

Advanced structural shape optimization with Ansys RBF Morph

Emanuele Di Meo
CAE Senior Engineer



Table of Contents

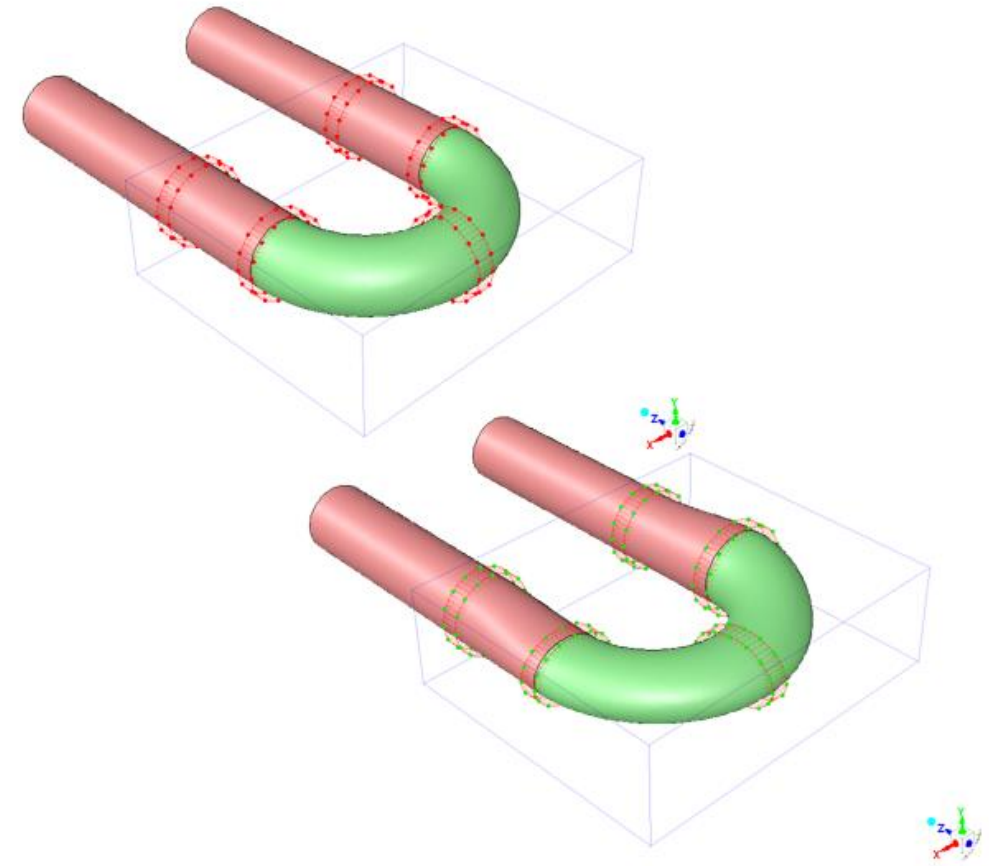
- An overview about Ansys RBF Morph technology
- Main uses of Ansys RBF Morph
- Ansys RBF Morph Fluids
- Ansys RBF Morph Structures
- Advanced Structural Shape Optimization
- Case Study: Flexible PCB
- Conclusions

An overview about Ansys RBF Morph technology



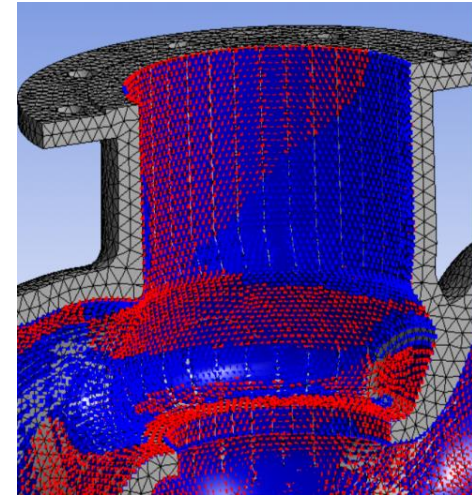
Shape parameterization strategy

- Geometric parameterization by **mesh morphing**
- The principle is to take the control on a set of point and to transfer the deformation to the whole mesh
- A **new shape** of the CAE model **ready to run**
 - for structural analysis in the FEA solver
 - for flow analysis in the CFD solver



Radial Basis Functions mesh Morphing

- We offer **Radial Basis Functions** (RBF) to drive mesh morphing (smoothing) from a list of source points and their displacements.
 - Surface shape changes
 - Volume mesh smoothing.
- RBF are recognized to be one of the **best mathematical tool** for mesh morphing.



$$\begin{cases} s_x(\mathbf{x}) = \sum_{i=1}^N \gamma_i^x \varphi(\|\mathbf{x} - \mathbf{x}_{s_i}\|) + \beta_1^x + \beta_2^x x + \beta_3^x y + \beta_4^x z \\ s_y(\mathbf{x}) = \sum_{i=1}^N \gamma_i^y \varphi(\|\mathbf{x} - \mathbf{x}_{s_i}\|) + \beta_1^y + \beta_2^y x + \beta_3^y y + \beta_4^y z \\ s_z(\mathbf{x}) = \sum_{i=1}^N \gamma_i^z \varphi(\|\mathbf{x} - \mathbf{x}_{s_i}\|) + \beta_1^z + \beta_2^z x + \beta_3^z y + \beta_4^z z \end{cases}$$

Radial Basis Functions mesh Morphing



www.rbf-morph.com

- Main advantages
 - No re-meshing
 - Can handle any kind of mesh
 - Can be integrated in the CAE solver (FEM/CFD/FSI)
 - Highly parallelizable
 - Robust process
 - The same mesh topology is preserved (adjoint/ROM)
 - CAD morphing (iso-brep)

Radial Basis Functions mesh Morphing

- An RBF mesh morphing solution fully embedded in **Ansys**
 - **Ansys RBF Morph Fluids** – an Add On for Fluent
 - **Ansys RBF Morph Structures** – an ACT App for Mechanical
- Full integration with **optiSLang** and **Twin Builder**
- Support for **LS-DYNA** and **APDL**



Add-On Packages

Ansys RBF Morph



↓ Fluids

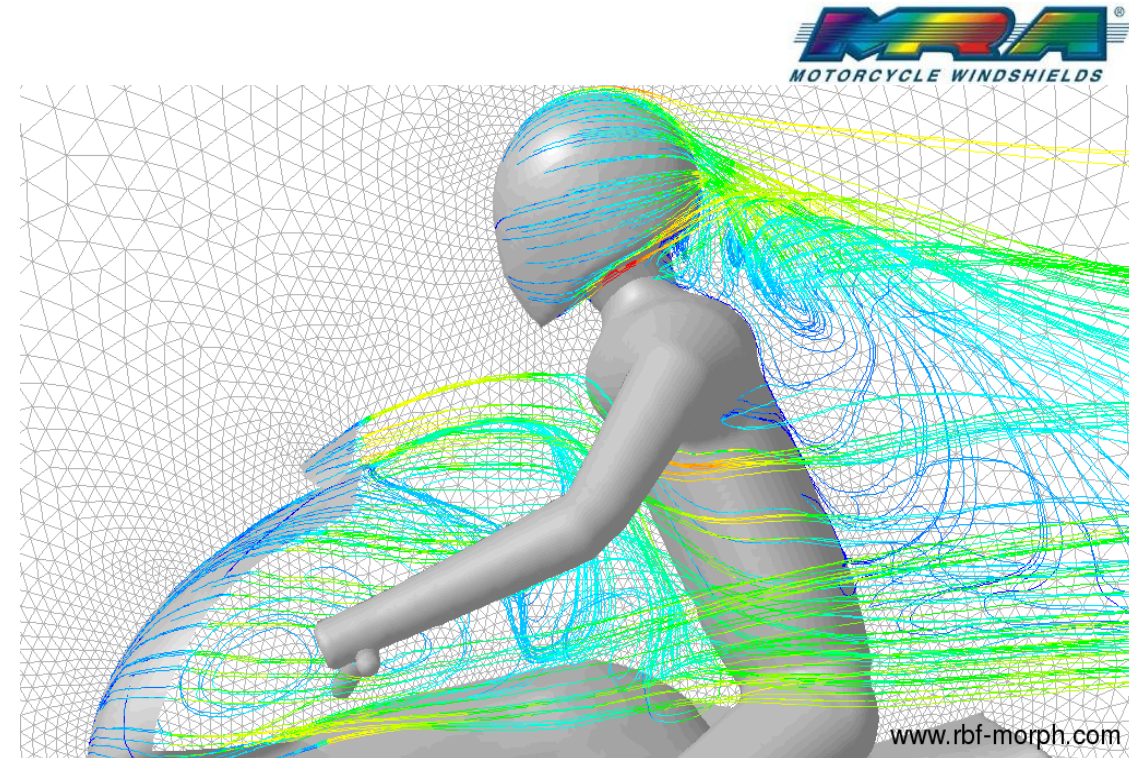
↓ Structures



www.rbf-morph.com

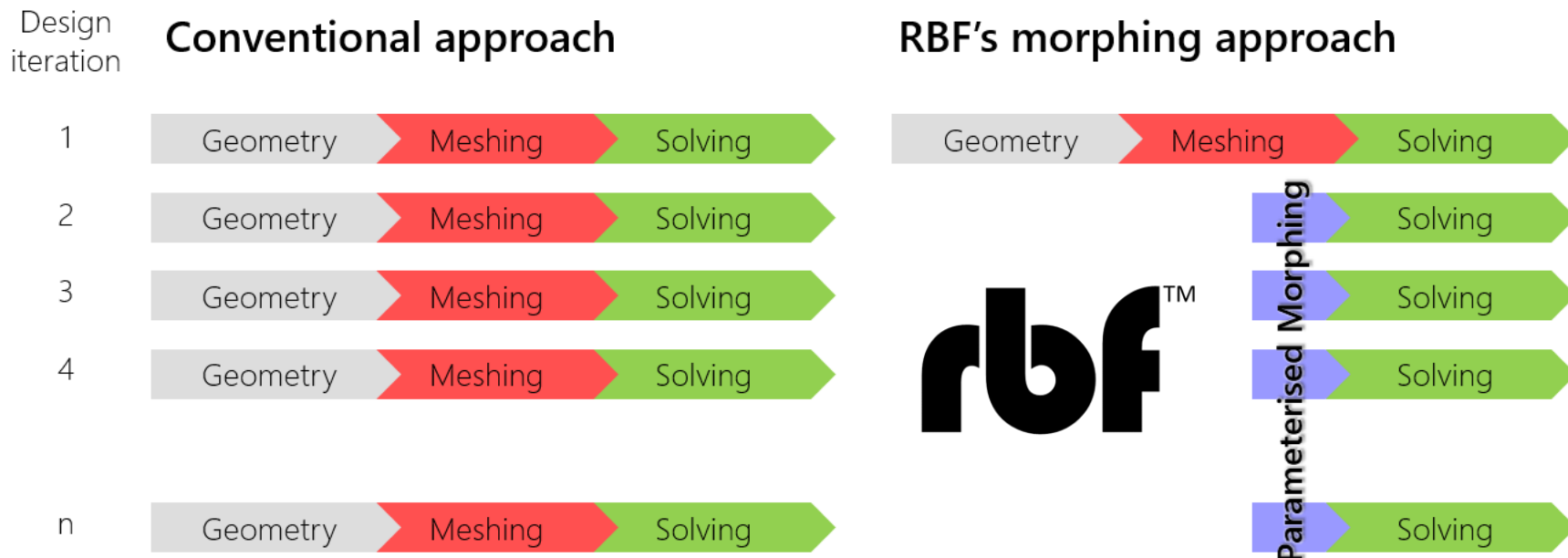
We make CAE models parametric

- RBF Morph makes the CAE model **parametric** with respect to the shape
- Works for any size of the mesh. Shape parameters are driven by **optiSLang**
- Shape parameters can be used to generate snapshots for ROM and Digital Twins – **Twin Builder**



We make CAE models parametric

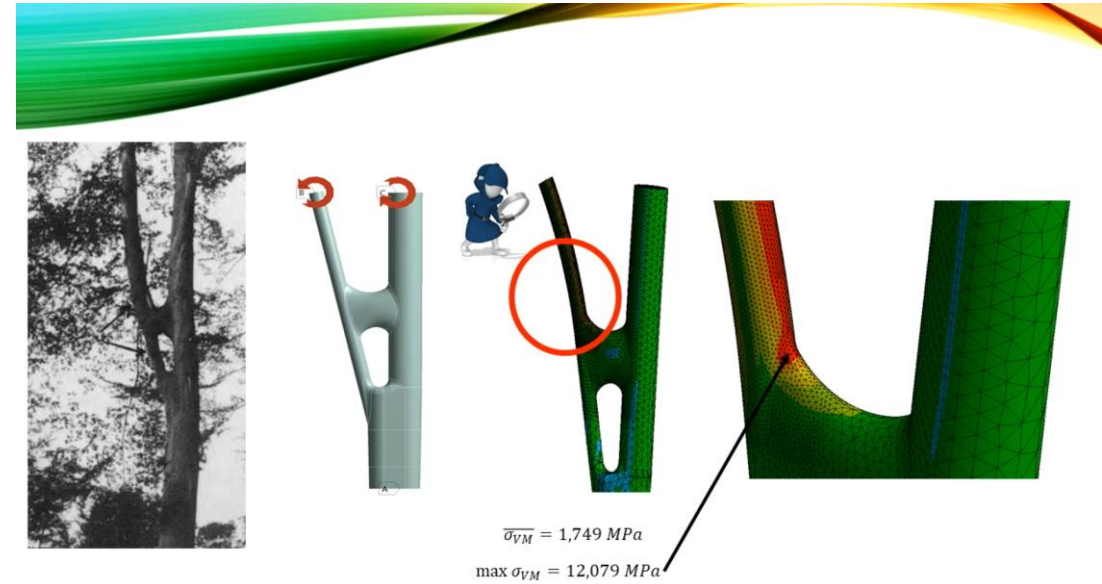
- Morphing is a **key enabler** for optimization and Digital Twins
- The turnaround time of the optimization is usually **reduced by a factor five** (weeks becomes days)



Parameter-free shape optimization

<https://youtu.be/myt2hndckso>

- The new shape can be guided by the CAE solution itself (organic shapes)
 - Coupled with the Fluent **adjoint** solver
 - **BGM** (Biological Growth Method) optimizer in **Mechanical**
- Free form freedom but under control
 - Packaging constraints
 - Symmetry constraints
 - Thickness constraints



Porziani, Stefano, and Marco E. Biancolini. "Bio-inspired Optimization Based on Biological Growth Method and Mesh Morphing Surface Sculpting." Bioinspired Optimization Methods and Their Applications: 9th International Conference, BIOMA 2020, Brussels, Belgium, November 19–20, 2020, Proceedings 9. Springer International Publishing, 2020. https://doi.org/10.1007/978-3-030-63710-1_11

Main uses of Ansys RBF Morph



Main uses of RBF Morph

Usage	Mechanical	Fluent	optiSLang	Twin Builder
Automated and quick variable design space exploration.	✓	✓		
Optimization (Single physics or multi-physics). Shape optimization for stress reduction, mass reduction, fluid-structure interaction	✓	✓	✓	
Digital twin development (static ROMs)	✓	✓	✓	✓
Lifing applications Simulate defects such as corrosion pits, spalling of material, erosion, chips, etc.	✓	✓		
Examine the effects of non-conformance and manufacturing variability	✓	✓		
Robust Design	✓	✓	✓	

RBF Morph usage at Nissan

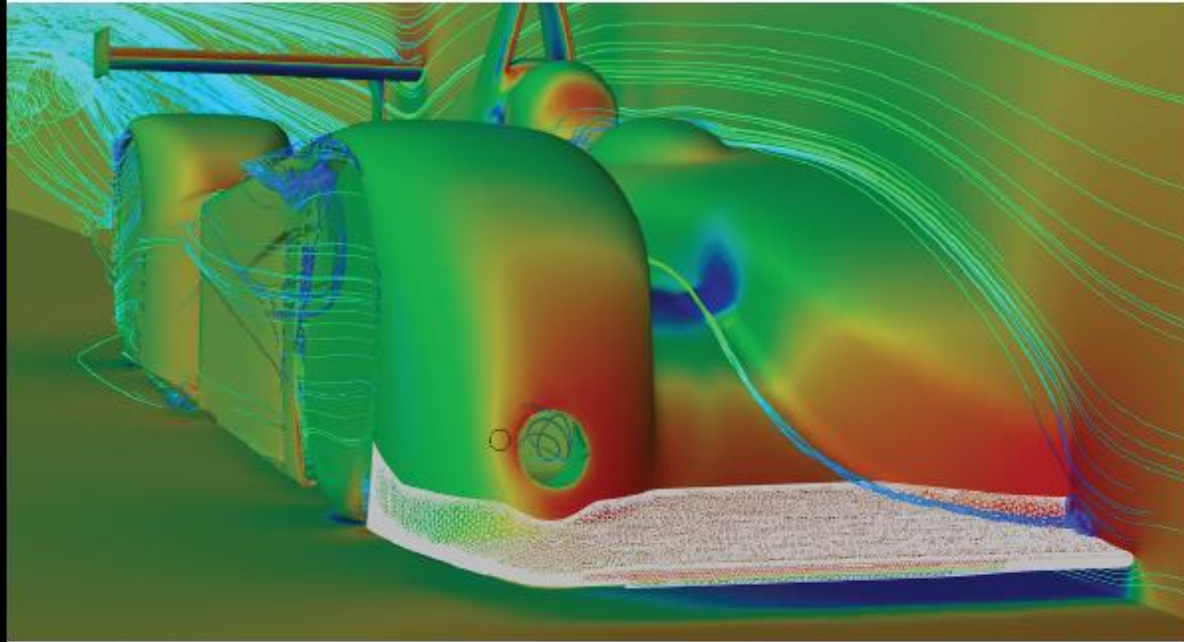


"We worked with RBF Morph to perform the structural optimization of the front chassis and suspension lower arms of a Nissan Micra. Our objective was an increase of driving comfort, achieved by controlling the lateral stiffness while acting on thickness and shape variation of subframe elements. RBF mesh morphing tools were essential to conduct different structural tests and finally achieve optimization".

CLAUDIO PONZO
Chassis Manager
Nissan Motor Corporation

<https://www.rbf-morph.com/wp-content/uploads/2022/12/FEA-Shape-Optimization-of-a-Nissan-Micra-Front-Subframe.pdf>

RBF Morph usage at Dallara



"FSI and multiphysics are key enablers for modern racing car development, where geometries are very complex and high accurate solutions are required. RBF Morph proved to be the driving tool for the FSI two-way coupled approach. It successfully faced our Morotsport challenge, matching the FEM model displacement with the aero loads mapping in a simplified model of a Dallara Le Mans prototype car".

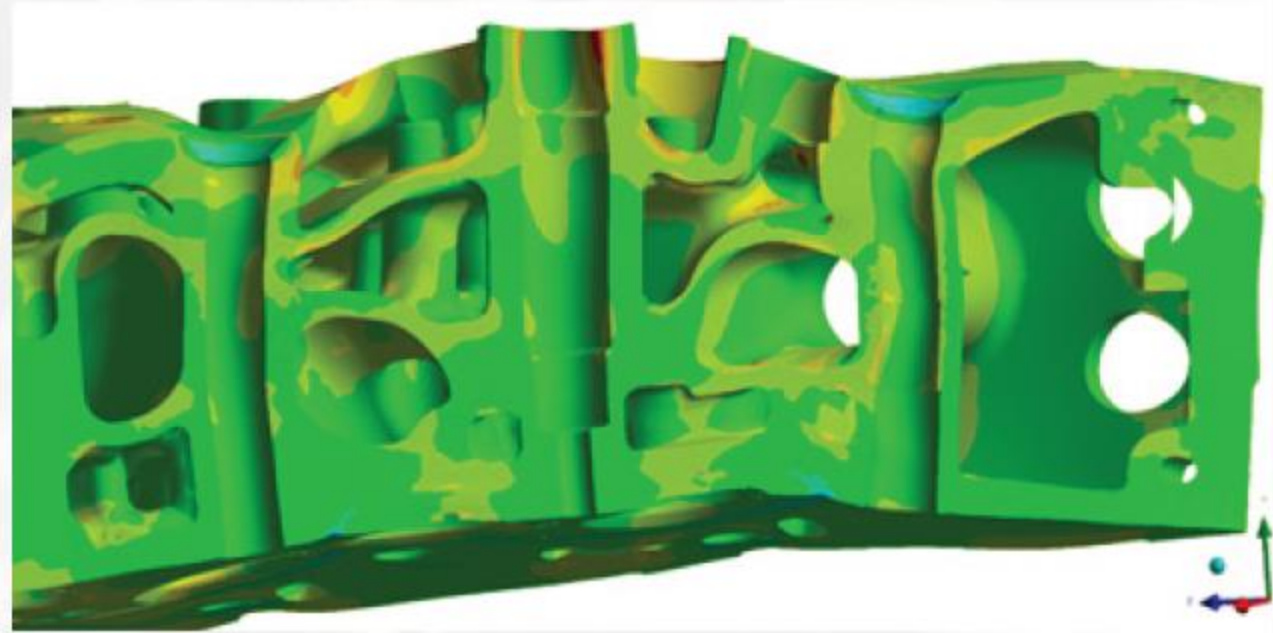
ELISA SERIOLI
Head of CFD Methodology
Dallara

<https://www.rbf-morph.com/wp-content/uploads/2022/12/Two-Way-Coupled-Aeroelastic-Analysis-of-Dallara.pdf>

RBF Morph usage at Cummins

"Static structural FEA and fatigue analysis was carried on a combustion engine cylinder head assembly model. Design and analysis iterations, which are typically carried out manually since the complex casting topology makes geometry parameterisation nearly impossible, were simulated with the RBF Morph Biological Growth Method which allows for effective parameterisation of complex geometry at the mesh level. The outcome was excellent".

MARCEL SCHUBERT
Applied Mechanics Analytical, Technical Advisor
Cummins, Inc.

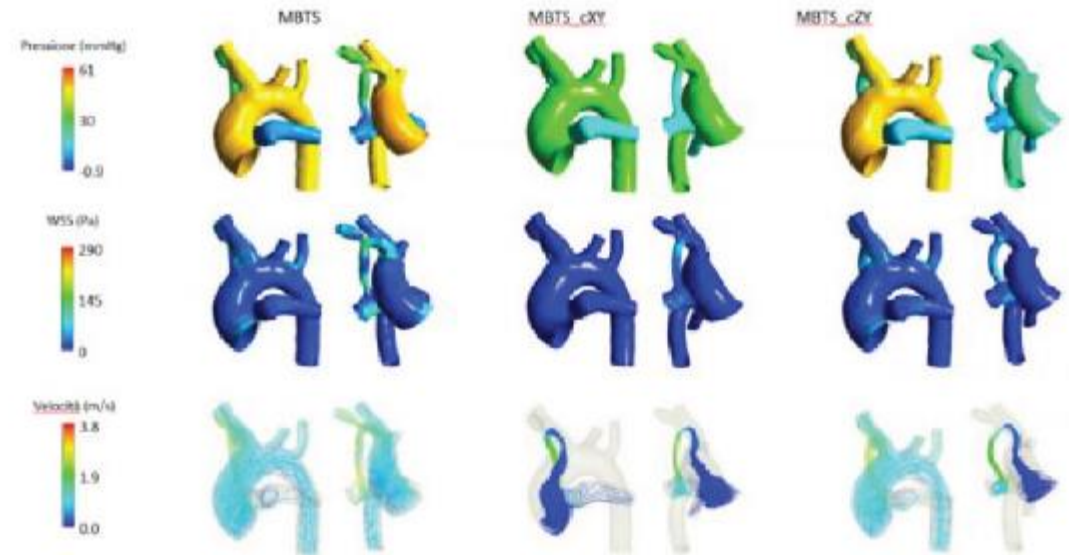


<https://www.rbf-morph.com/wp-content/uploads/2022/12/Cylinder-Head-FEA-Shape-Optimisation.pdf>

RBF Morph usage at RINA

"We worked with RBF Morph and other partners on the Copernicus project, whose aim was to provide a medical digital twin of the patient to support the surgery planning of Modified Blalock Taussing Shunt under critical conditions. RBF Morph Fluids was key to complete the Copernicus workflow, and it helped increase the know-how on the application of radial basis function mesh morphing in the medical sector."

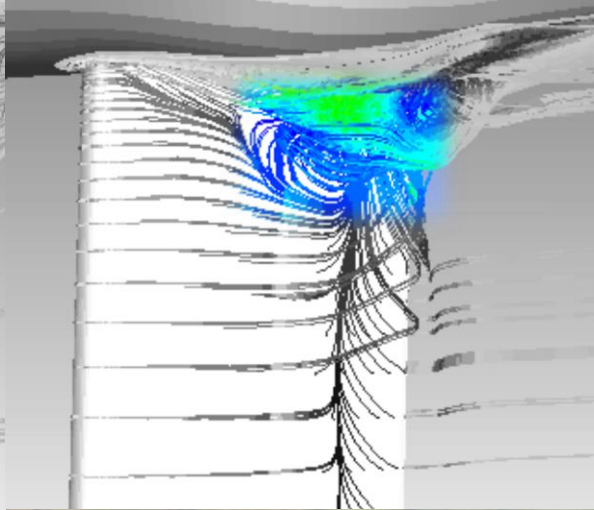
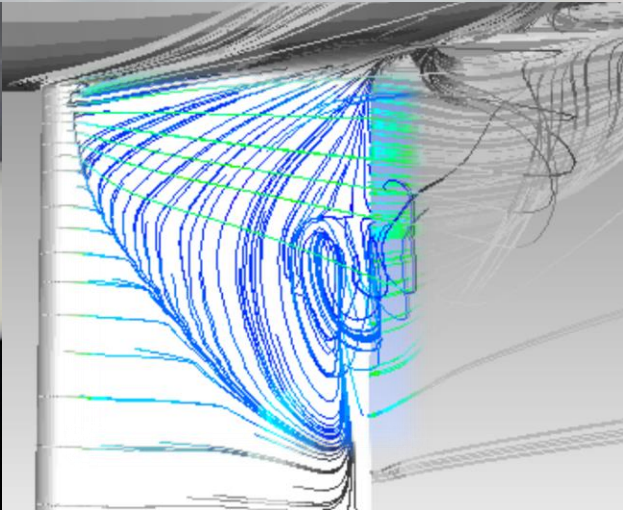
ALESSANDRO BOZZOLO
Industrial Design & CAE Manager
RINA



<https://www.rbf-morph.com/wp-content/uploads/2022/12/The-digital-twin-and-the-future-of-pediatric-surgery.pdf>

Quick Hands-on



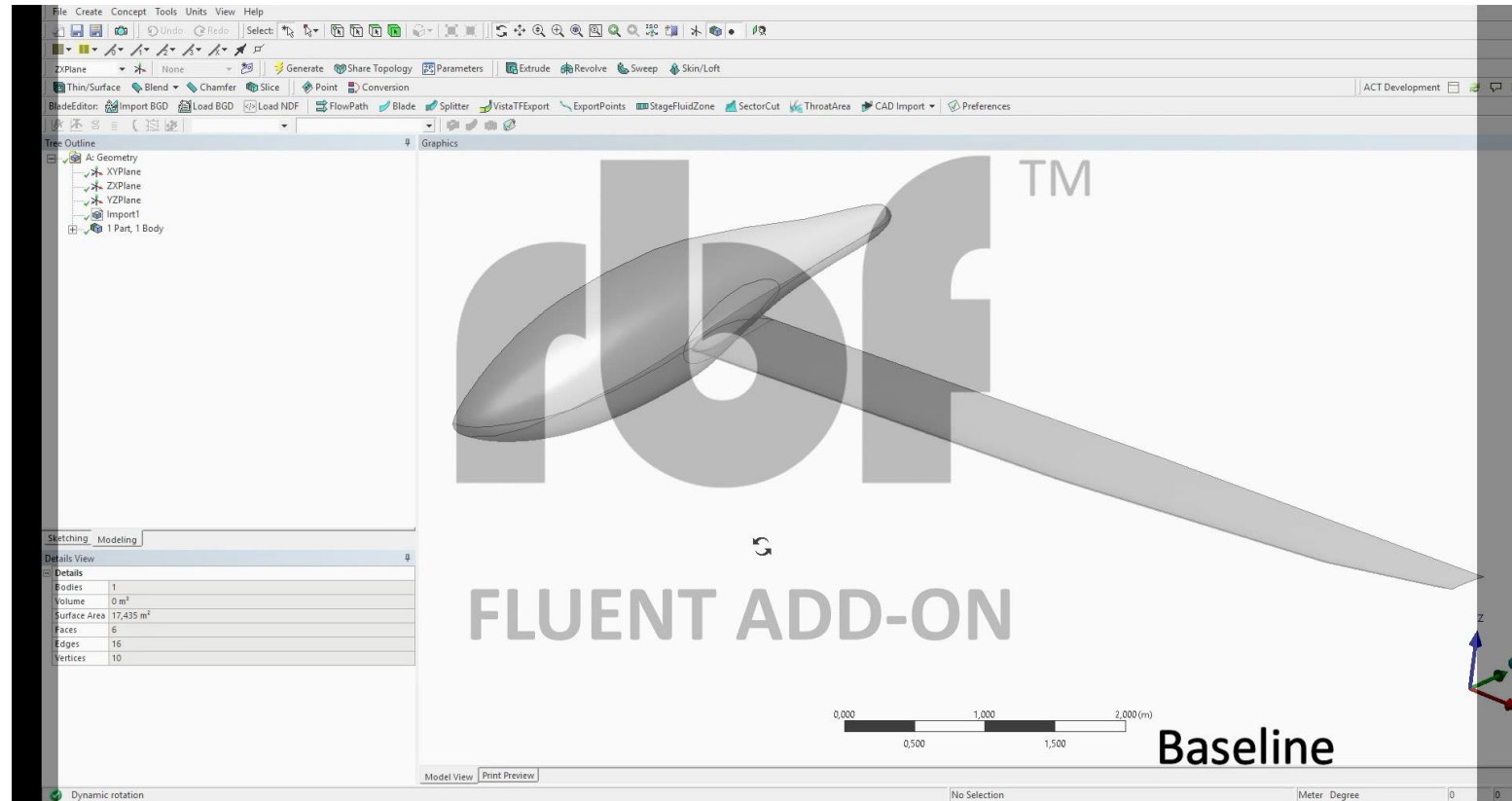


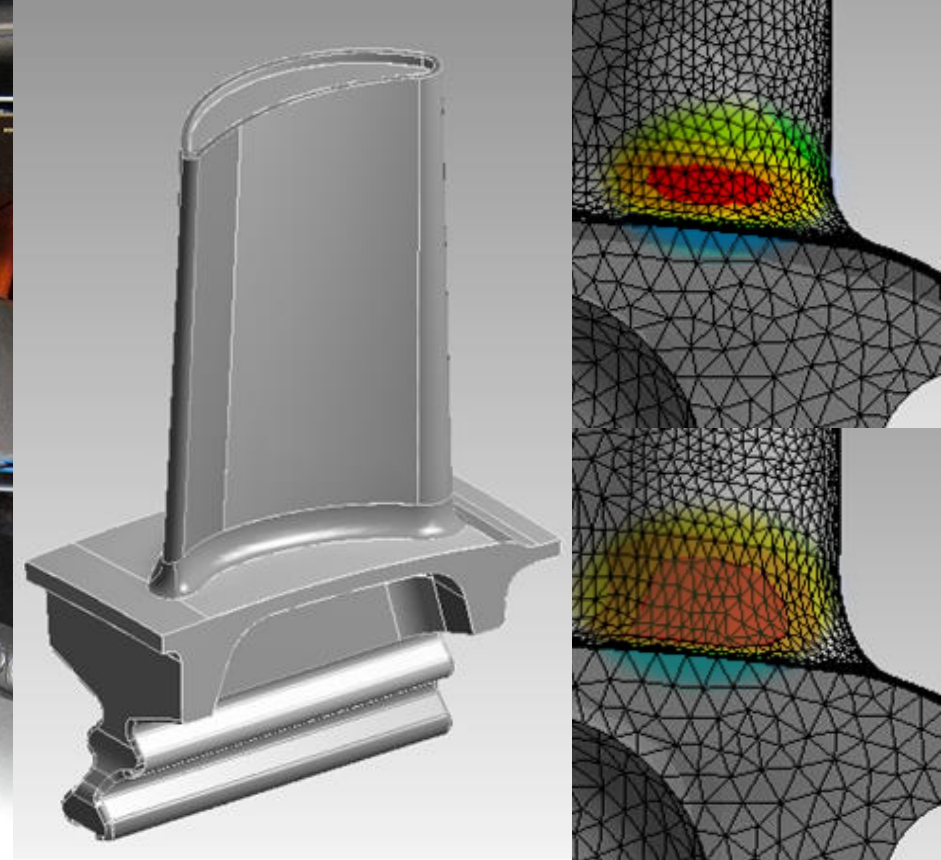
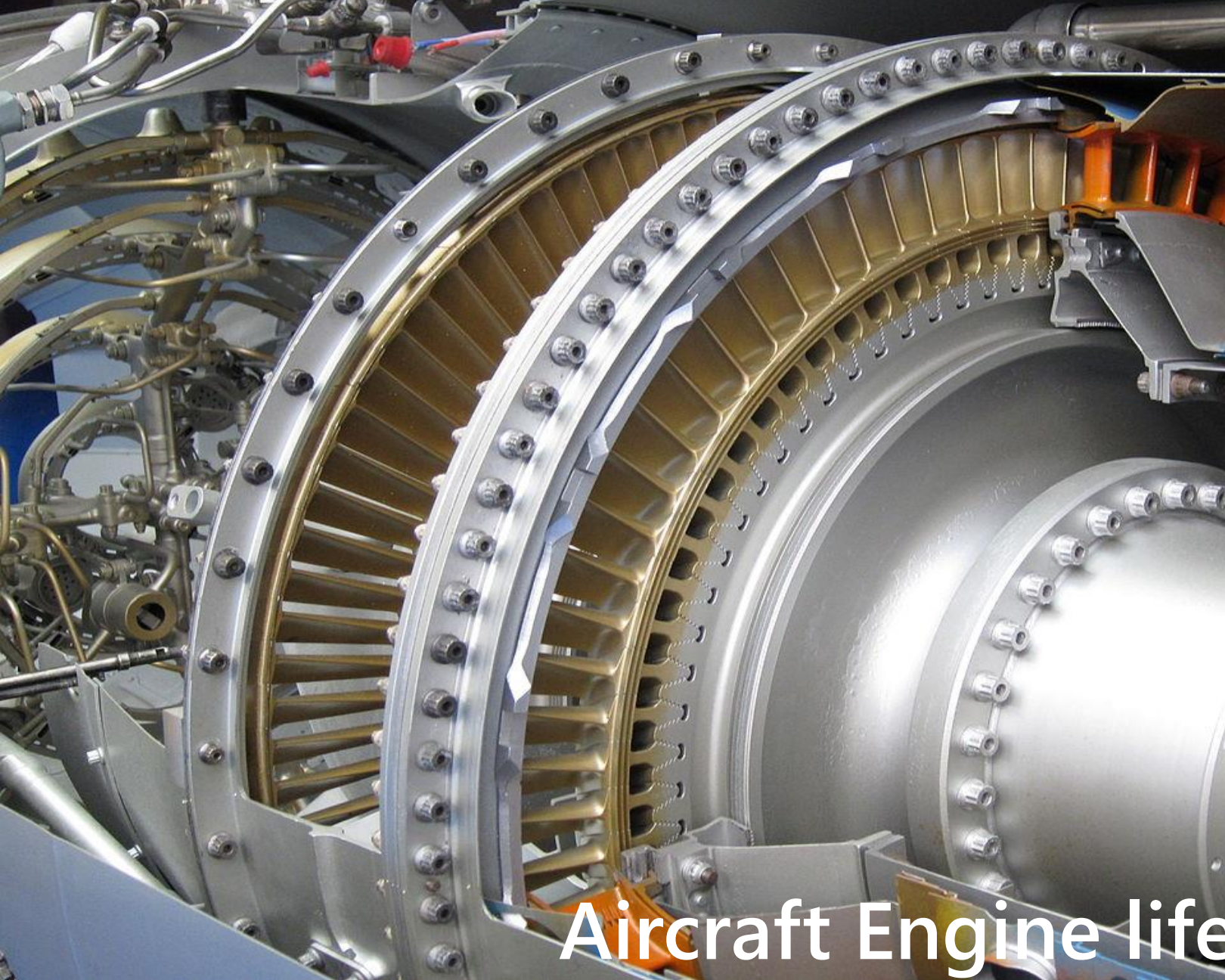

PIPISTREL

Glide further!
35% more wing efficiency

Parameter based mesh morphing (design points/snapshots)

- **Morphing regions** are identified by fluid zones or by user defined domains
- Surfaces are controlled by two sculpting tools (cylinders)
- Design points are computed by changing the **two parameters** to achieve the optimal design

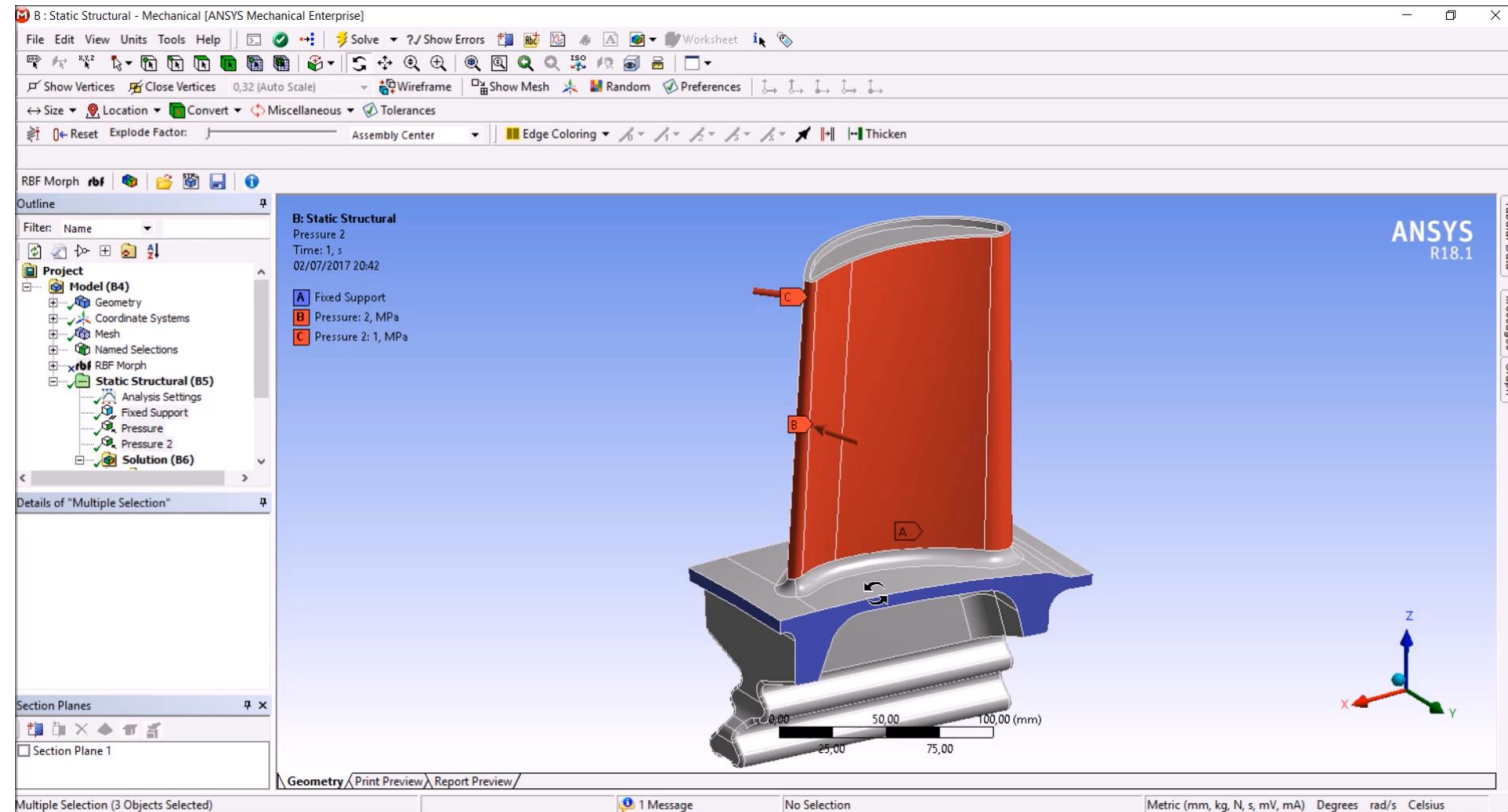




Aircraft Engine life extended!
25% stress reduction

Parameter based mesh morphing (design points/snapshots)

- **Morphing regions** are identified and added to the tree (volume mesh)
- Surface are controlled by modifying two closed **curves**
- Design points are computed by changing the **two parameters** to achieve the optimal design

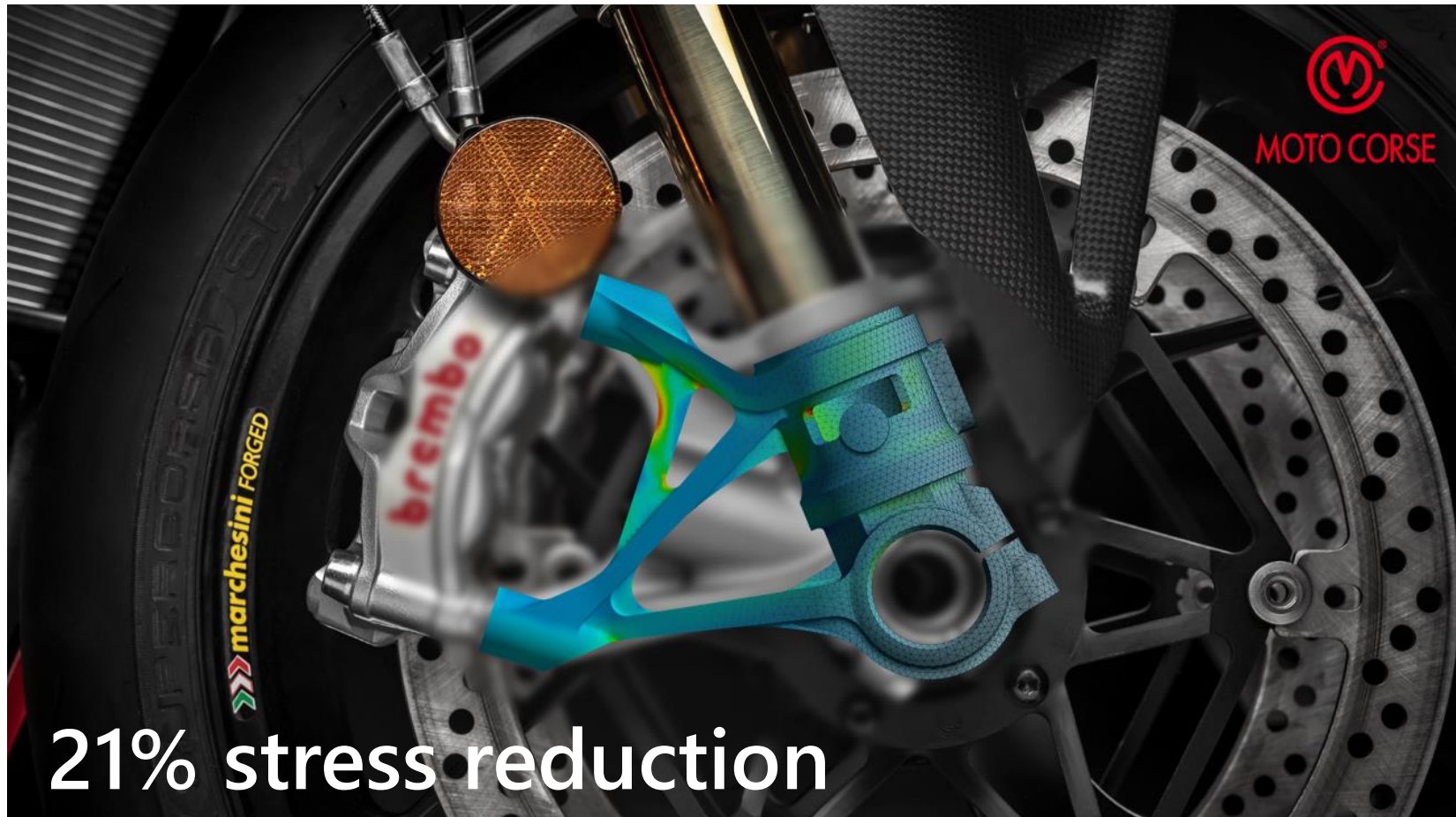


Porziani, Stefano, et al. "Automatic shape optimisation of structural parts driven by BGM and RBF mesh morphing" *International Journal of Mechanical Sciences* 189 (2021): 105976.
<https://doi.org/10.1016/j.ijmecsci.2020.105976>

Advanced Structural Shape Optimization

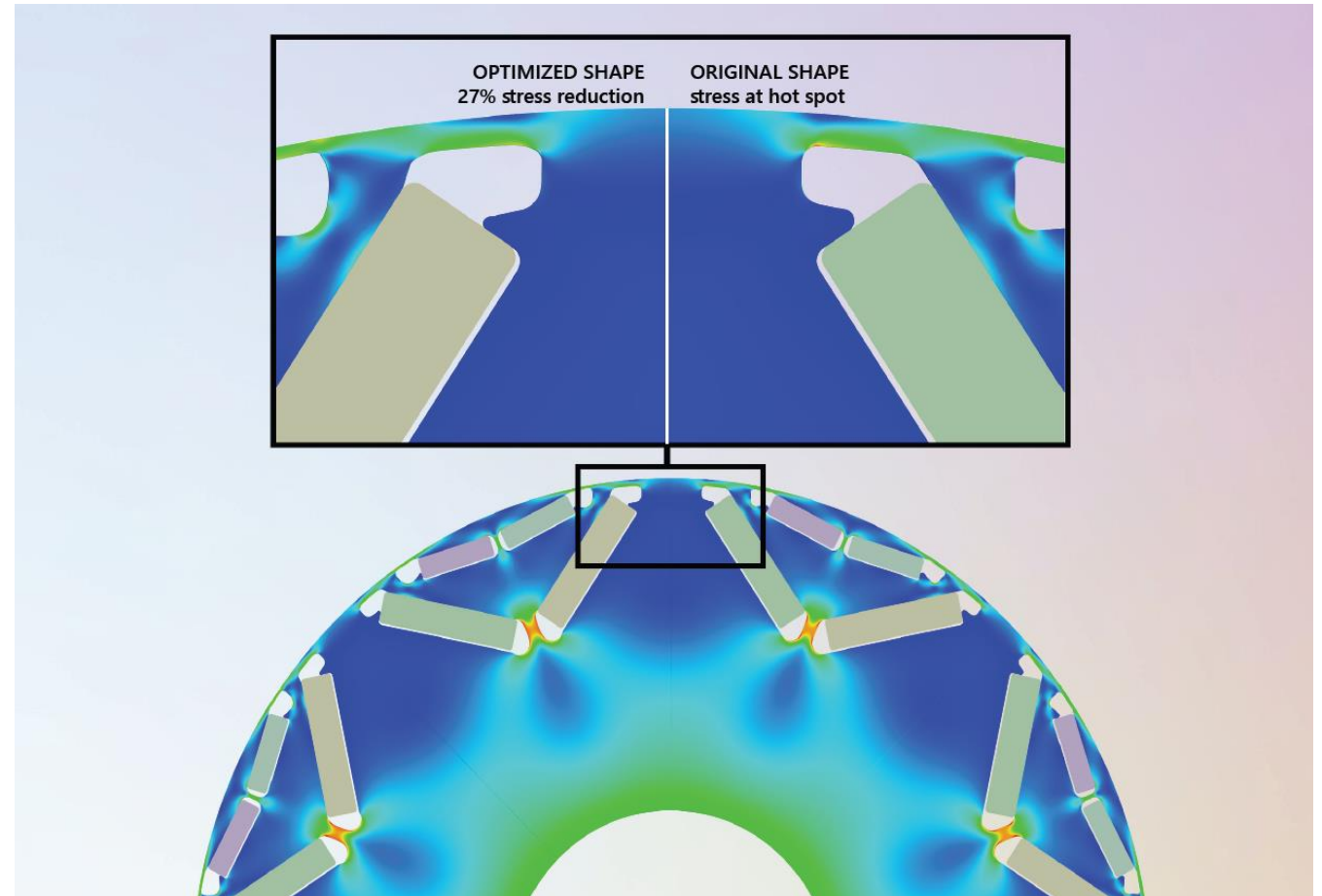


Lighter design of a wheel hub

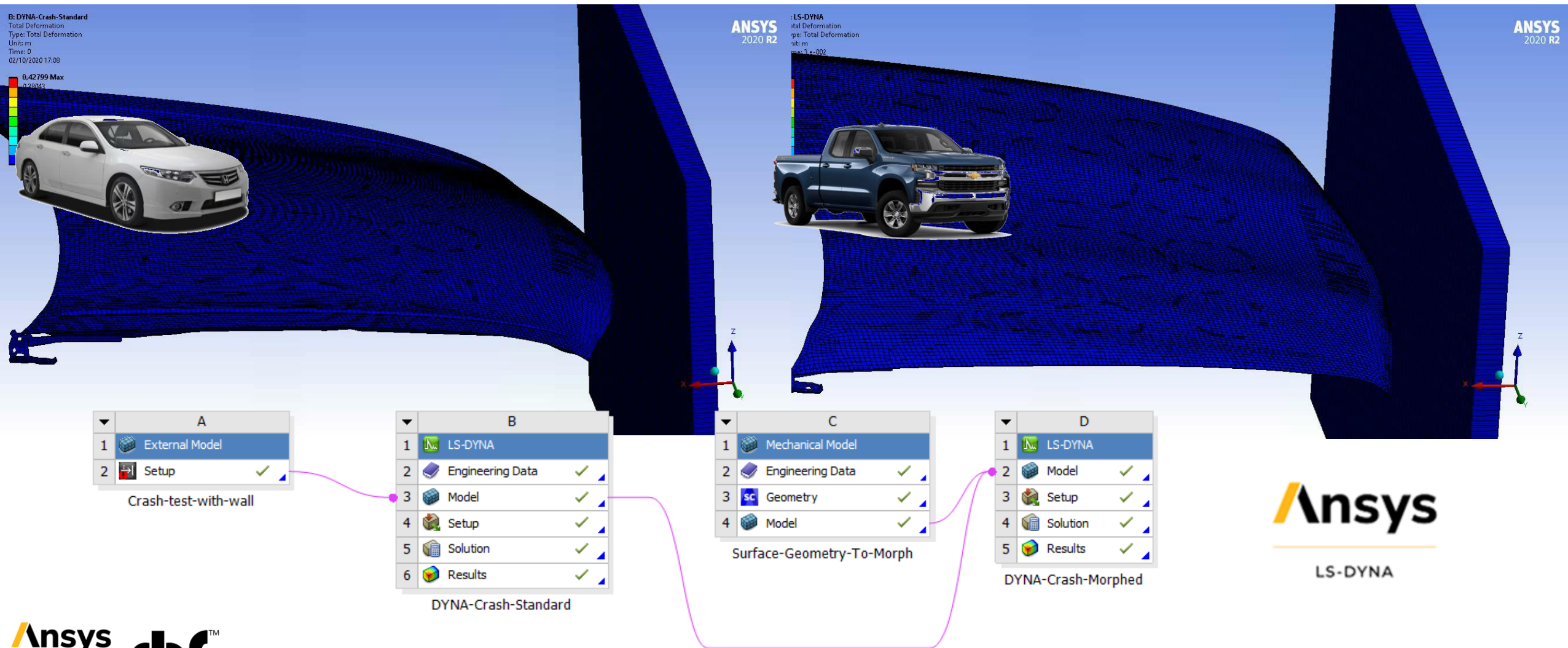


Electric motor design

- Example of 2d shape optimization
- Hot spots mitigated after the EM calculation by Maxwell
- Biological Growth Method in Ansys Mechanical



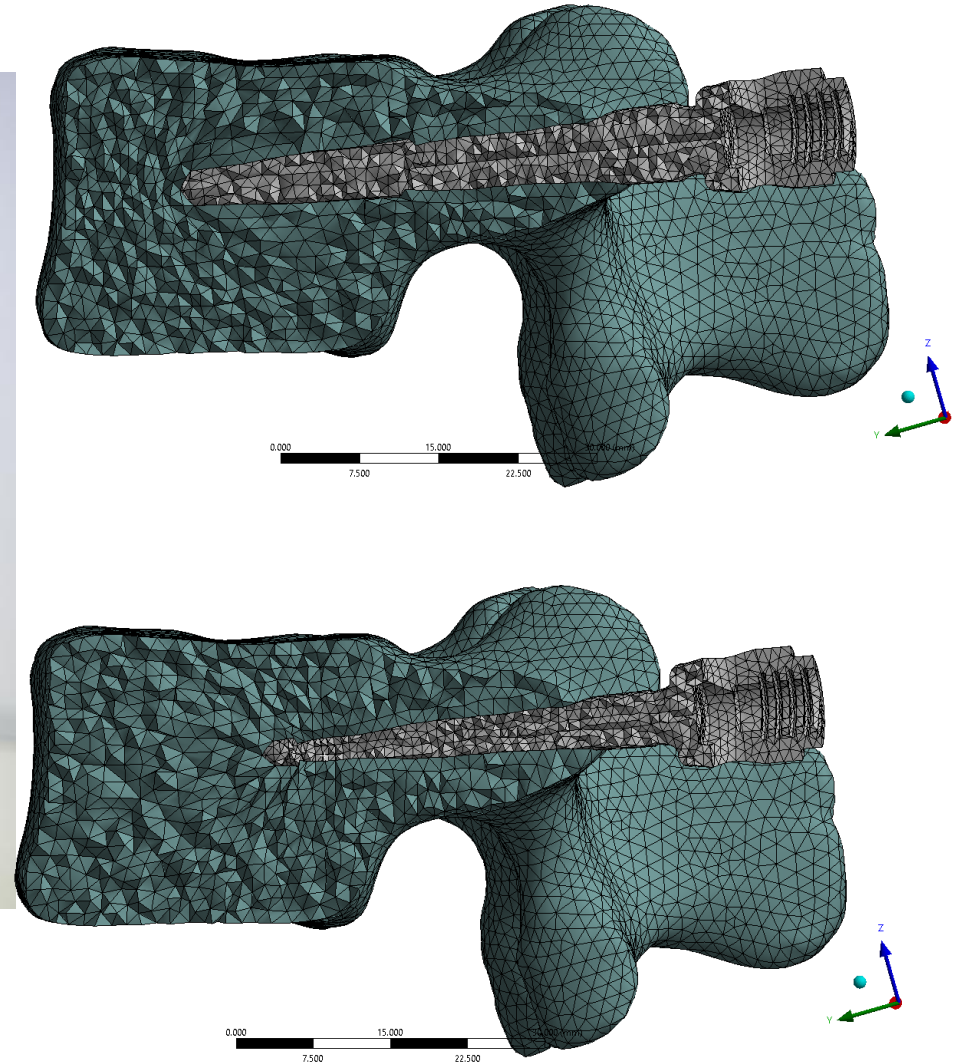
Reuse the LS-DYNA model of a different car!



Spine surgery Digital Twin



spinner
next generation spine experts



Plastics and Composites Optimization



- Composite structures shape optimization

- Combination of layup and shape optimization



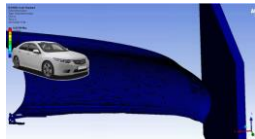
- Light systems weight and structural optimization.
Lamp cooling

- FEA & CFD analyses and shape optimization



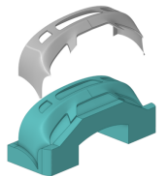
- Airbox pressure drop and noise reduction

- Pressure drop reduction by CFD, harmonic signature matching



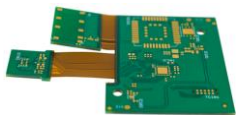
- Bonnet crash test

- Mesh morphing in LS-DYNA model



- Mould bumper material and shape optimization

- Thermo-mechanical manufacturing cycle analysis and mesh morphing



- Modeling flexible curved PCBs

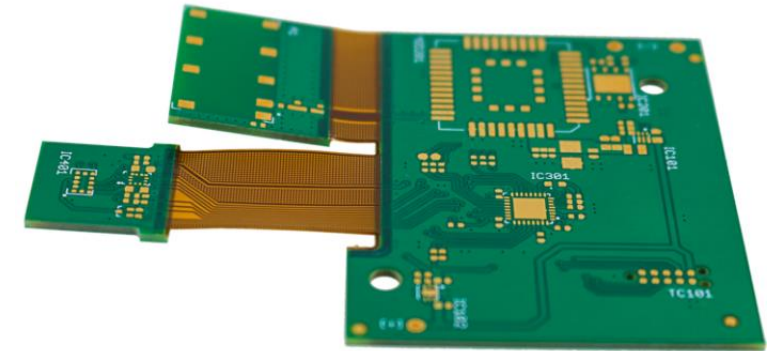
- Morphing flat structure onto the mounting shape preserving trace mapping

Flexible PCBs



PCBs – Introduction

- As electronic devices have become smaller and more ubiquitous, the **printed circuit boards (PCBs)** and components that drive them face evermore complexity. To ensure product reliability and performance, **accurate and detailed analysis methodologies** are necessary
- A **PCB is a multi-layer and multi-material component** used in a vast number of electronic applications
- A Flexible PCB majorly comprises very thin (in the range of microns) circuit **patterns of copper embedded in a non-conductive polymer layer** (mostly polyimide)
- **Flexes enable the circuitry to be designed to fit** the electronic device or product as opposed to building the device to conform the circuit board



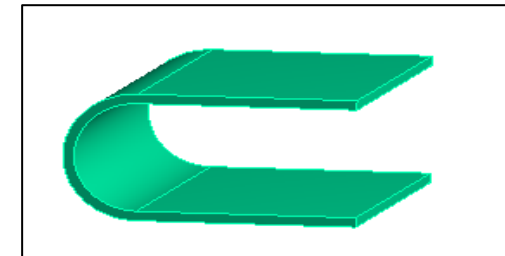
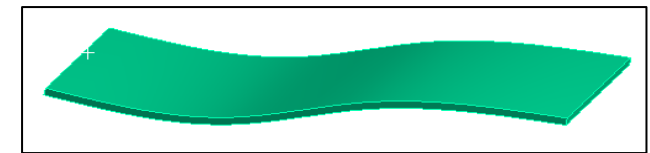
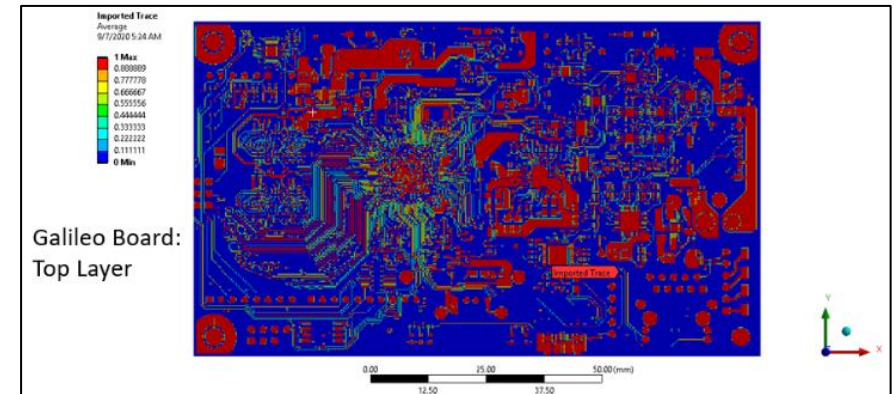
PCBs
Source: Epectec.com



Flexible PCBs

PCBs – Modeling Challenges and Goals

- The detailed design is typically only available **on a flat shape (ECAD)** and
 - the boards are built with layered materials
 - traces have a complex configuration
 - complexity of modelling ranges from **shell structures with traces mapped** up to **solid models** with traces full represented
- Numerical modeling of such structures requires a full nonlinear analysis to **deform the structure onto the installation shape** (hours of simulation on HPC)
- There is a **need for a clear and simple methodology** to adapt the FEA mesh onto the curved shape while preserving the trace mapping and trace modeling typically used while working with Electronic-CAD files
- In this study we explore the potential of **advanced mesh morphing** based on **Radial Basis Functions**



Deformed Shapes of Galileo Board

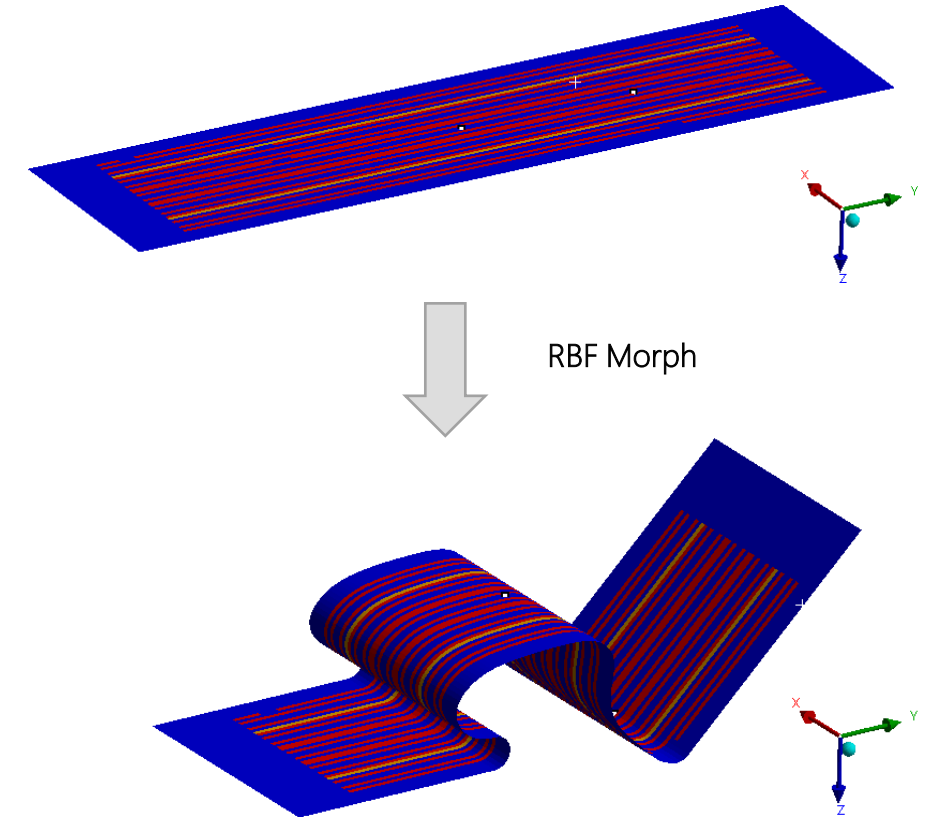
Workshop: FCB Cable

Goal:

- To morph the mesh from a flat FCB cable to its installed state

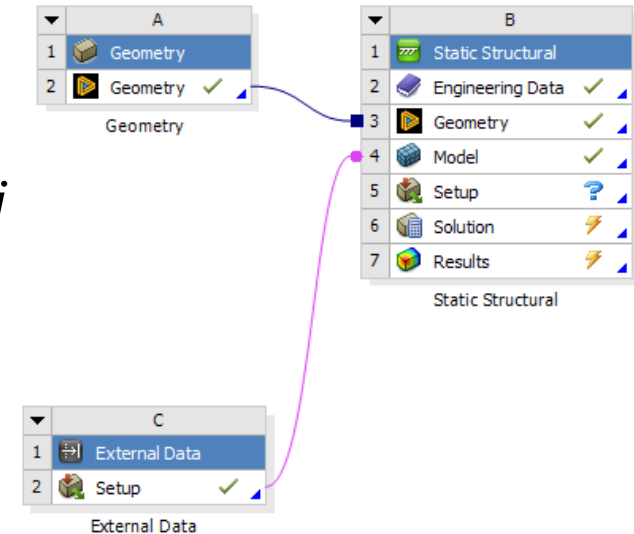
Model Description:

- FCB cable is a single layer 100 microns thick geometry
- The base or flat board is meshed with **shell elements**
- **Tracemapping** is used to represent the **ECAD** data
- The target geometry is installed state of the FCB



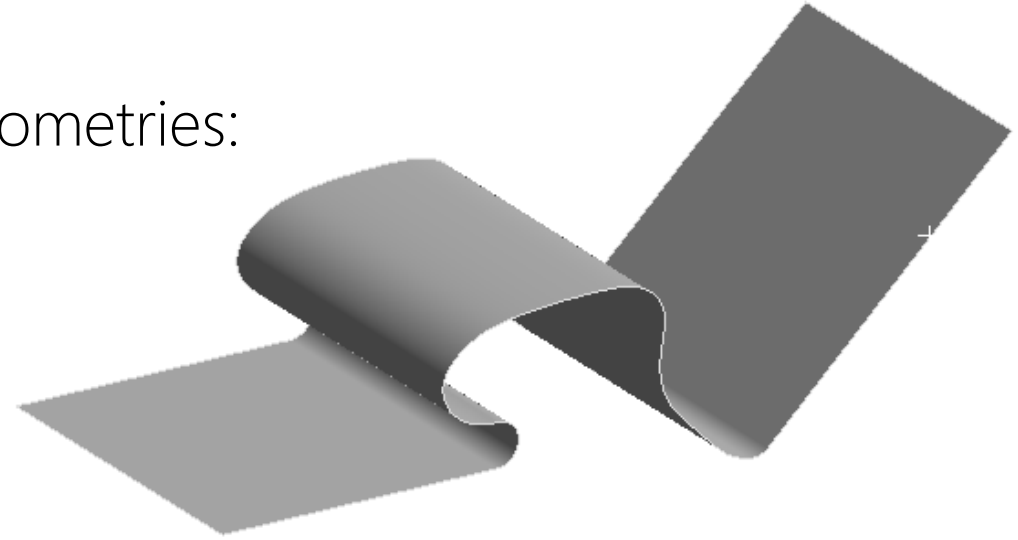
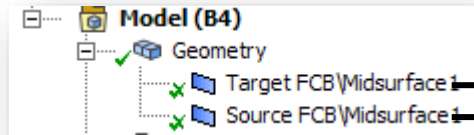
STEP 1: Opening the model in Ansys WB

- Launch Ansys Workbench from windows start button
- Once Ansys WB is opened, install the RBF Morph ACT. Installation directions are specified in the ACT download (Ansys store download link: [RBF Morph](#))
- Next, open the *RBF_Morph_Shell_Tracemapped_FCB.wbpz* file
- "Save As" the above file as *RBF_Morph_Shell_Tracemapped_FCB.wbpj* in the appropriate location
- Project Schematic should look like the image shown on right
- Double click on the Model cell to launch Mechanical

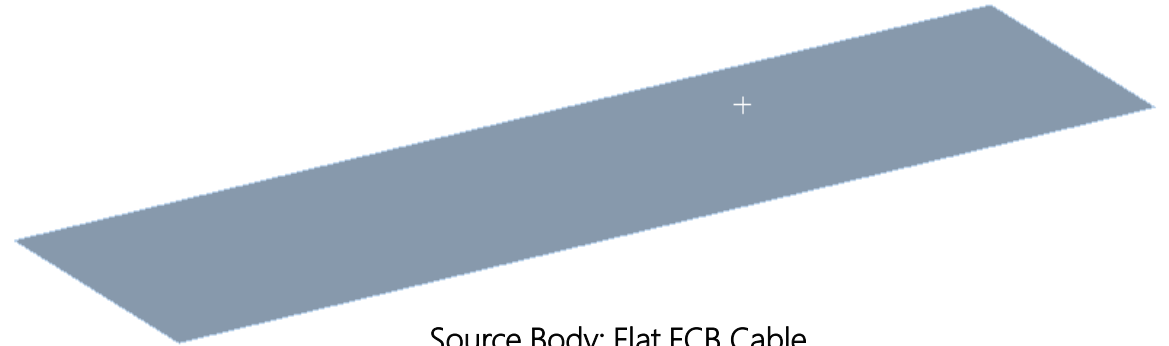


STEP 2: Geometry

- In Mechanical, verify the following geometries:



Target Body: Installed FCB Cable

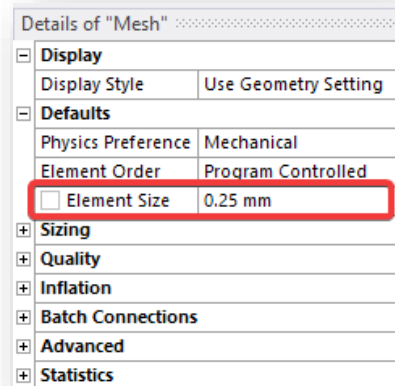
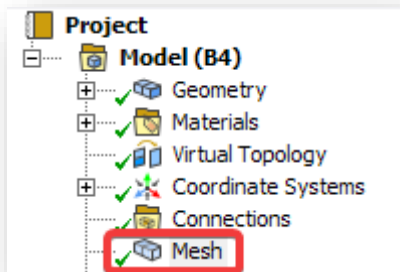


Source Body: Flat FCB Cable

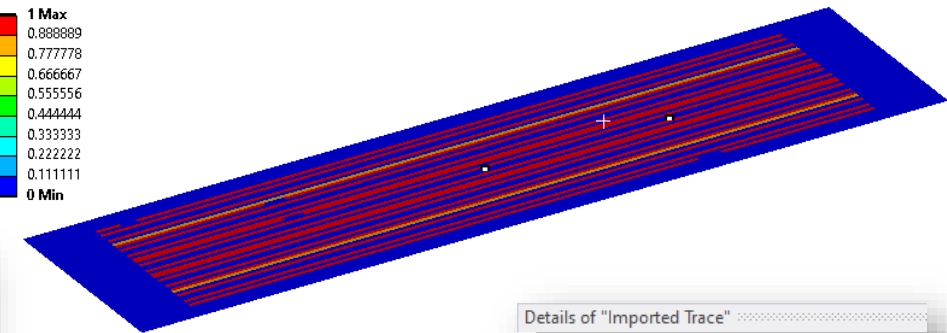
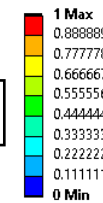
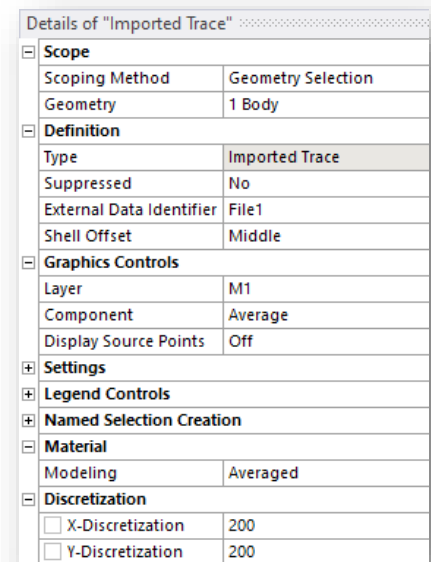
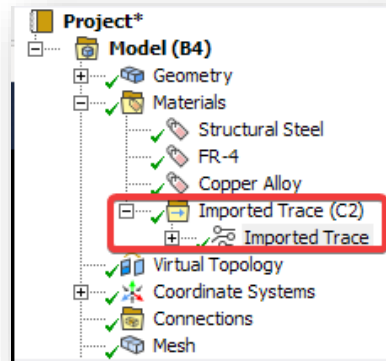
STEP 3: Mesh and Tracemapping

- The model shared with this document is meshed and tracemapped
- Verify the mesh and tracemapping settings

Mesh settings

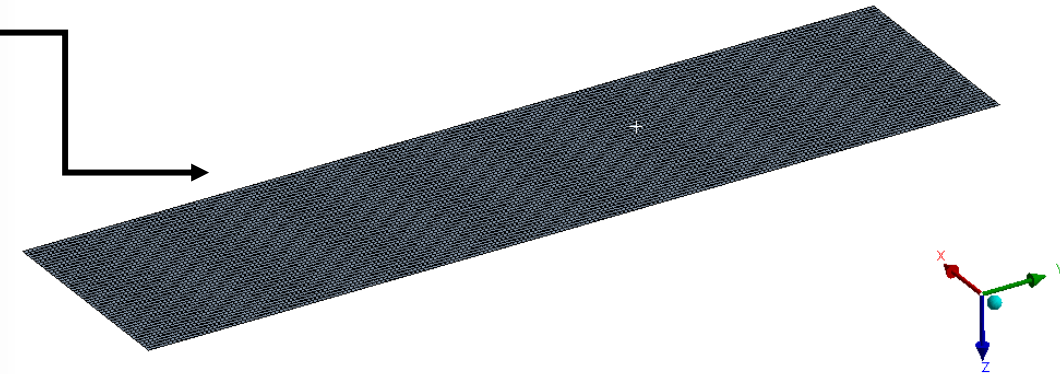
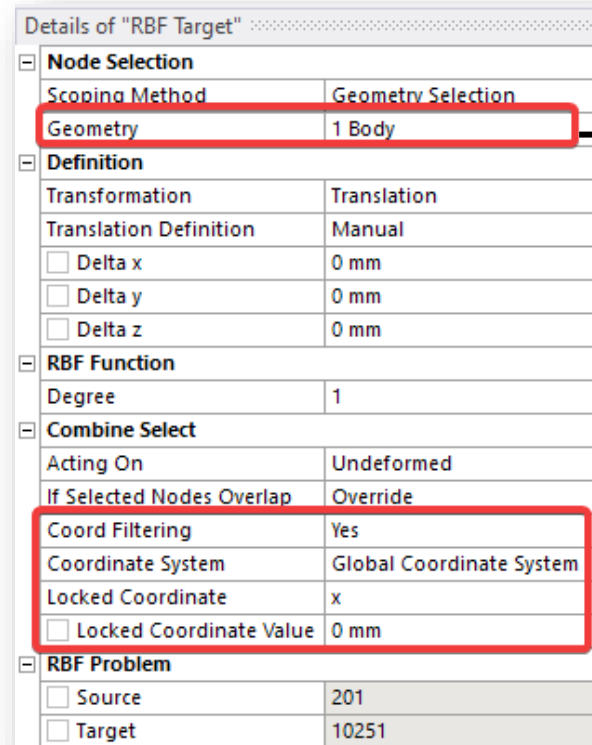
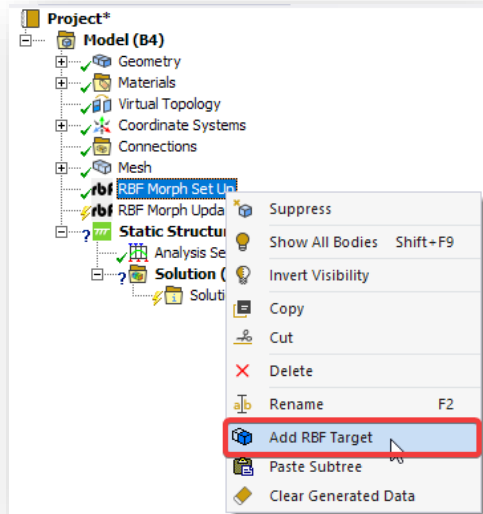
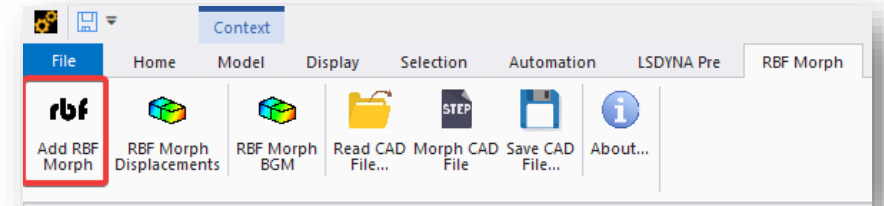


Tracemapping settings



STEP 4: RBF Morph Setup

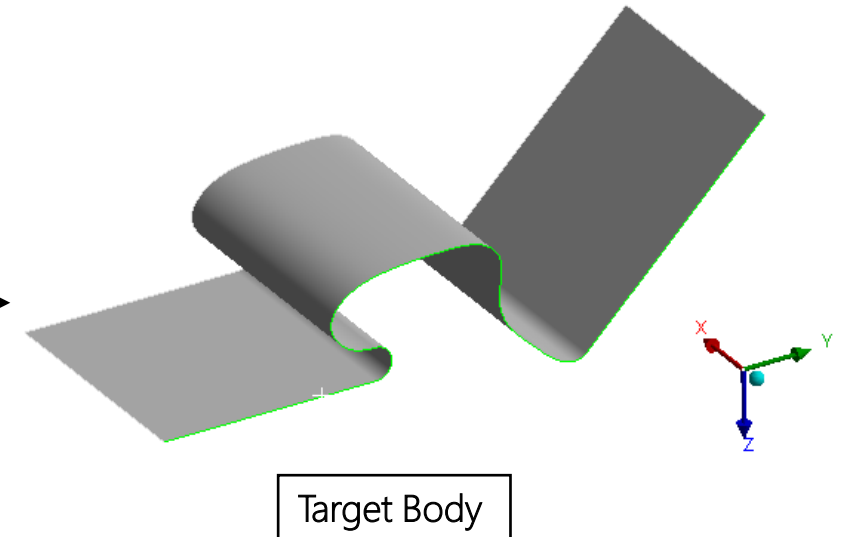
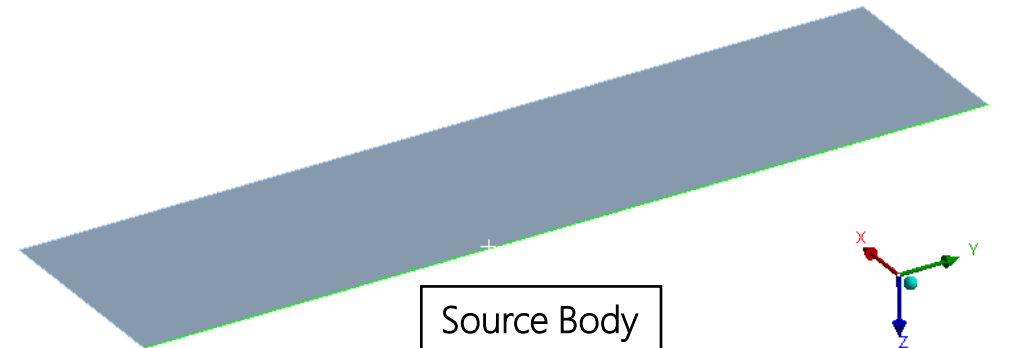
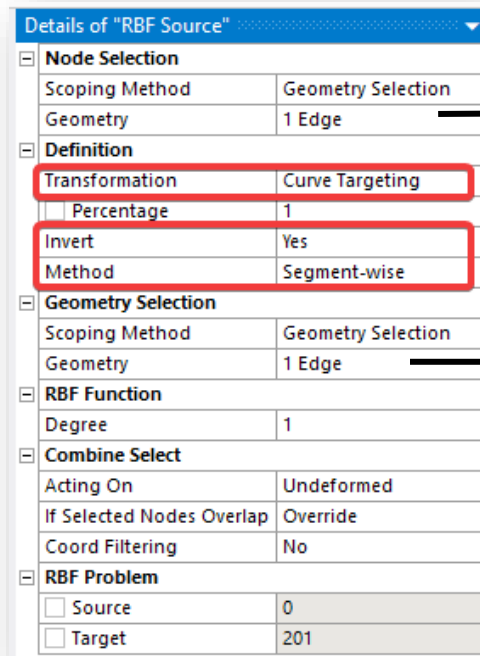
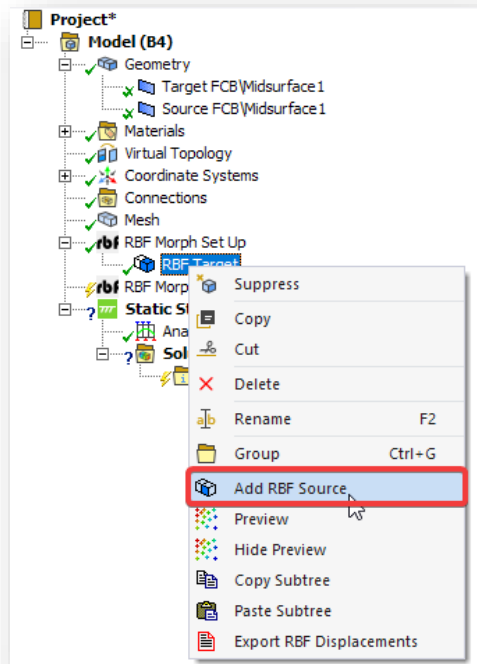
- Add *RBF Morph* from the top ribbon
- Right click on *RBF Morph Set Up* and Add *RBF Target*



- Select Source FCB under geometry Scoping
- Turn on the *Coord Filtering* option and choose Global Coordinate System
- Lock the X axis of the Coordinate system

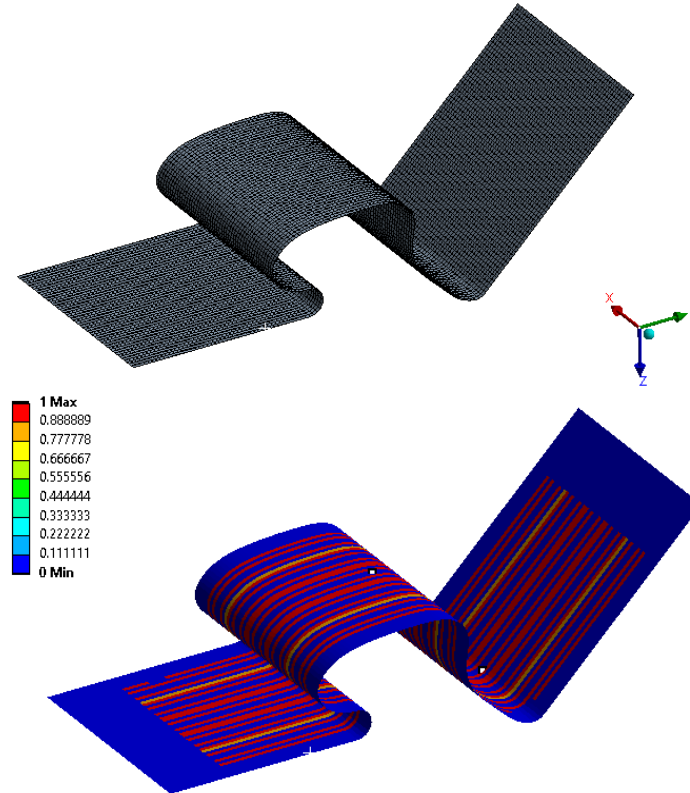
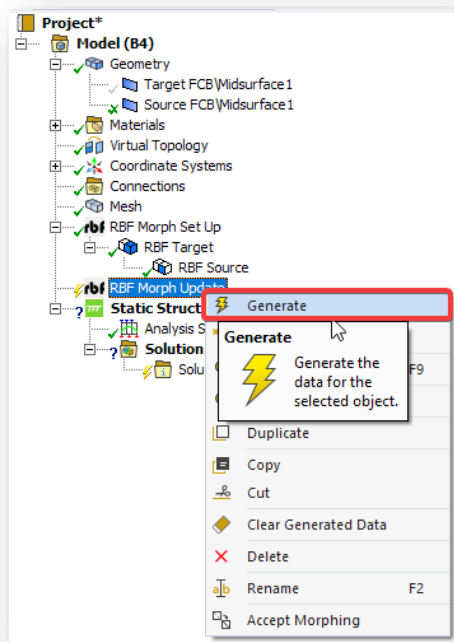
STEP 4: RBF Morph Setup

- Right click on *RBF Target* and *Add RBF Source*



STEP 4: Generate Morphed Mesh

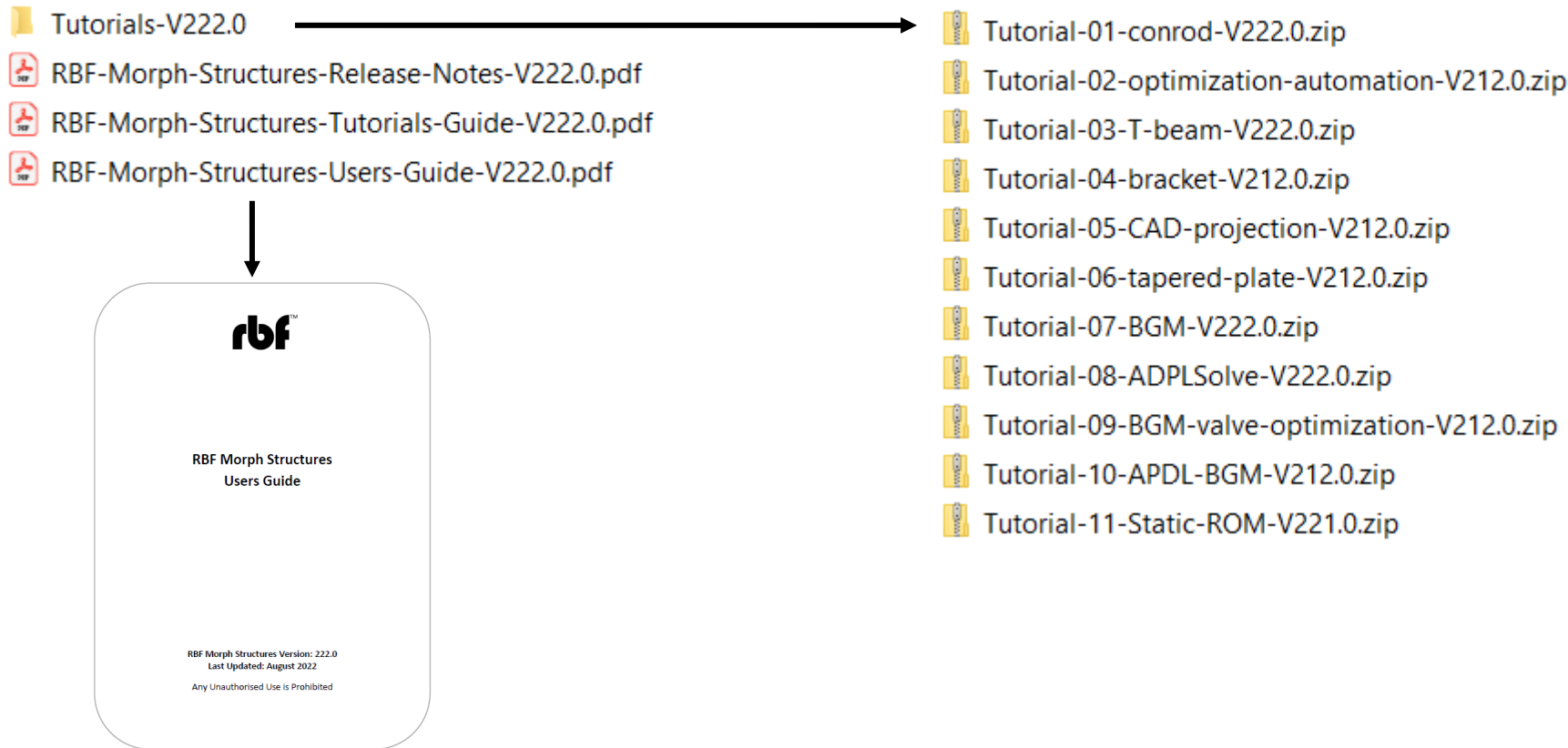
- Right click on *RBF Morph Update* and *Generate*. This will generate the morphed data
- A tracemapped FCB cable in installed state will be generated



Final Morphed Mesh – Installed FCB Cable

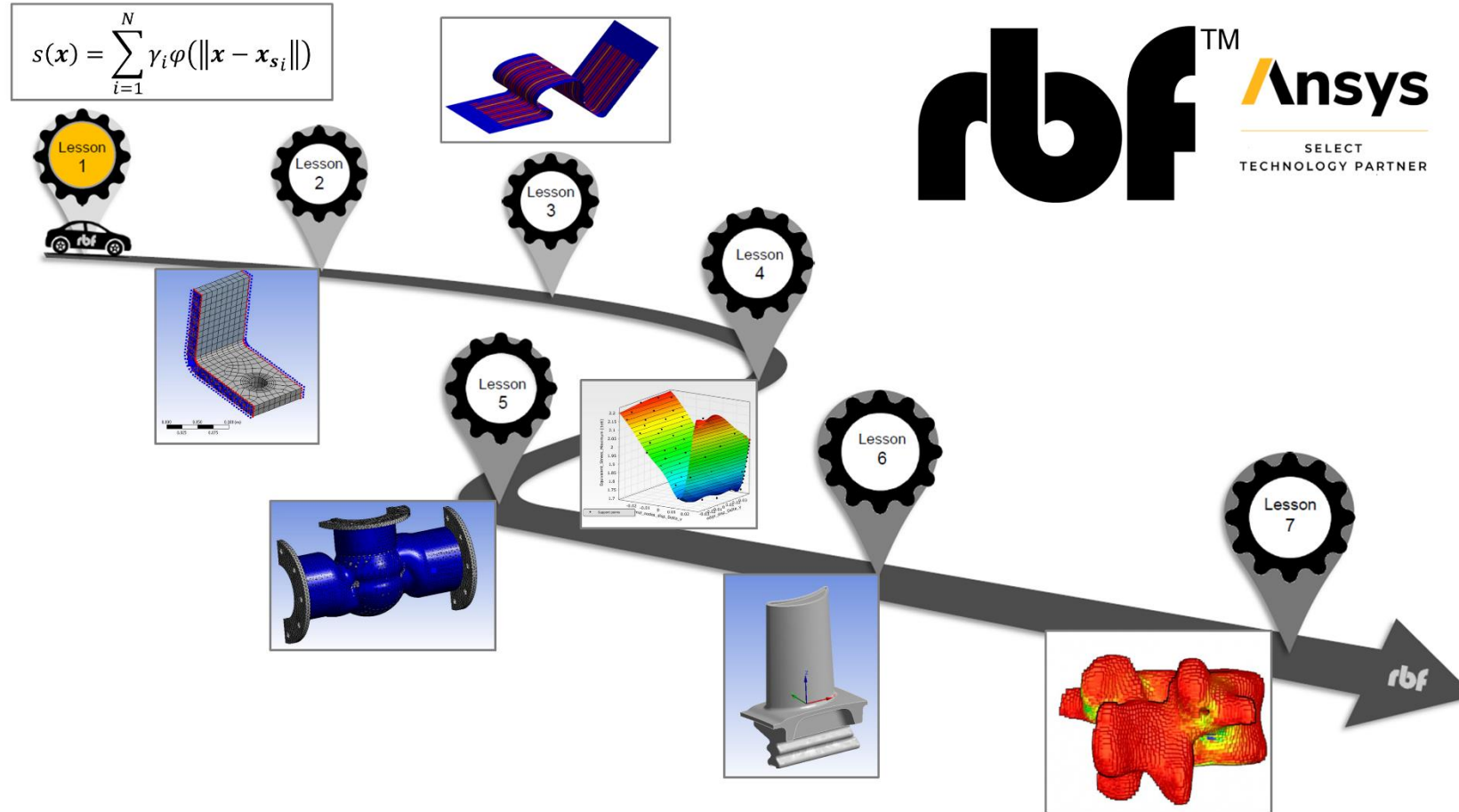
Additional Resources

In addition to the examples in this presentation, RBF Morph has comprehensive User Guide and extensive set of tutorials included in the download packages



Additional Resources

- Ansys Learning Hub: Ansys RBF Morph Structures Getting Started (Self-paced Learning Available)
- <https://www.ansys.com/training-center/course-catalog/structures/ansys-rbf-morph-structures-getting-started>



Conclusions

- Advanced **mesh morphing** with RBF Morph has been demonstrated for Structural and Fluids applications
- Shape optimization, **parameter based or parameter free**, is available within Mechanical (and MAPDL with our CDB morphing tool) and Fluent
- Snapshots for **reduced order models** and digital twin definition can be easily generated using as input shape parameters
- Mesh morphing can also be used for **morphing onto a prescribed target** (a new CAD variation, the actual manufactured shape captured by 3d scan)
- To learn more about the technology and how it can help your design visit our **booth** and our website www.rbf-morph.com

emanuele.dimeo@rbf-morph.com



linkedin.com/company/rbf-morph



youtube.com/user/RbfMorph



rbf-morph.com

