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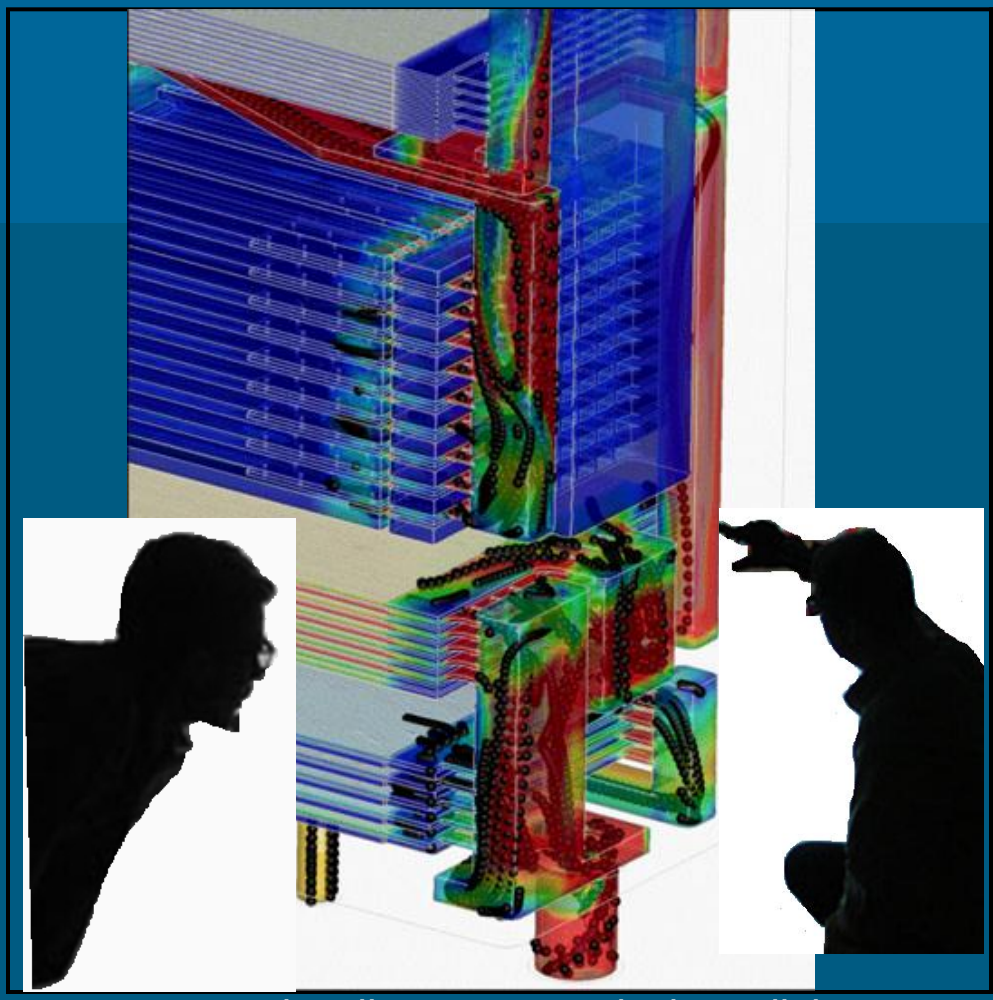

3D Fuel Cell System Analysis -Jülich

Introduction to Multiphysics Modelling

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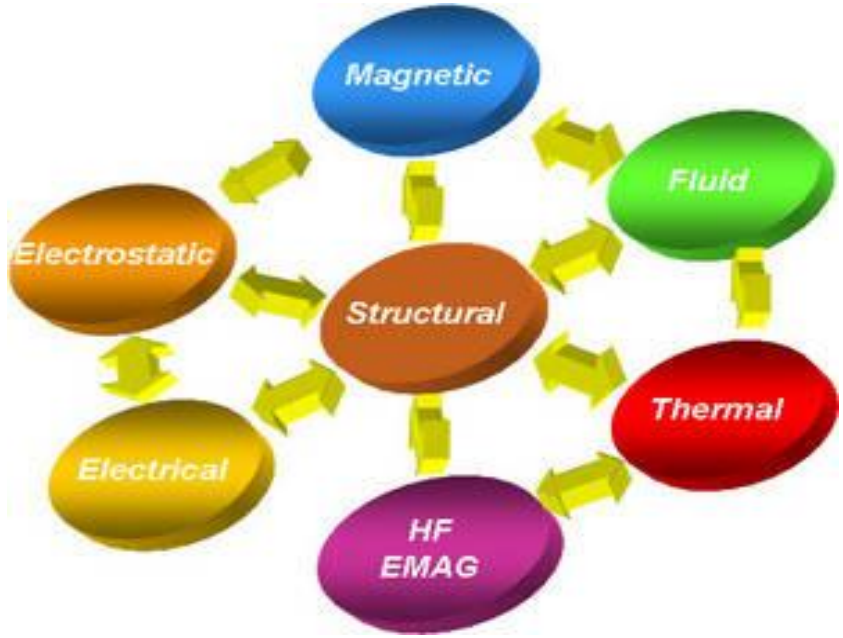
Syllabus

- What is Multiphysics and Why to Model?
- Multiphysics Classifications
- Challenges in Multiphysics Modelling
- Multiphysics Methodology
- Concluding Remarks

1.1 What is Multiphysics and Why to Model?

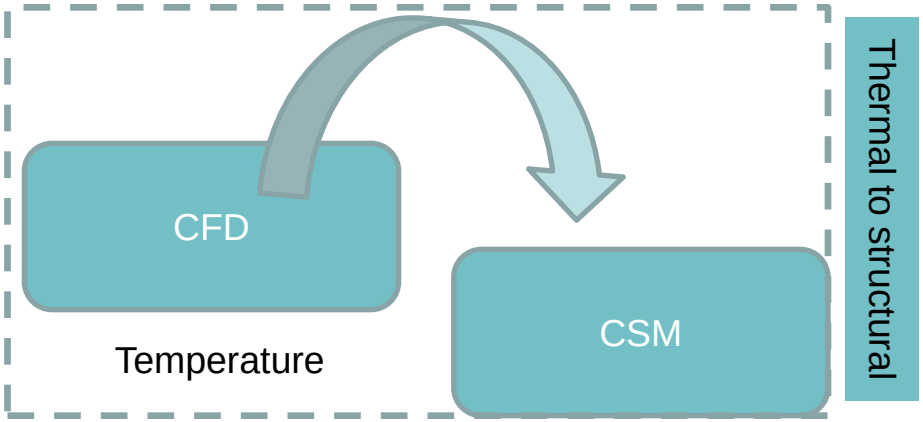
- Various real world phenomena interacting simultaneously build up multiphysics.

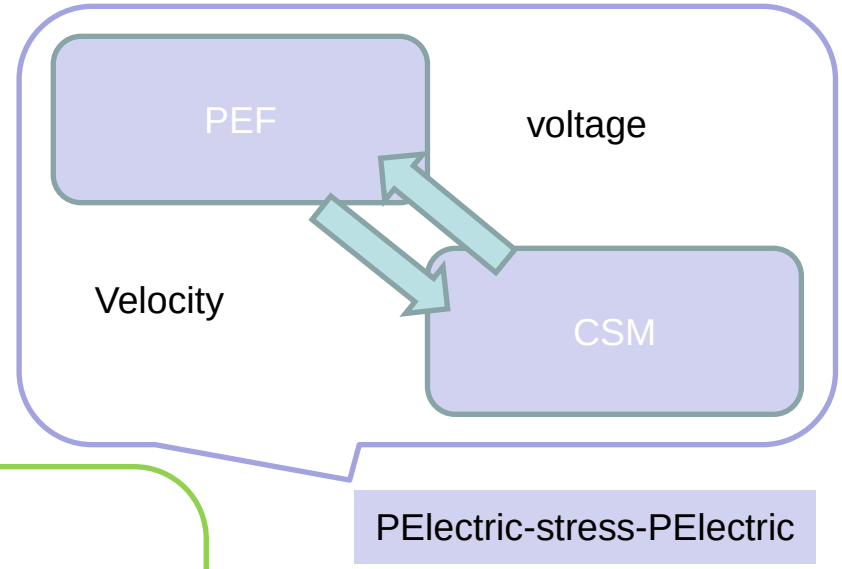


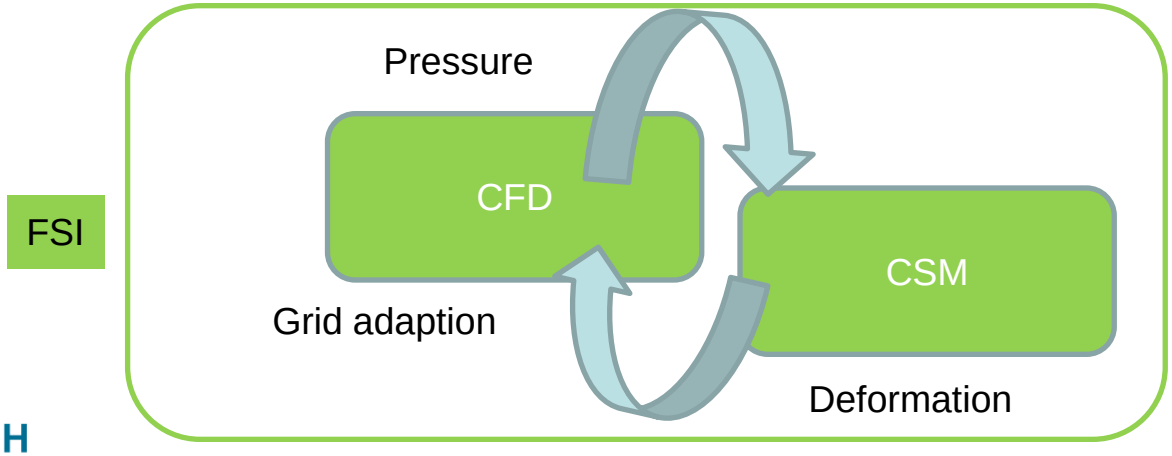
- Real time interactions among disciplines needs to be considered.
- The desire to understand and improve complex features and processes.

1.2 Multiphysics Classifications

- Multi-disciplinary: utilises data generated by one code as input for another.
- Multi-physics: two way exchange of information e.g. piezoelectric analysis.
- Closely coupled multiphysics: time and space accurate exchange of used data e.g. fluid–structure interaction (FSI).







1.3 Challenges in Multiphysics Modelling

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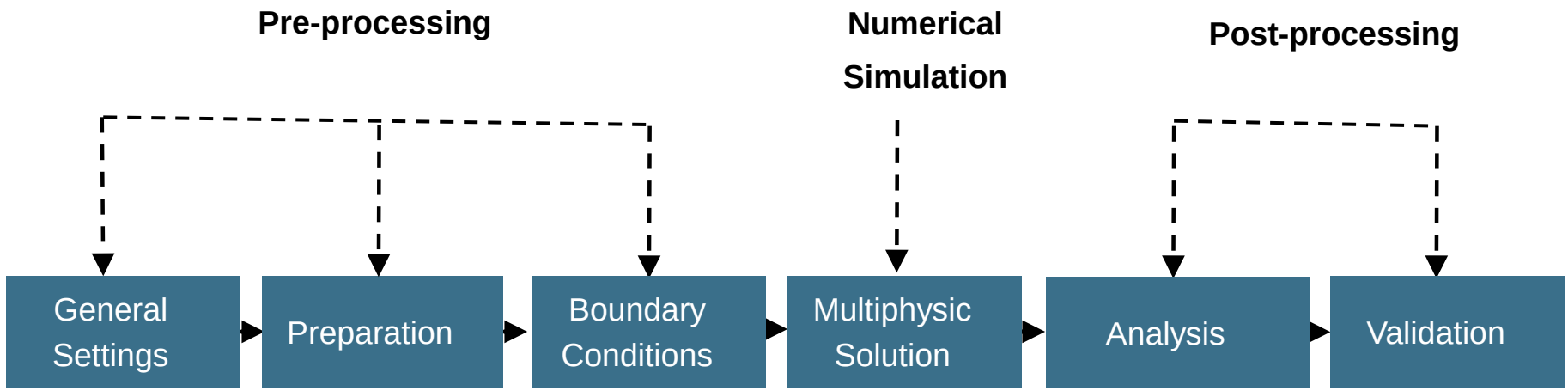
- Requires expertise in many engineering fields as well as software and hardware
- Closely coupled interactions between multiple phenomena
- Analysis software usually phenomena specific:
  - Finite element techniques with direct solver structure
  - Finite volume techniques with segregated iterative solvers
- Accurate filtering and data mapping for boundary and initial conditions
- Must ensure the accurate deformation capability of the mesh and geometry where required
- Parallel computing issues

1.4 Multiphysics Modelling Methodology



- **Engineering Data**
- **Models**

- **Solid Modelling**
- **Clean up**
- **Meshing etc.**

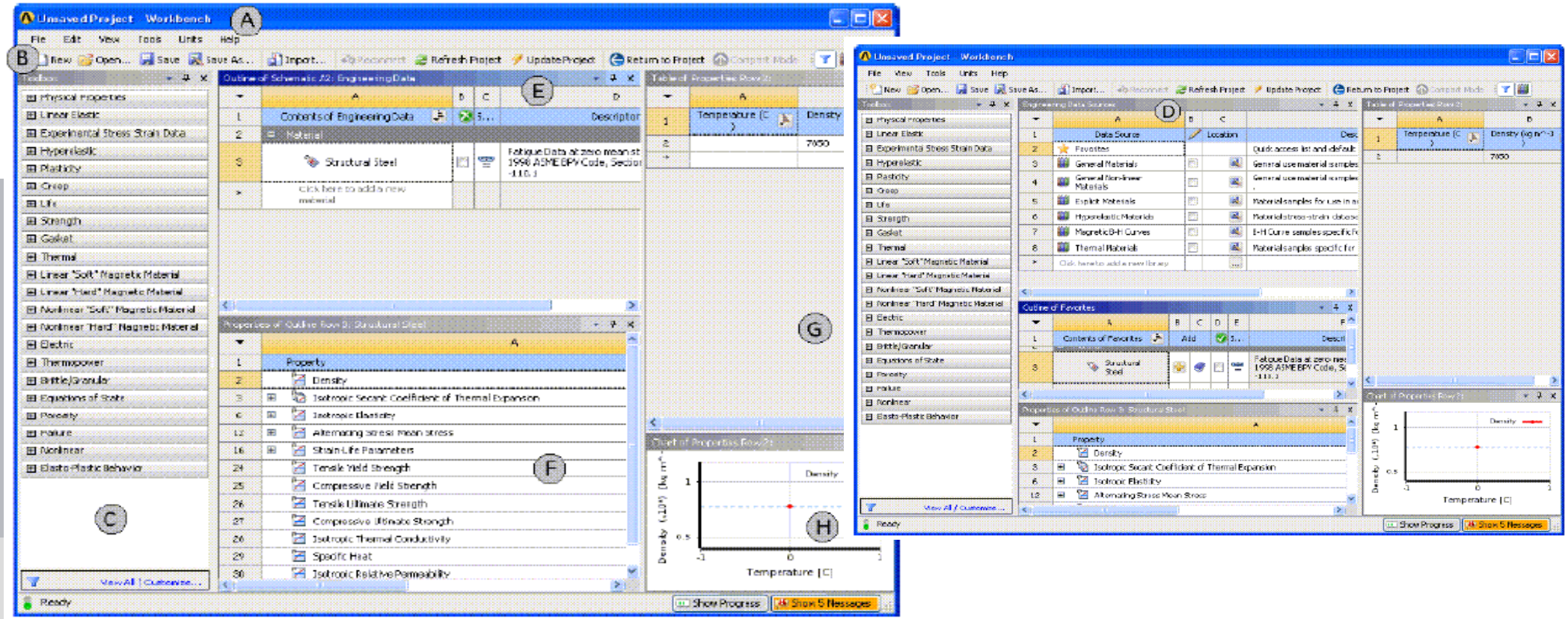
- **Flow rate,**
- **Temperature,**
- **Force etc.**

- **Solution methods,**
- **Spatial Discretisation etc.**

- **Contour plots**
- **Graphics**
- **Integration etc.**

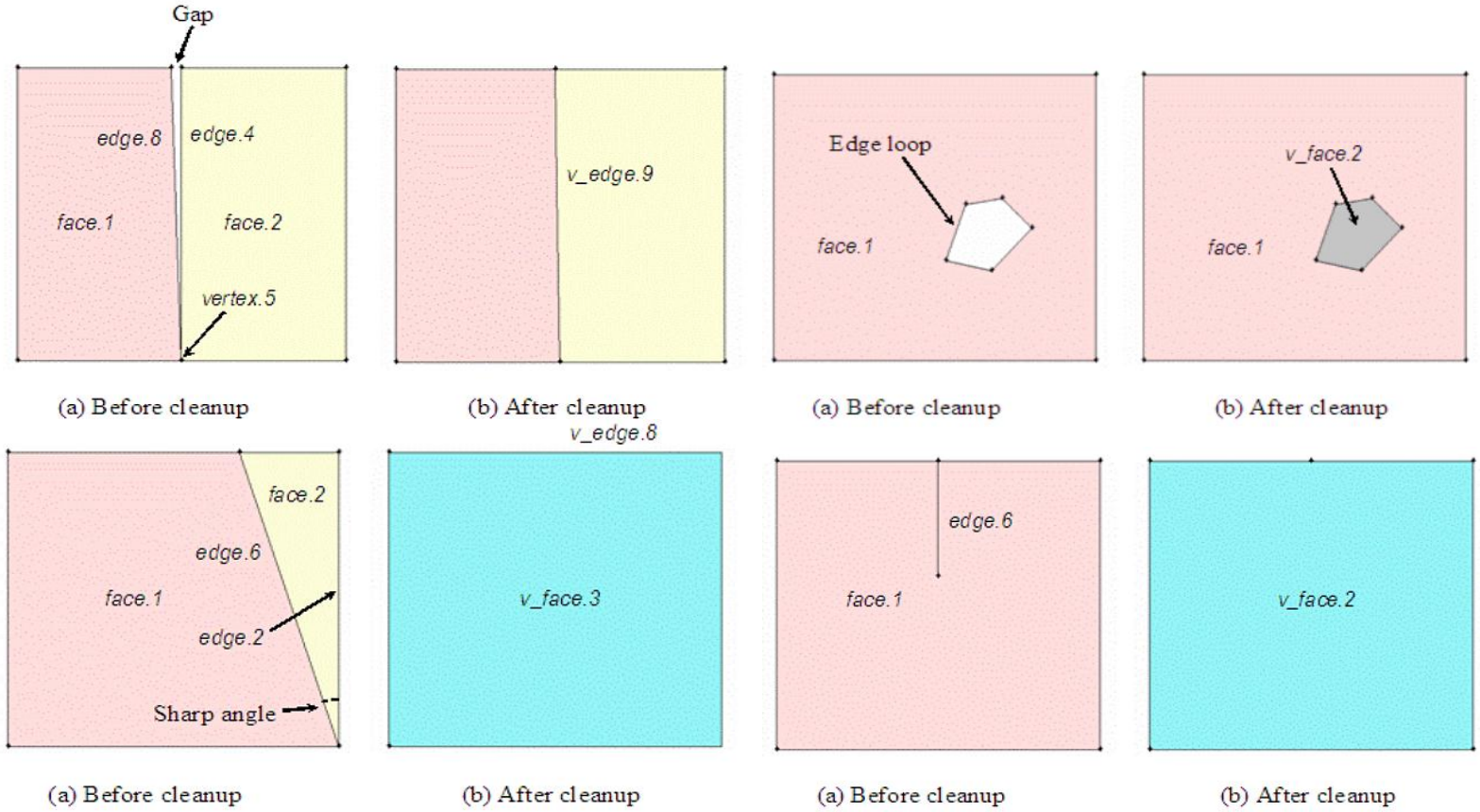
- **Image**
- **Measurement**

1.4.1 Pre-processing/Engineering Data

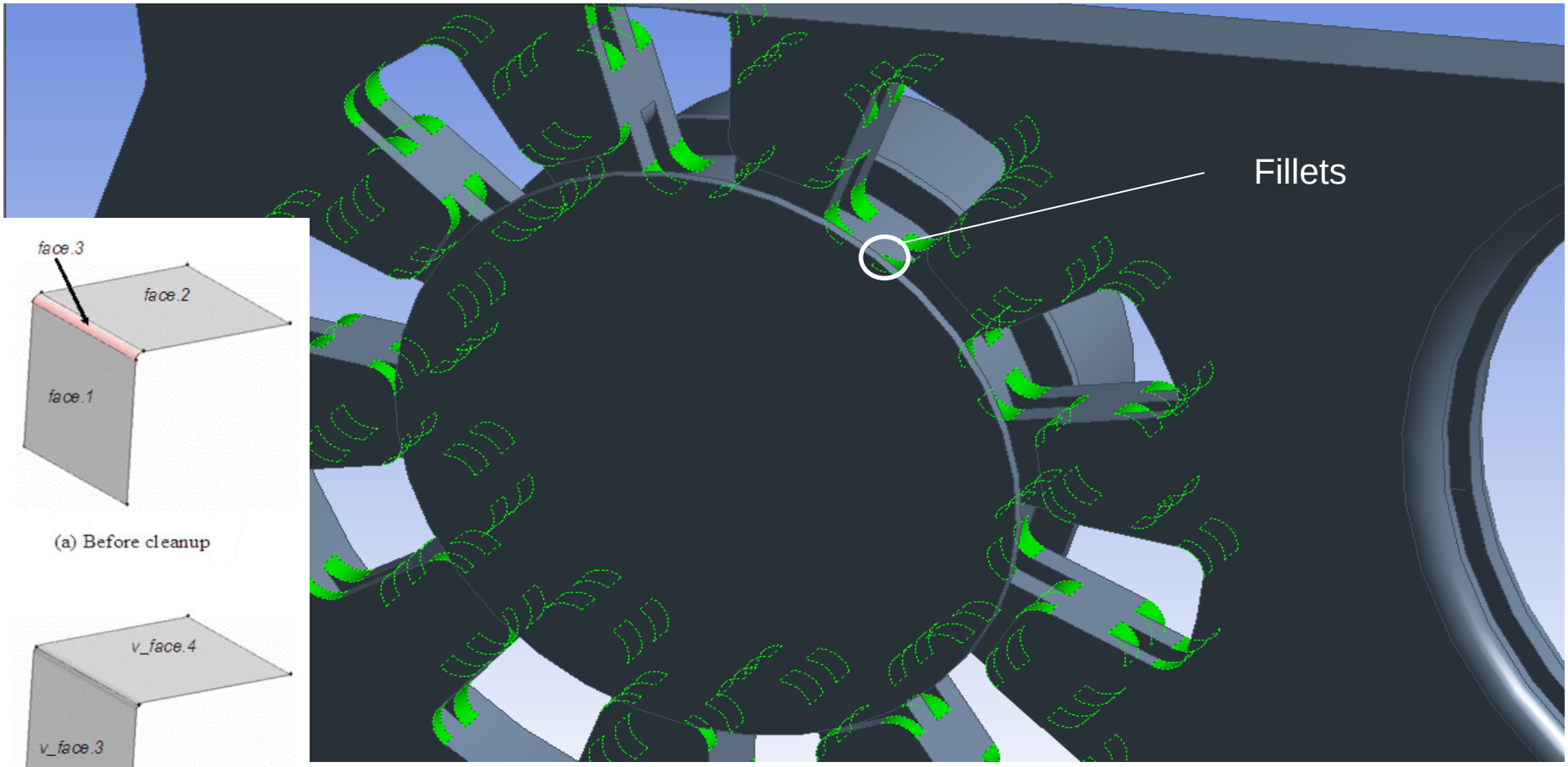


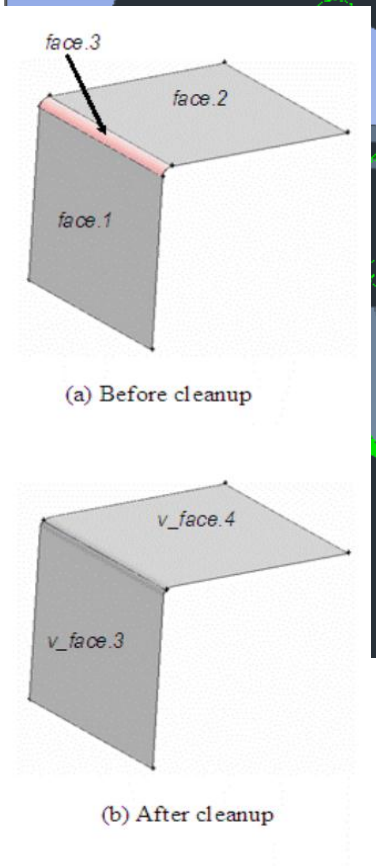
1.4.2 Pre-processing/Clean-up

- Repair edges, holes, cracks, sharp angles etc.
- Simplify fillets, solid geometry.
- Conduct operations, add-subtract domains
- Create, adjust additional volumes etc.



1.4.2 Pre-processing/Clean-up

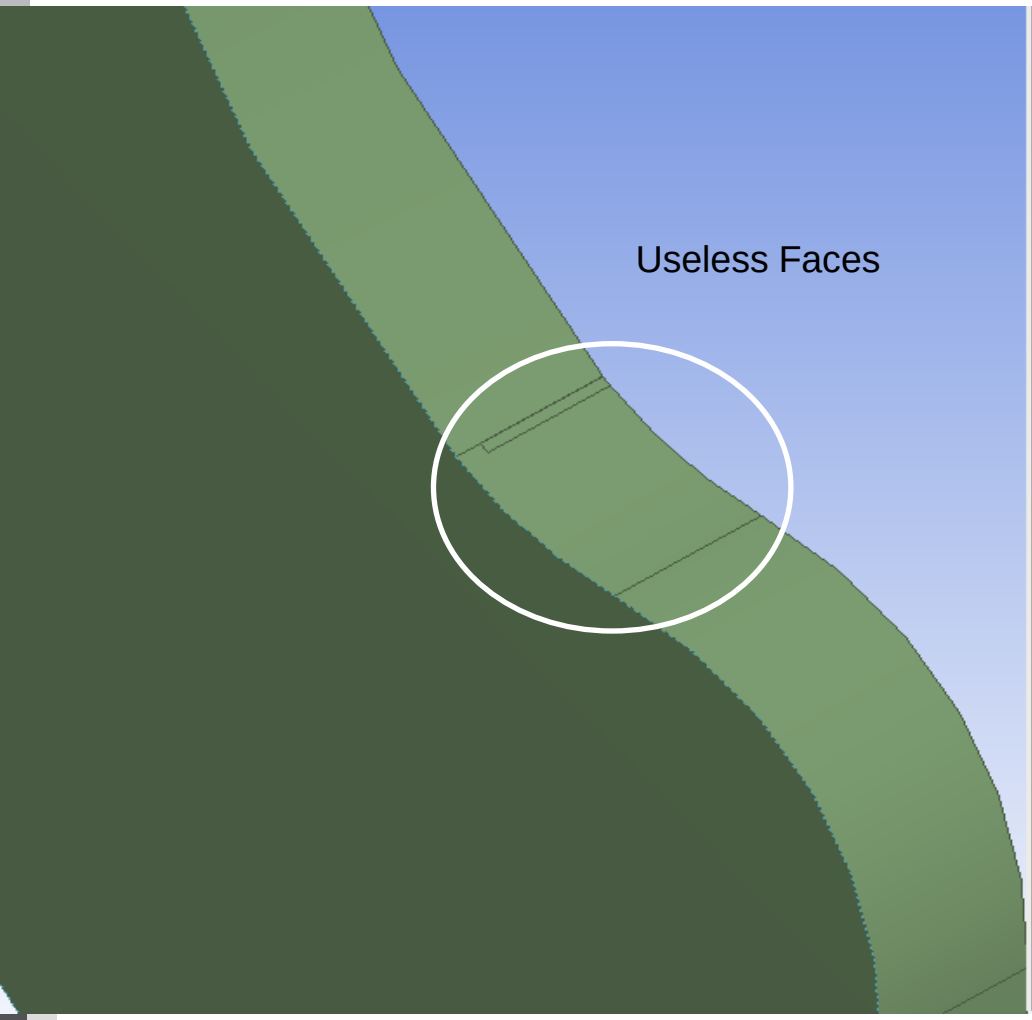


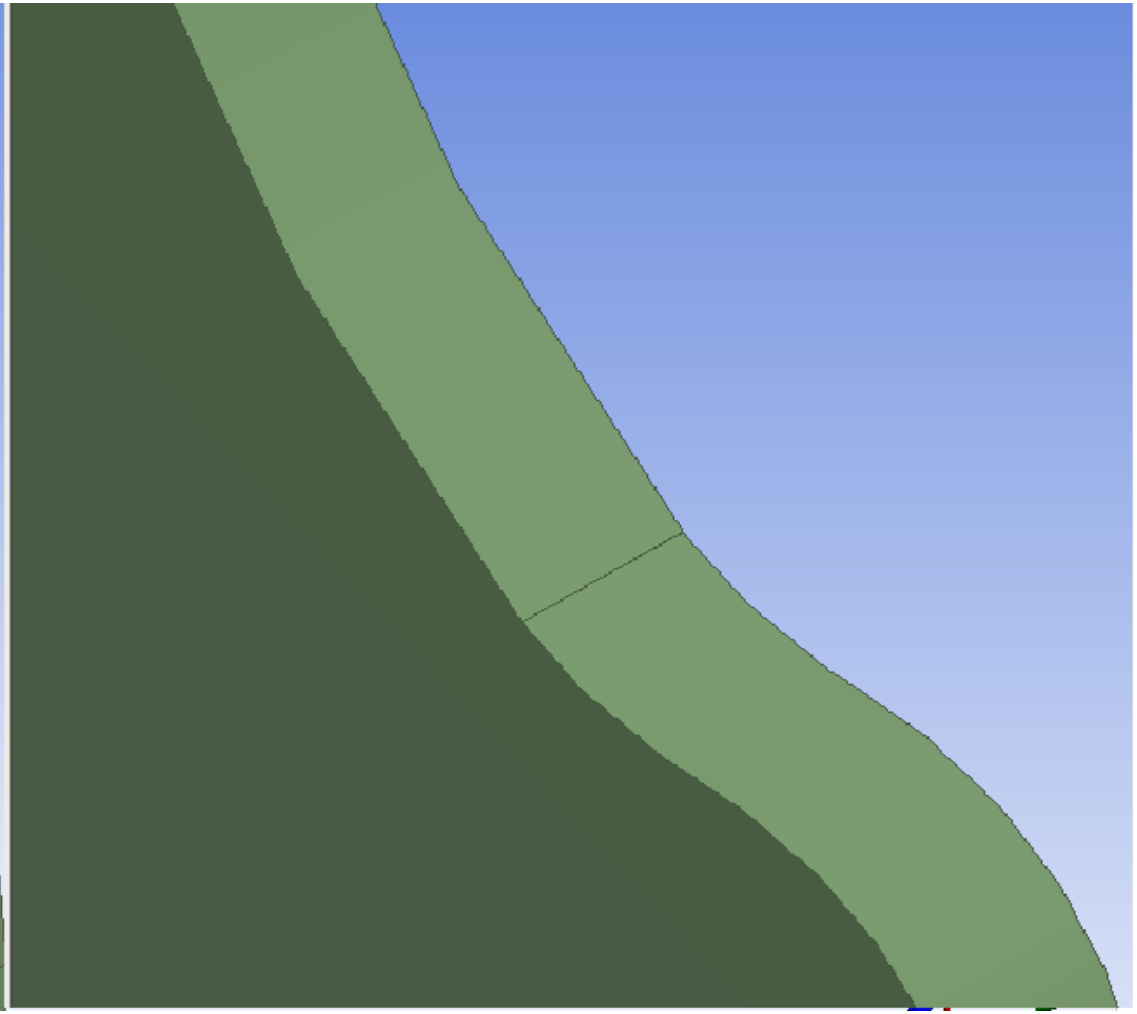


(a) Before cleanup

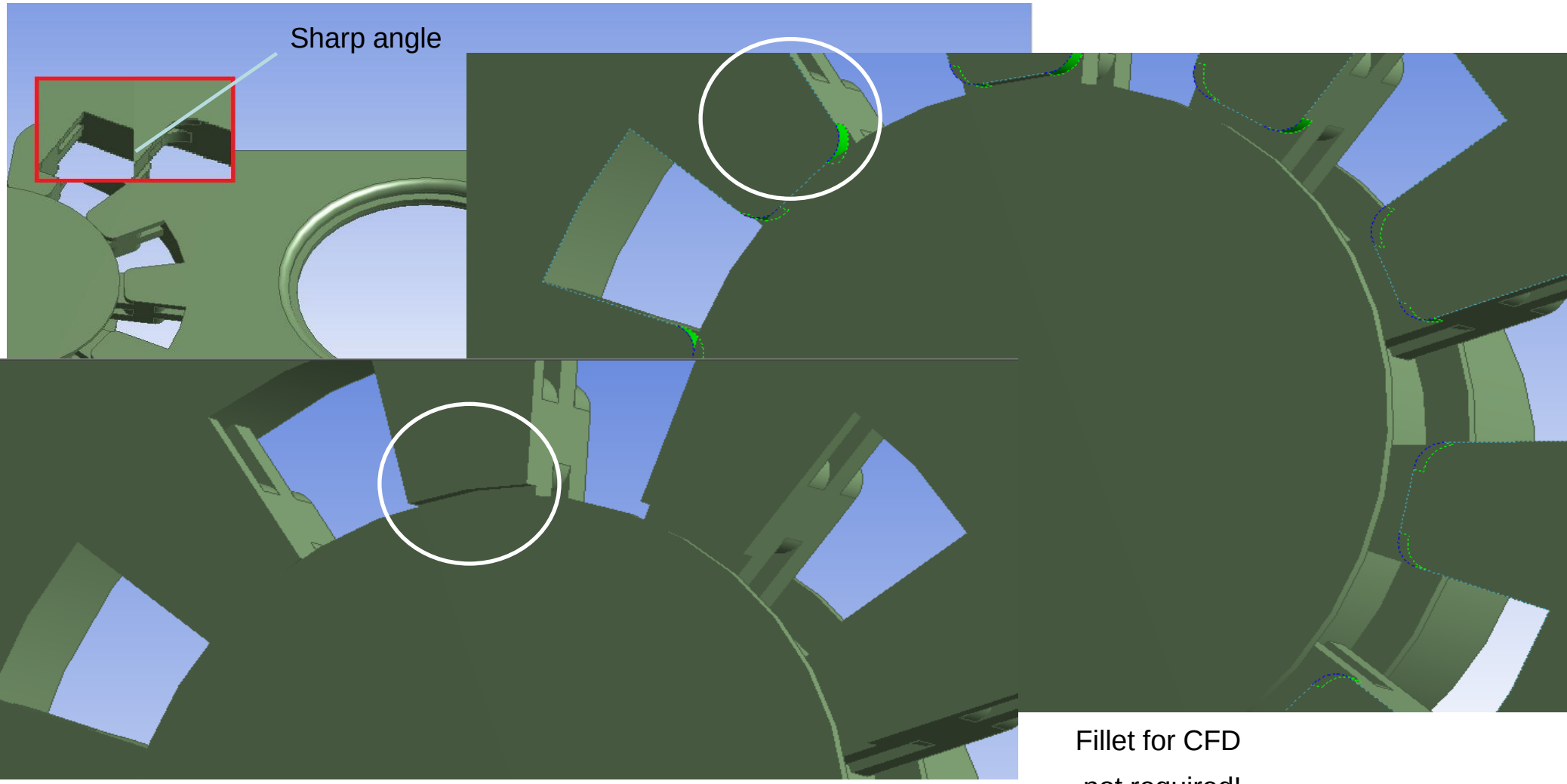
(b) After cleanup

1.4.2 Pre-processing/Clean-up





1.4.2 Pre-processing/Clean-up



Fillet for CFD
not required!

1.4.2 Pre-processing/Clean-up

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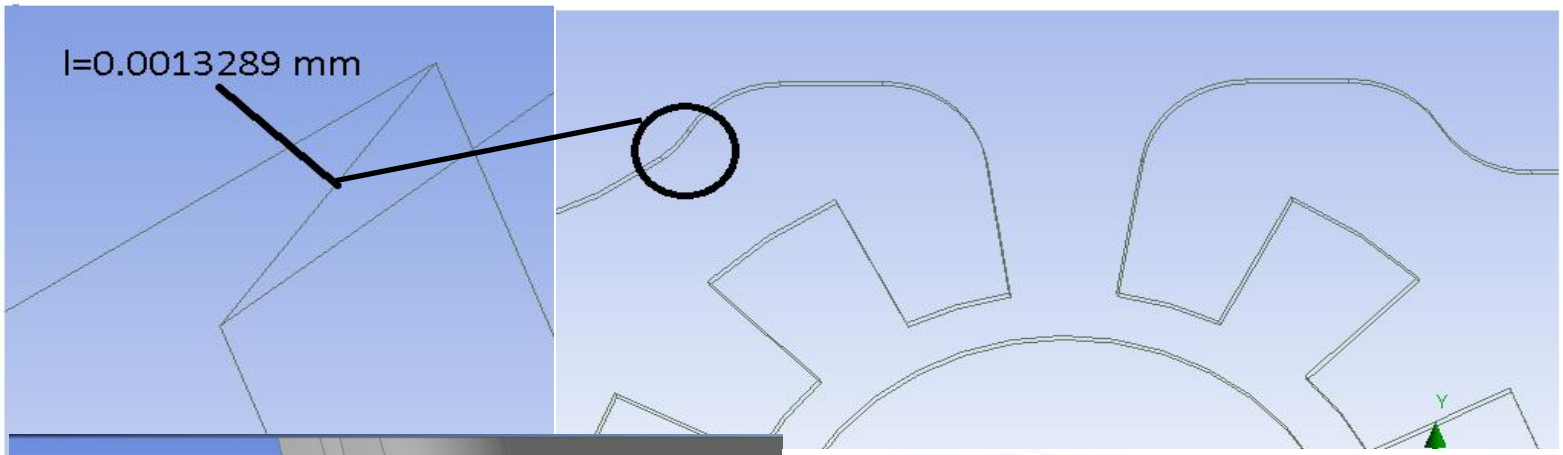
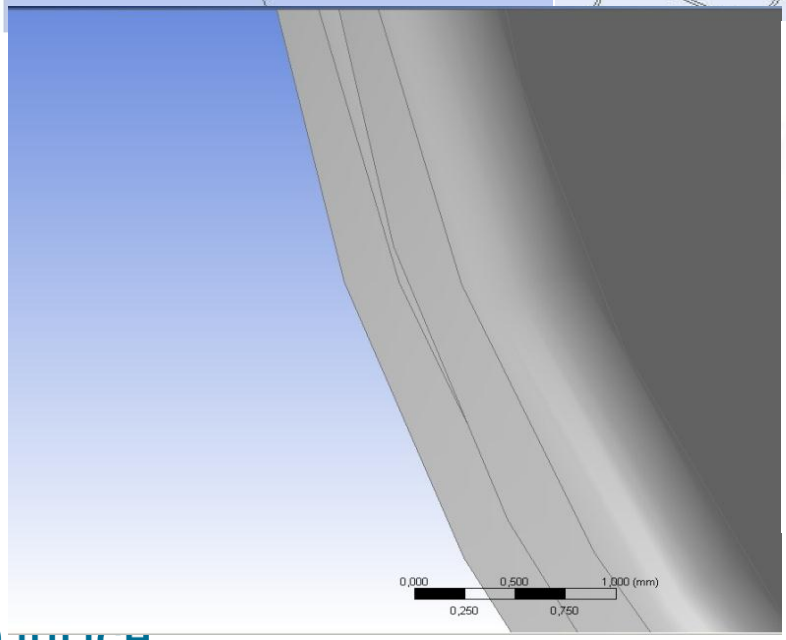
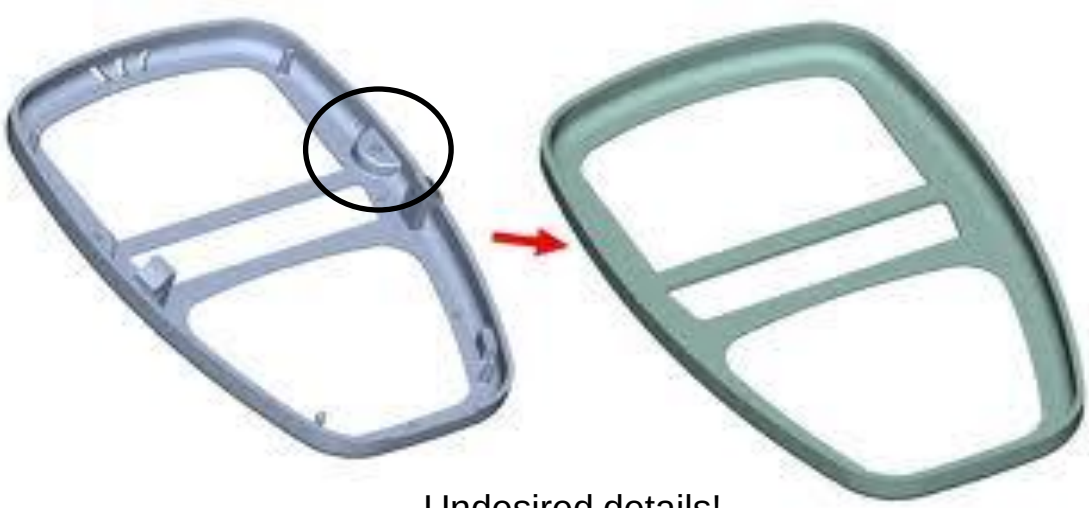
Small features must be removed or merged!

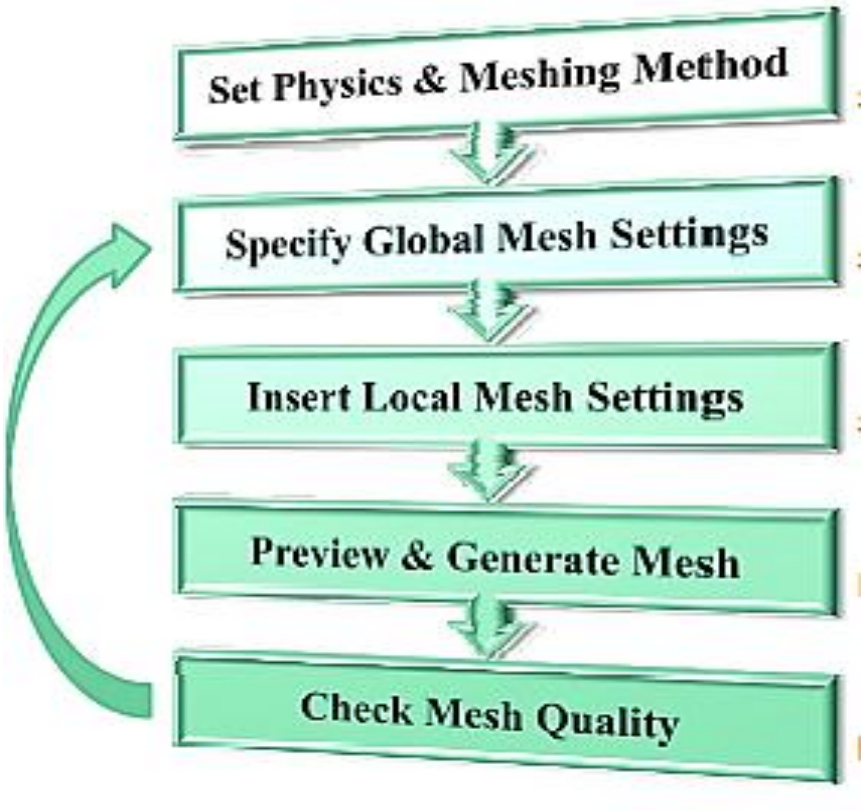






Undesired details!

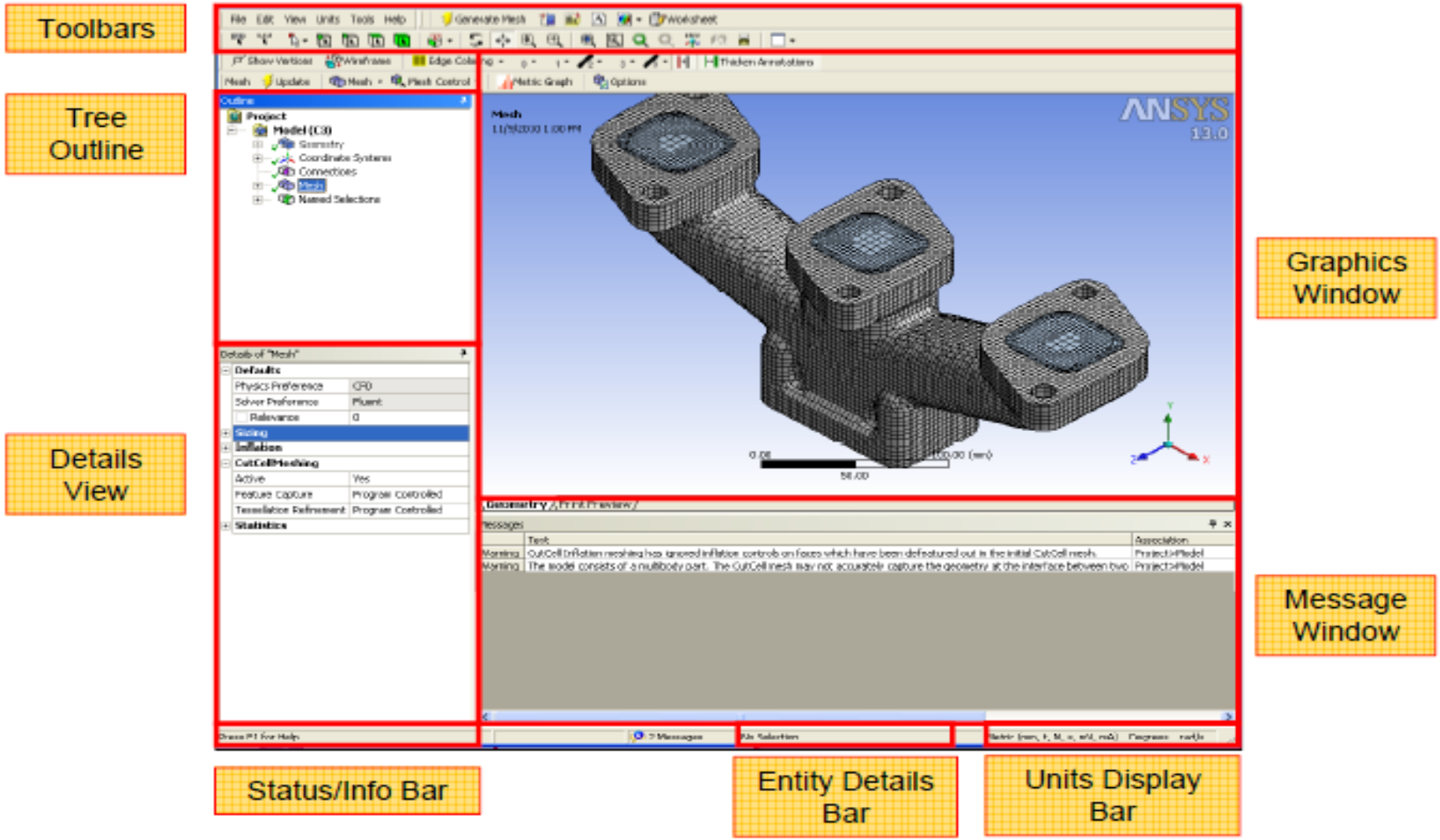
1.4.3 Pre-processing/Meshing



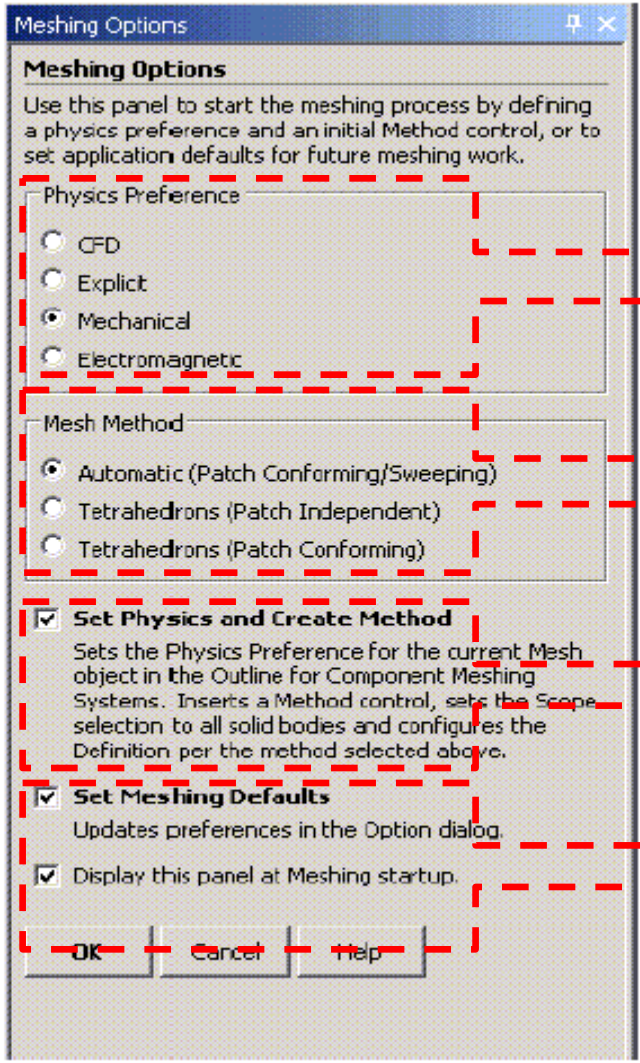
- Remember! Different physics and different solvers have different requirements for mesh quality!

- Structural, CFD, EM etc.
  - Sizing, Pinch etc.
- Sizing; refinement etc.
- Preview surface mesh
  - Mesh metrice

1.4.3 Pre-processing/Meshing



1.4.3 Pre-processing/Meshing

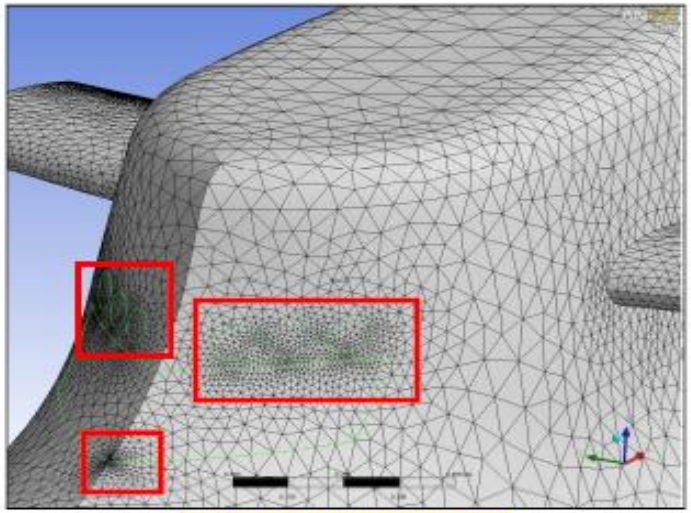


Meshing Options panel appears at the startup

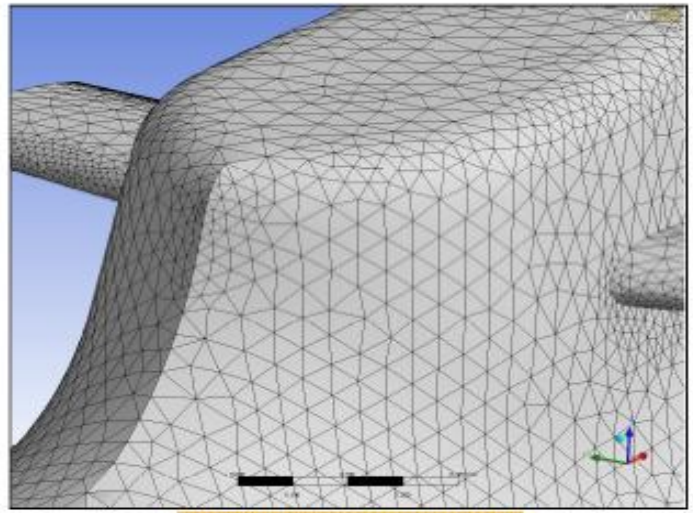
- Helps in setting meshing preference
- Can also be accessed through Tool bar

- **Physics Preference :**
  - Select the type of physics to be solved
  - Default Meshing parameters differ for each physics type
- **Mesh Method :**
  - Any Meshing Method can be used for any Physics Preference
- **Set Physics and Create method :**
  - Sets selected Physics in Details View of Mesh
  - Inserts a Method control with all solid bodies selected and defines the Mesh method as selected above
- **Set Meshing Defaults :**
  - Updates physics preference in Option Dialog box
- Option to display this panel at Meshing startup

1.4.3 Pre-processing/Meshing

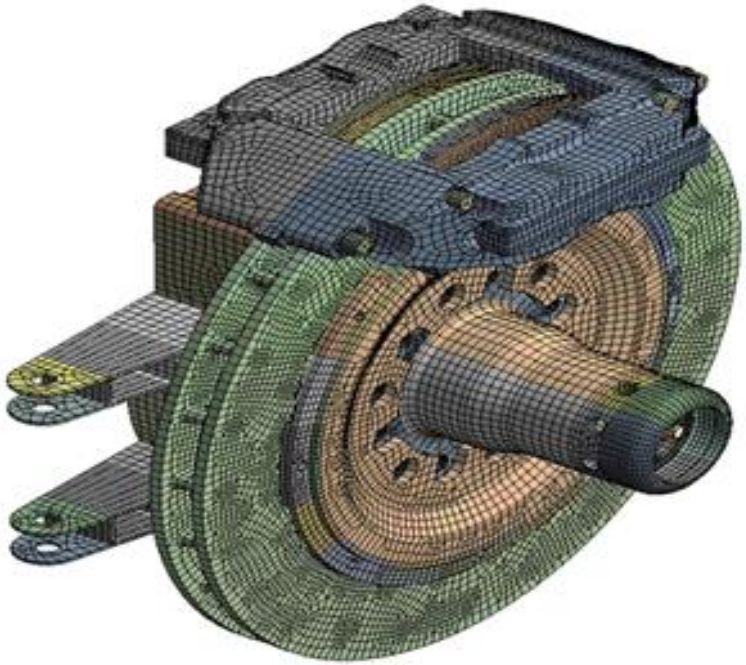


Patch Conforming



Patch Independent

- Tetrahedral meshing approach of an aeroplane segment



- Hex mesh of brake assembly using combination of hex meshing methods including sweep, thin sweep, MultiZone and hex-dominant

1.4.3 Pre-processing/Meshing

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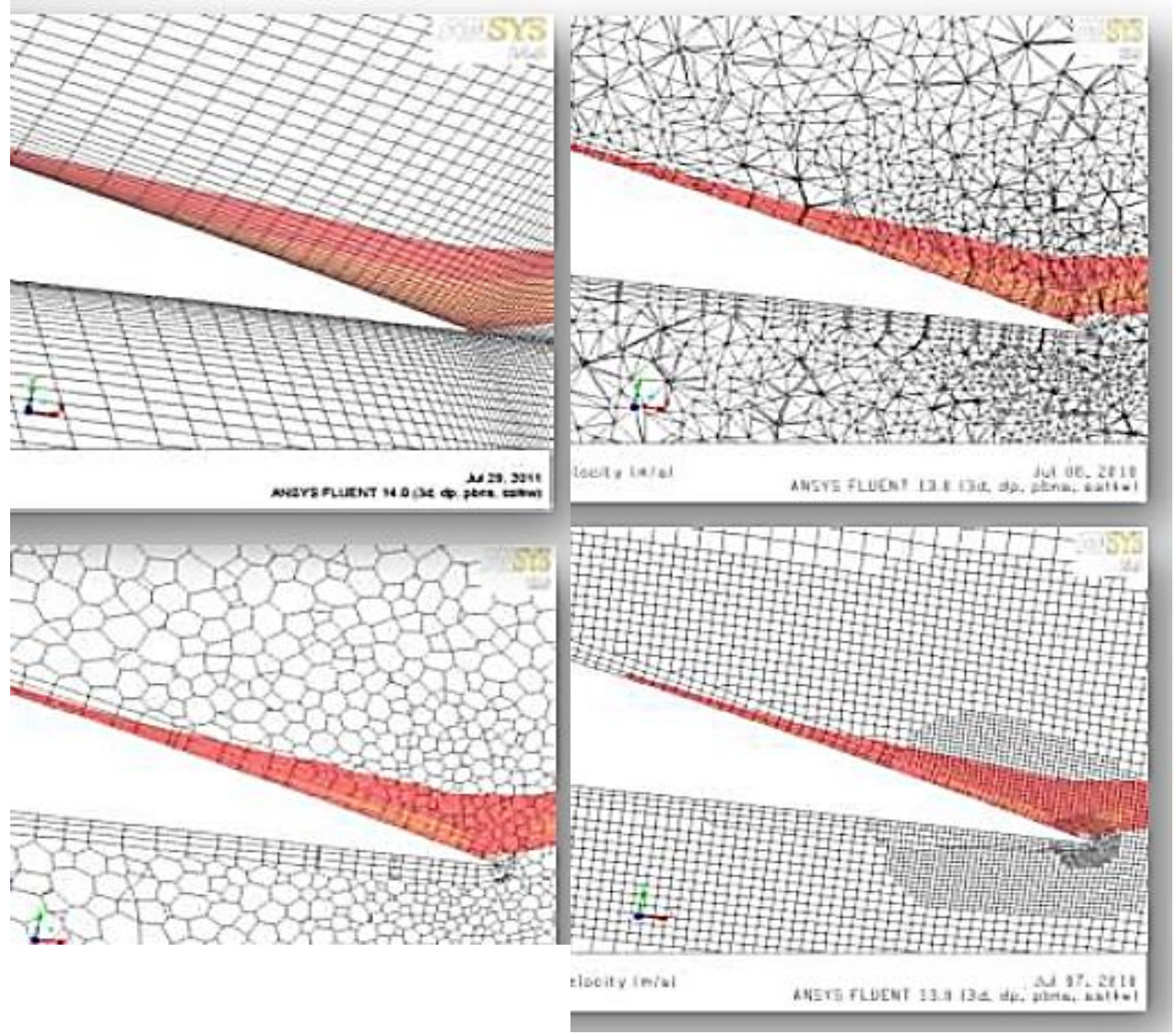
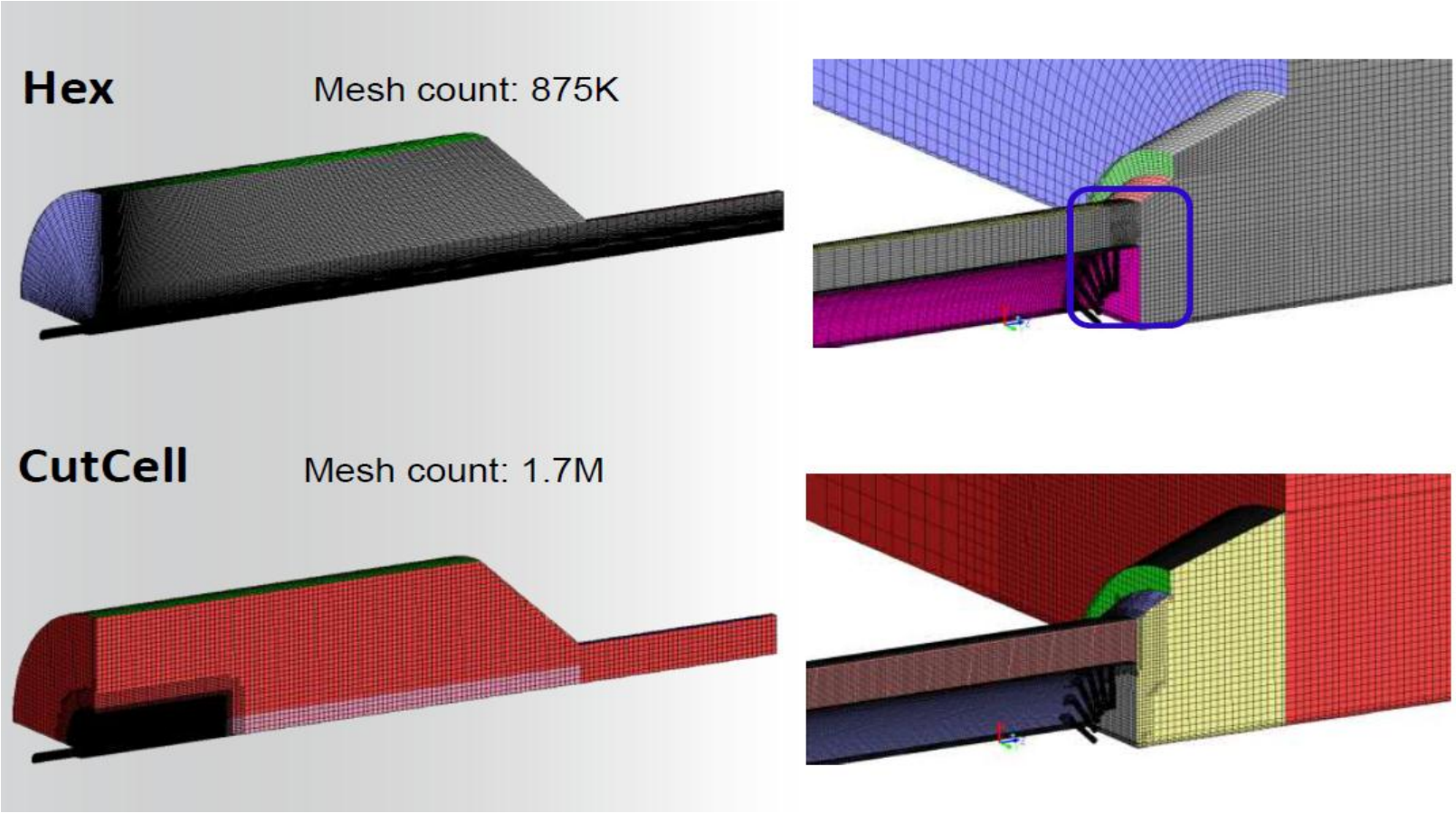
Typical Mesh Variants

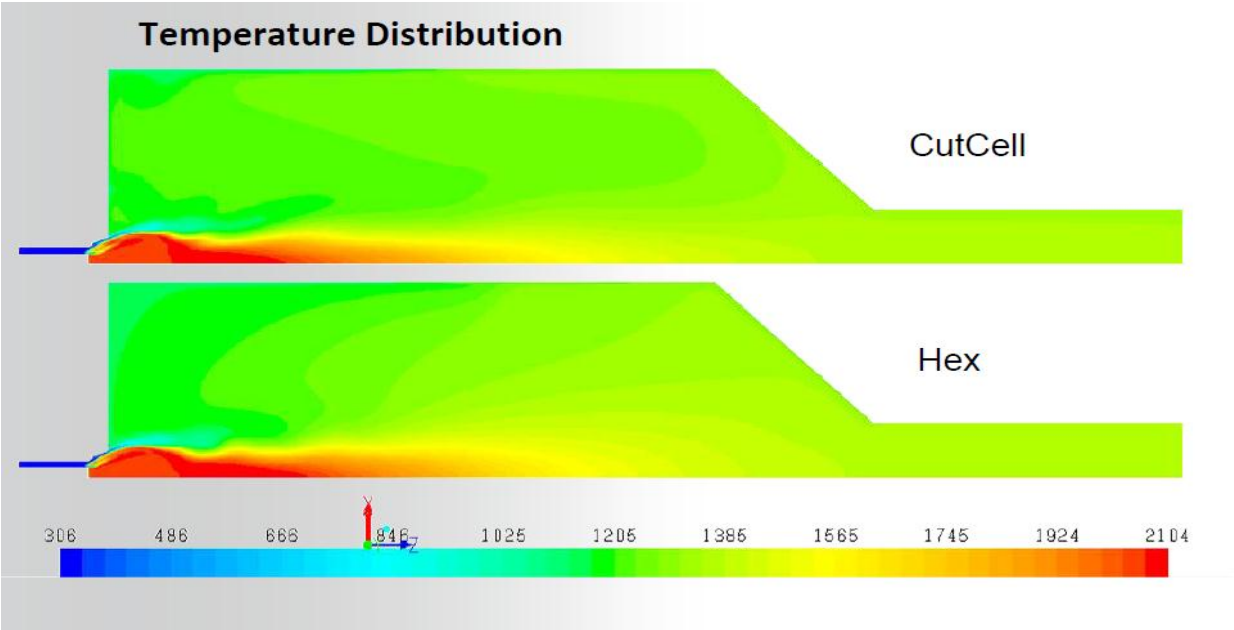
- Hexa
- Tetra
- Poly
- Cut-cell etc.

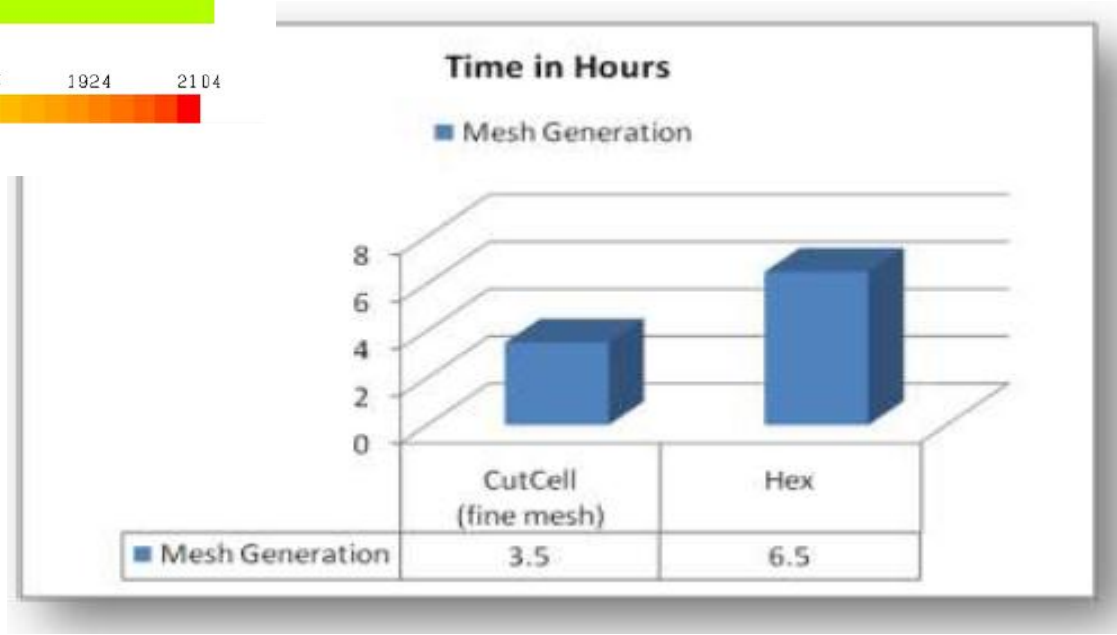


1.4.3 Pre-processing/Meshing

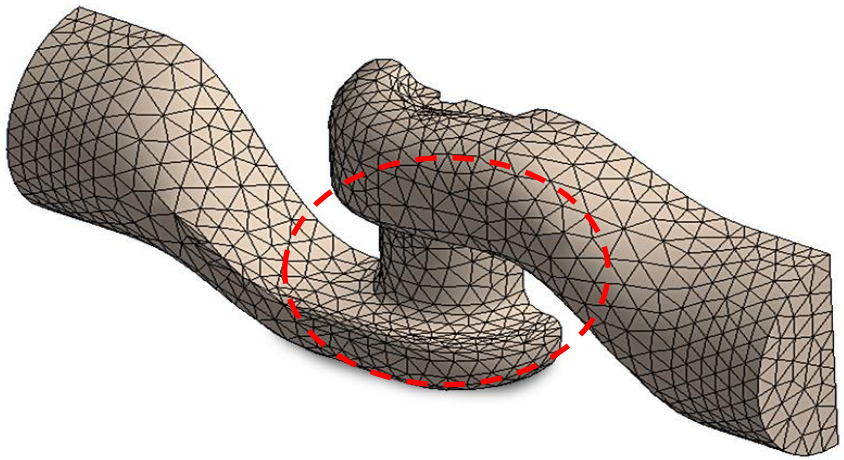


1.4.3 Pre-processing/Meshing

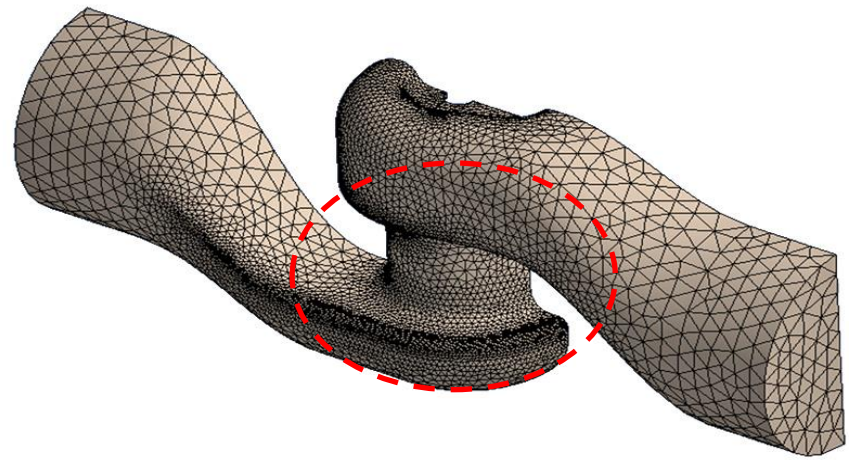




1.4.3 Pre-processing/Meshing/Mesh settings



Mesh using standard size function

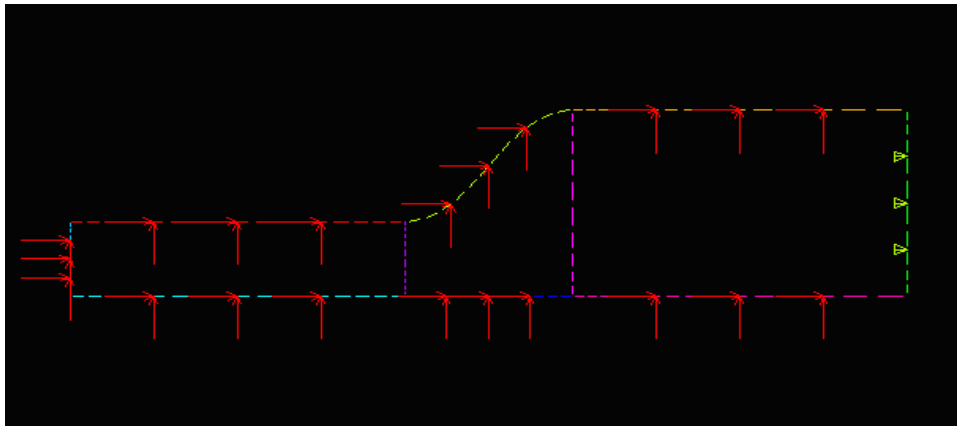


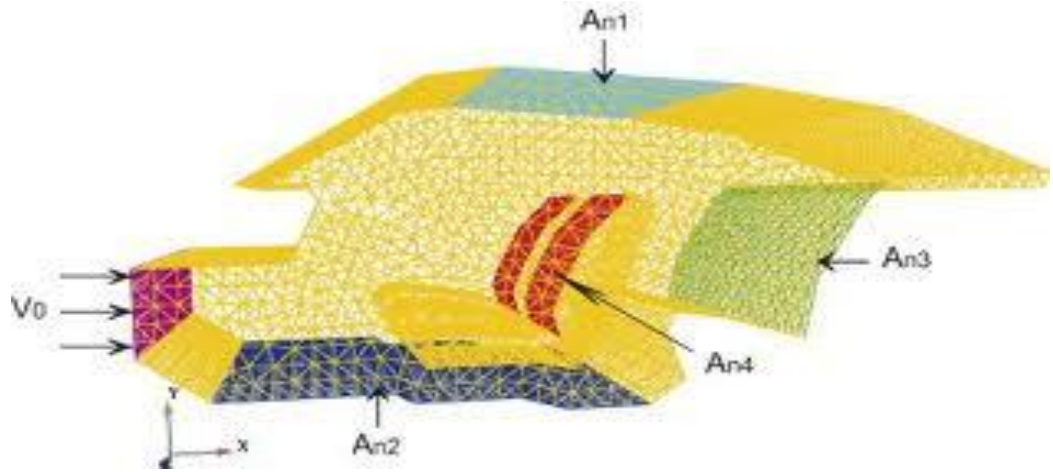
Mesh using advanced size function

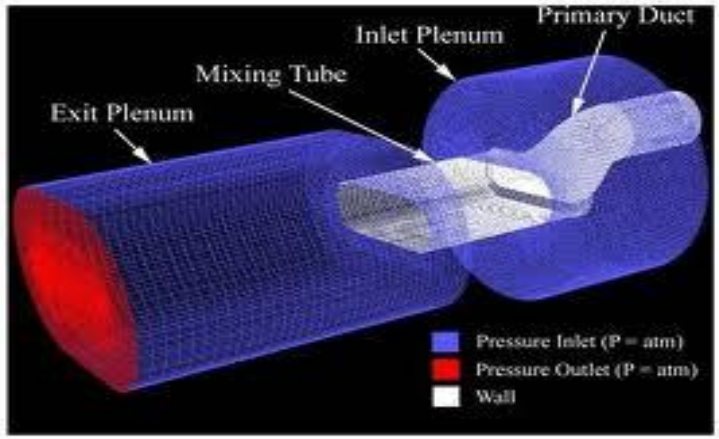
*The default size function for structural mechanics applicatio is designed to accurately capture the geometry while minimizing the number of elements in the model.

The advanced size function is the default for fluids applications and is designed to accurately capture the geometry while maintaining a smooth growth rate between the regions of curvature and/or proximity

1.4.4 Pre-processing/Boundary conditions







1.4.5 Numerical Simulation/Multiphysics Solution

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- Information regarding the solution settings must be specified.
- Output of the solver program must be specified
- Upon the multiphysics environment, methods and solver types are chosen (Pressure based, implicit, Gauss-Seidel, algebraic multigrid (AMG) method etc.

Remember! The whole analysis cannot be done by just executing a list of tasks one after the other.

The solver may be run, the results being checked and then the computer model rebuild.

1.4.6 Post- processing/Analysis

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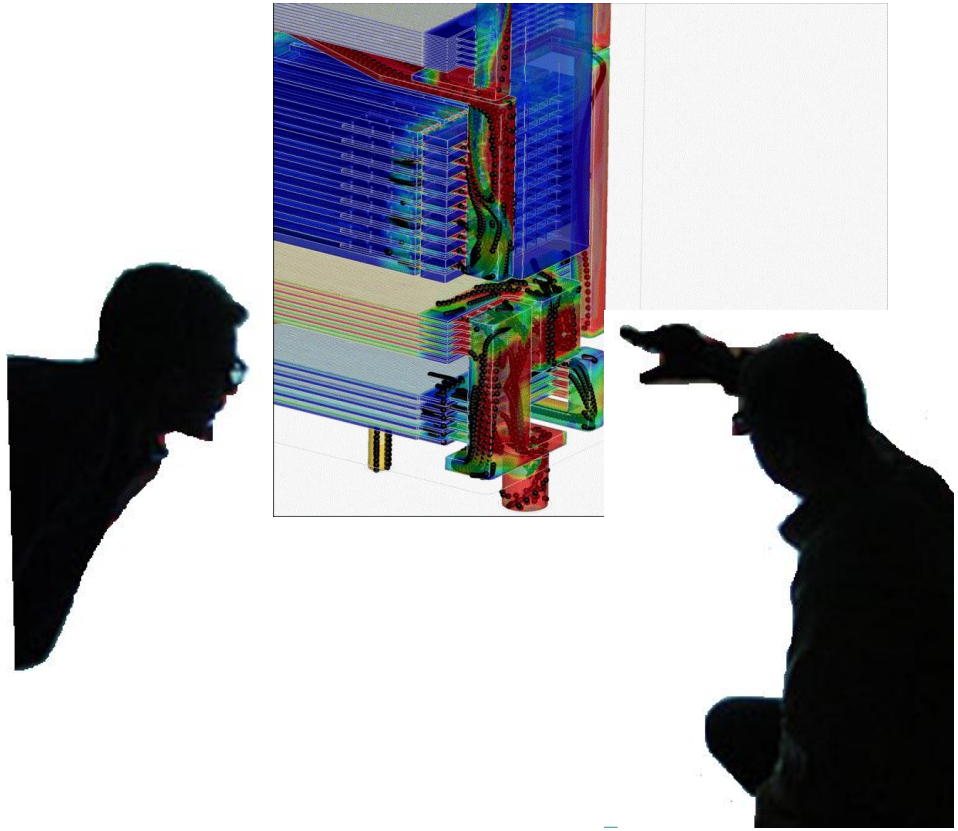
What can be analysed?

- Solution convergence
  - residuals
  - variables at specified locations
- Produced data of the entire domain.
  - show the geometry
  - modify the view
  - display the results



Visual analysis of a fuel cell system

1.4.7 Post- processing/Validation

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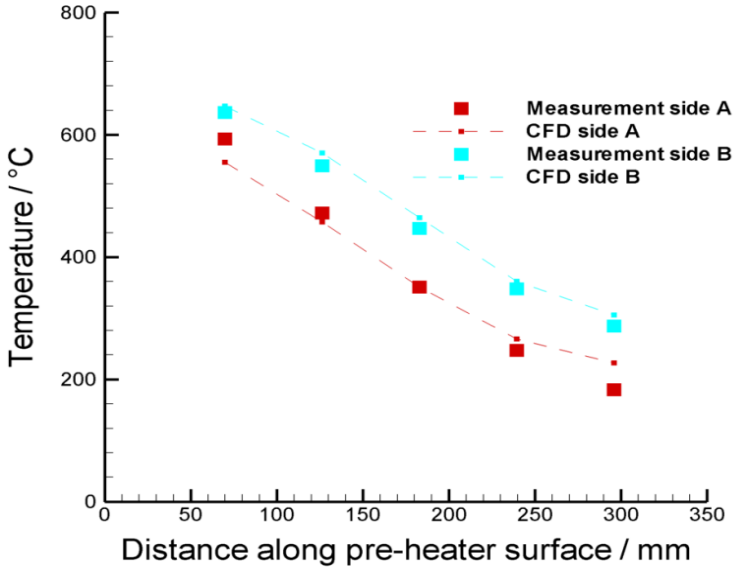
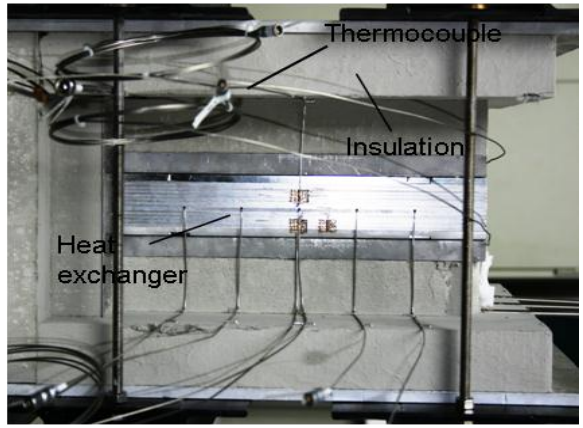
Error sources for incorrect results

- Wrong Input data
- Inappropriate type of mesh
- Poor mesh quality
- Wrong boundary conditions





Concluding remarks

- Multiphysics modelling is an essential tool for predicting and simulating complex engineering systems that comprise coupled phenomena
- The execution of any multiphysics problem can be sub-divided into pre-processing, numerical solution and post-processing
- The nature of the problem has to be carefully understood prior setting up the multipyhsics model
- Modelling of multiphysics in general is a very challenging task and requires expertise in engineering as well as software and hardware knowledge
- Clean-up, numerical grid quality have particular importance, directly affecting the solution time and quality of the results
- Results of multiphysics simulations have to be carefully analysed and validated using experimental data or mathematical methods
- Employing multiphysics analyses can save tremendous time and invaluable information early in the process and product development

Thank You for Your Attention!