ANSYS
Coventry, UK • May, 2-3, 2018
INNOVATION CONFERENCE

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ANSYS PREFERRED SOLUTION PARTNER

Automatic shape optimisation using the Biological Growth Method (BGM) with RBF Morph ACT Extension and ANSYS Mechanical

Università di Roma Tor Vergata

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Outline

- RBF Morph UTV synergy
- Parametric CAE
- Software line
  - RBF Morph Fluent Add On
  - RBF Morph ACT Extension
- BGM sculpting
  - BGM Background
  - RBF Background
  - Examples
- Conclusions

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Welcome to the World of Fast Morphing!

www.rbf-morph.com

A powerful synergy

Academic | **CAE business**

UTV + ISV RBF Morph

- A variety of applications ranging from **research** to **industrial** exploitation can be tackled
- **Technology transfer** is boosted (including personnel)
- **Funds** access is facilitated
- A **network** of **partners** (Industries, Universities, Research Institutes, CAE Companies)

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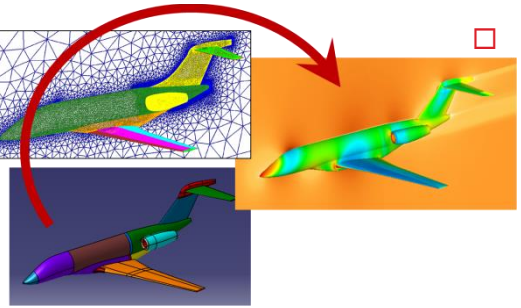
Geometry - CAE link

RBF mesh Morphing

- Main advantages
  - No re-meshing
  - Can handle any kind of mesh
  - Can be integrated in the CAE solver
  - Highly parallelizable
  - Robust process
- Main disadvantages
  - Can't handle topology change
  - Back to CAD procedure required



CAD to mesh

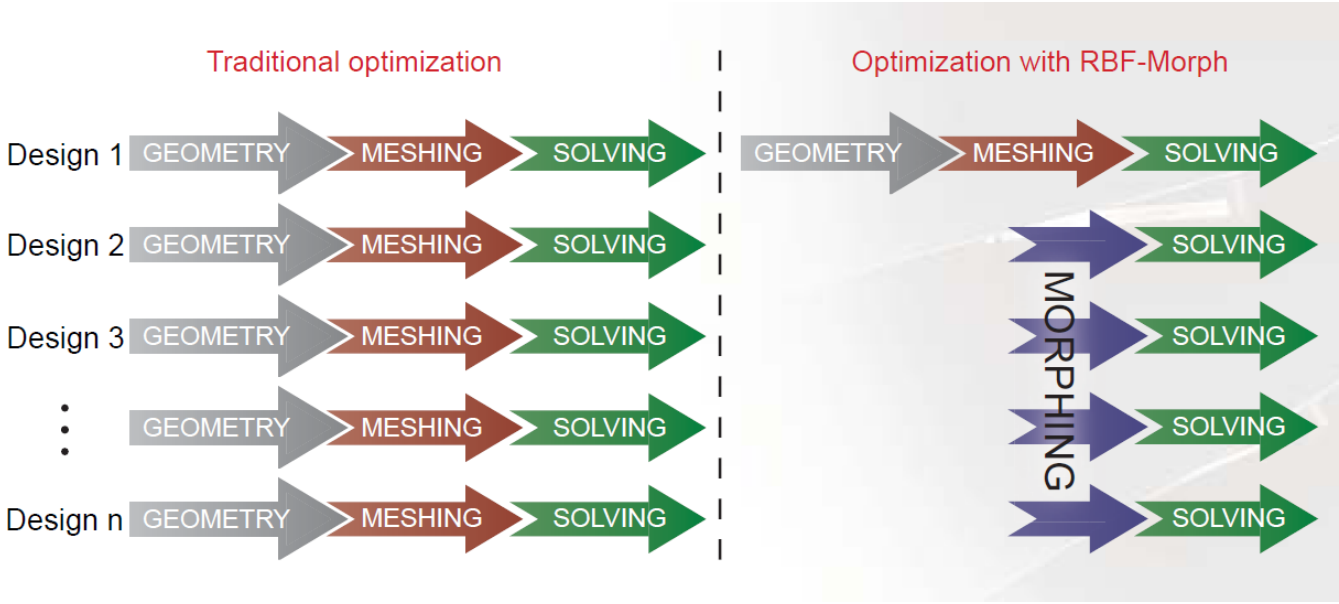
- Main advantages
  - Accurate geometry quality control
  - High constraints setup flexibility
  - No "back to CAD" required
- Main disadvantages
  - Complex setup
  - Highly skilled CAD user required
  - Robustness
  - Remesh required

Parametric CAE models

RBF Morph makes the CAE model **parametric** with respect to the **shape.**

Works for **any size of the mesh.**

Shape parameters can be steered with the **optimizer of choice.**



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RBF Morph software line

Fluent Add On

- Released in **2009**
- Fully integrated within Fluent (GUI, TUI & solving stage), Workbench and **Adjoint Solver**
- Multi physics features (**FSI**)

Stand Alone

- Released in **2012**
- Tcl/Tk GUI accepts **CGNS** and **STL** (Linux only)
- **Cross solver** (OpenFoam, CFD++, SU2, Fluent, Nastran, ANSYS, Abaqus)

ACT Extension

- Released in **2015**

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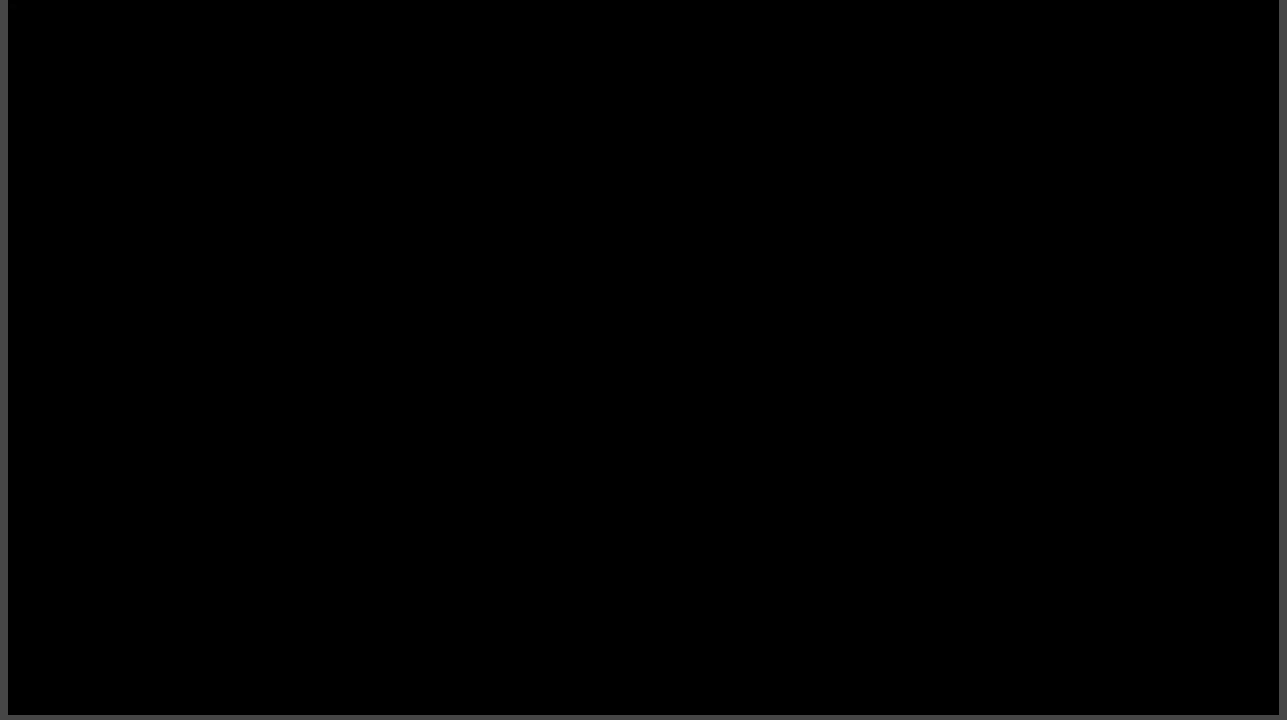
- Fully embedded in ANSYS **Mechanical** (parametric)
- Benefits of **underlying geometry** (or aux geo with dead meshes)
- …**WB** Meshing

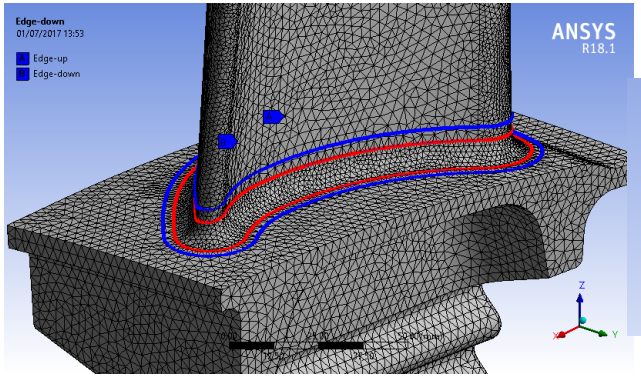


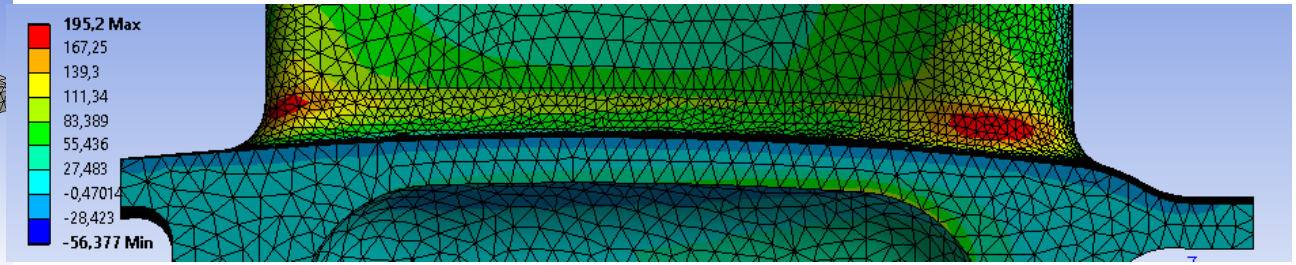
RBF Morph ACT Extension

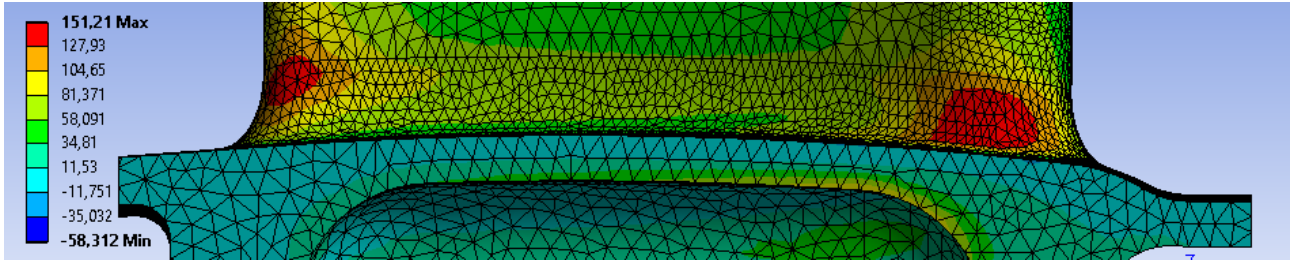
Released in 2015. Available also on the ANSYS App Store.

https://youtu.be/TUOJGAG7Wtk

Blade fillet stress reduction



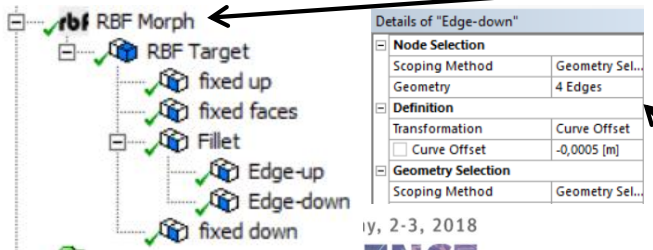


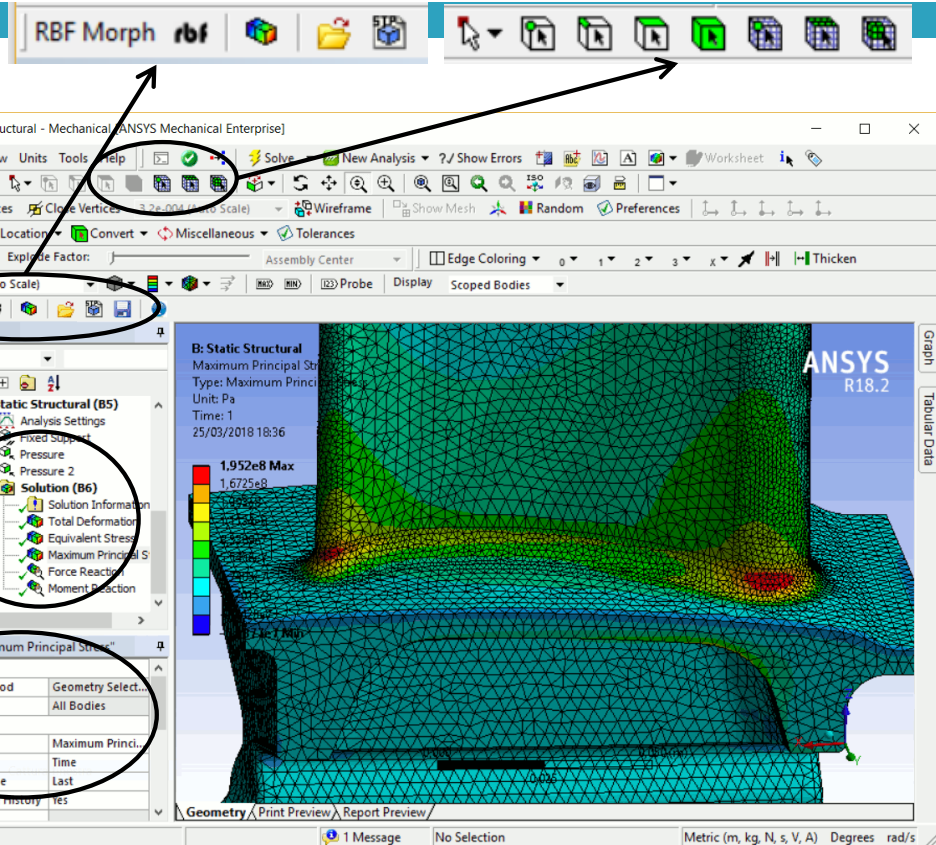


- Two parameters allow to get a 22.5% stress **reduction**

ACT Extension for Mechanical

- Deeply integrated in ANSYS Mechanical: same **look & feel,** same interaction logic, **same parameters!**
- 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 library** (OpenMP and CUDA powered)
- Child **hierarchical** logic for complex morphing (two steps, three steps, …, n steps setups)





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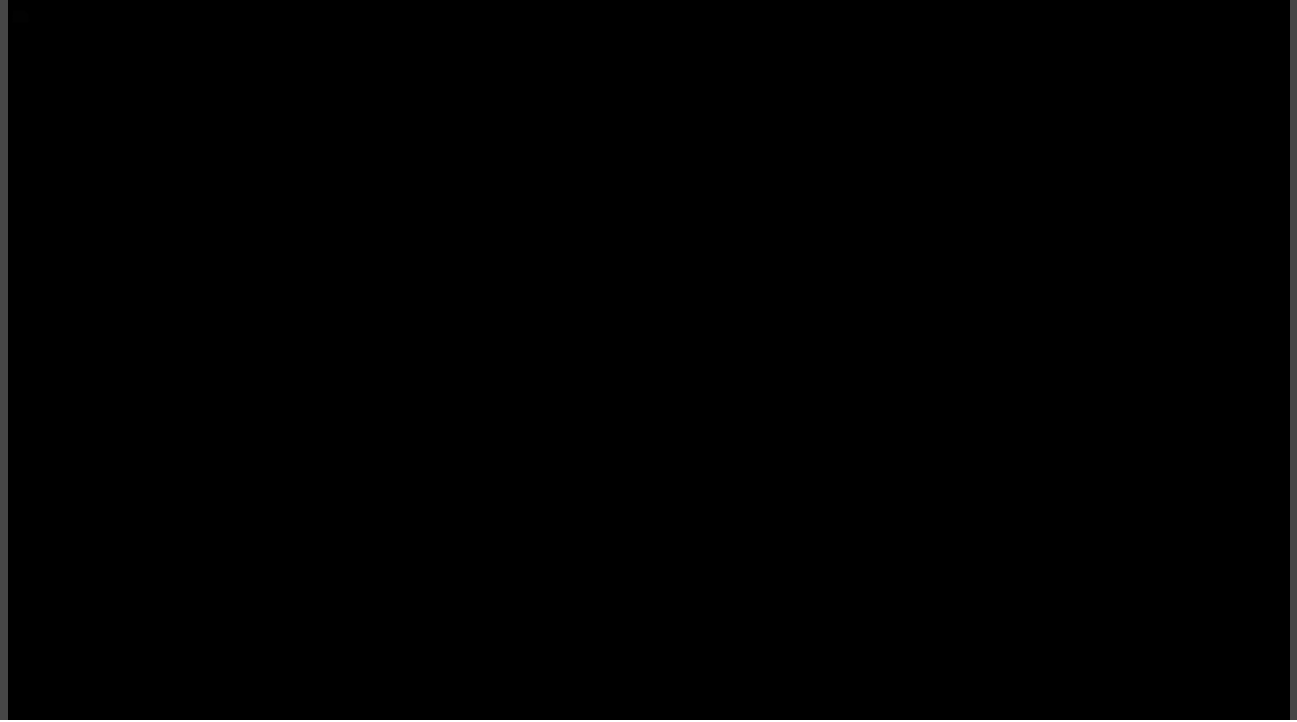
BGM SCULPTING APPROACH

ACT Extension based workflow



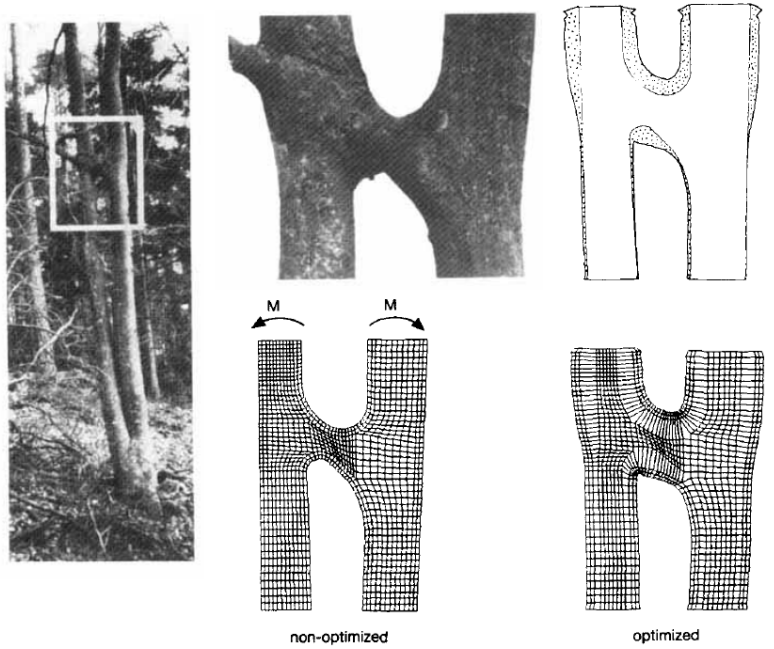
Stress reduction at a circular hole

The circular shape is transformed onto a rectangular filleted one

https://youtu.be/HShUgsK4Avk

BGM Background

- **Biological** structures growth is driven by local level of stress
- Bones and trees' trunks are able to **adapt the shape** to mitigate the stress level due to applied loads
- The process is driven at surface. Material can be removed or added according to the **stress** level
- Introduced by Mattheck in 1990



BGM Background

- The idea of BGM is that the local growth can be expressed by a linear law provided a given **threshold**

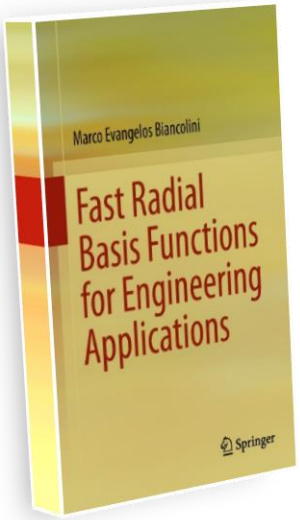
$$\dot{\varepsilon_v} = k\left(\sigma_{Mises} - \sigma_{ref}\right)$$

- The concept has been refined by **Waldman** proposing a multi peaks approach

$$d_i^j = \left(\frac{\sigma_i^j - \sigma_{th}^j}{\sigma_{th}^j}\right) s \cdot c, \sigma_{th}^j = \max\left(\sigma_i^j\right) if\ \sigma_i^j > 0\ or\ \sigma_{th}^j = \min\left(\sigma_i^j\right) if \sigma_i^j < 0$$

- Updating of the structural mesh is a **challenge** that can be tackled by advanced RBF mesh morphing

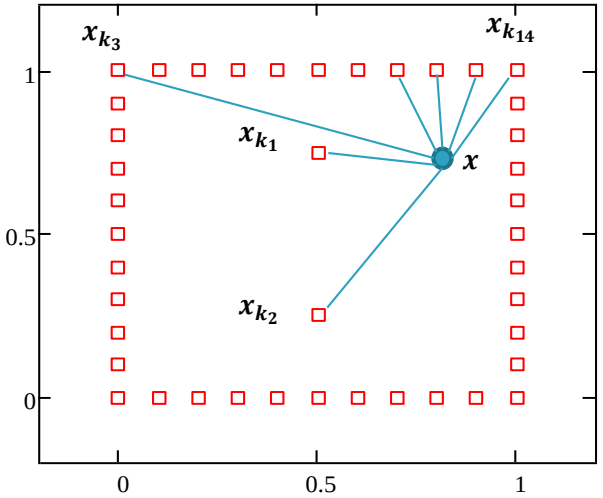
RBF Background



- RBFs are a mathematical tool capable to **interpolate** in a generic point in the space a function **known** in a discrete set of points (**source points**).
- The interpolating function is composed by a **radial basis** and by a **polynomial**.

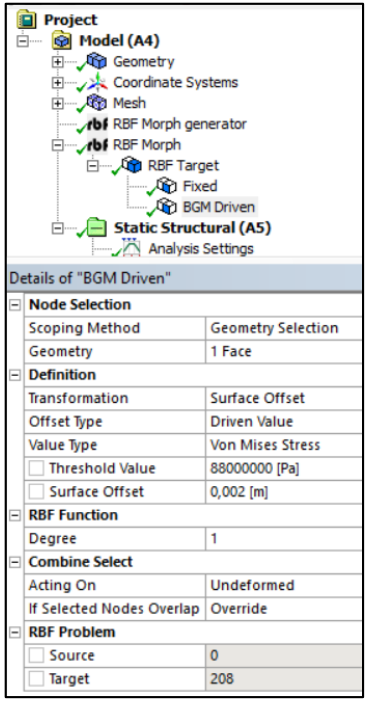
radial basis polynomial

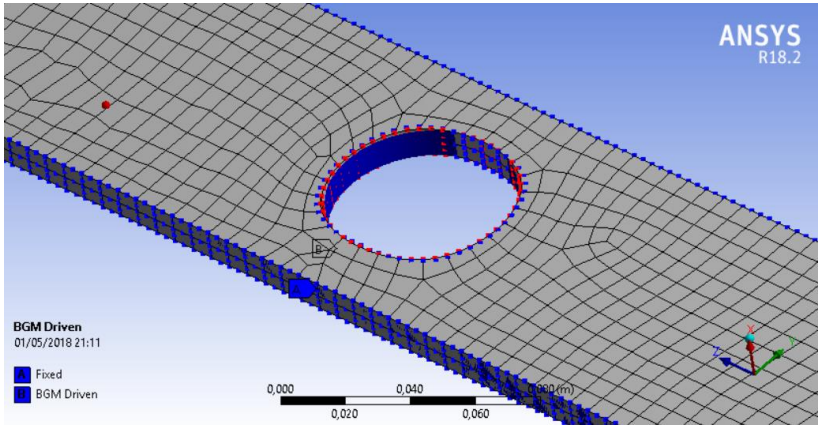
$$s(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i \varphi\left(\left\|\boldsymbol{x} - \boldsymbol{x}_{\boldsymbol{k}_i}\right\|\right) + h(\boldsymbol{x})$$



BGM implementation

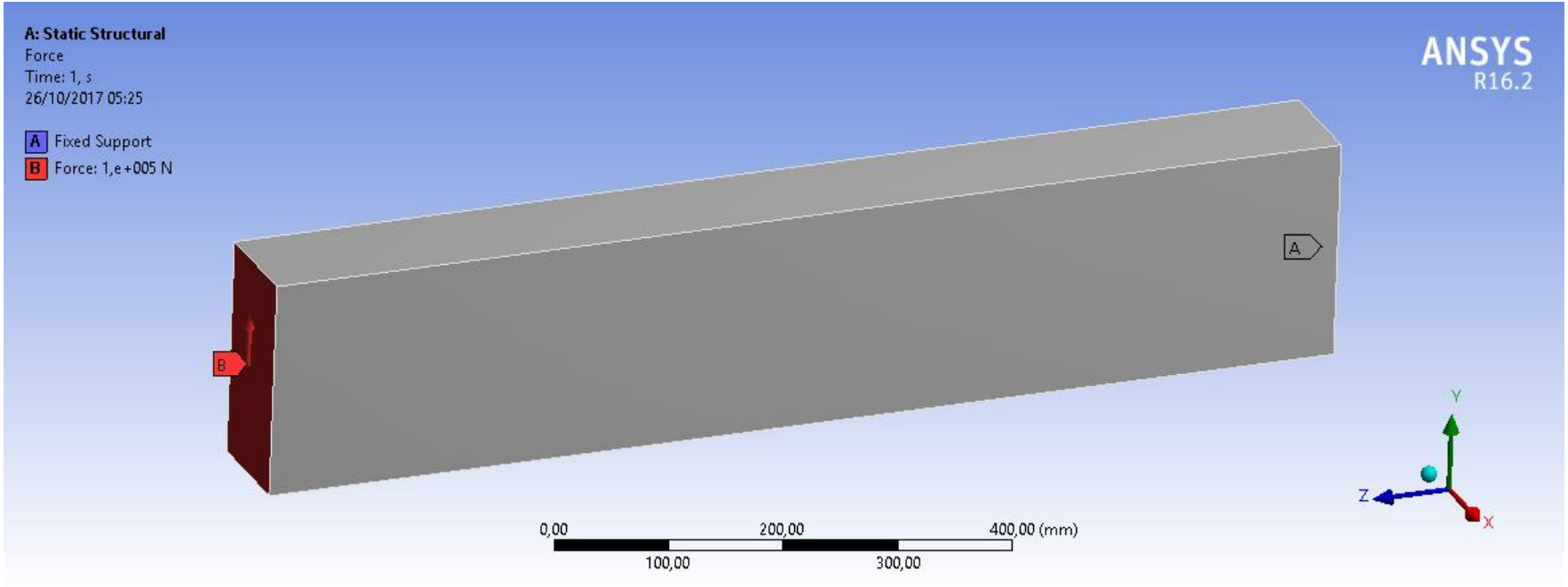
- The offset operator of RBF Morph can be driven by the **Driven Value** option
- Many set of surfaces can be controlled with set wise rules for BGM **Threshold** and **intensity** (i.e. max **Offset**)
- The "**BGM mode**" allows to suppress automatic Generate and morphing happens after solution
- DPs are populated with the BGM growth **sequence**



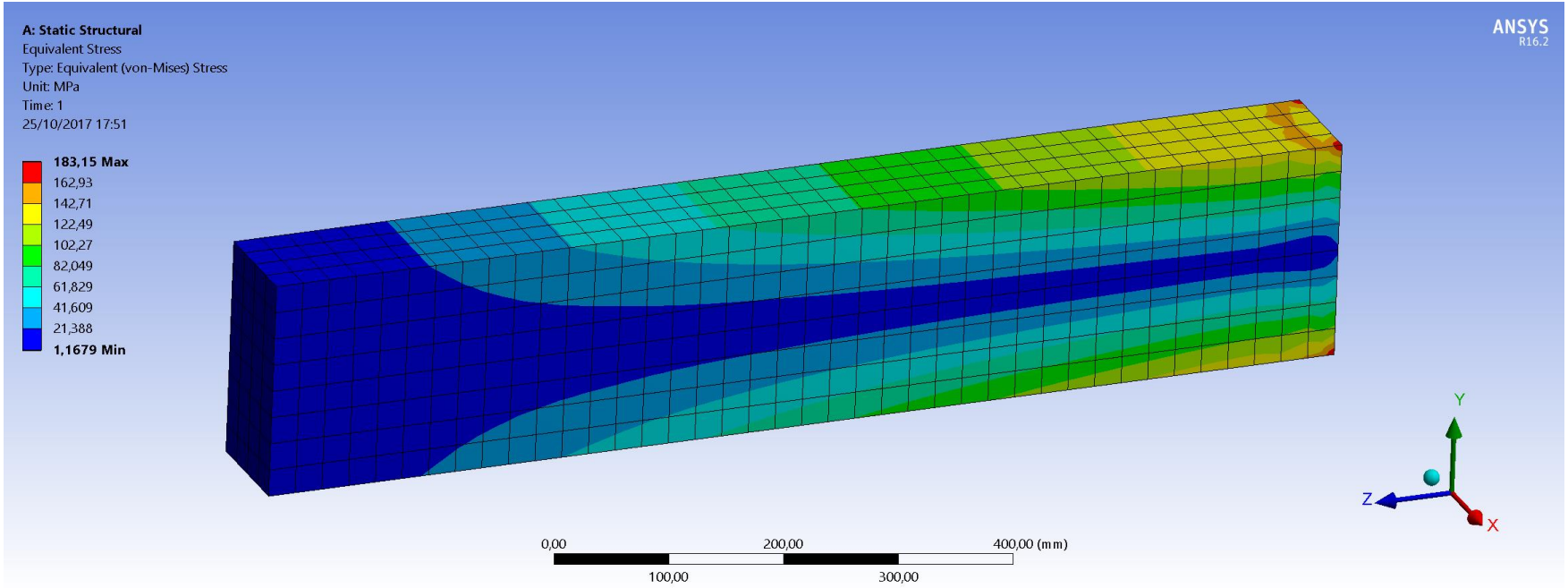


Definition	
Transformation	Surface Offset
Offset Type	Driven Value
Value Type	Von Mises Stress
Threshold Value	88000000 [Pa]
Surface Offset	0,002 [m]

Examples: cantilever beam



Examples: cantilever beam



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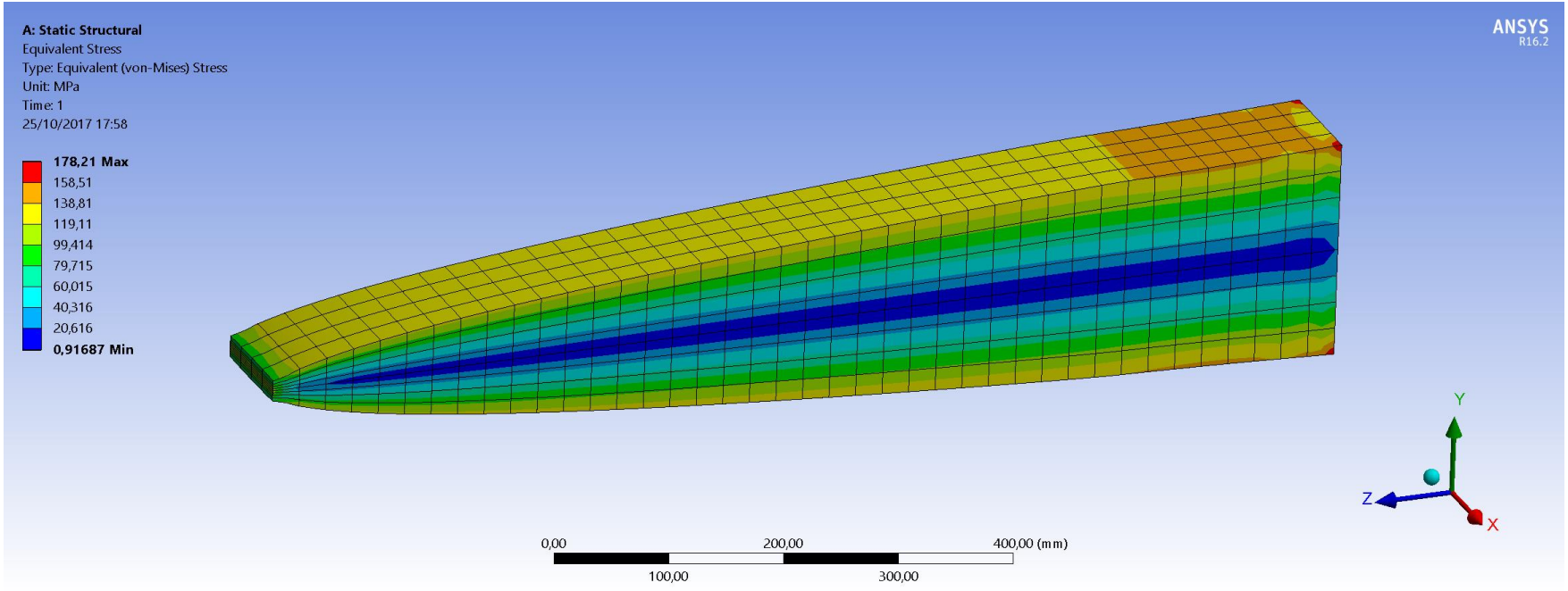
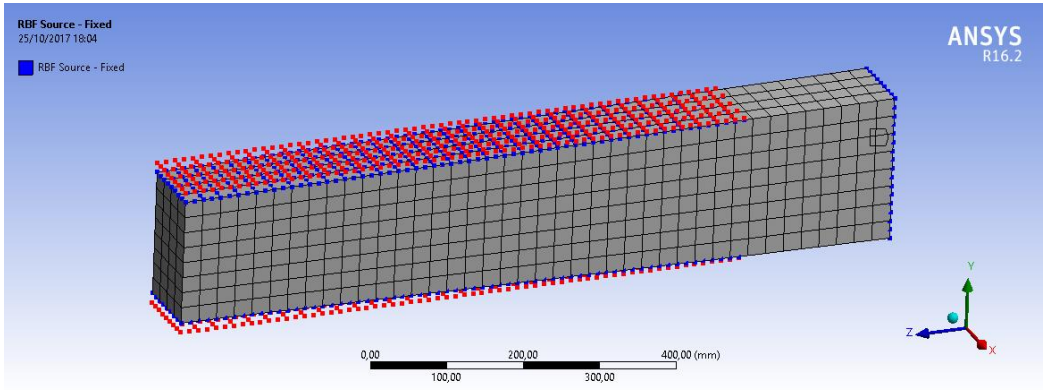
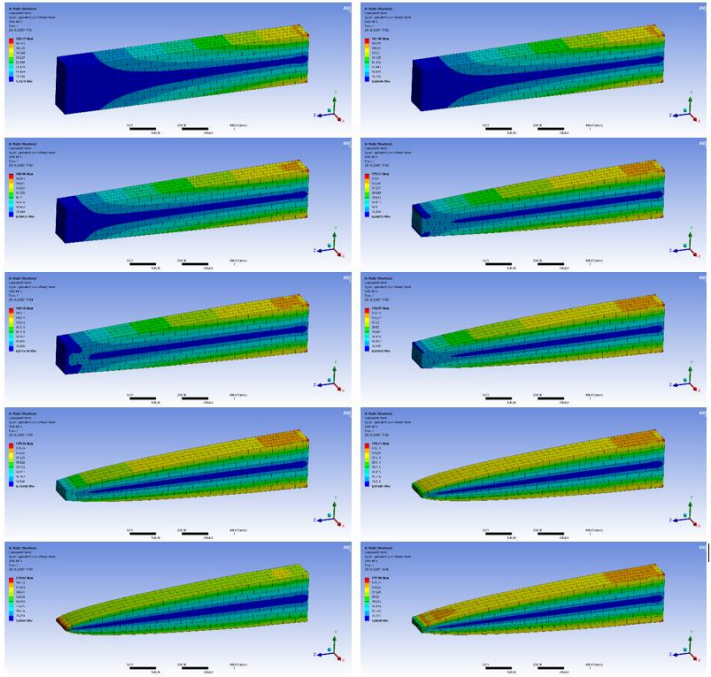


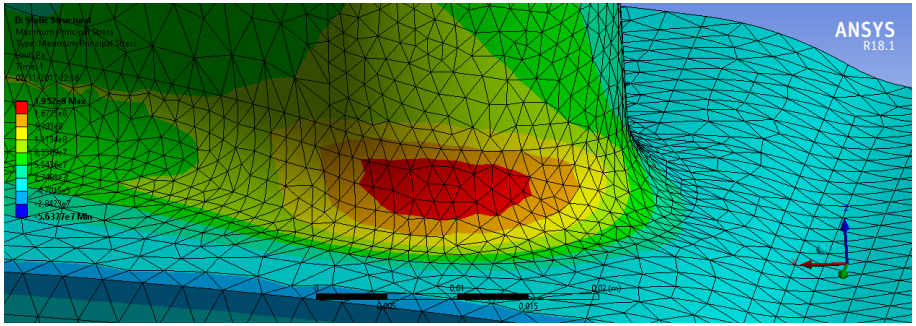
Examples: cantilever beam

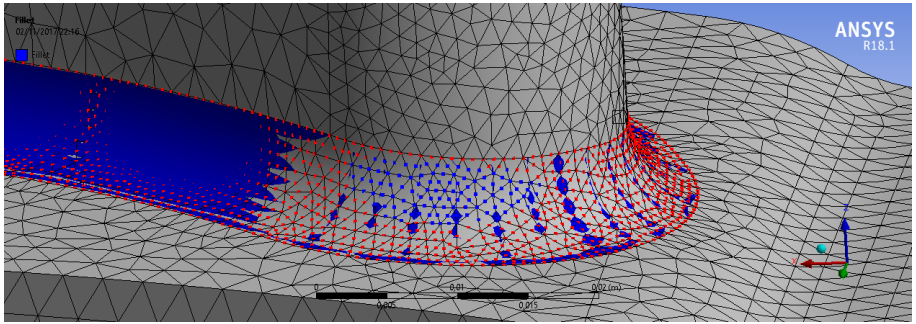


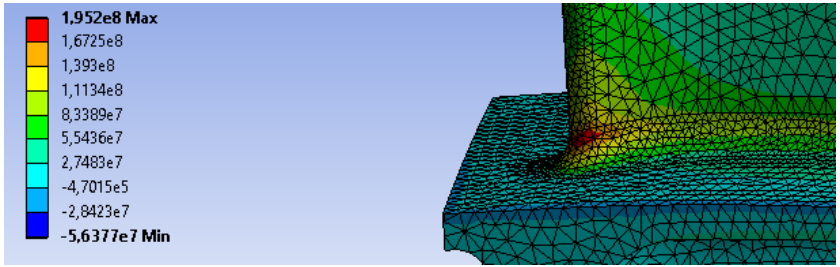


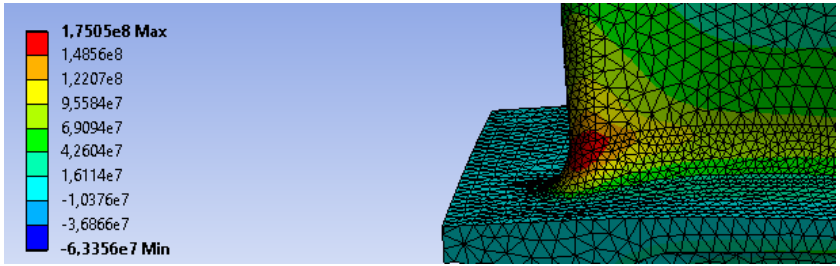
- Stress sculpted
- Parabolic shape and uniform stress
- 33% mass reduction

Examples: turbine blade









- 10% stress reduction

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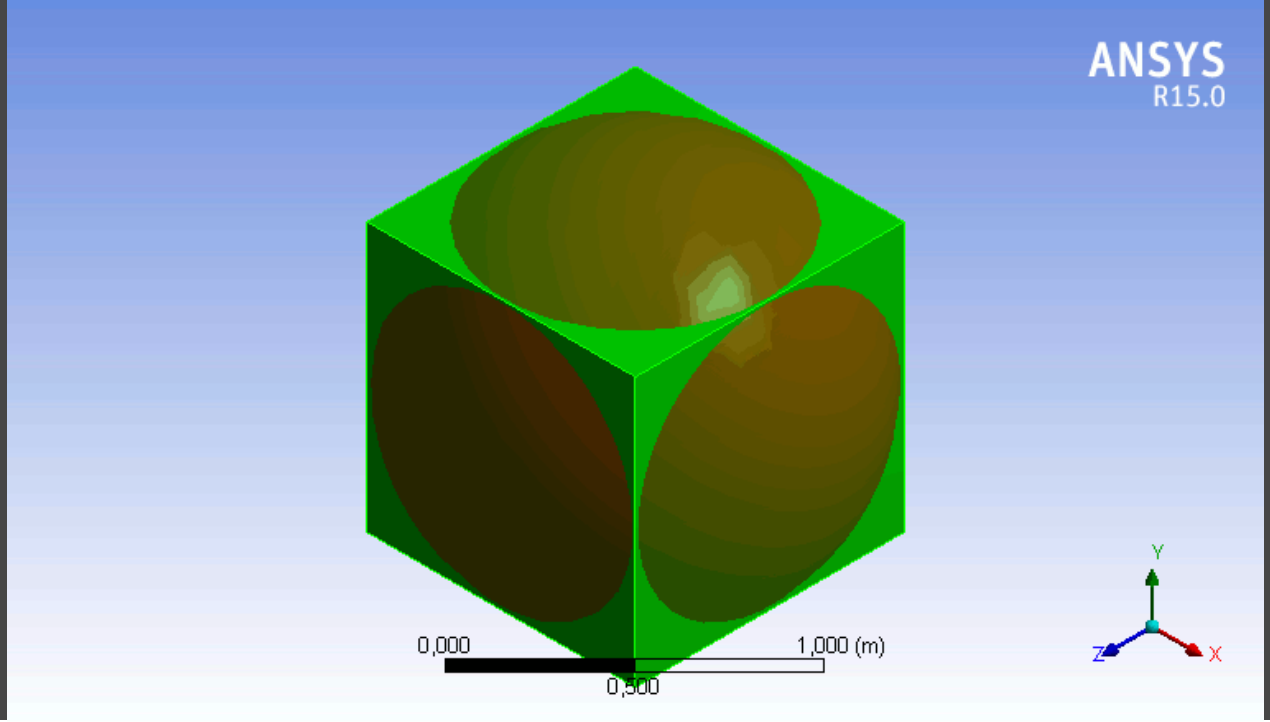
WHAT MORE?

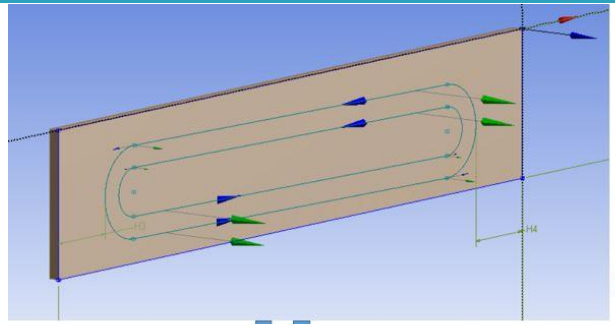
ACT Extension based workflows

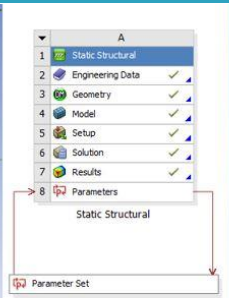


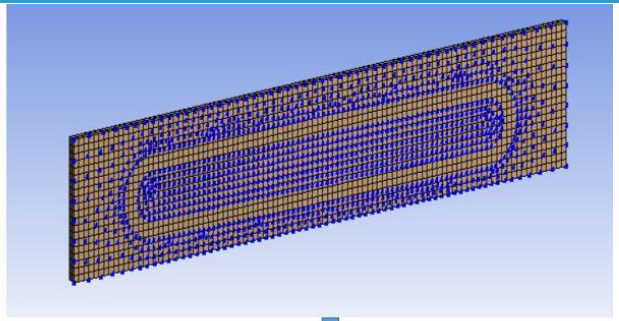
Morphing using geometrical targets

Squaring of the circle? Sphering of the Cube!

Parametric clew



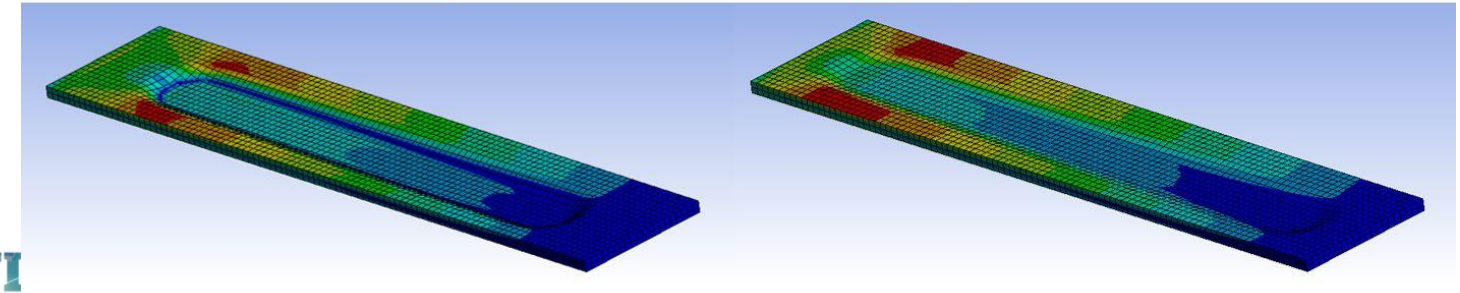




Clew location controlled by **DesignModeler**

Name	P1 - XYPlane.H3	P2 - XYPlane.H4	P5 - extrude slot Delta z	P4 - Equivalent Stress Maximum
Units	m	m	m	Pa
DP 0 (Current)	1	1	0	7,169E+07
DP 1	1	1	-0,12	1,132E+08
DP 2	0,5	0,5	-0,12	1,1825E+08
DP 4	0,5	0,5	-0,06	1,0043E+08

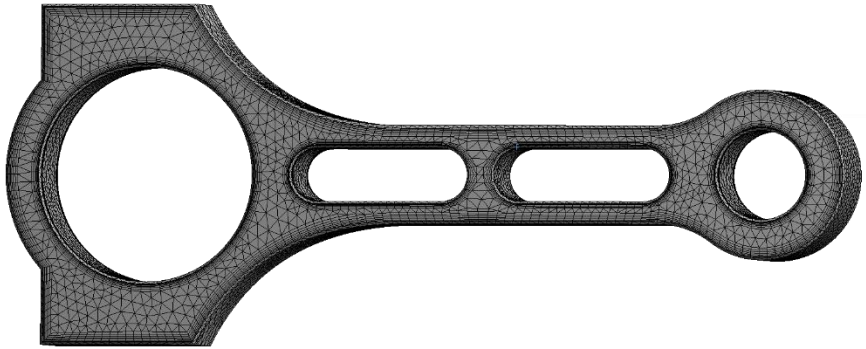
Clew depth controlled by **RBF Morph**



Connecting rod optimization

Original design 358.7g

Optimal design 334.4g



- Four parameters allow to get a 7% mass reduction

Ductile iron castings

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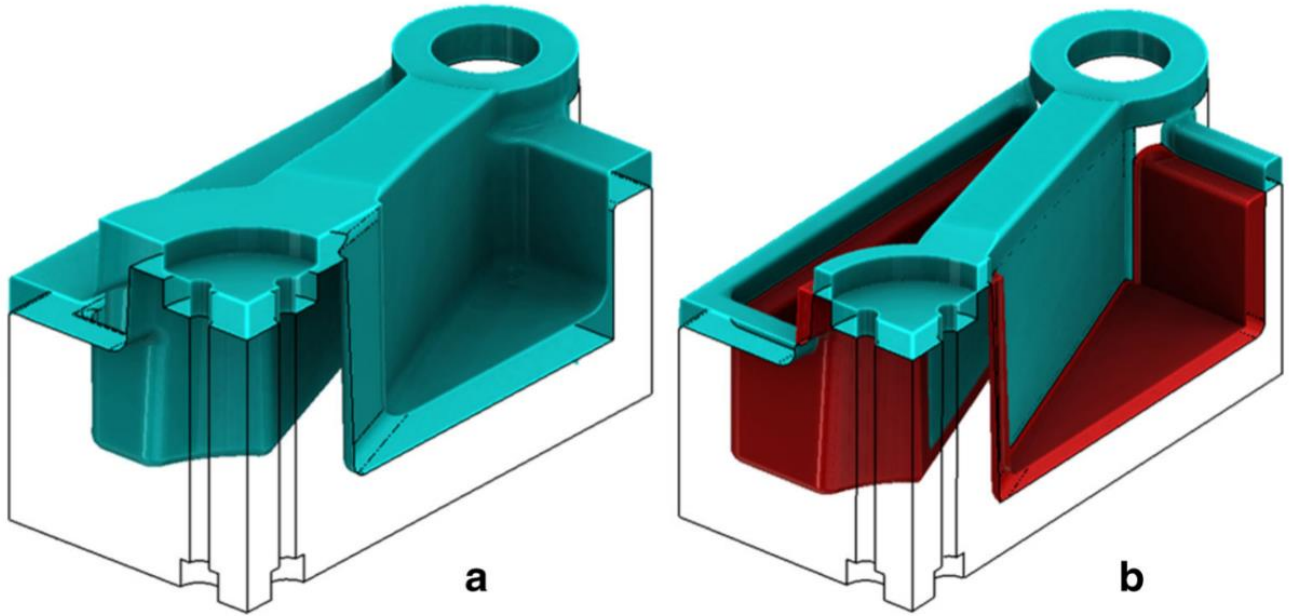

https://doi.org/10.1007/s00158-018-1929-z

CAD driven mesh morphing

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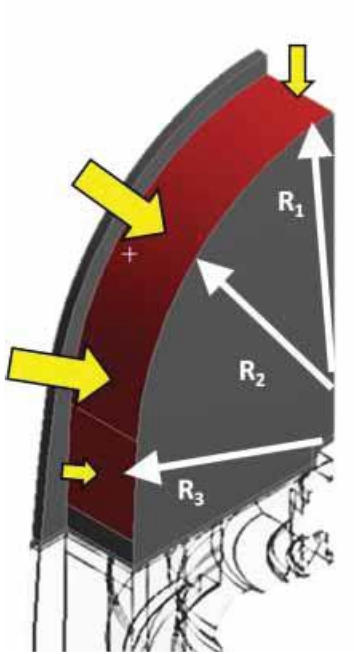
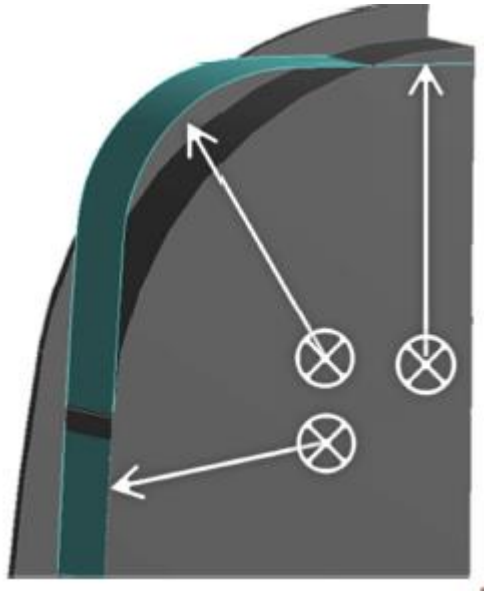
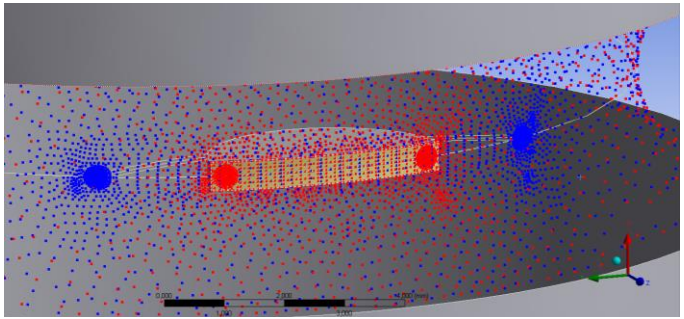
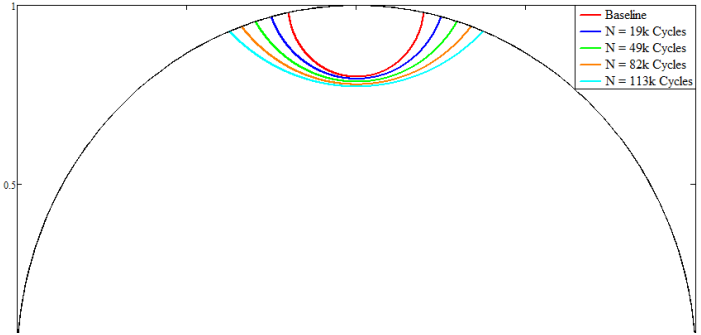




Fracture propagation (RBF4CRACKS)





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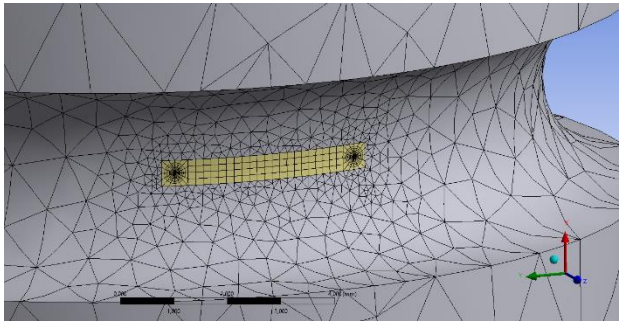

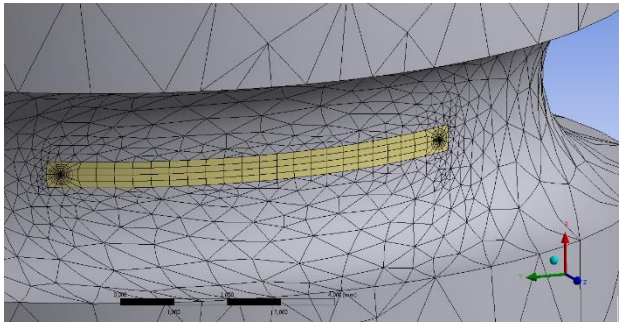

Conclusions

- RBF Morph is an advanced **mesh morphing** technology based on Radial Basis Functions
- A **shape parametric** mesh is obtained. Parameters can be steered using standard optimization tools. On the fly computed **shape evolution can be pursued as well!**
- Strong integration in **ANSYS products**: an Add On for Fluent & ACT Extension for Mechanical (and more…)
- BGM capabilities of RBF Morph ACT Extension are today demonstrated
- Many advanced industrial applications can be faced. Visit our web site www.rbf-morph.com to learn more.

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Many thanks for your kind attention!

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