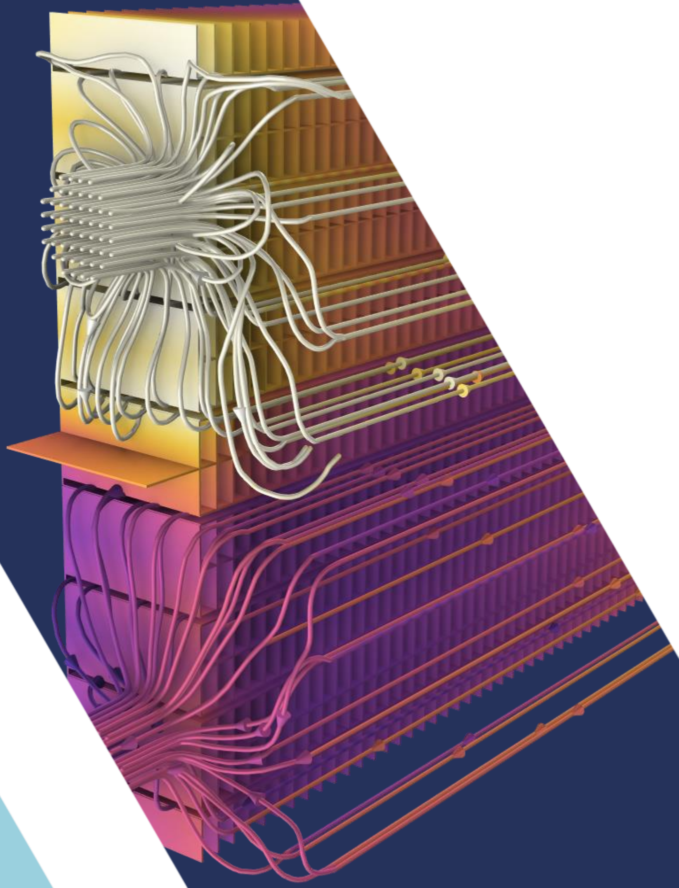
3_induction_heating_MK-CFD-and-PipeFlow-final.mph - COMSOL Multiphysics
File
Home
Definitions
Geometry
Materials
Physics
Mesh
Study
Results
Developer
Magnetic Flux Density Norm (mf)
Plot
Plot In
Volume
Arrow Volume
Surface
Slice
Isosurface
Arrow Surface
Line
Contour
Streamline
Arrow Line
Mesh
Annotation
Image
More Plots
Add Plot
Color Expression
Deformation
Filter
Material Appearance
Selection
Transparency
More Attributes
Attributes
Evaluate Along Normal
First Point for Cut Line
Second Point for Cut Line
Cut Line Direction
Cut Line Surface Normal
First Point for Cut Plane Normal
Second Point for Cut Plane Normal
Cut Plane Normal
Cut Plane Normal from Surface
Select
Image
Animation
Export
Model Builder
Air (cyl3)
Single Conductor Coil – Line Wire, Cylindrical, Open Cc
Form Union (fin)
Ignore Edges 1 (ige1)
Materials
Copper (mat1)
Water, liquid (mat2)
Air (mat3)
Water, liquid 1 (mat4)
Magnetic Fields (mf)
Heat Transfer in Solids (ht)
Laminar Flow (spf)
Nonisothermal Pipe Flow (nipfl)
Fluid 1
Pipe Properties 1
Pressure 1
Temperature 1
Initial Values 1
Inlet 1
Heat Outflow 1
Wall Heat Transfer 1
Internal Film Resistance 1
Equation View
Equation View
Multiphysics
Electromagnetic Heating 1 (emh1)
Nonisothermal Flow 1 (nitf1)
Pipe Wall Heat Transfer 1 (pwhtc1)
Meshes
Mesh: Magnetic Fields
Mesh 2: CFD
Information 1
Information 2
Study 1
Study 2
Study 3
Step 1: Stationary
Results
Datasets
Derived Values
Tables
Magnetic fields
Magnetic Flux Density Norm (mf)
Losses
Settings
3D Plot Group
Plot
Label: Magnetic Flux Density Norm (mf)
Data
Dataset: Study 1/Solution 1 (sol1)
Parameter value (freq (Hz)): 16000
Selection
Title
Plot Settings
View: Automatic
Show hidden entities
Propagate hiding to lower dimensions
Plot dataset edges
Color: From theme
Frame: Spatial (x, y, z)
Color Legend
Show legends
Show maximum and minimum values
Show units
Position: Right
Text color: From theme
Number Format
Plot Array
Window Settings
Graphics
Convergence Plot 2
Convergence Plot 1
freq(1)=16000 Hz
Multislice: Magnetic flux density norm (T)
▲ 0.0166
×10^-3
16
14
12
10
8
6
4
2
▼ 9.29×10^-9
mm
0
100
200
Messages
Progress
Log
Table 1
[May 23, 2023, 10:58 PM] Finalized geometry has 18 domains, 115 boundaries, 609 edges, and 518 vertices.
[May 23, 2023, 11:02 PM] Mesh consists of 215674 domain elements, 27288 boundary elements, and 4371 edge elements.
[May 23, 2023, 11:05 PM] Number of degrees of freedom solved for: 583897 (plus 109677 internal DOFs).
[May 23, 2023, 11:12 PM] Number of degrees of freedom solved for: 410438.
[May 23, 2023, 11:14 PM] Number of degrees of freedom solved for: 1856379.
[May 23, 2023, 11:26 PM] Solution time (Study 1): 818 s. (13 minutes, 38 seconds)
2.91 GB | 3.87 GB

Modeling proces overview

1. New parameters
2. New geometry part from library
3. Material for pipe fluid
4. Physics interface „*Nonisothermal Pipe Flow*“
5. Boundary conditions: Inlet, Heat Outflow, Wall Heat Transfer and Internal Film Resistance (thermal film theory)
6. Coupling „*Nonisothermal Pipe Flow*“ *with* „*Heat Transfer in Solids*“
7. Recomputing Study 1 – geometry changed!
8. Study 3
9. Postprocessing

Recommended webinar





Thank you
for your Attention!

Martin Kožíšek
kozisek@humusoft.cz
+284 011 745