Europska unija
Zajedno do fondova EU
Ministarstvo gospodarstva, poduzetništva i obrta
EUROPSKI STRUKTURNI I INVESTICIJSKI FONDOVI
Operativni program KONKURENTNOST I KOHEZIJA
BONLIM
PMF Prirodoslovno-matematički fakultet Sveučilište u Zagrebu
FSB Fakultet strojarstva i brodogradnje Sveučilište u Zagrebu

Automatic mesh generation for the low order dynamical analysis of marine structures

Luka Grubišić, Domagoj Lacmanović and Josip Tambača

Faculty of Science, Department of Mathematics

June 15, 2021

1. Introduction
2. Frontal mesh generators
3. Automatic mesh vs. hand generated mesh?
4. Mesh refinemenet algorithm
5. Virtual stiffener algorithm
6. References

Introduction

- MOL Comfort catastrophe
- MSC Napoli cracks

Introduction

- Direct ship structural analysis based on the FEM is a part of ship structural design process for determination of structural adequacy (Hughes and Paik, 2010).
- Automatic mesh generation to meet the acceptance criteria by the classification societies (Nersesian and Mahmood, 2009).
- Automatic meshers have a problem when dealing with linear constraints on the mesh, see (Jang et al., 2008).
- The proffered elements to be used are dominantly low degree shell elements – locking.

Requirements on the mesh

Up to 5% triangles are allowed, angles of all elements should be between 45° and 135°.
A girder should be meshed with at least 4 elements, and the smallest element should not be smaller than the thickness of the plate.

Frontal mesh generation in L^∞ norm

Cross-field (Lévy and Liu, 2010)

Algorithm is designed around the notion of the cross field. This is a heuristic function modeling the preferred orientation of the mesh.

- Cross field is taken to be parallel to the boundaries of the domain.
- Frontal meshing algorithms propagate the cross field from the boundaries and insert a point in the mesh so as to form an equilateral triangle.
- In the quad oriented algorithm, one uses the L^∞ norm and so the equilateral triangle is actually isosceles with an angle close to the right-angle.

Measuring regularity of the mesh

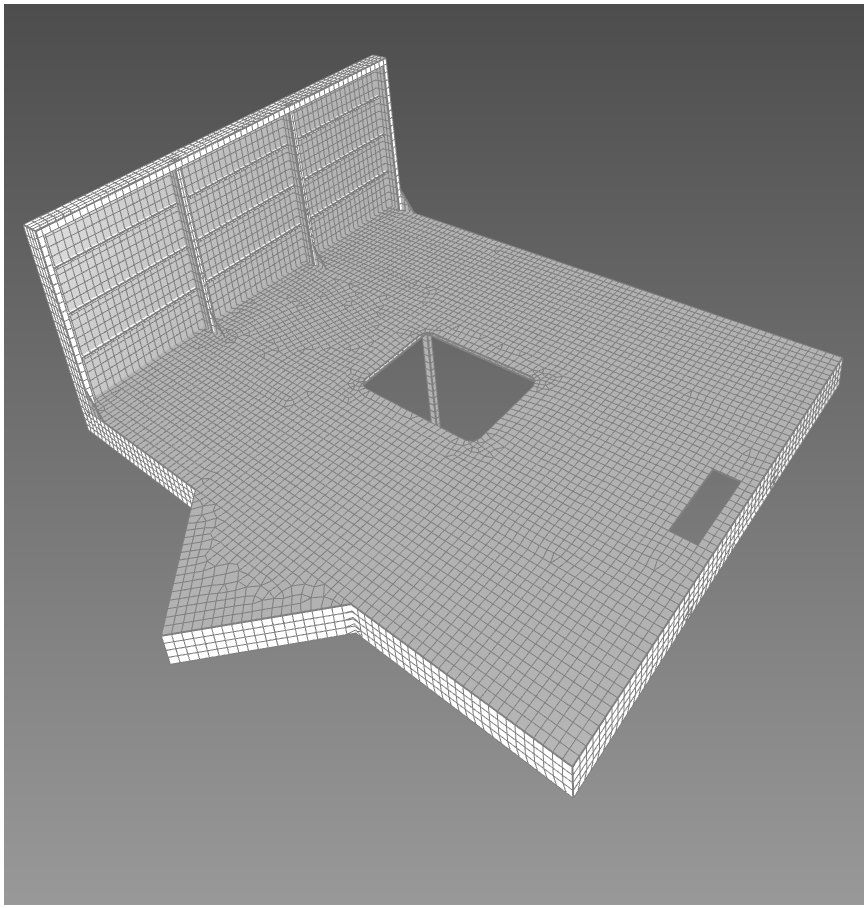
- For quadrilateral element q and its four internal angles $\alpha_k,\ k = 1, 2, 3, 4$, quality of the element is defined with $\eta(q)$ (Remacle et al., 2013) as

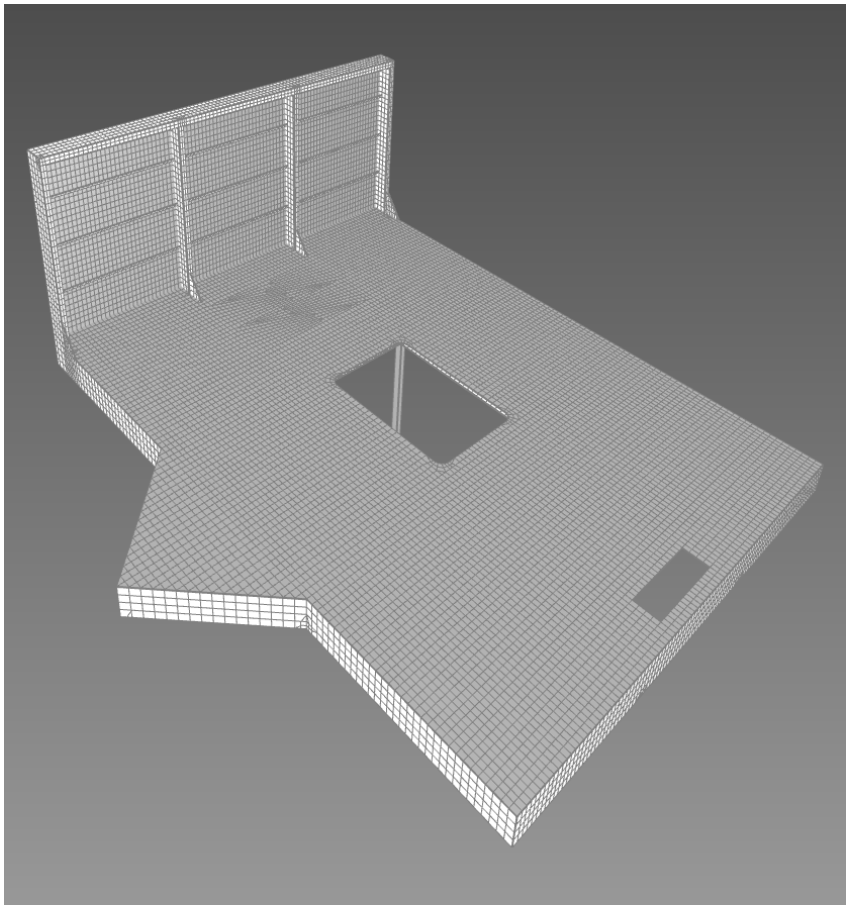
$$\eta(q) = \max\left[1 - \frac{2}{\pi}\max_i\left[\left|\frac{\pi}{2} - \alpha_i(q)\right|\right], 0\right].$$

- The element quality measure is equal to 1 for perfect square and it is zero in the presence of angles ≤ 0 and $\geq \pi$.
- Measure which assesses if the mesh consists mostly of regular elements is called τ and it measures the percentage of the edges which are close to the globally ideal mesh size. The typical values of the τ for triangular meshes are around 85%(Remacle et al., 2012).

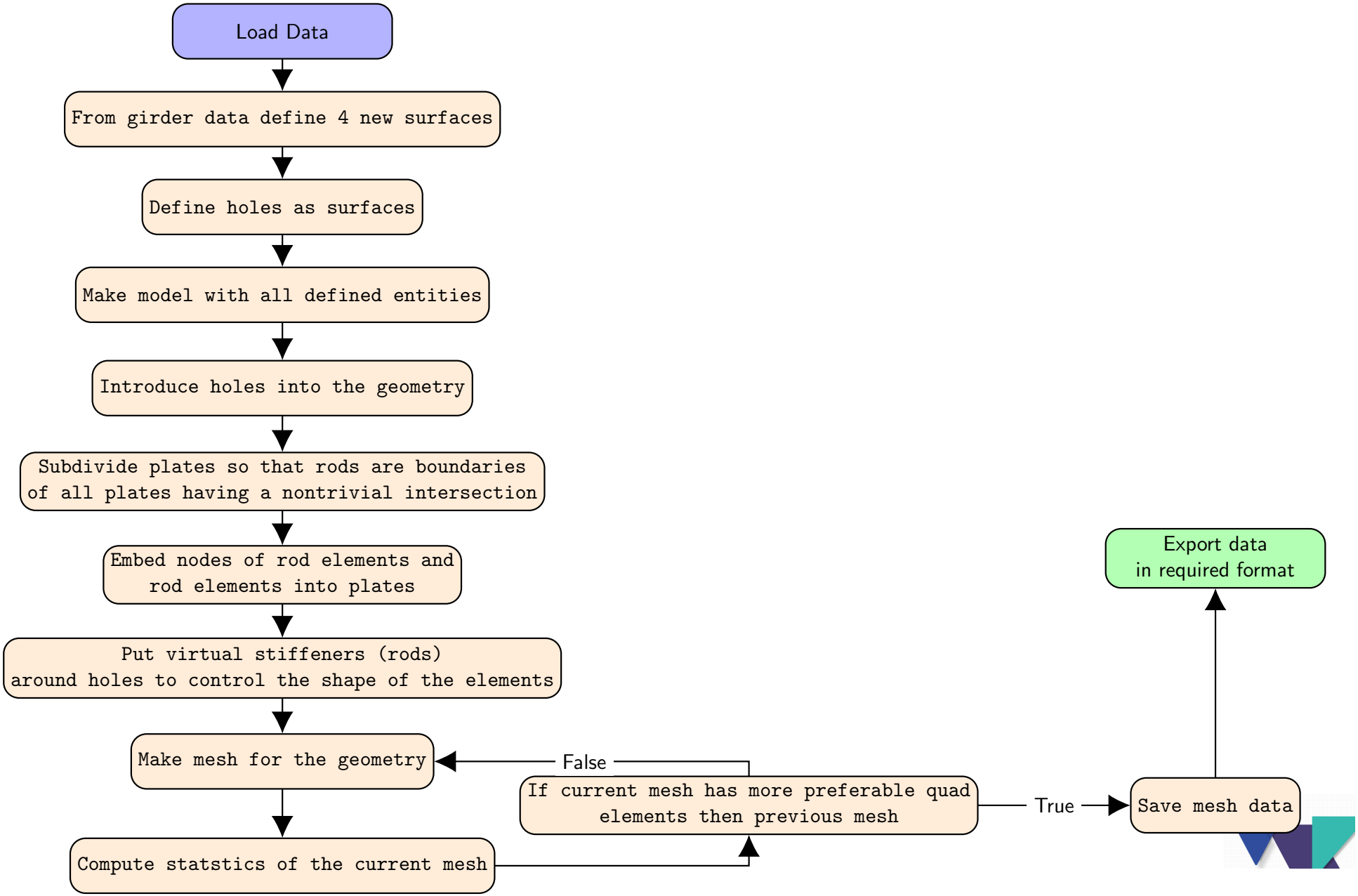
A case study – deck bulkhead section

Automatic mesh vs. hand generated mesh?

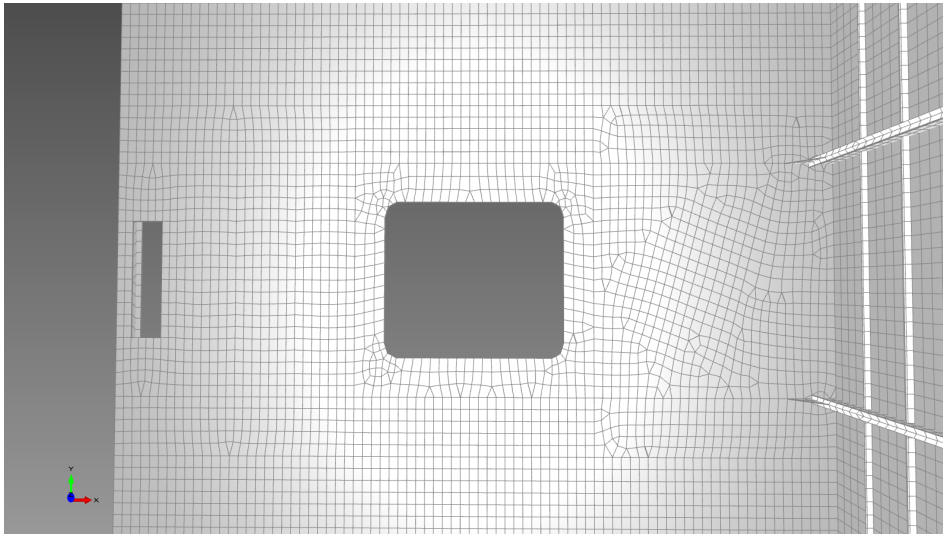




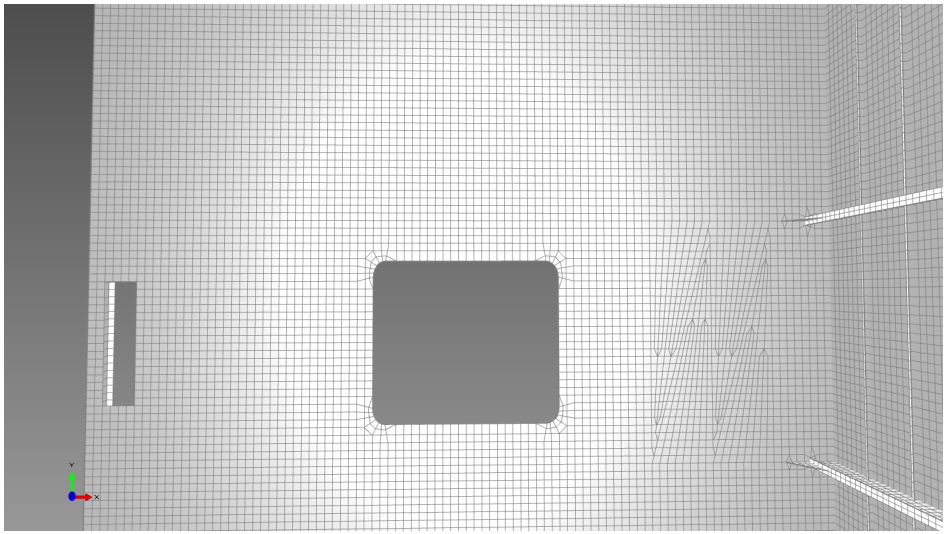
Automatic mesh generation



Automatic mesh vs. hand-generated mesh - view 1

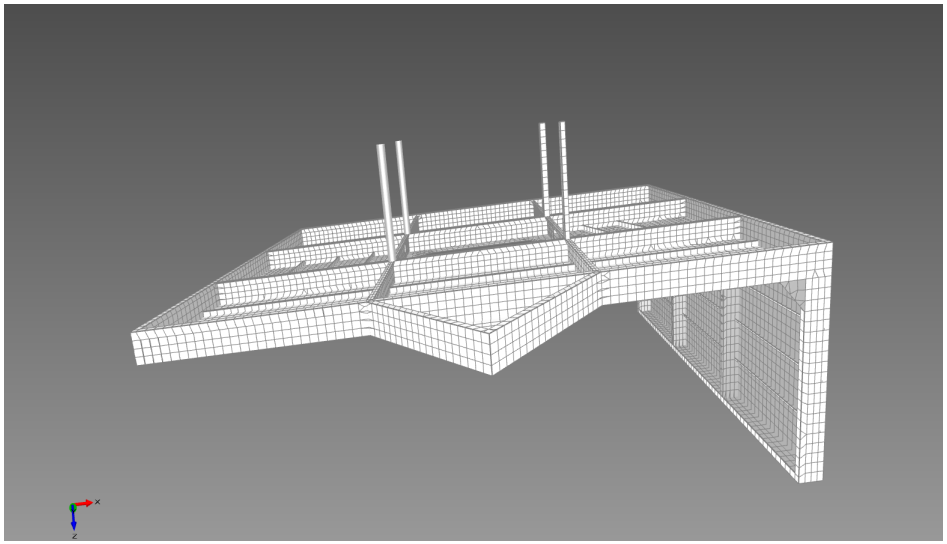


Automatic mesh

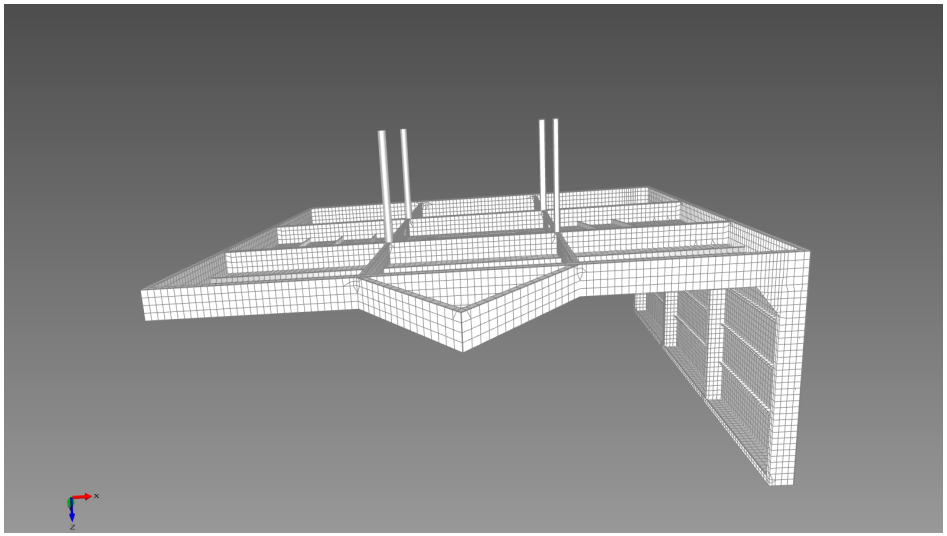


Hand generated mesh.

Automatic mesh vs. hand-generated mesh - view 2

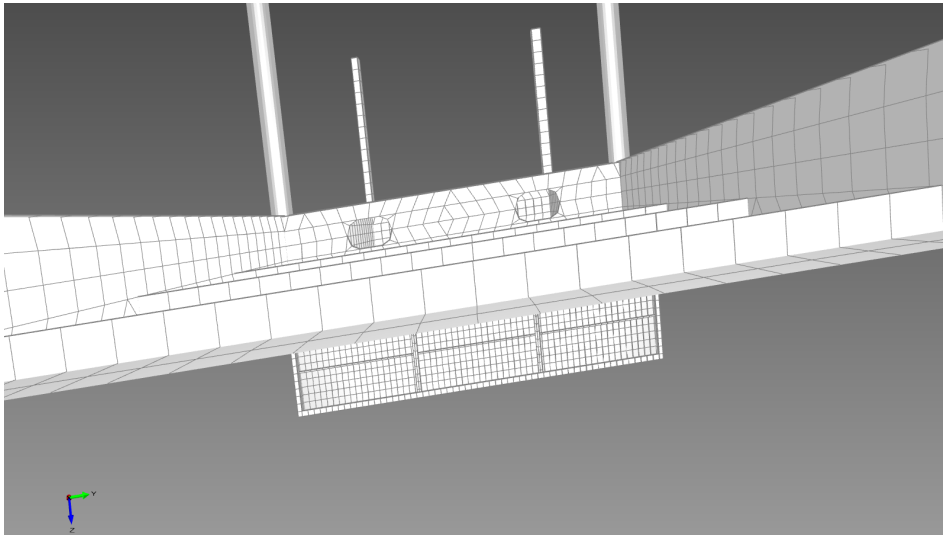


Automatic mesh

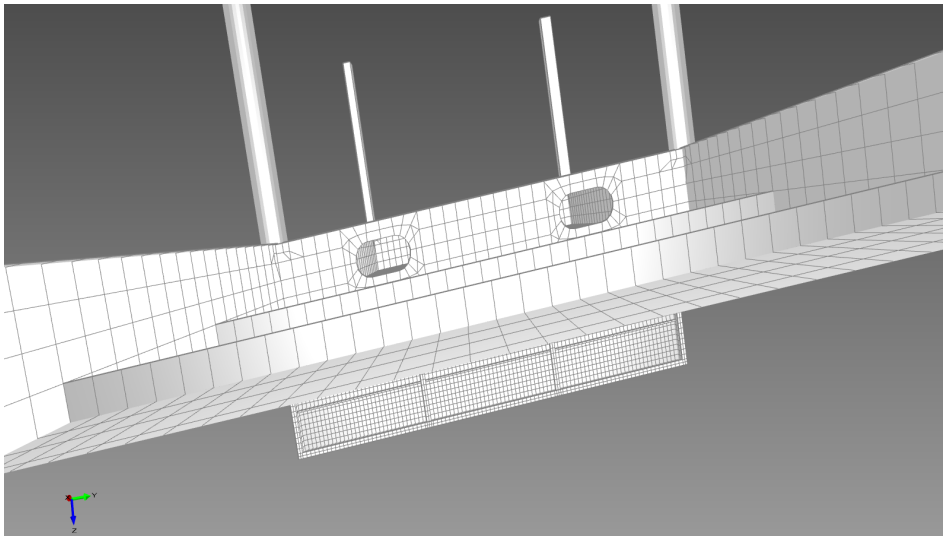


Hand generated mesh.

Automatic mesh vs. hand-generated mesh - view 3

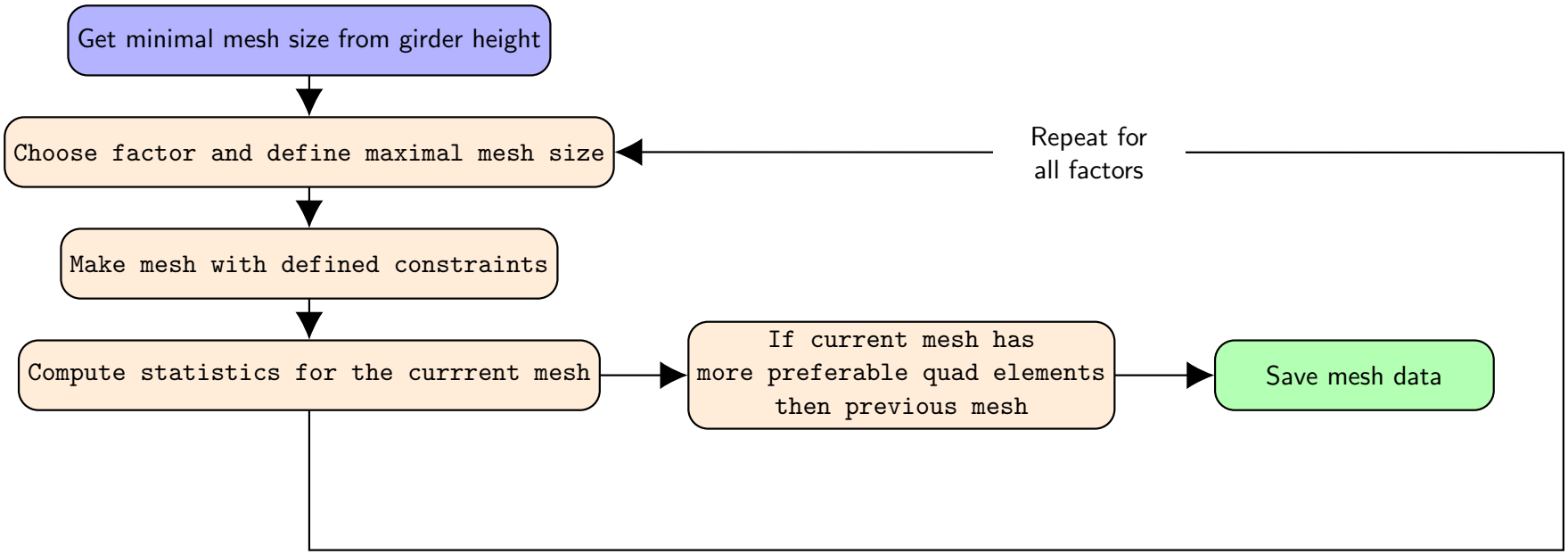


Automatic mesh



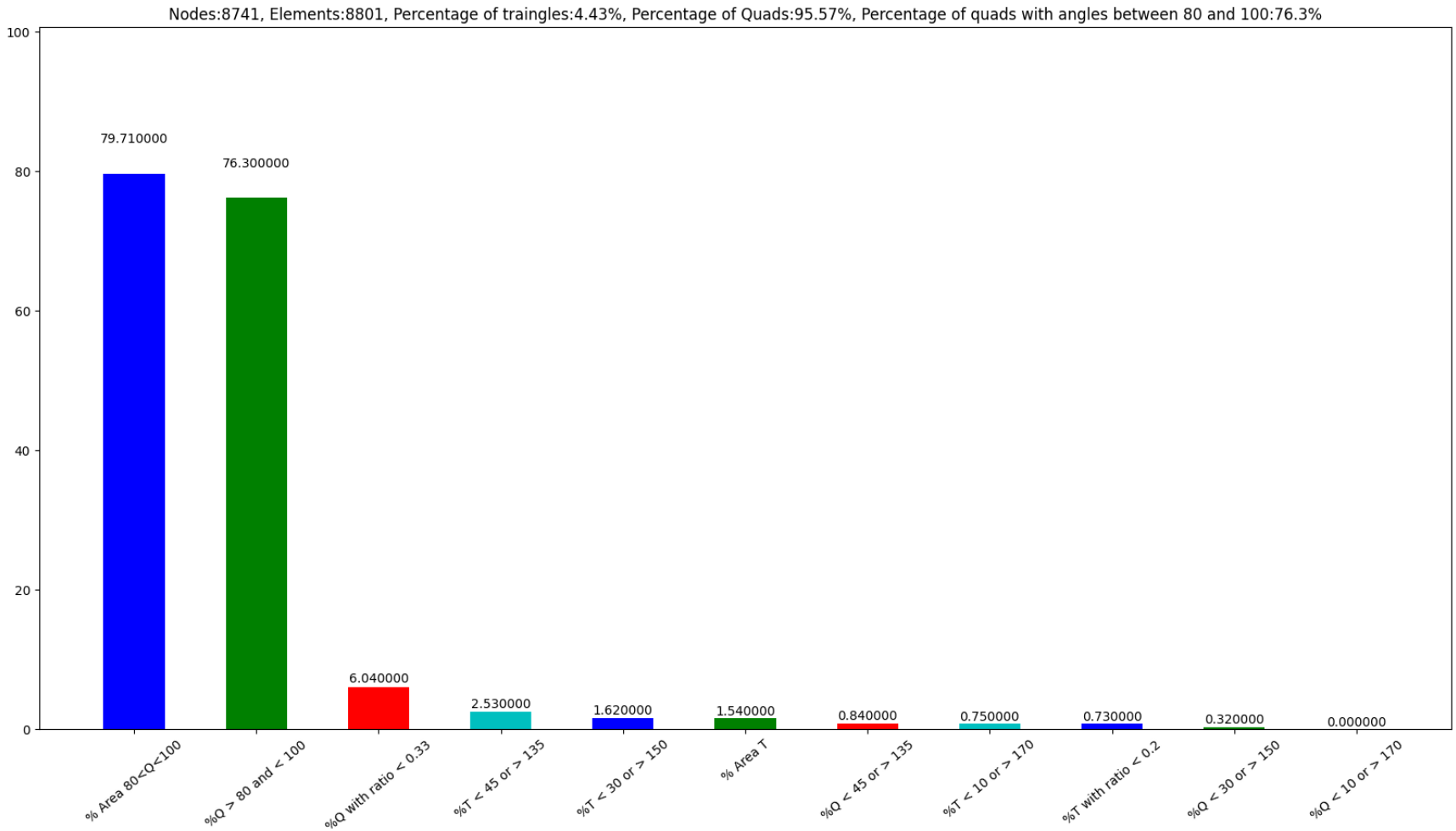
Hand generated mesh.

Mesh refinement algorithm



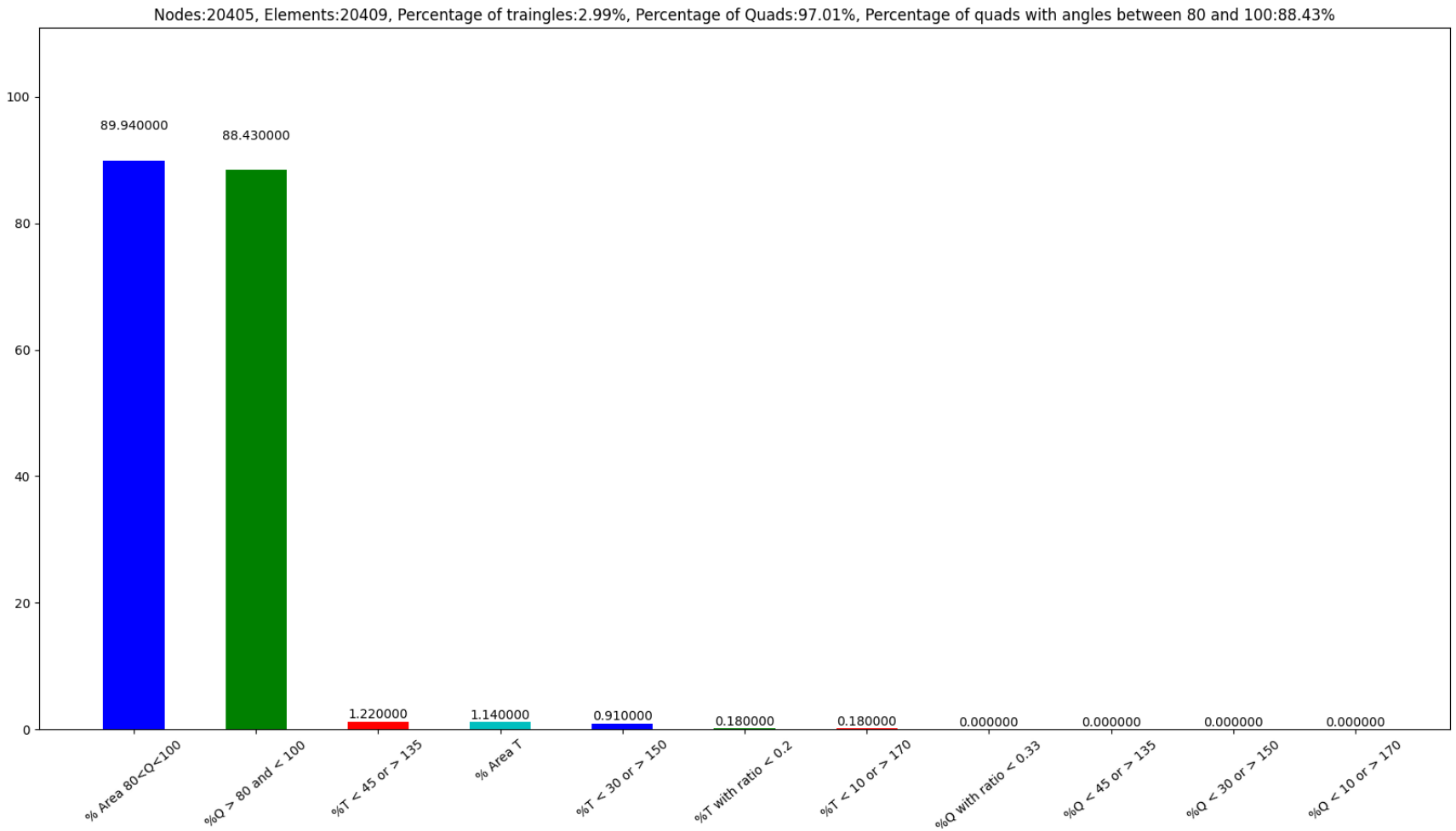
Quality control by mesh refinement

Minimal mesh size - 100, maximal mesh size - 175



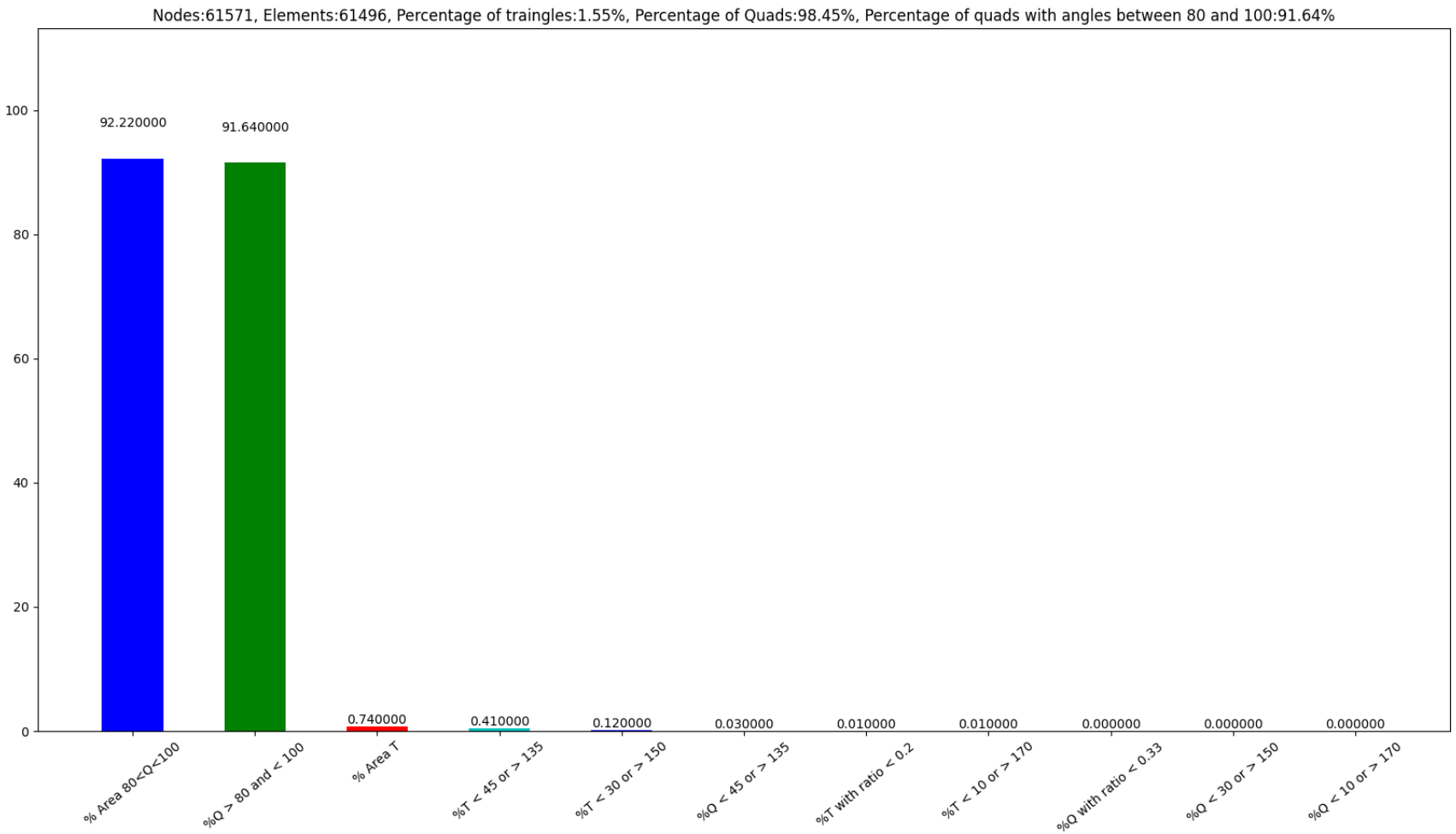
Quality control by mesh refinement

Minimal mesh size - 57, maximal mesh size - 100



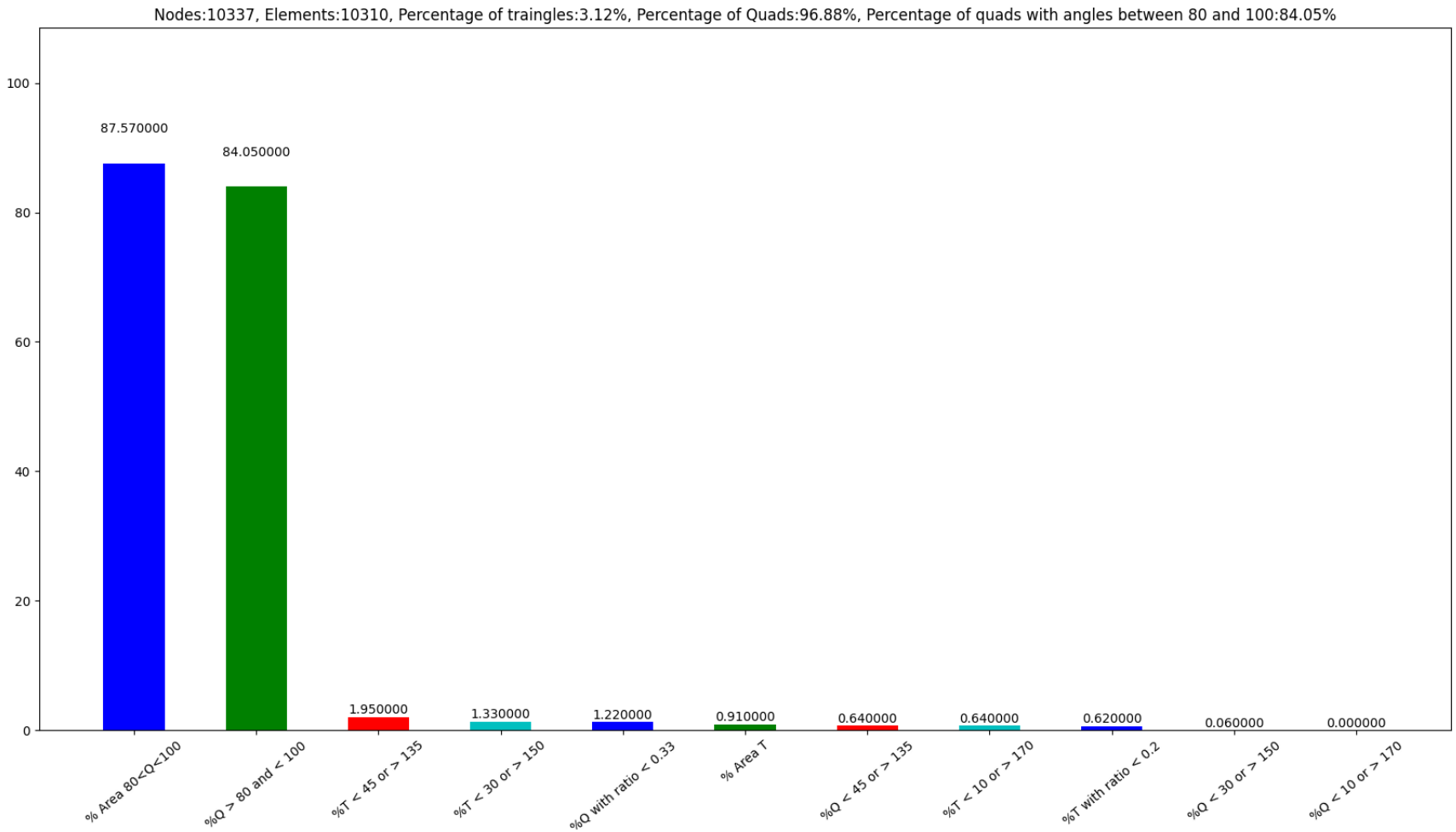
Quality control by mesh refinement

Minimal mesh size - 32, maximal mesh size - 57



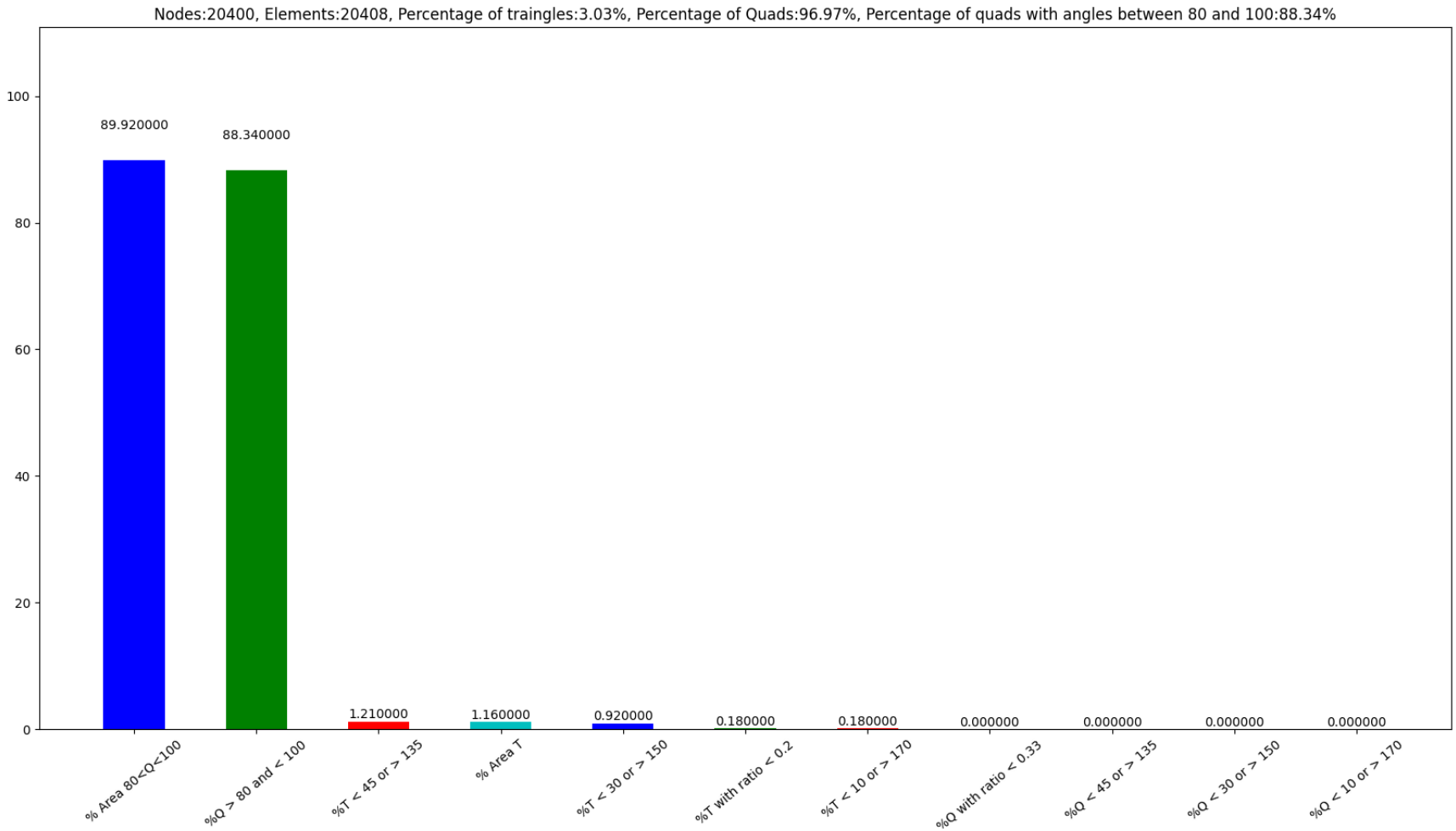
Quality control by mesh refinement

Minimal mesh size - 100, maximal mesh size - 150



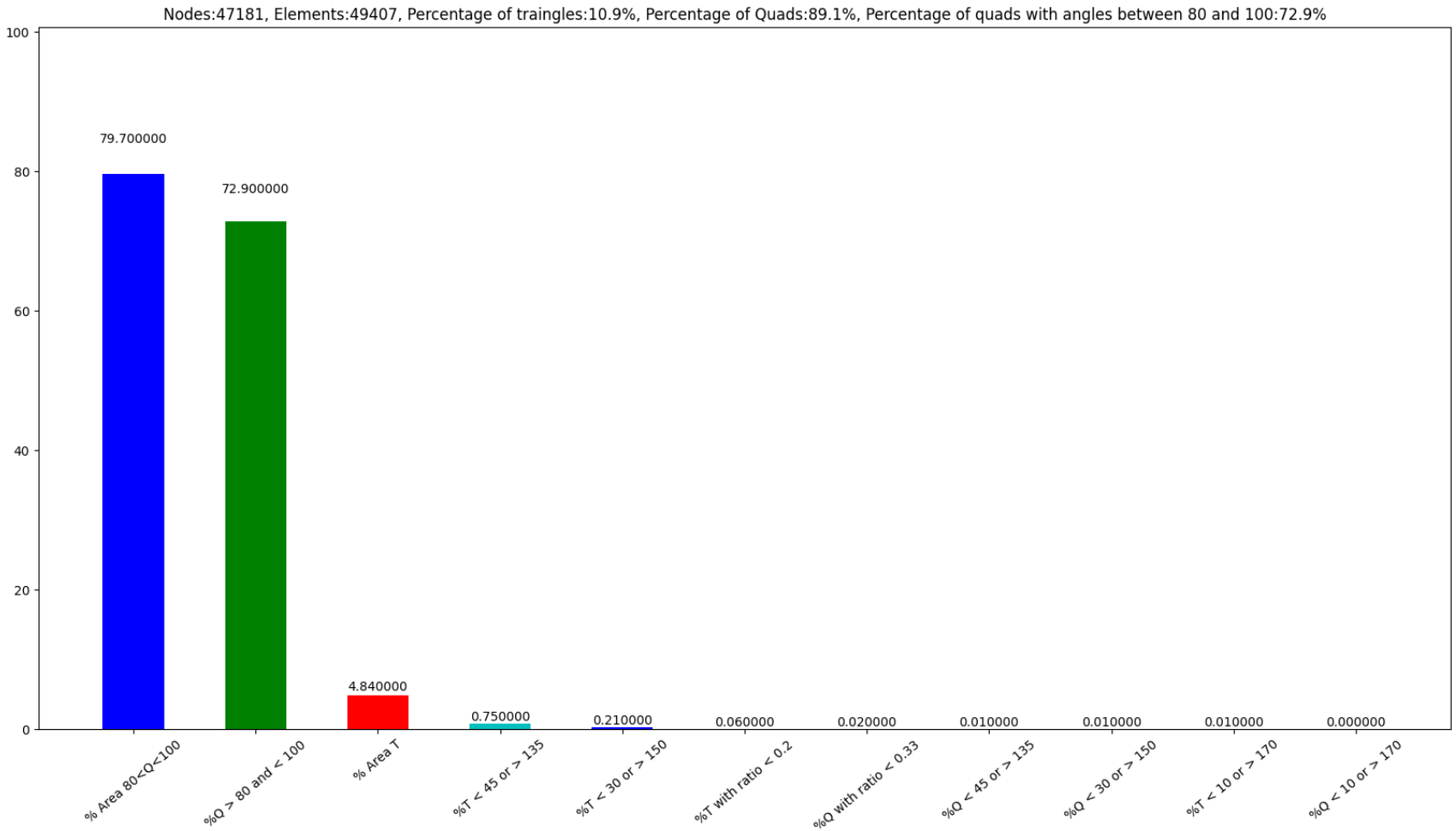
Quality control by mesh refinement

Minimal mesh size - 66, maximal mesh size - 100

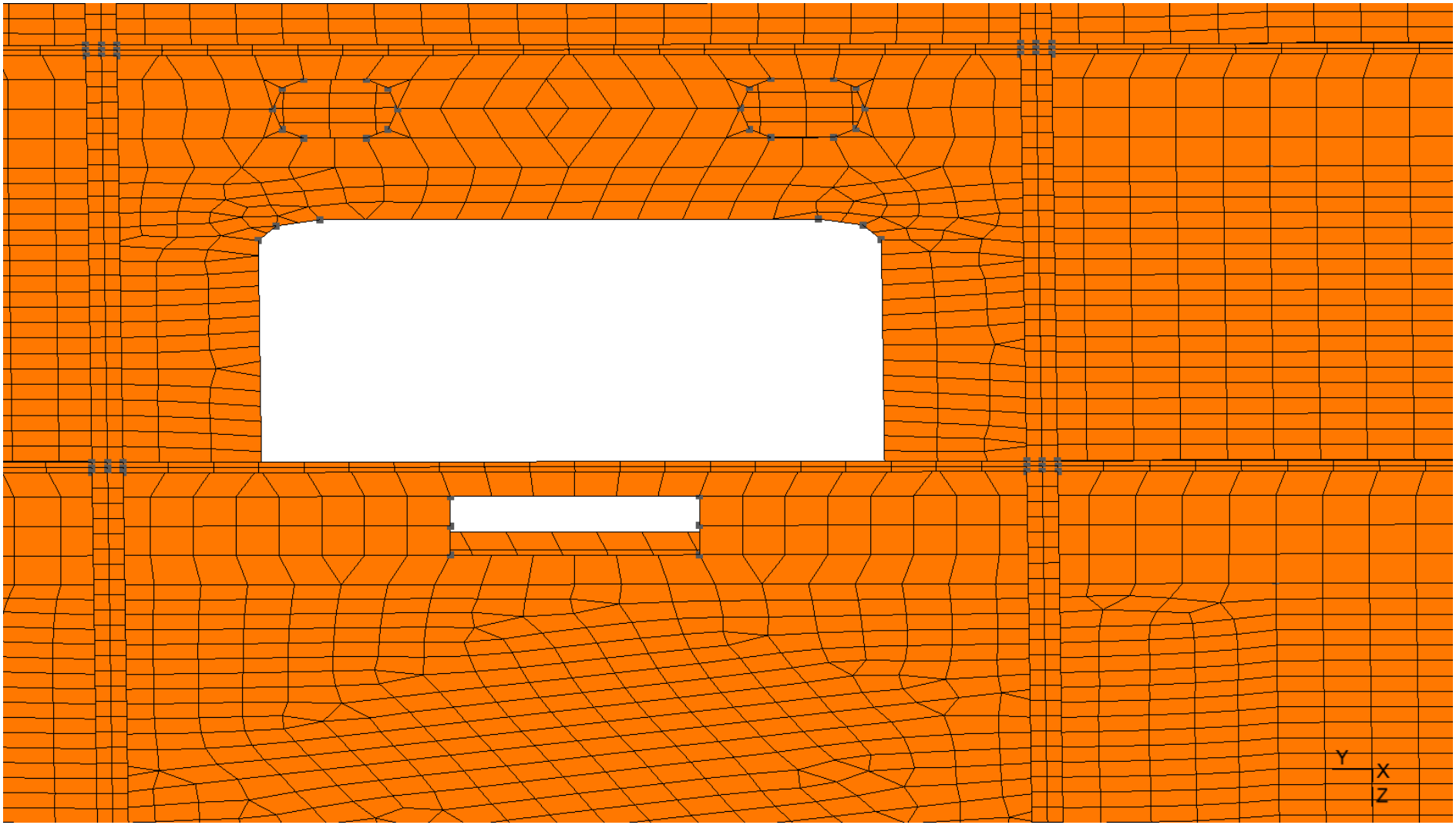


Quality control by mesh refinement

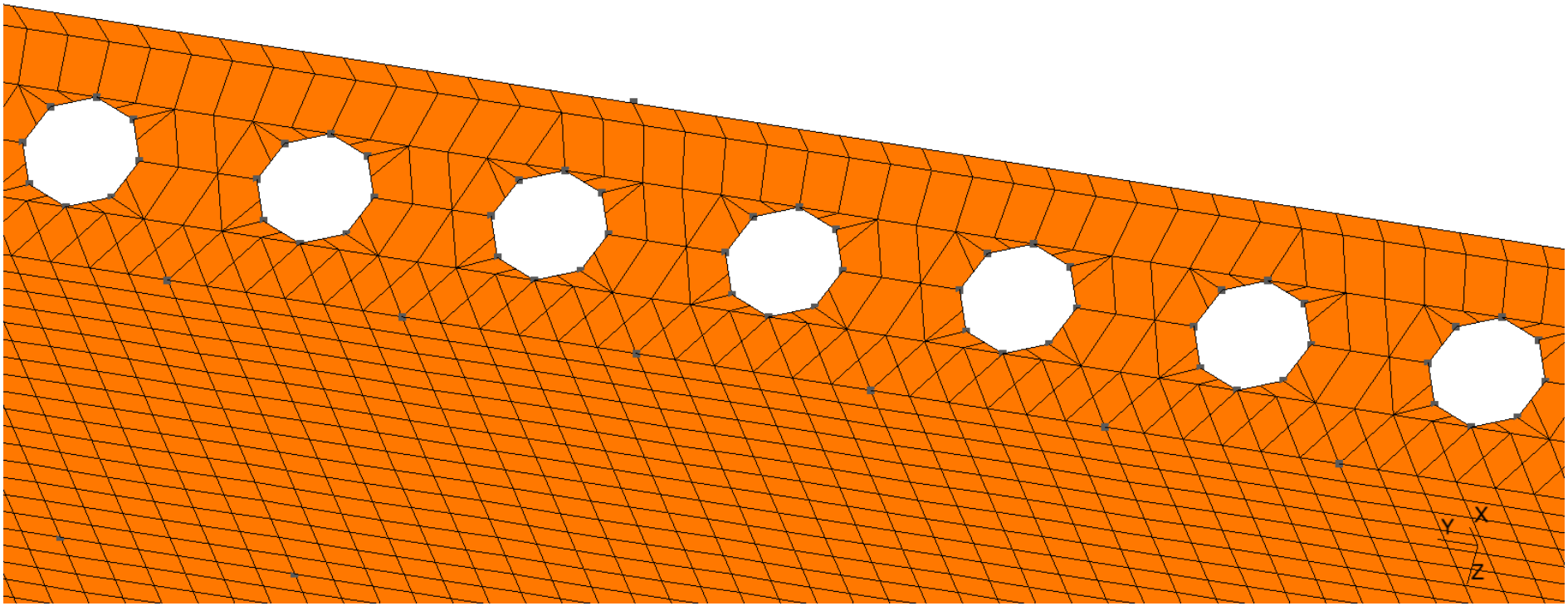
Minimal mesh size - 44, maximal mesh size - 66



Quality control by mesh refinement

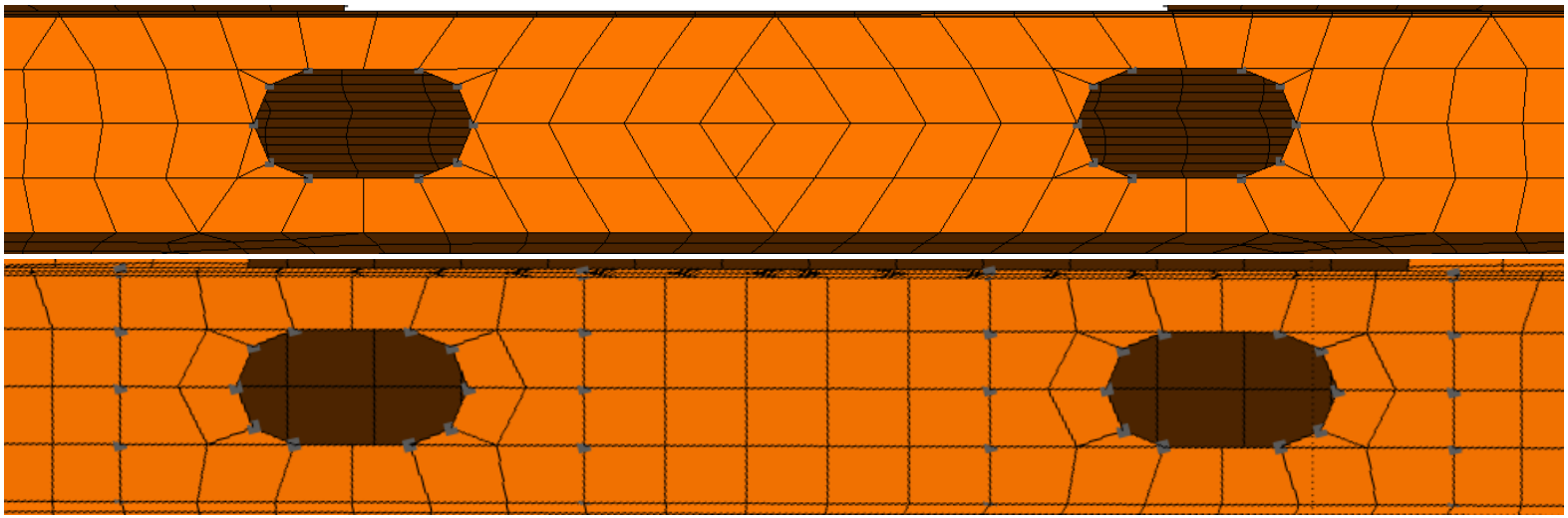


Quality control by mesh refinement



Virtual stiffener algorithm

- Insert virtual stiffener(rod) on girder and embed it into the mesh.
- Force mesh generator to localize triangles in the smaller area around the hole.
- It makes the cross field parallel to the virtual stiffeners.
- Future work: automatic insertion of virtual stiffener in geometry



Bibliography I

Owen Hughes and Jeom Kee Paik. *Ship Structural Analysis and Design*. New Jersey: The Society of Naval Architects and Marine Engineers, 2010.

Beom-Seon Jang et al. "Automatic FE modeler using stiffener-based mesh generation algorithm for ship structural analysis". In: *Marine Structures* 21.2 (2008), pp. 294–325. ISSN: 0951-8339. DOI: https://doi.org/10.1016/j.marstruc.2007.08.001. URL: https://www.sciencedirect.com/science/article/pii/S0951833907000469.

Bruno Lévy and Yang Liu. "Lp Centroidal Voronoi Tessellation and Its Applications". In: *ACM Trans. Graph.* 29.4 (July 2010). ISSN: 0730-0301. DOI: 10.1145/1778765.1778856. URL: https://doi.org/10.1145/1778765.1778856.

Bibliography II

Roy Nersesian and Subrina Mahmood. "International association of classification societies". In: (Oct. 2009), pp. 765–774. DOI: 10.1163/ej.9789004163300.i-1081.675.

J.-F. Remacle et al. "A frontal Delaunay quad mesh generator using the L^∞ norm". In: *International Journal for Numerical Methods in Engineering* 94.5 (2013), pp. 494–512. DOI: https://doi.org/10.1002/nme.4458. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/nme.4458. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/nme.4458.

Jean-François Remacle et al. "Blossom-Quad: A non-uniform quadrilateral mesh generator using a minimum-cost perfect-matching algorithm". In: *International Journal for Numerical Methods in Engineering* 89 (Feb. 2012), pp. 1102 –1119. DOI: 10.1002/nme.3279.

Financing

Name: Razvoj efikasne metodologije za analizu konstrukcije plovnih objekata metodom konačnih elemenata - REMAKE
Location: Zagreb, Republika Hrvatska
Duration: 42 months
Funding: 3.832.321,00 HRK
Applicant: BONUM d.o.o.
Partners:

- Sveučilište u Zagrebu, Fakultet strojarstva i brodogradnje (FSB)
- Sveučilište u Zagrebu, Prirodoslovno – matematički fakultet (PMF)