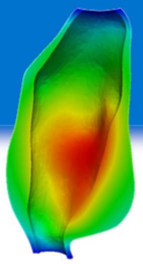

Influence of meshing software in AAA wall and thrombus calculation

STUDENT PROJECT
Computational Bioengineering Laboratory SS2014

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Introduction

The strength of results in the finite element context is affected by locking phenomena and mesh quality. By generating a hex-dominant mesh (Harpoon) of an abdominal aortic aneurysm (AAA) on one hand and a tetrahedral-only mesh (Gmsh) on the other hand, the complexity of each workflow to generate the model respectively is to be compared. Principal objective of the comparison is discuss which mesh depicts the best compromise between accuracy and quality of the results. Furthermore the limits of the simulation are to be stated.

Segmentation and meshing

From Computional Tomography data, the lumen and thrombus of an abdominal aortic aneurysm (AAA) were segmented using Mimics (Thresholding, Cropping, Region growing, Calculate 3D). Surfaces were first smoothed by removing undesired voxels. The remeshing of the surfaces was done in 3-matic.

Workflow Gmsh

- 3-matic:
  - creation of an external surface („offset option“)
  - 2D Meshing; finer Maximal Triangle Edge Lenght for the external surfaces
- Gmsh:
  - 3D Meshing („Frontal“ algorithm) of the thrombus and the external wall separately
  - Merging of the two volumes (thrombus and wall)

Workflow Harpoon

- Import STL from Mimics
- Defining element size
- Creation of hex-dominant mesh
  - Correction of errors (Adding missing elements, local refinement of mesh)
- Wall-extrude python script to add 1 mm aortic wall
- Wall-extrude with ICEMCFD to add 3x0.33 mm aortic wall

Table 1: Overview of elements and nodes

	Gmsh rough mesh	Gmsh fine mesh	Harpoon rough mesh	Harpoon fine mesh
nodes	59.034	96.883	63.997	106.181
elements	208.790	371.312	112.390	178.799

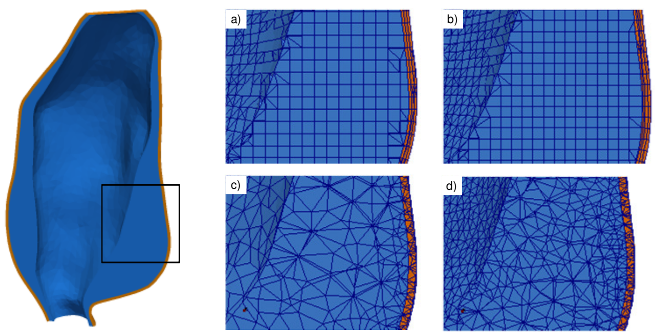

Figure 1: Comparison of different mesh solutions - Harpoon hexahedral mesh rough/fine a)/b), Gmsh tetrahedral mesh rough/fine c)/d); Blue: Thrombus, Orange: Wall

Results

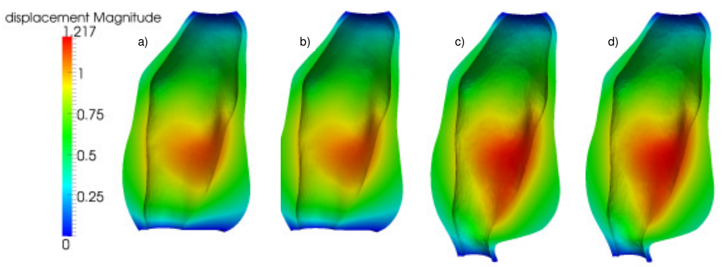

Figure 2: Simulation results for displacement - Harpoon hexahedral mesh rough/fine a)/b), Gmsh tetrahedral mesh rough/fine c)/d)

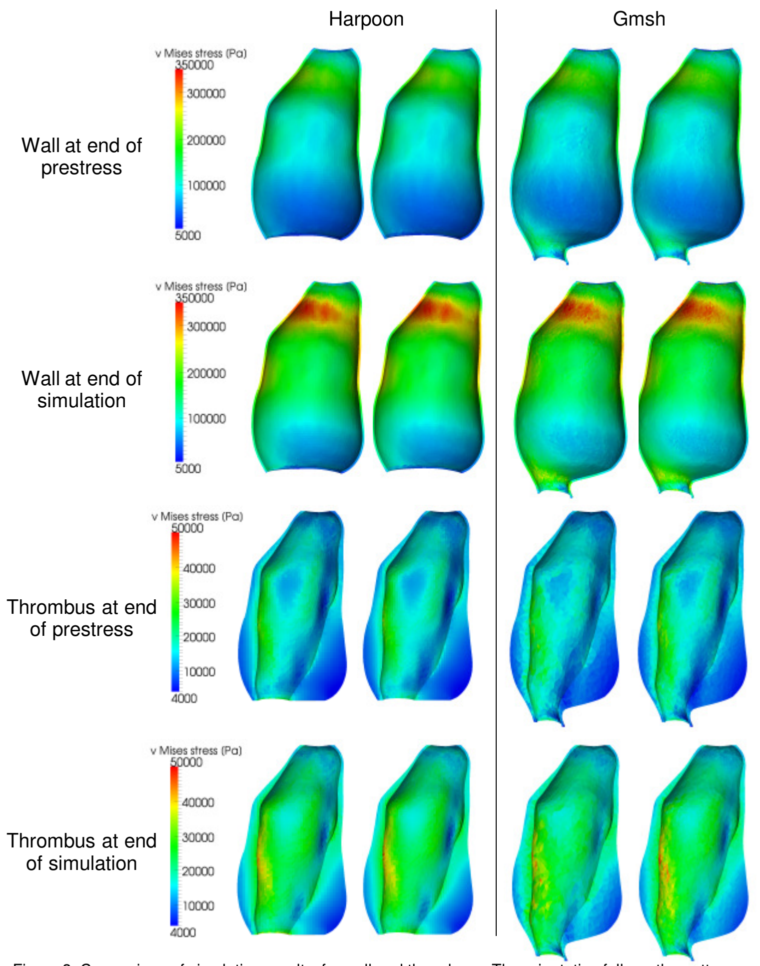

Figure 3: Comparison of simulation results for wall and thrombus – The orientation follows the pattern of figure 2

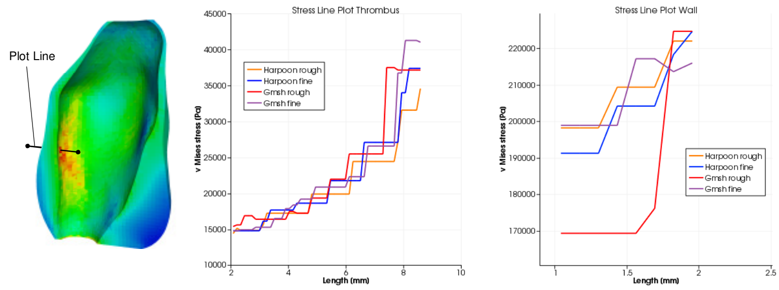

Figure 4: Comparison of stresses along the shown plot line for thrombus and wall

- No significant differences in displacements and stresses between fine and rough meshes
- Hex-dominant mesh exhibits smoother progression in cross-sectional distribution of stresses than tetrahedral-only mesh
- Same qualitative distribution of displacements in Harpoon and Gmsh, yet with higher maxima in latter one

Discussion

- Wall extrusion for workflow using Harpoon mesh creation had to be modified, as designated scripting led to element penetration in concave curvature at bifurcation which made detachment of bifurcation area necessary
- Even though tetrahedral meshes are supposed to be stiffer than hexahedral meshes, higher displacements occurred, which for one reason might be explained by the longer distance between maximum displacement and boundary condition
- Assumption that finer mesh leads to more accurate results could not be confirmed → Therefore critical reflection particularly with regard to time consumption for calculation
- No nodal displacements at inlet/outlet due to simplified boundary conditions with zero DOF → Constraints with spring/damper elements are assumed to lead to more realistic results

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[2] Heng M.S. et al. (2007), Peak wall stress measurement in elective and acute abdominal aortic aneurysms, Journal of Vascular Surgery, 47(1): 17-22.