

# RBF Morph software

## RBF mesh morphing ACT extension for ANSYS Mechanical

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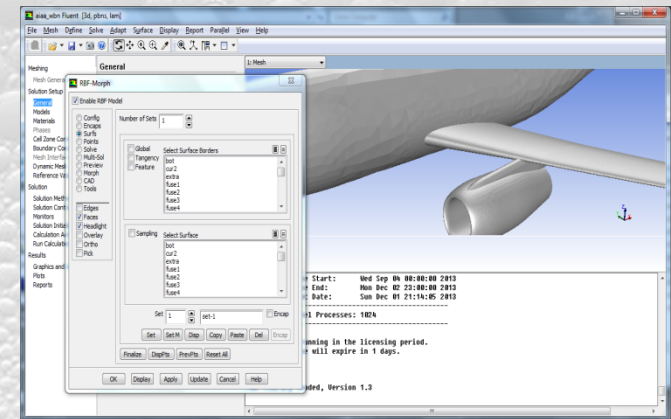
biancolini@ing.uniroma2.it

- Company Introduction
- RBF Morph Software Line
- Ongoing Researches
- ACT Module for ANSYS Mechanical

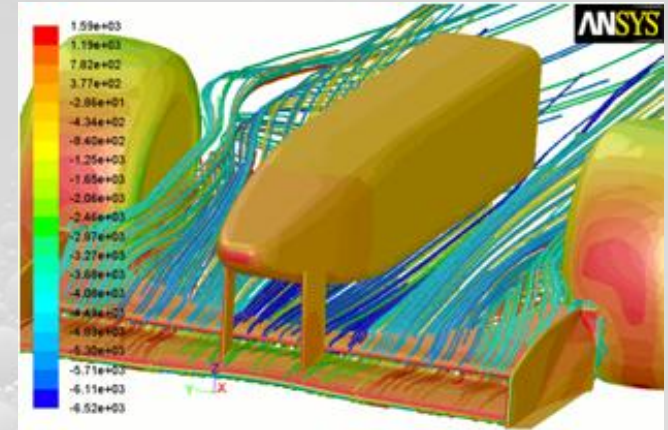


RBF Morph is a pioneer and world-leading provider of numerical morphing techniques and solutions conceived to efficiently handle shape optimization studies concerning most challenging industrial applications. We are an independent software-house and vendor. Our main product is **RBF Morph™**, that is a unique morpher that combines a very accurate control of the geometrical parameters with an extremely fast mesh smoothing properly designed to be integrated in advanced computational optimization procedures.

The **RBF Morph** tool is currently available in the market mainly as add-on of the CFD commercial code ANSYS® Fluent®.

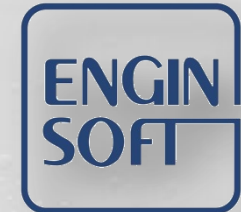


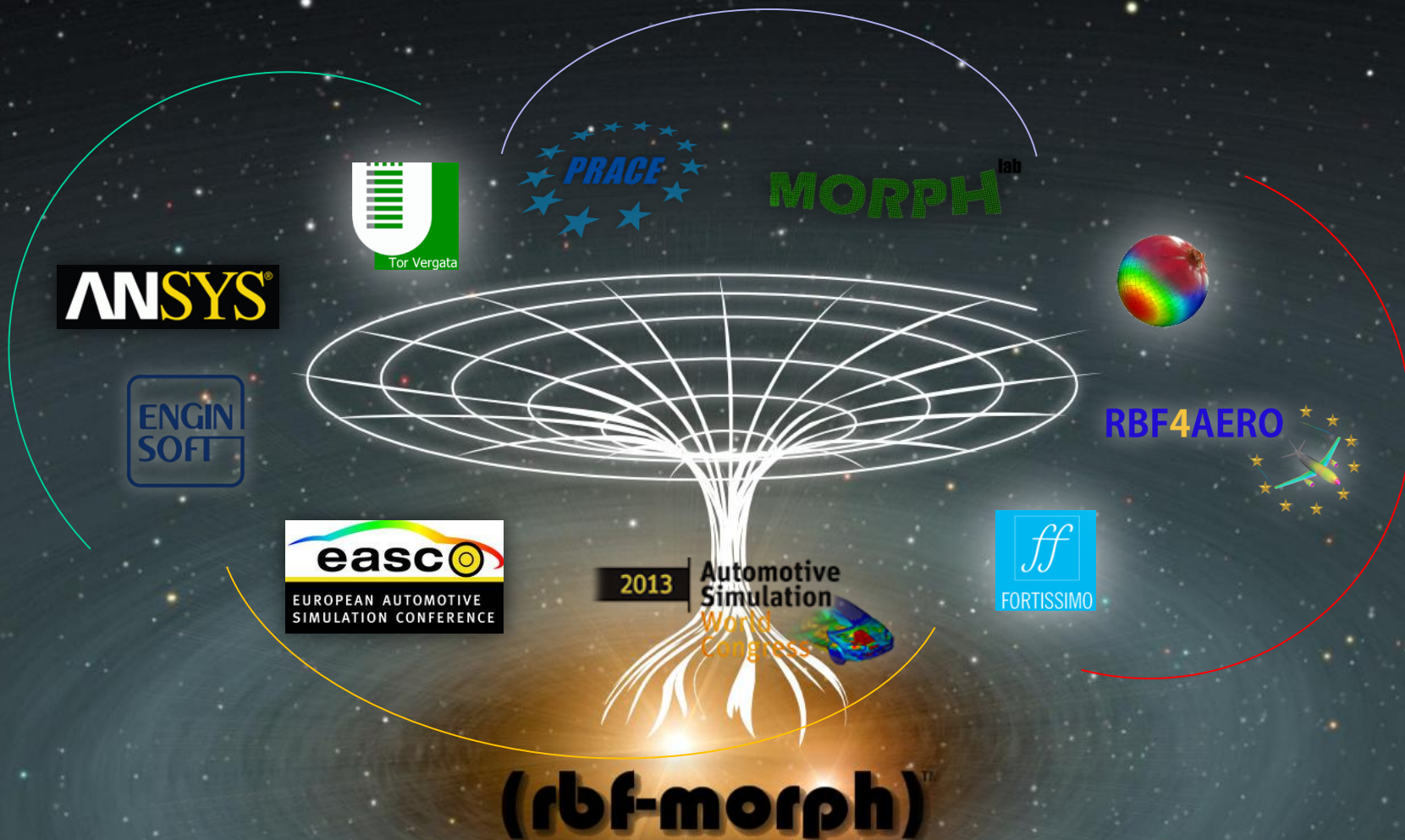
The **RBF Morph** tool had its inception in 2008 as on-demand solution for a Formula 1 top team. The need was a novel technology able to change the shape of large CFD numerical models as fast as possible. The final result had been so good that the technology was packaged in a commercial software product and launched onto the market.



At present, Dr. Marco Evangelos Biancolini is the unique owner of the **RBF Morph** technology and, as Director, avails himself of the collaboration of several experts for the deliver of products and services.

- Morphing-based numerical tools and services
- RBF Morph Milestones
  - ✓ 2008: tool implementation for Formula 1 top team consultancy activity
  - ✓ 2009: founded in Italy
  - ✓ 2009: Software Partner of ANSYS
  - ✓ 2009: at EASC **RBF Morph** won the *Most Advanced Approach Award Most Innovative Approach using Simulation Methods*
  - ✓ 2011: strategic partnership with Tor Vergata University (Rome)
  - ✓ 2012: OEM partner of ANSYS
  - ✓ 2013: beneficiary of an FP7 AAT Project RBF4AERO
  - ✓ 2013: at ASWC **RBF Morph** awarded for the *Best use of HPC*
  - ✓ 2013: Partner of Enginsoft
  - ✓ 2014: beneficiary of FP7 Project RIBES
  - ✓ 2014: beneficiary of FPT Fortissimo





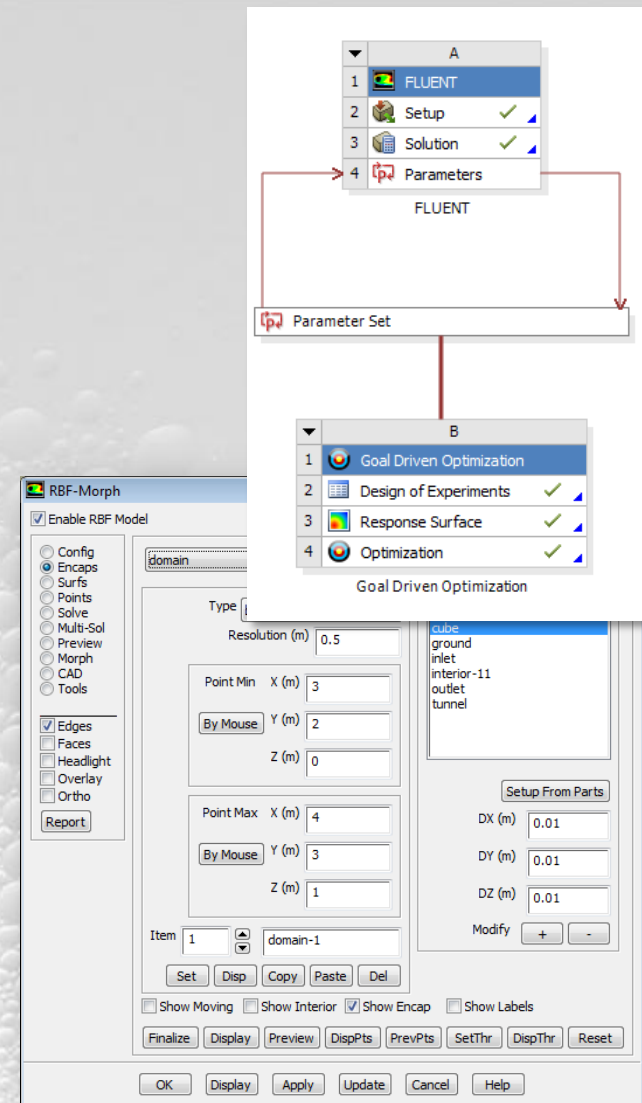
# RBF Morph software line

- Awarded mesh morphing software available as an add-on for **ANSYS Fluent** CFD solver
- HPC RBF **general purposes** library (state of the art algorithms, parallel, GPU)
- Stand alone morphing software + smoothing commands for different mesh formats
- ANSYS Mechanical **ACT module** (first release planned in June 2014)

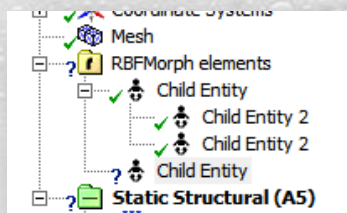




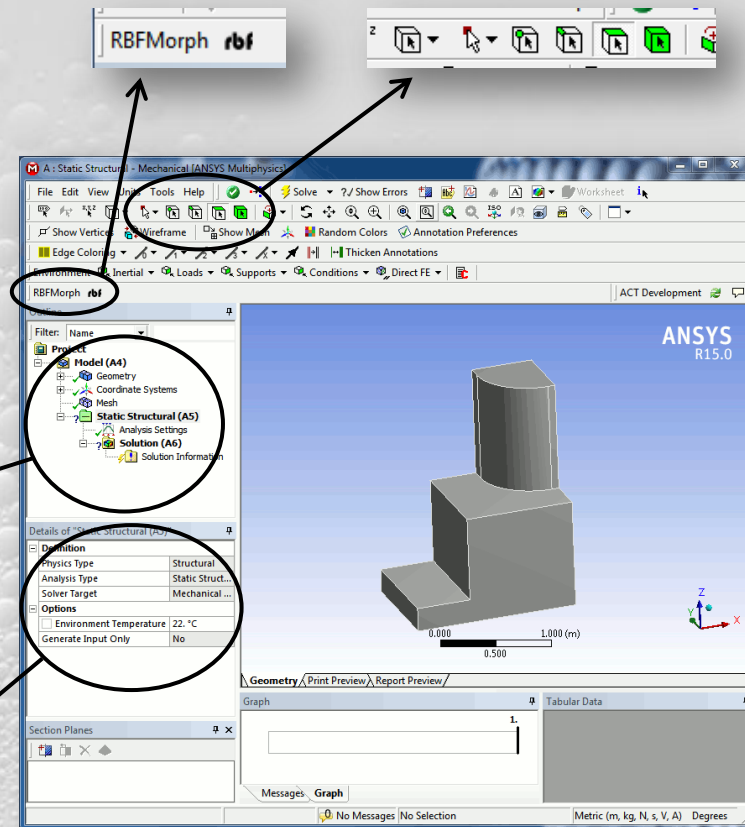
- **Add on** fully integrated within **Fluent** (GUI, TUI & solving stage), **Workbench** and **Adjoint Solver**
- **Mesh-independent** RBF fit used for surface mesh morphing and volume mesh smoothing
- **Parallel** calculation allows to morph **large size** models (many millions of cells) in a short time
- Management of **every kind of mesh** element type (tetrahedral, hexahedral, polyhedral, etc.)
- Support of the **CAD re-design** of the morphed surfaces
- **Multi fit** makes the Fluent case truly parametric (only 1 mesh is stored)
- **Precision**: exact nodal movement and exact feature preservation (**RBF** are better than **FFD**)



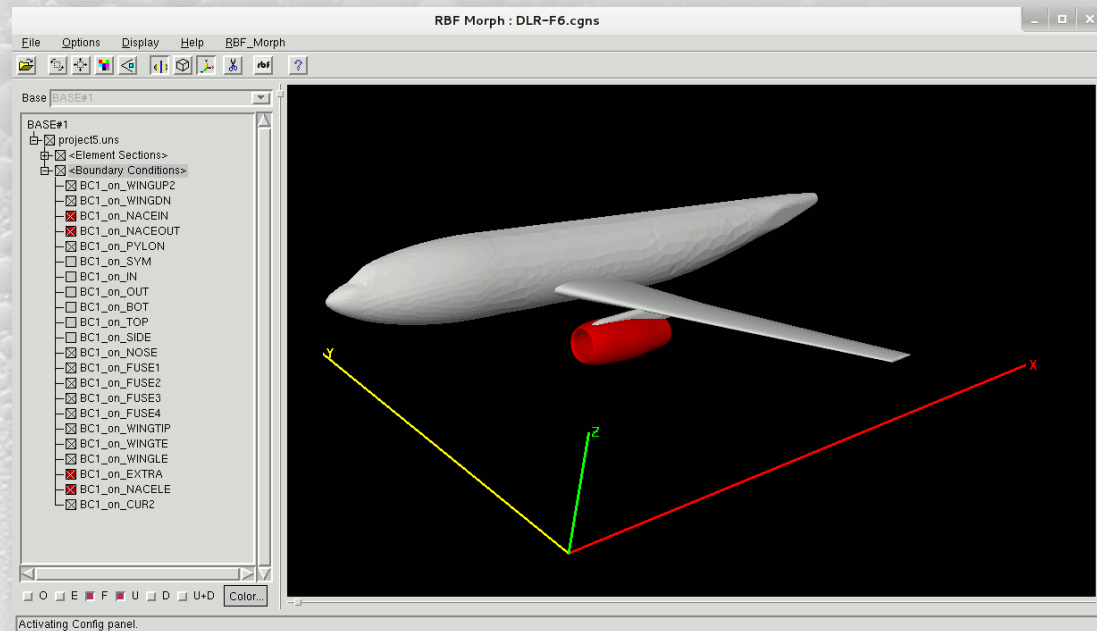
- Deeply integrated in ANSYS Mechanical: same look & feel, same interaction logic
- Nested in the usual Mechanical tree as an added object, shares its scoping tools for **geometrical** and **mesh elements** selections
- Written in **python** and **xml**, uses external RBF Morph core libraries
- Child **hierarchical logic** for complex morphings (two steps, three steps, ..., n steps setups)



Node selection	
Scoping Method	Geometry Selection
Geometry	Apply Cancel
Definition	
delta_x	0
delta_y	0
delta_z	0.4

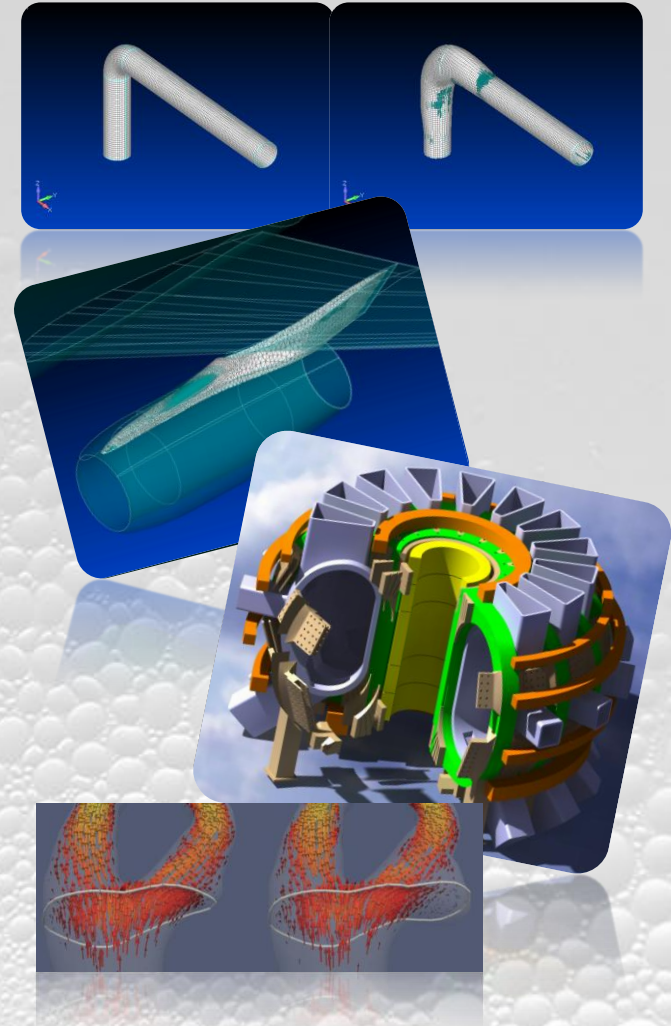


- RBF solutions are fully compatible and **exchangeable** between add-on and standalone versions
- Support for STL and CGNS file formats. Selected morphed surfaces can be exported in STL format and **back to CAD** is possible via STEP files
- **Add-on-like** interface
- **Solver independent** process currently supports many mesh formats
- Functions **scriptable** via tcl
- Global supported bi-harmonic functions and  $C^0$ ,  $C^2$ ,  $C^4$  compact supported functions available



# Ongoing RBF Morph Researches

- RBF Morph and Adjoint coupling: Adjoint sculpting, Adjoint preview, Augmented DOE
- **STL** targeting, **CAD** controlled surfaces
- **Mesh to CAD** features
- Mapping of **magnetic** and **pressure** loads
- Interpolation of **hemodynamic** flow fields acquired *in vivo*
- Strain and **stress calculation** (experimental data, coarse FEM, isostatic lines)



- “Innovative Benchmark Technology for Aircraft Engineering Design and Efficient Design Phase Optimisation” –

**ACP3-GA-2013-605396**

- [www.rbf4aero.eu](http://www.rbf4aero.eu)

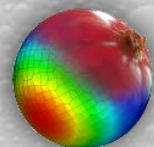


**RBF4AERO**

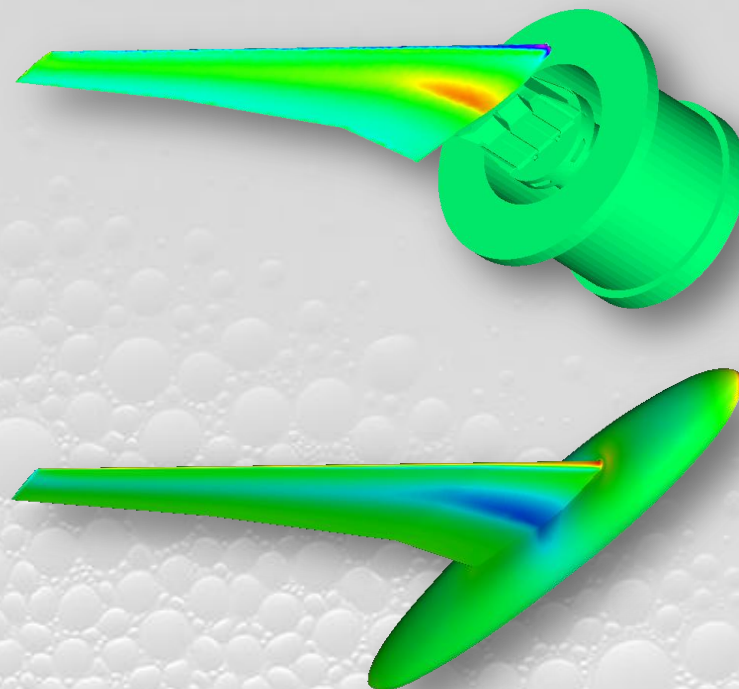


- Radial basis functions at fluid Interface Boundaries to Envelope flow results for advanced Structural analysis

JTI-CS-2013-GRA-01-052



RIBES



# RBF mesh morphing ACT extension for ANSYS Mechanical



- It allows to have parametric shape mesh that preserves the original topology. **Remeshing noise** is avoided.
- It allows to update the shape of a **validated FEM model** without rebuilding a new mesh.
- New shapes can be investigated even if the underlying **CAD geometry** is missing.
- The mesh can be updated to measured shapes (i.e. accounting for **manufacturing tolerances**)
- It's usually faster than remeshing.

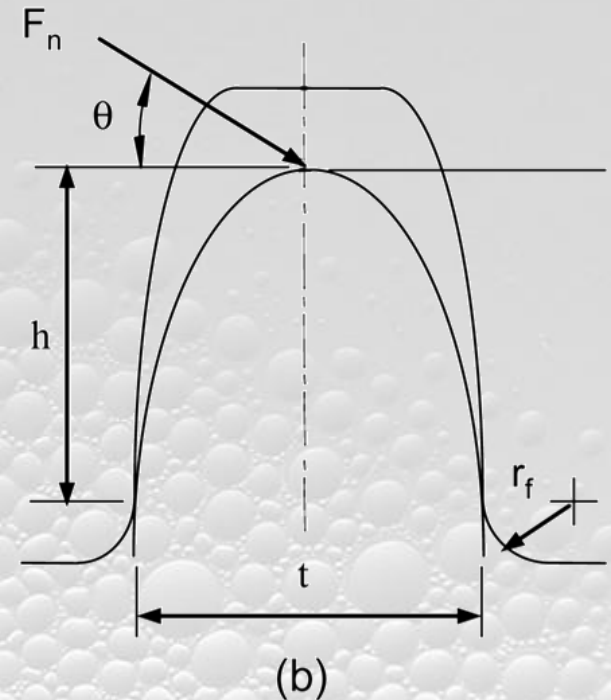
- RBF Morph is a best in class product crafted to deal with challenging CFD application (**huge meshes**)
- 7 years of experience on industrial applications of Radial Basis Functions (RBF)
- RBF are **recognized** as one of the best mesh morphing tool available in the industrial and scientific community
- A new vision (we have started the new project from scratch) to put in the hands of **ANSYS Mechanical** Users the fastest and easiest mesh morphing tool
- Satisfy the needs of **many users** asking for such a kind of technology available in ANSYS Mechanical

- Fully **embedded** in ANSYS Mechanical with same “look & feel”
- Integration in the tree and founded on the working principles of **ANSYS Workbench**
- Based on the ACT (Application Customization Toolkit) **extension** concept
- Geometrical and mesh scoping to set-up the mesh morphing problem
- Parametric (coming soon! In ANSYS 16 ACT modules parameters will be exposed natively)
- RBF **fast solver** (including parallel and GPU support)

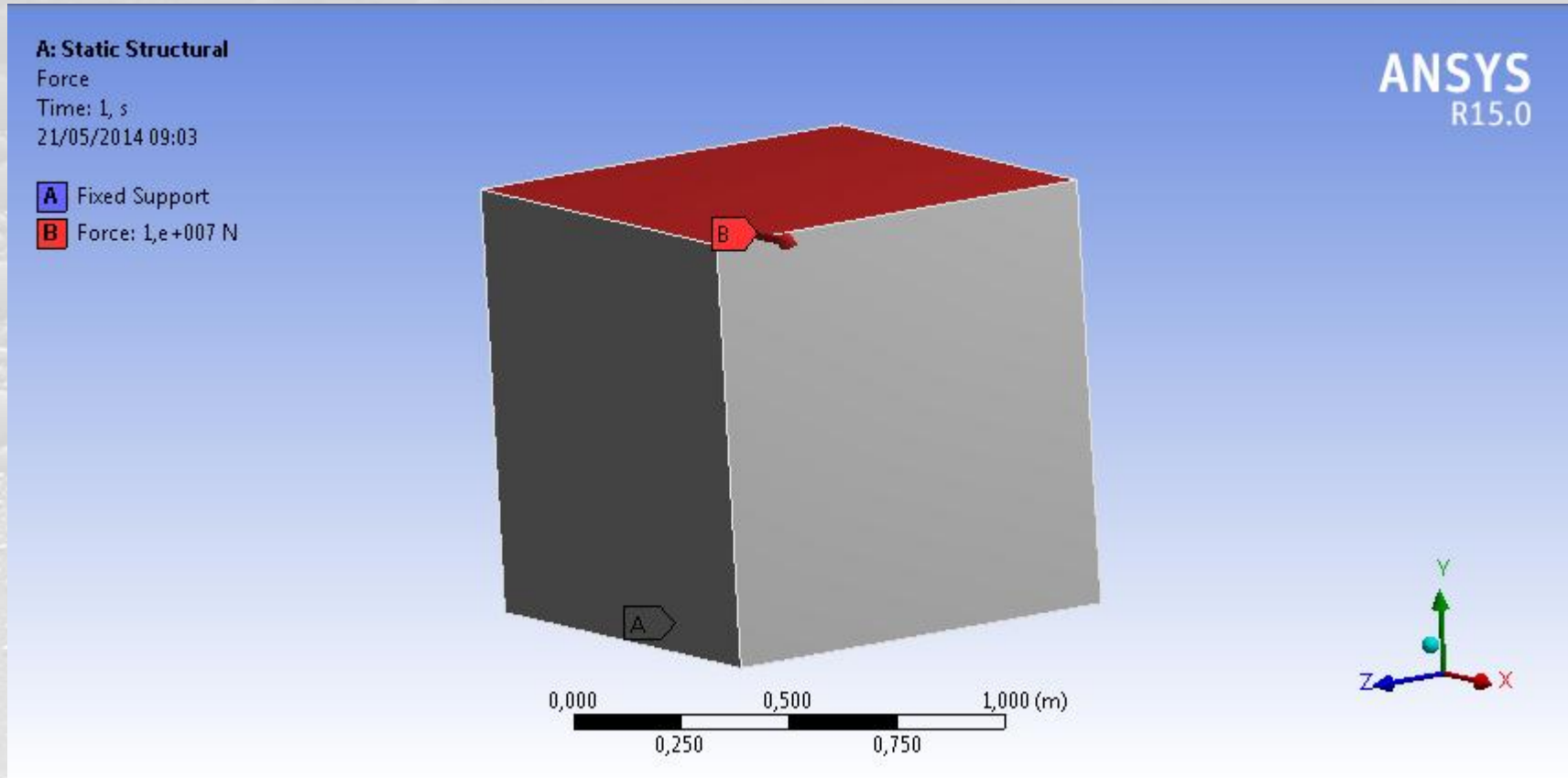
- Easy to use, flexible and **expressive**.
- Powered by multi-step RBF technology (which effectiveness has been extensively proven in RBF Morph)
- **RBF fitting and mesh morphing** happen as a unique **HPC process** at each shape update. This allows the maximum flexibility with respect to parameterization
- RBF component set-up data stored and persistent with the ANSYS Mechanical project.
- Advanced **interaction with DM** to enable CAD resynchronization after morphing (coming soon)

- **Hierarchical** multi-step RBF approach
- Each morphing **target** can be controlled using the superposition of a constant translation (other modifiers will be introduced) and an RBF field generated by its **sources** (if any)
- **Source points** are extracted using the motion of all the **children**
- If the child is a leaf its movement is known otherwise **it becomes a target** and has to be solved descending the tree
- Sounds complicated? Let's explain it with an example!

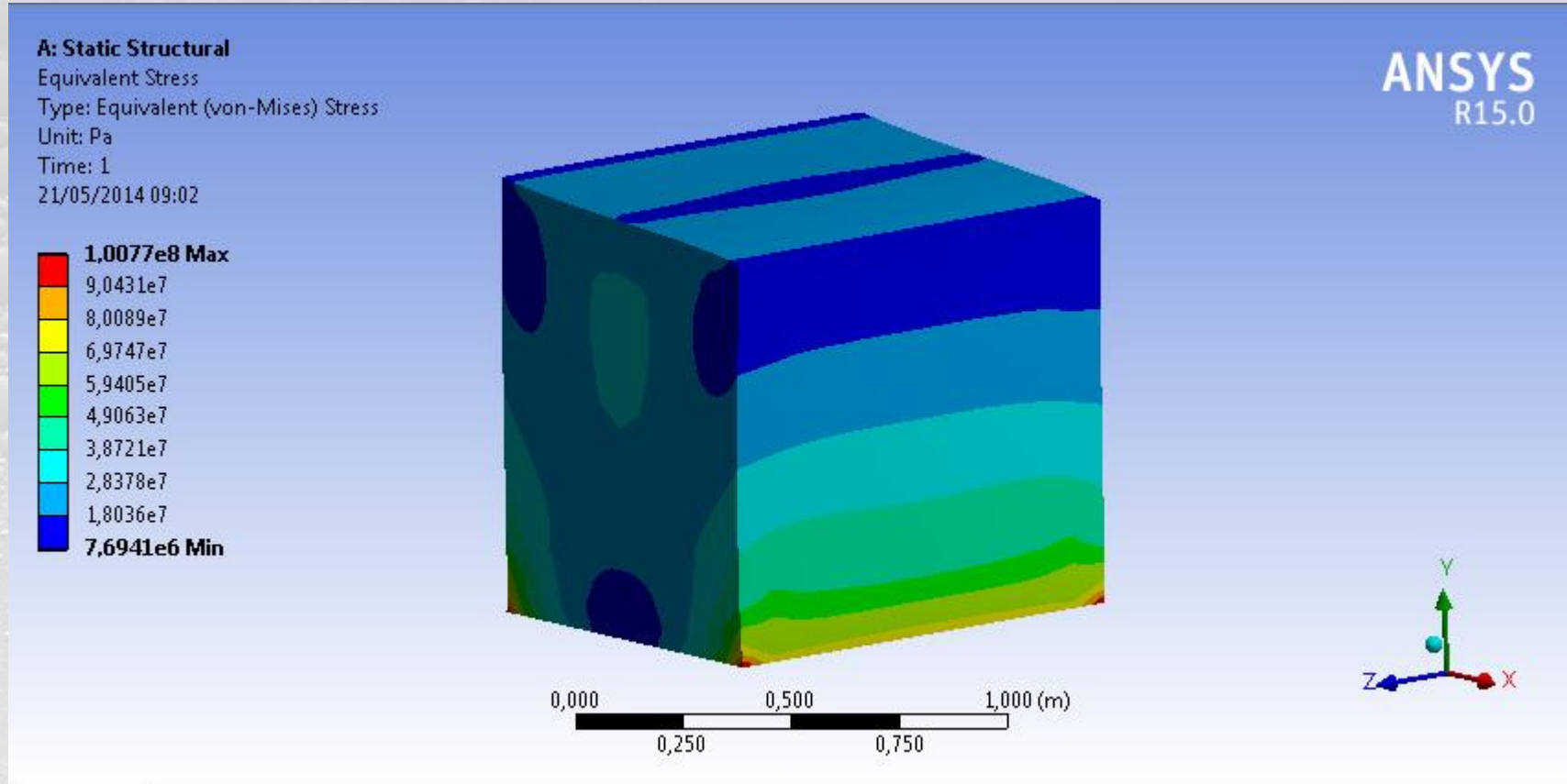
- A simple **cube** is loaded on the top and clamped to the bottom
- **Structural mechanics** tell us that this structure can be optimized adopting a tapered profile
- A parabola is obtained if we look for constant **bending stress** beam
- The theory is well known in gear design as the **Lewis formula** used for the stress assessment of a teeth



- Boundary conditions

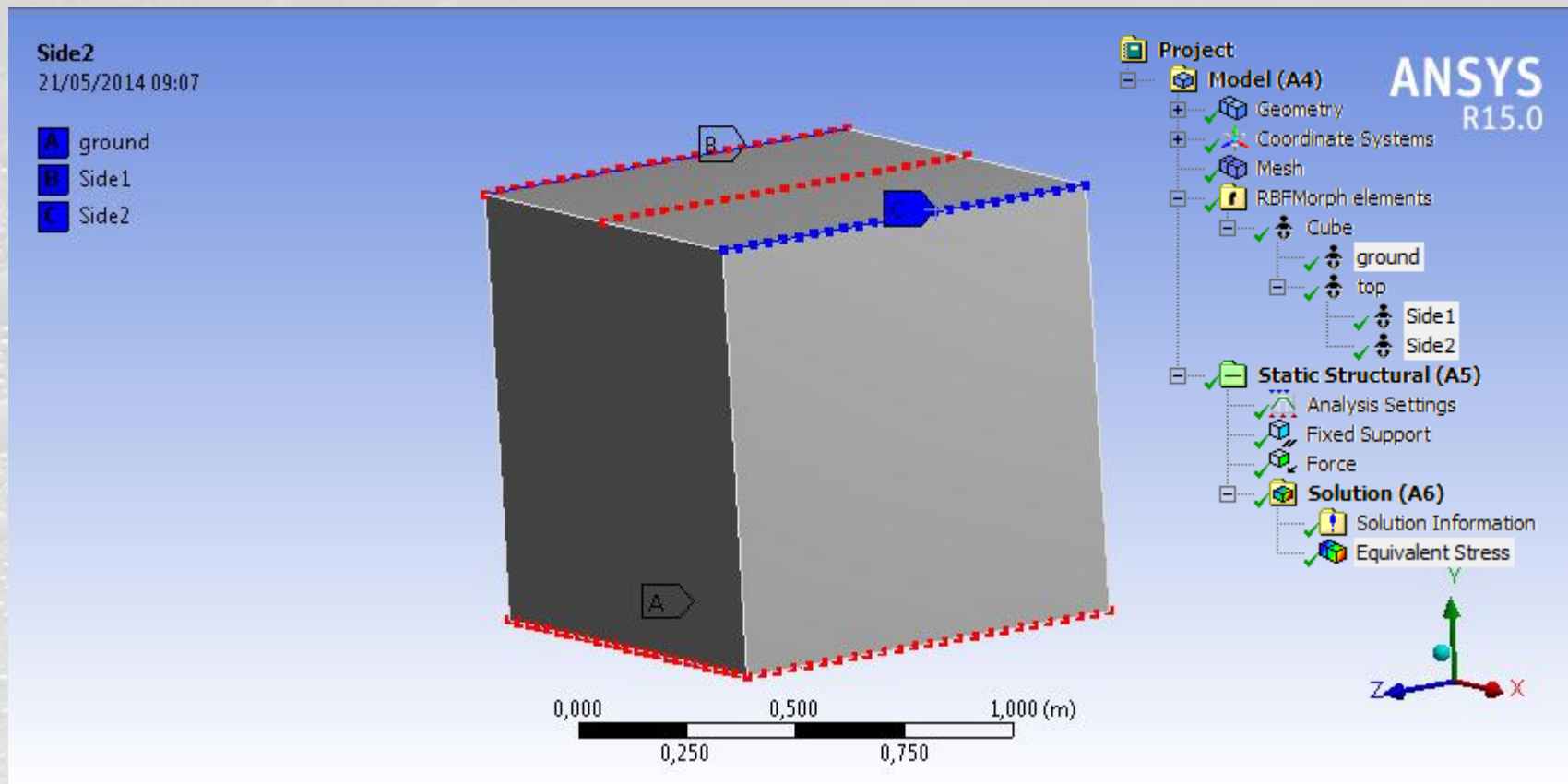


- Baseline solution

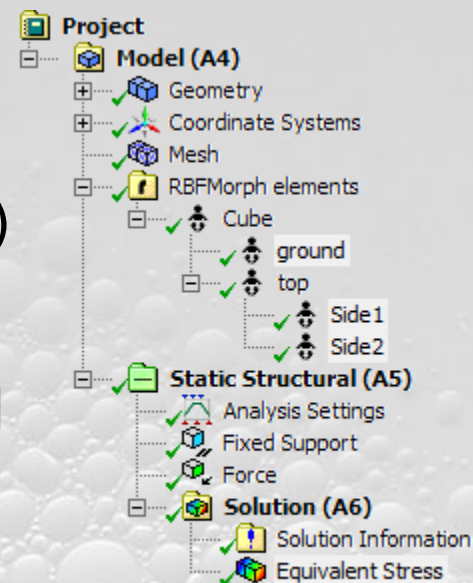




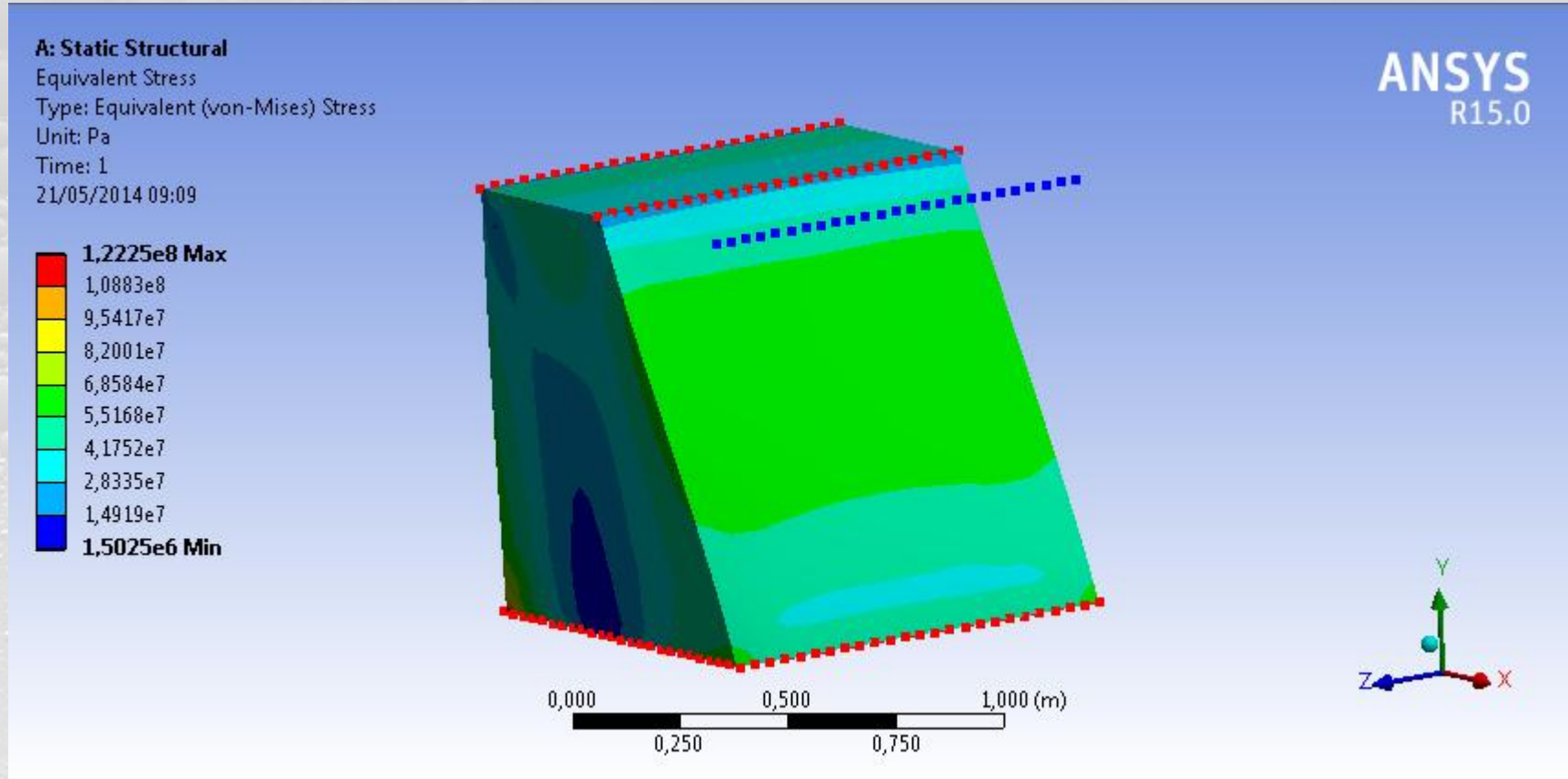
- First morphing set-up!



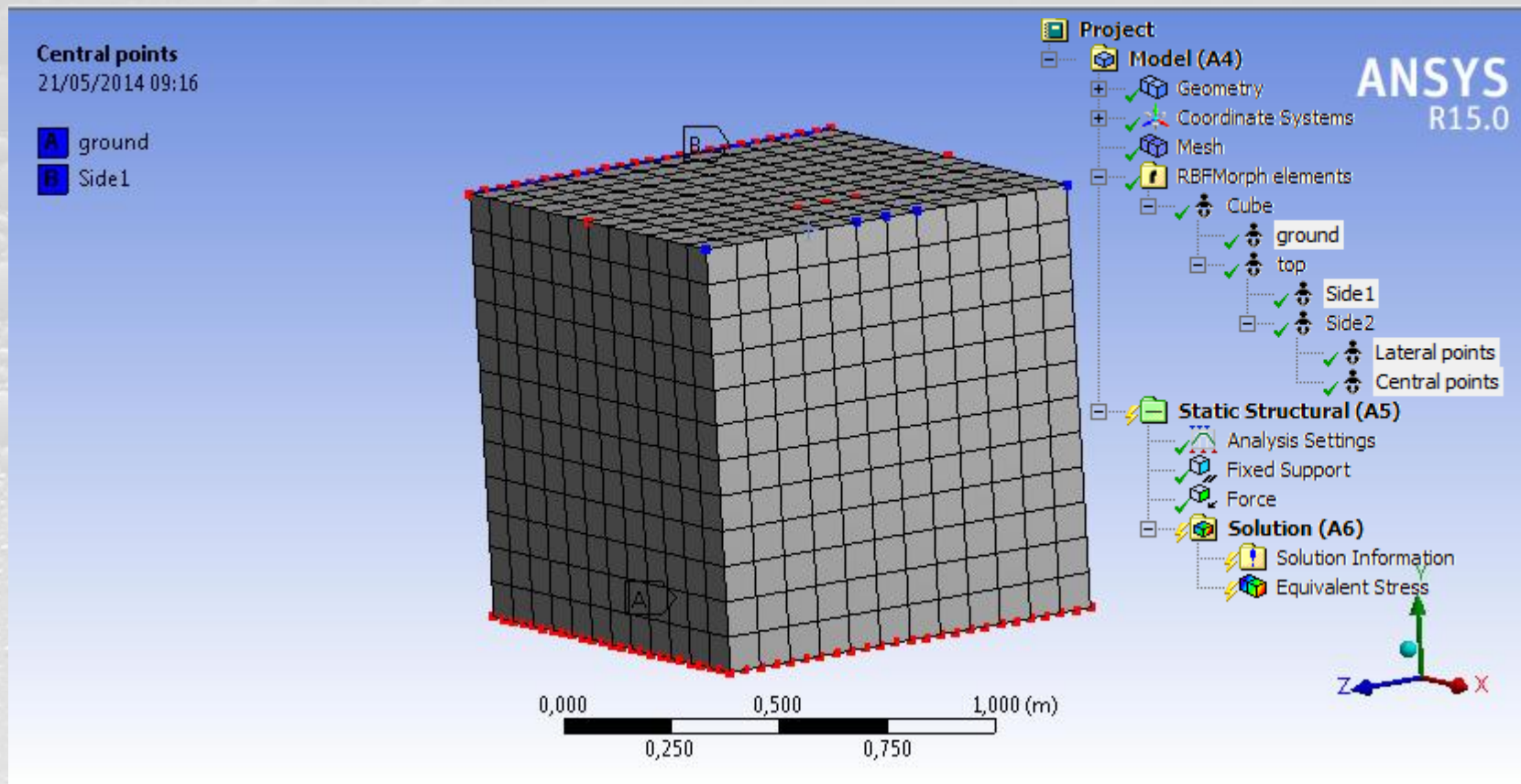
- The first level set **Cube** (volume scoping) define the mesh to be morphed. Controlled by ground and top.
- At second level (surface scoping) we have two sets: **ground** (fixed and leaf of the tree) and **top** (controlled by Side1 and Side2).
- At third level (edge scoping) we have **Side1** (fixed) and **Side2** (moving in negative X direction).



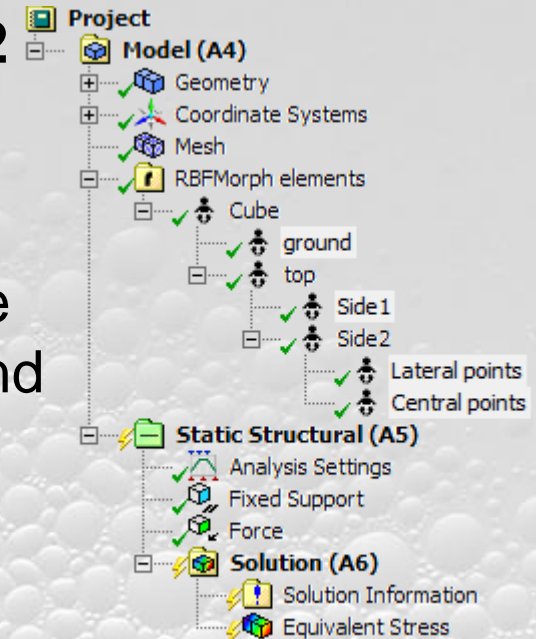
- Morphed solution #1



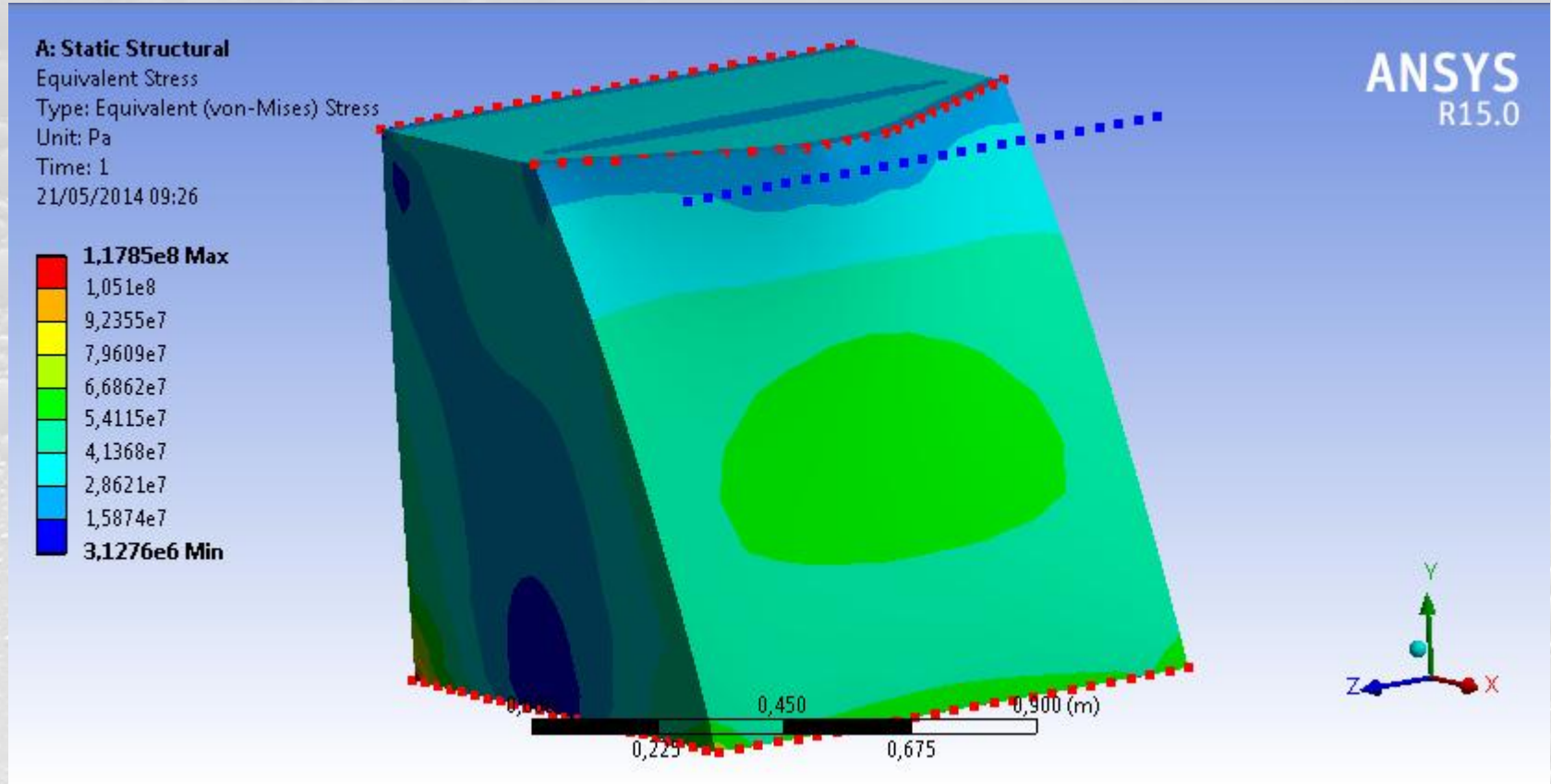
- Second morphing set-up!



- The previous set-up has been refined and now we have a fourth level (scoping points and nodes) to control the shape of **Side2** that is controlled by Lateral Points and Central Points
- Individual movements are imposed in the negative X direction to **Lateral Points** and **Central Points**
- At this level it would be good to control curvature changing the **order** of RBF function (coming soon!)



- Morphed solution #2



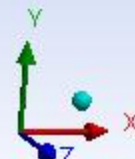
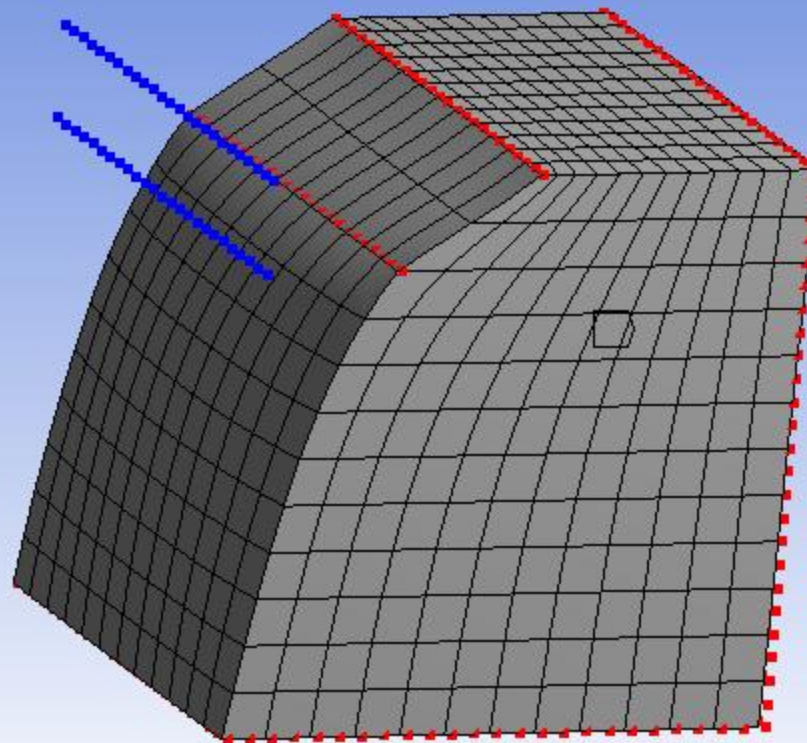
- The set-up #1 and #2 are explained in detail.
- The set-up can be further enriched to fulfill the desired shape.
- Some example follows...

Child Entity

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Child Entity 2

ANSYS  
R15.0





### Equivalent Stress

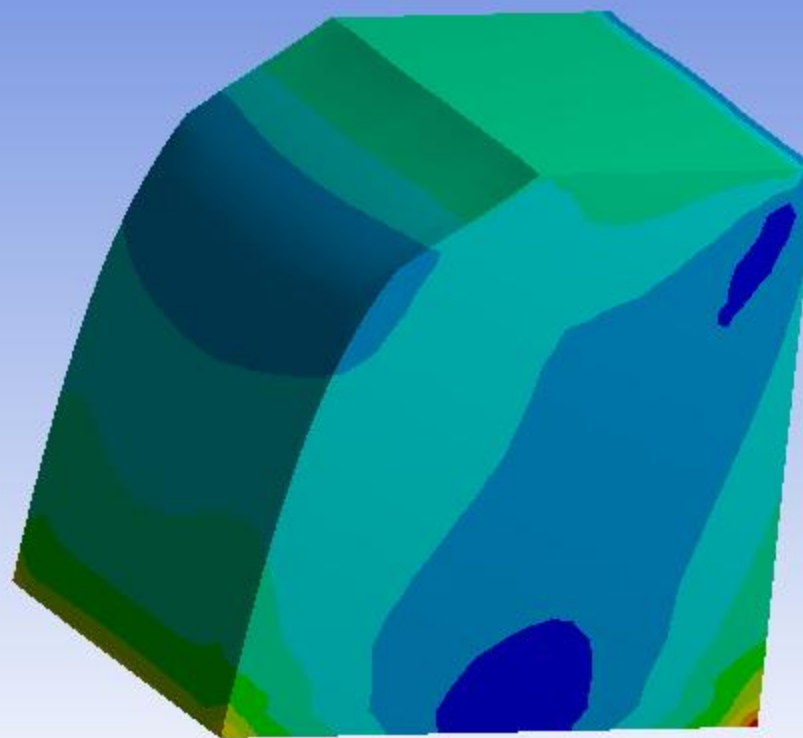
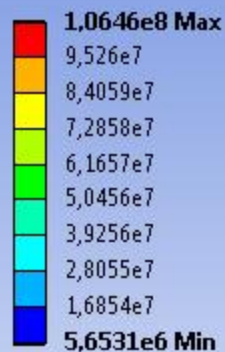
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Unit: Pa

Time: 1

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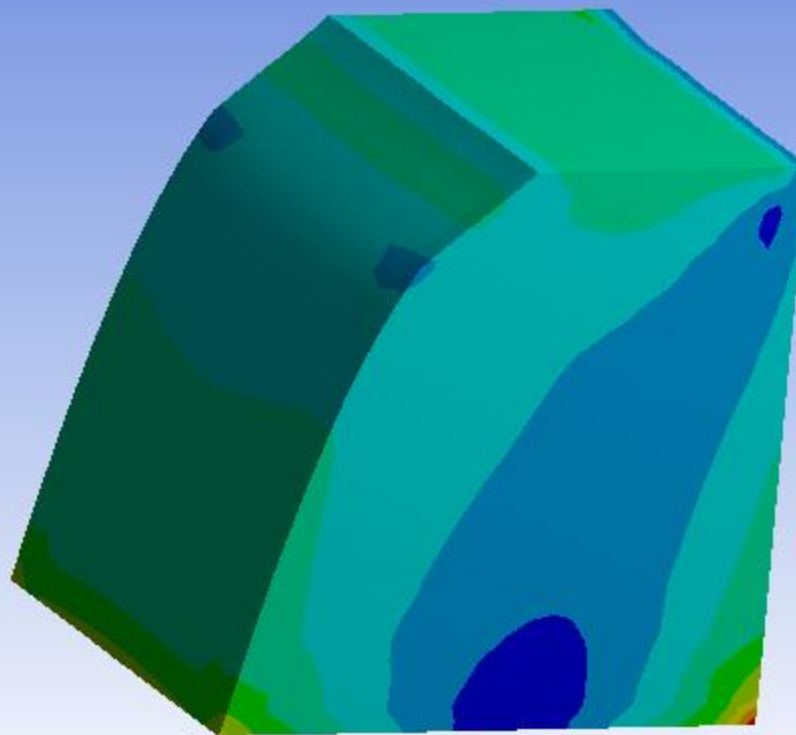
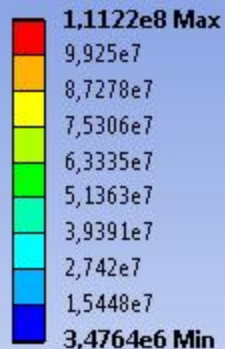
### Equivalent Stress

Type: Equivalent (von-Mises) Stress

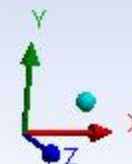
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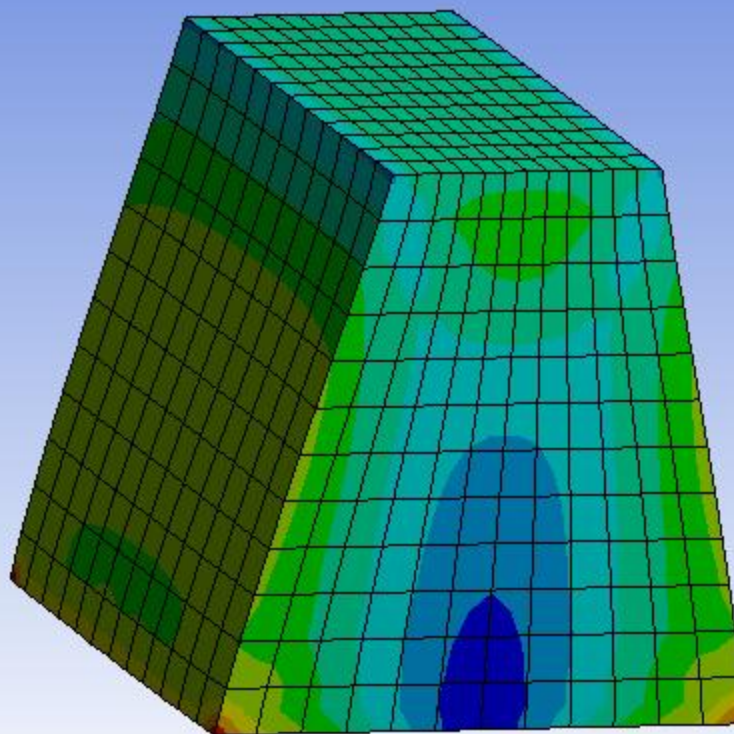
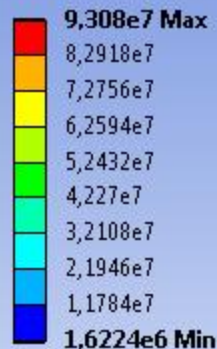
### Equivalent Stress

Type: Equivalent (von-Mises) Stress

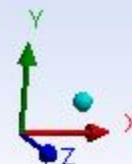
Unit: Pa

Time: 1

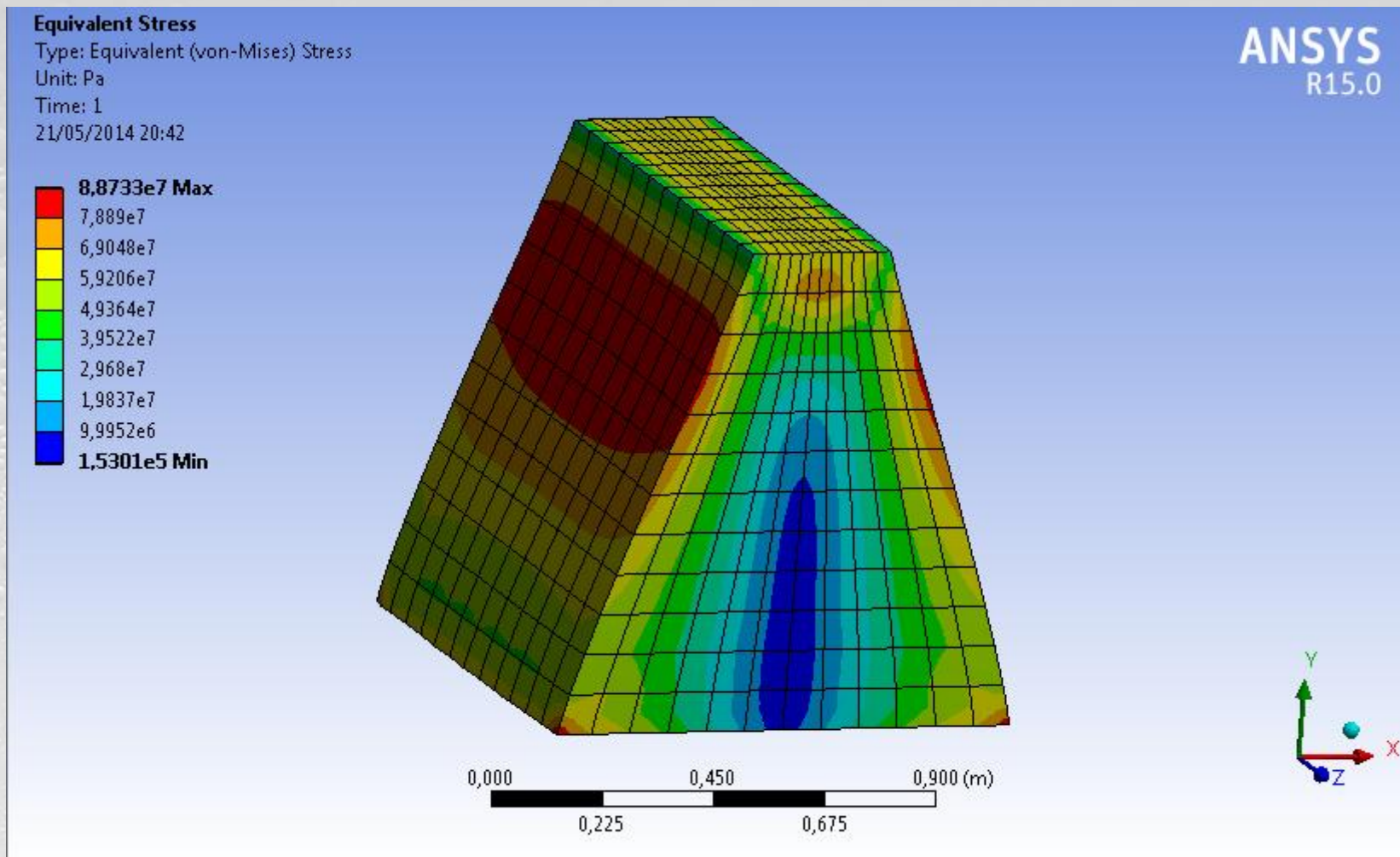
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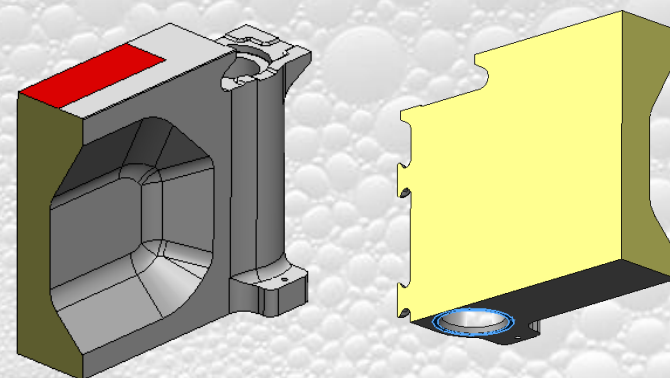
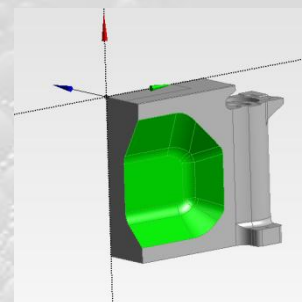
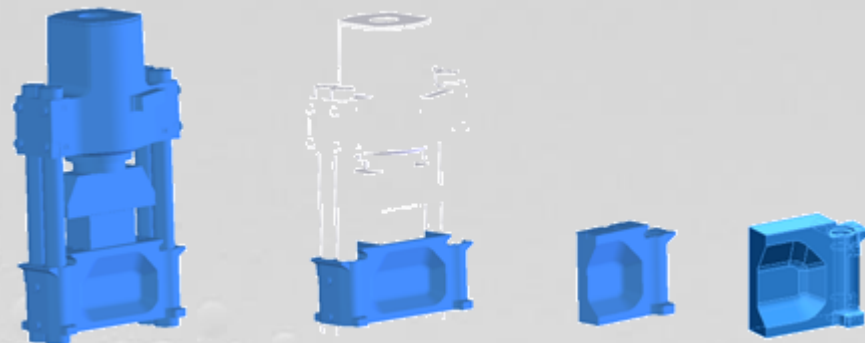


- Mass reduction 36% Stress reduction 12%

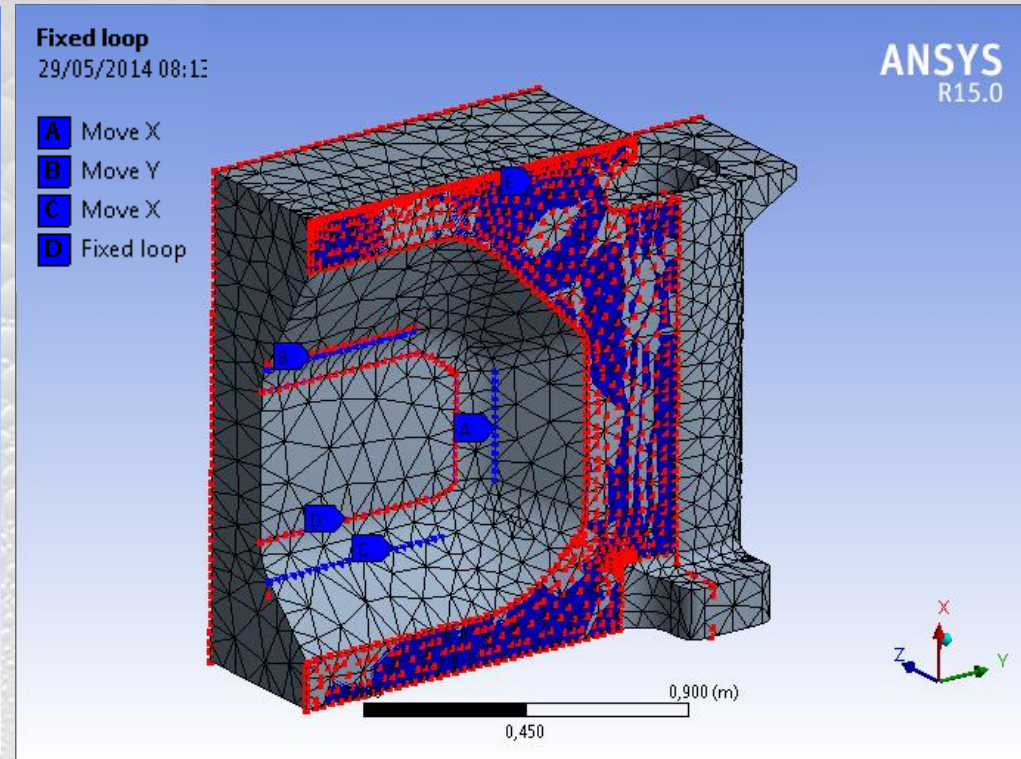
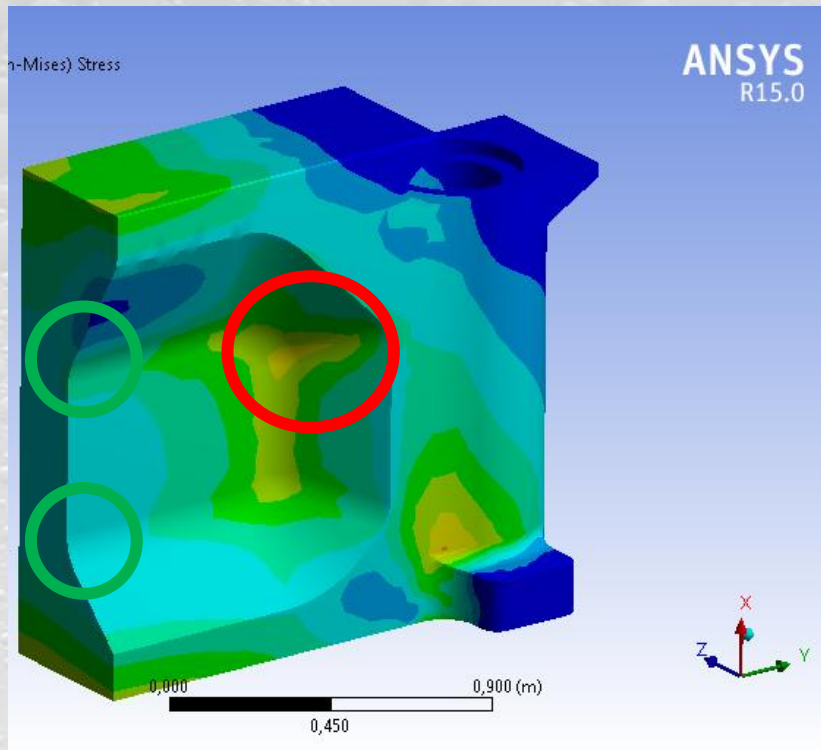




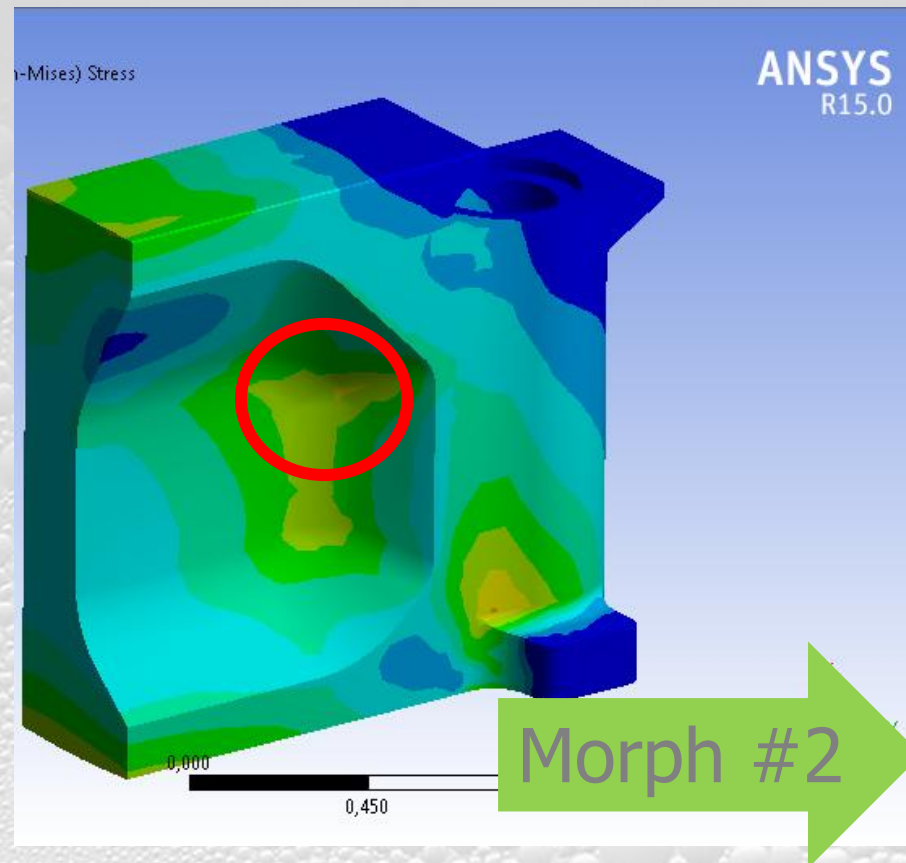
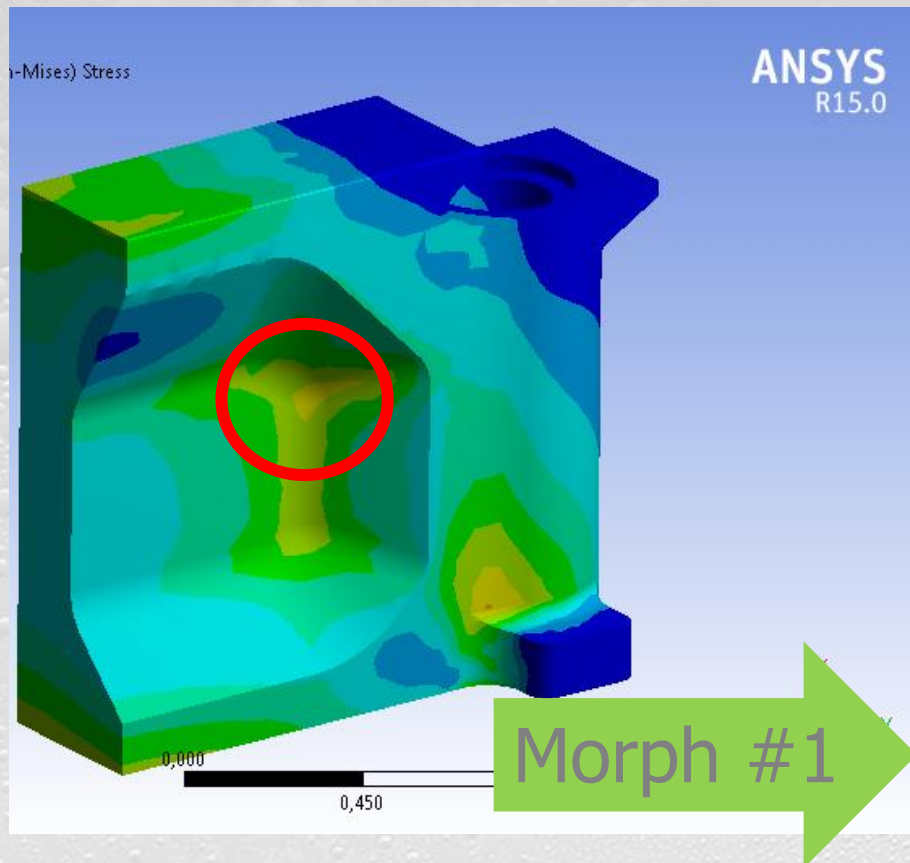
- This is a simple mesh morphing **feasibility study** for a geometry relevant for SACMI
- Part studied is a quarter of the basement of a press
- Area to be optimized is the one highlighted in **green**
- **Simple boundary** conditions are used to stress the part (red fixed, yellow symmetry, blue loaded)



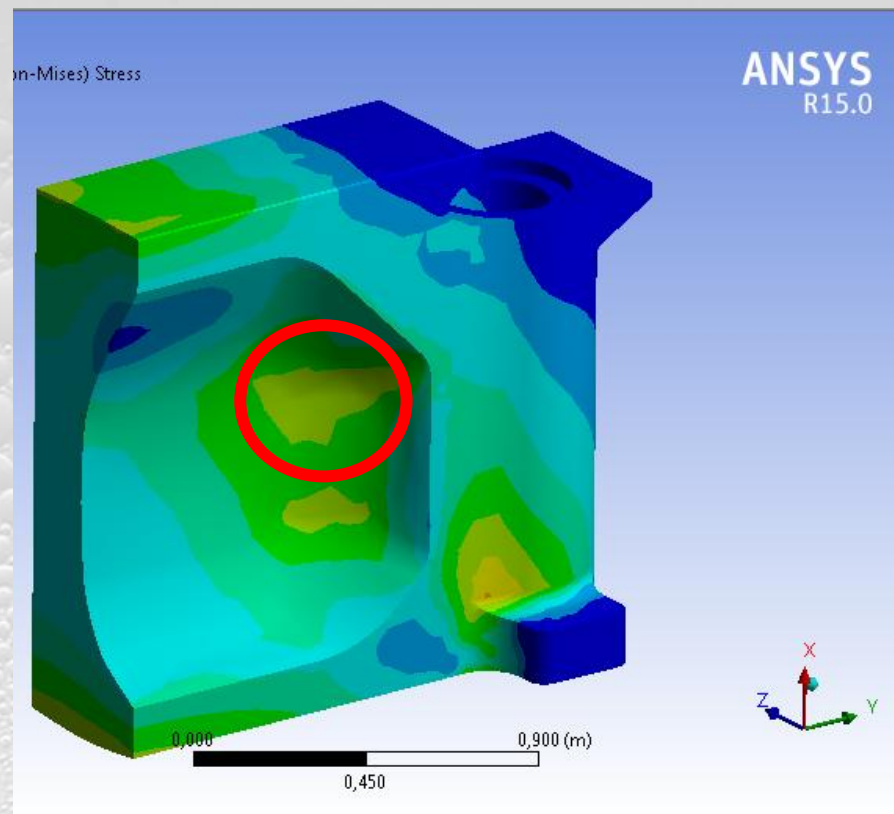
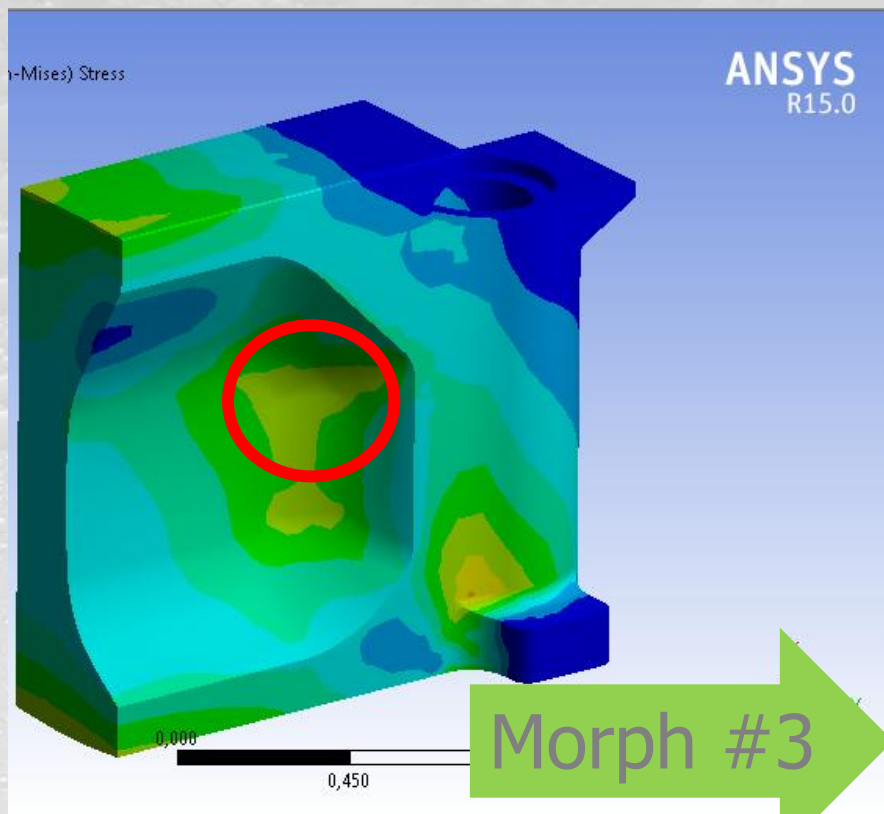
- Mesh morphing has been used to reduce the **stress concentration** acting on the shape of the **fillet**.



- As the fillet is smoothed a stress redistribution is observed.

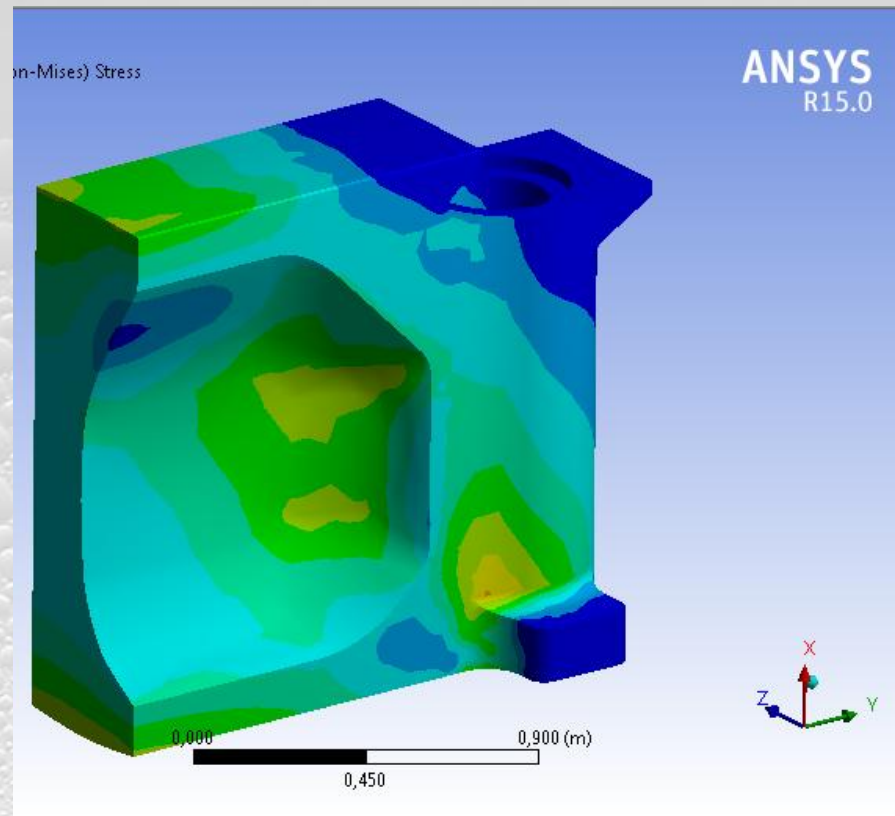
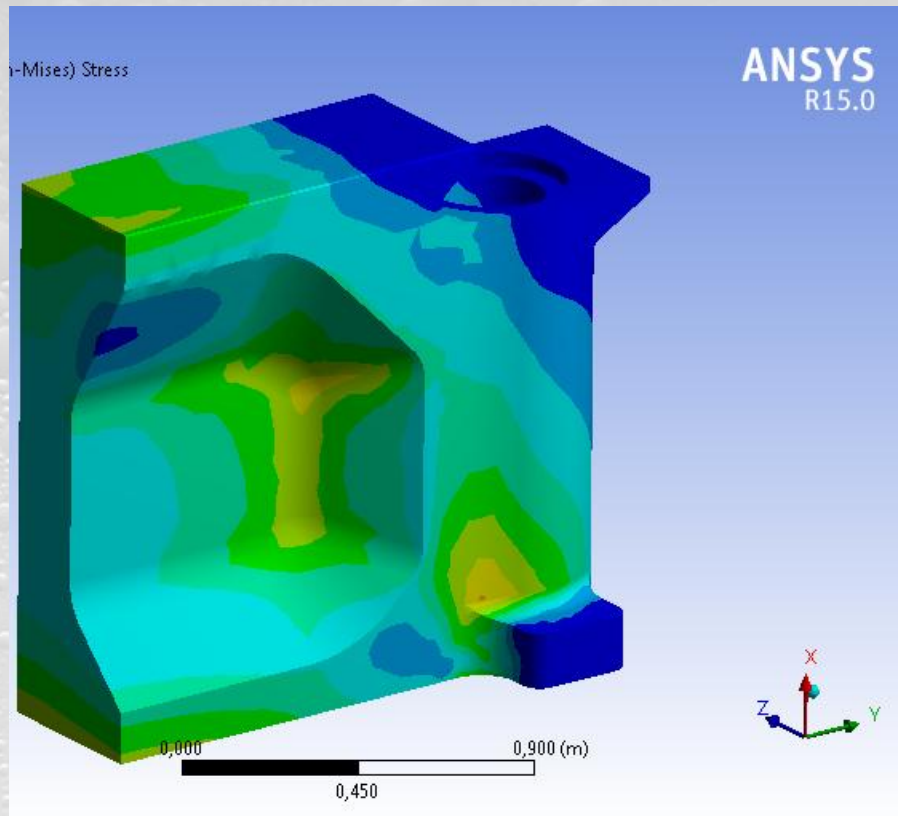


- Notice that high mesh deformation is properly accommodated thanks to RBF mesh morphing





- Original vs. Optimised (13% reduction of stress peak)



- A novel mesh morphing tool has been implemented in **ANSYS Mechanical** using ACT extension technology
- **Radial Basis Functions** are used for multistep set-up
- The new software benefits of past experience on RBF Morph **ANSYS Fluent** add-on (mainly CFD)
- Nevertheless we have restarted all the developments **from scratch** i.e. reusing **knowledge** and **ideas** (no cross compatibility between tools)
- Basic capability of the first software prototype are demonstrated on a simple FEM mesh and on an **industrial FEM model**
- **How can we do better? Please do not hesitate to tell us your needs!**

# Grazie per l'attenzione!

Prof. Marco Evangelos Biancolini

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Web: [www.rbf-morph.com](http://www.rbf-morph.com)



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