Mesh morphing techniques for the numerical analysis of Flexible PCBs

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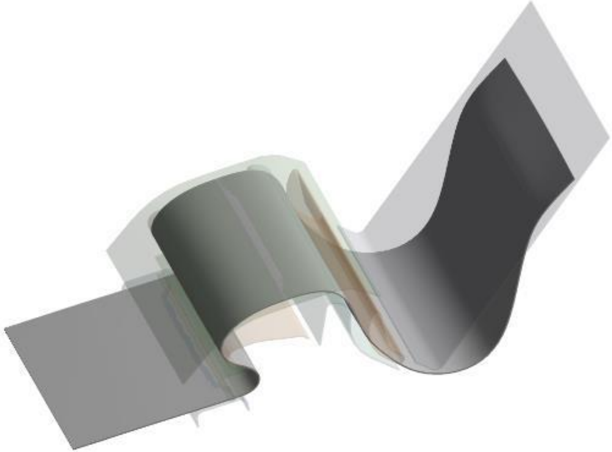
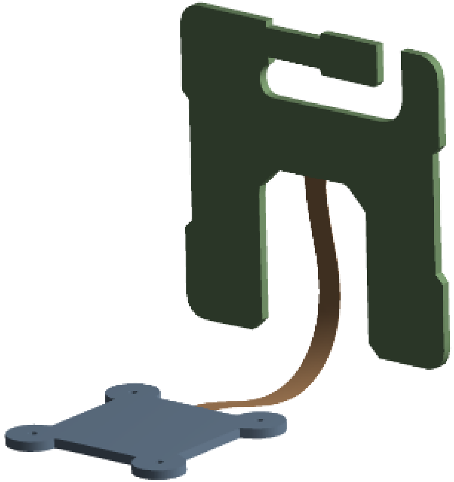
Outline

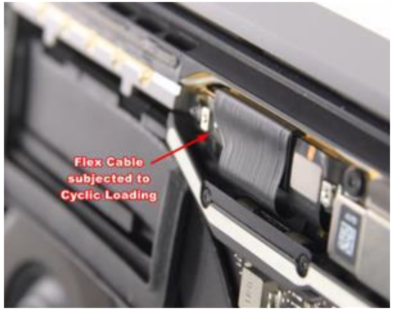
- Introduction
- Challenge and Goals
- RBF mesh morphing
- Mesh morphing workflow
  - Case 1: Galileo Board
- Applications and Results
  - Case 2: Analysis of FCB Cable
  - Case 3: Analysis of a Rigid Flex PCB
- Conclusions





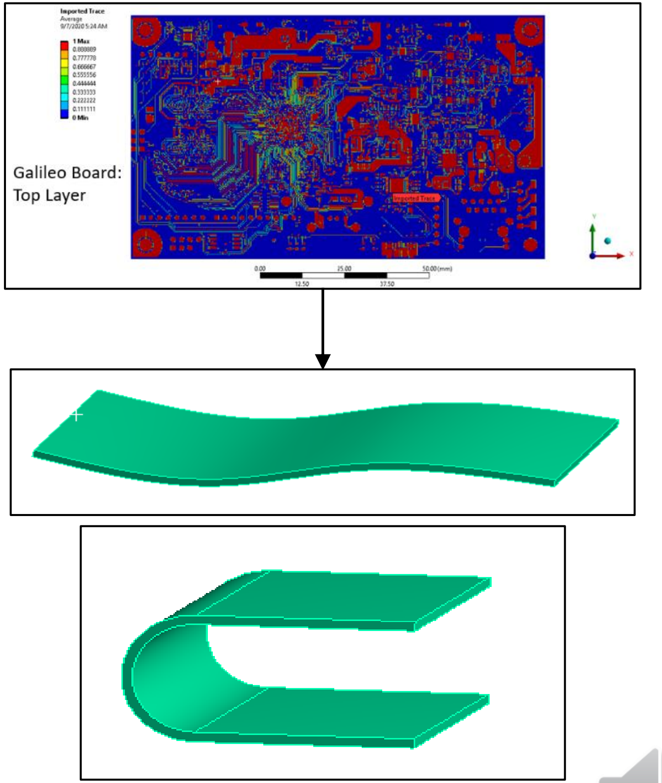
Electronic industry needs

- **What are FCBs?**
  - Flexible Circuit Boards are distinctly patterned circuitry designed to connects different parts of an electronic device.
- **Why FCB over traditional PCB?**
  - **Saves Space:** 10% of the space and weight of an ordinary circuit board assembly.
  - **Max. Reliability:** FCBs require fewer interconnects.
  - **Enhanced Capabilities:** FCBs are compatible with virtually any type of connector and perform very well in extreme temperatures.



Challenges and Goals

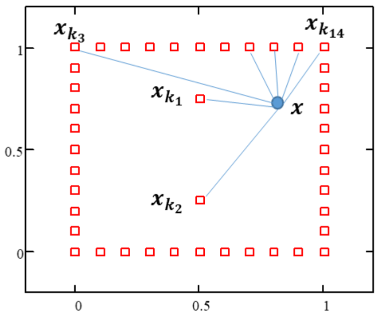
- The detailed design is typically only available **on a flat shape (ECAD)** and
  - the boards are built with layered materials
  - traces have a complex configuration
  - complexity of modelling ranges from **shell structures with traces mapped** up to **solid models** with traces full represented
- 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**.

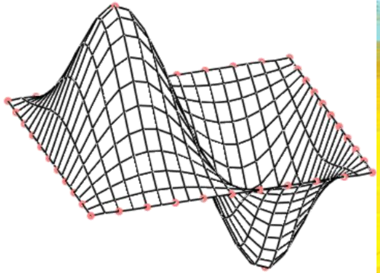


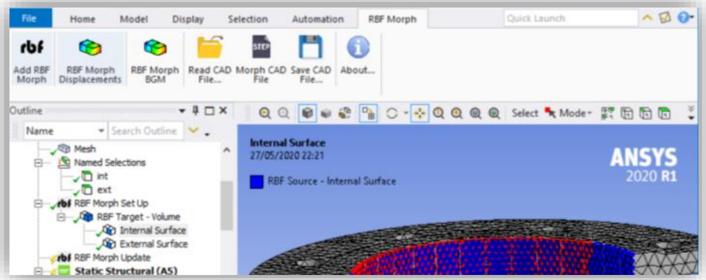
RBF Morph software for ANSYS Mechanical

- Radial Basis Functions (RBF) are a mathematical tool capable of **interpolating** in a generic point in space using a function **known** in a discrete set of points (**source points**).
- The three components of a displacement field are interpolated to control and morph a mesh.
- ACT Extension **fully integrated** with ANSYS Mechanical implements Radial Basis Functions mesh Morphing
- Powered by a **fast, parallel RBF solver** that tackles any sized problem. Enables **CAD based mesh morphing**

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





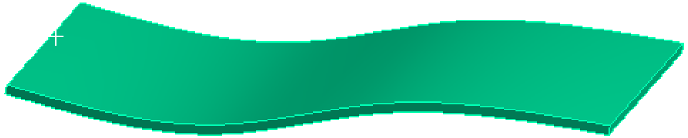


Case 1: Galileo Board

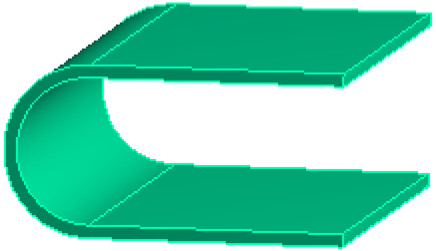
PCB tested: Galileo Board (11 Layers)

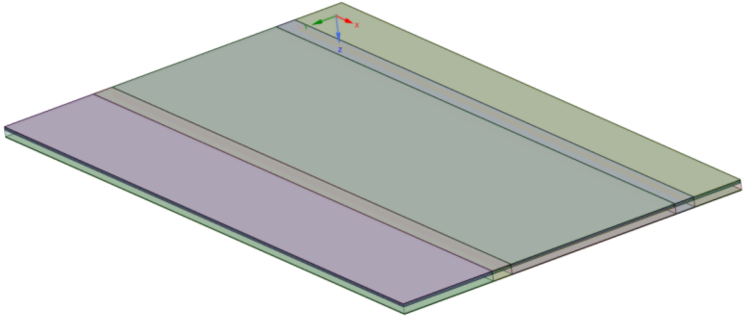
Target Geometries:

- Wavy Structure



- Wrap Structure





Objective

For both Target Geometries, wrapping should be possible for:

- Shell Trace Mapping
- Solid Trace Mapping
- Solid Trace Modeling

Case 1: Solid Trace Mapping – Wavy (Morph Logic)

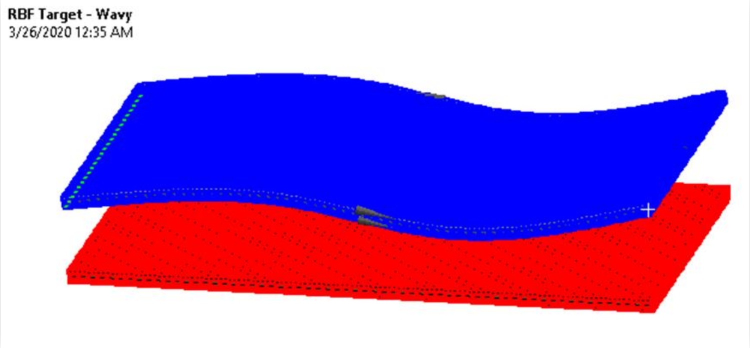
Morph Approach for Wavy Structure:

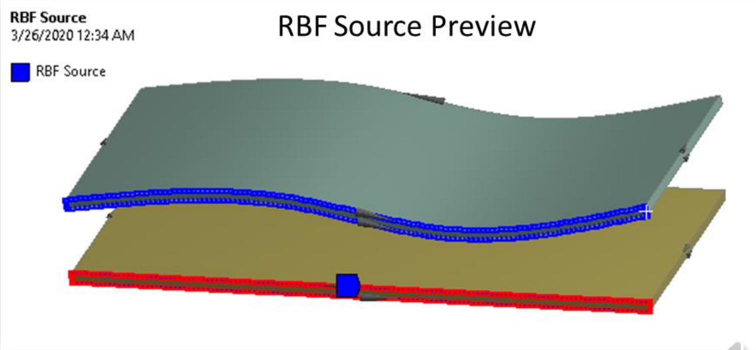
- An auxiliary Surface/Solid is defined to drive 2d morphing
- Curves are connected
- The 2d morphing action is propagated on the complete solid mesh by turning on Coordinate Filtering

rbf RBF Morph Set Up
RBF Target - Wavy
RBF Source

Details of "RBF Target - Wavy"

Node Selection	
Scoping Method	Geometry Selection
Geometry	11 Bodies
Definition	
Transformation	Translation
Translation Definition	Manual
Delta x	0 mm
Delta y	0 mm
Delta z	0 mm
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	Yes
Coordinate System	Coordinate System
Locked Coordinate	y
Locked Coordinate Value	0 mm
RBF Problem	
Source	520
Target	177287



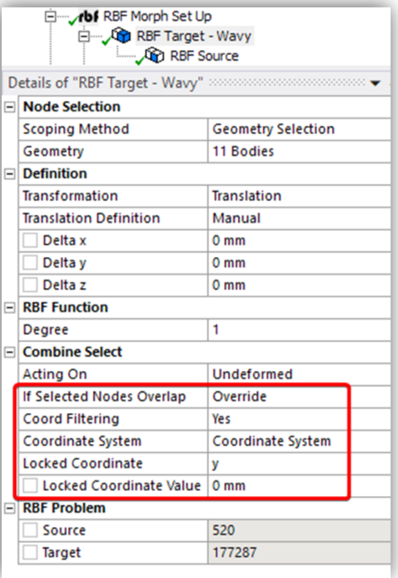


Case 1: Solid Trace Mapping – Wrap (Morph Logic)

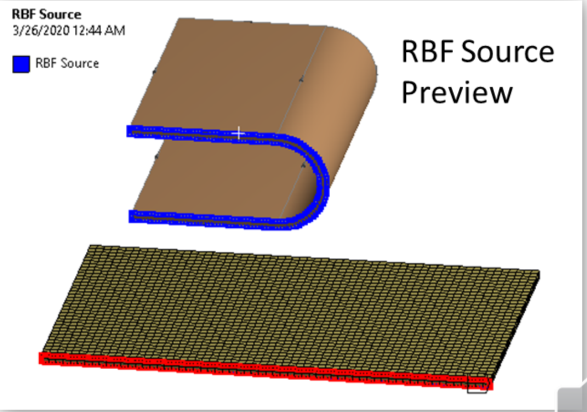
Morph Approach for Wrap Structure:

A 2 Step Process using RBF Morph:

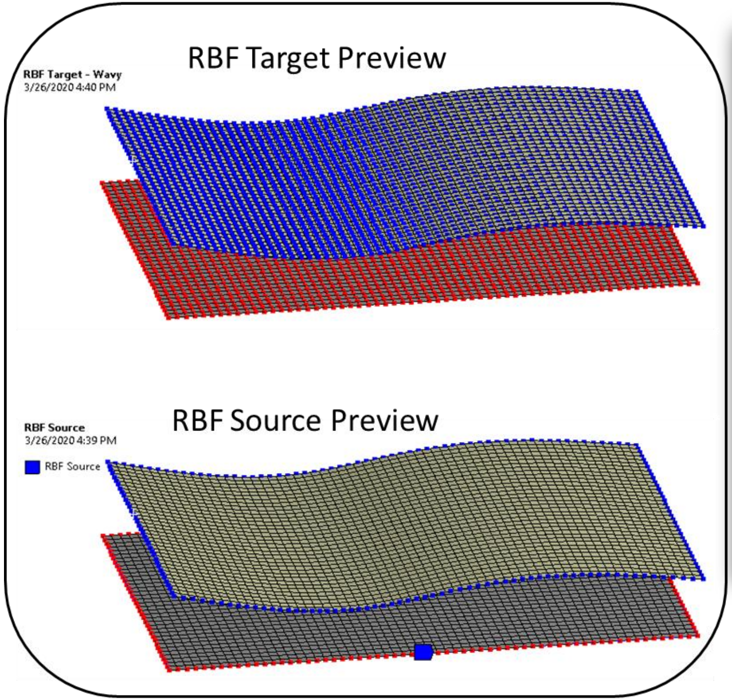
- Create an Auxiliary Surface/Solid
- A 2 object RBF Morph Setup
    - Select the PCB
    - Turn on Coordinate Filtering
    - Select the RBF Source Edges



Node Selection	
Scoping Method	Geometry Selection
Geometry	11 Bodies
Definition	
Transformation	Translation
Translation Definition	Manual
Delta x	0 mm
Delta y	0 mm
Delta z	0 mm
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	Yes
Coordinate System	Coordinate System
Locked Coordinate	y
Locked Coordinate Value	0 mm
RBF Problem	
Source	520
Target	177287



Case 1: Shell Trace Mapping (Morph Logic)

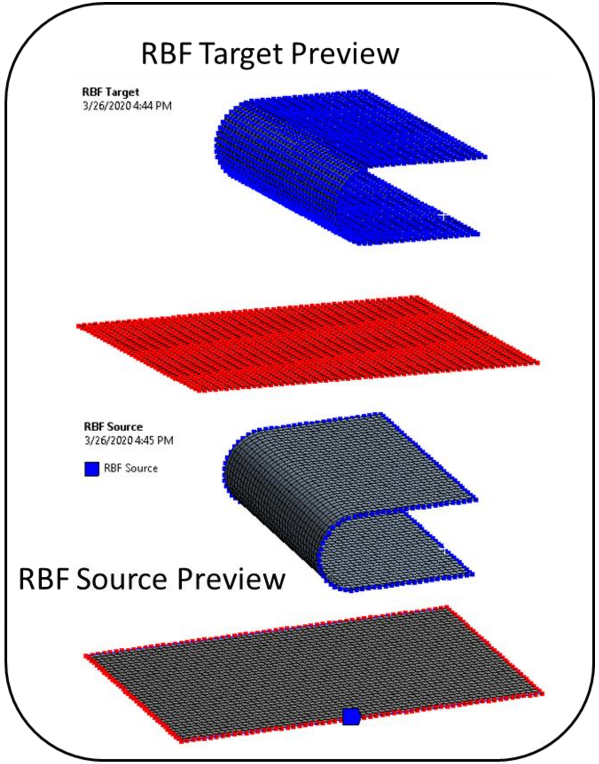


Wavy Structure

RBF Morph Set Up
RBF Target - Wavy
RBF Source

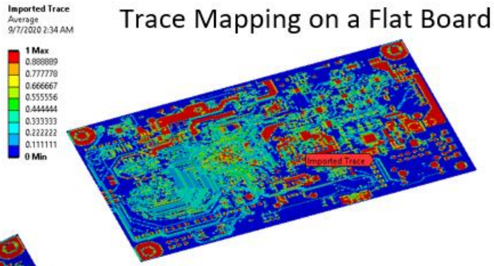
Details of "RBF Target - Wavy"

Node Selection	
Scoping Method	Geometry Selection
Geometry	11 Bodies
Definition	
Transformation	Translation
Translation Definition	Manual
Delta x	0 mm
Delta y	0 mm
Delta z	0 mm
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	Yes
Coordinate System	Coordinate System
Locked Coordinate	y
Locked Coordinate Value	0 mm
RBF Problem	
Source	520
Target	177287

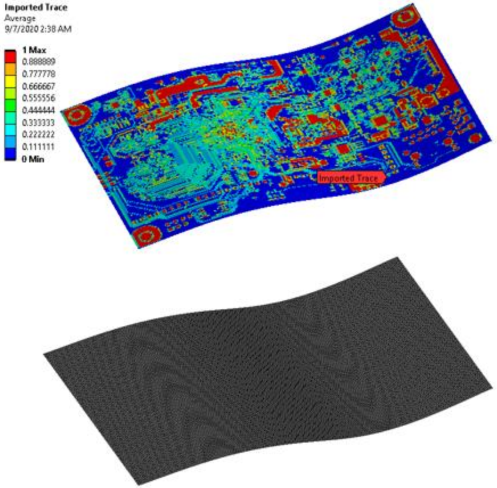


Wrap Structure

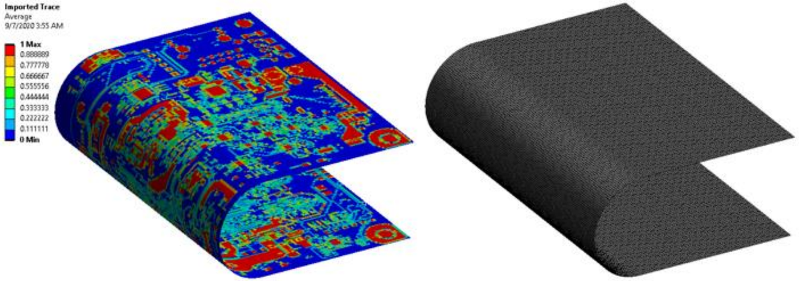
Case 1: Shell Trace Mapping (Results)



Trace Mapping on a Flat Board

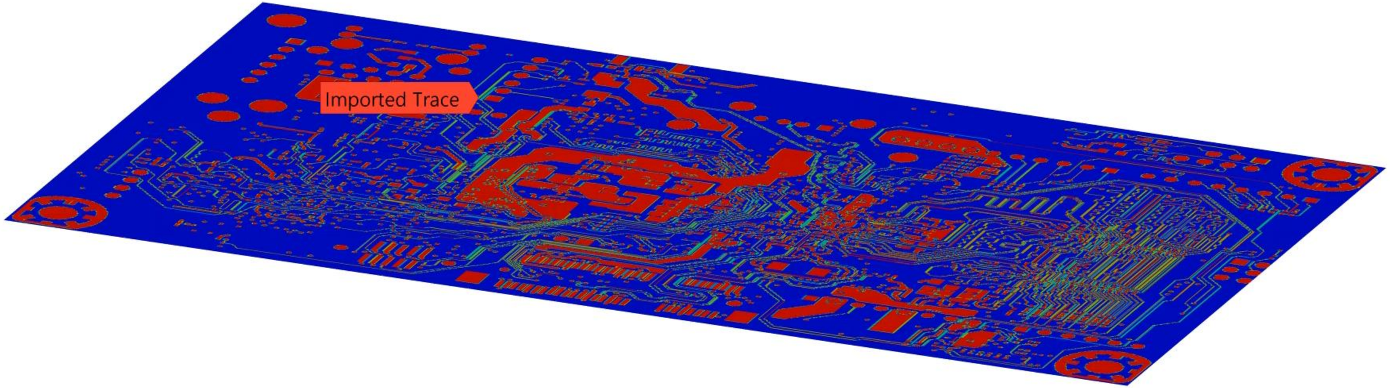


Trace Mapping and Morphed Mesh on the Wavy structure



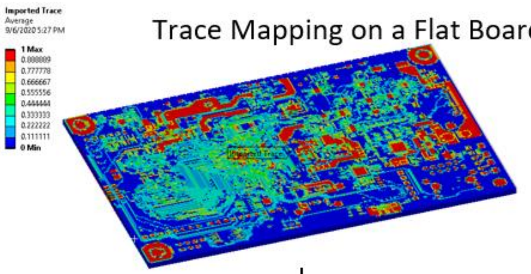
Trace Mapping and Morphed Mesh on the Wrap structure

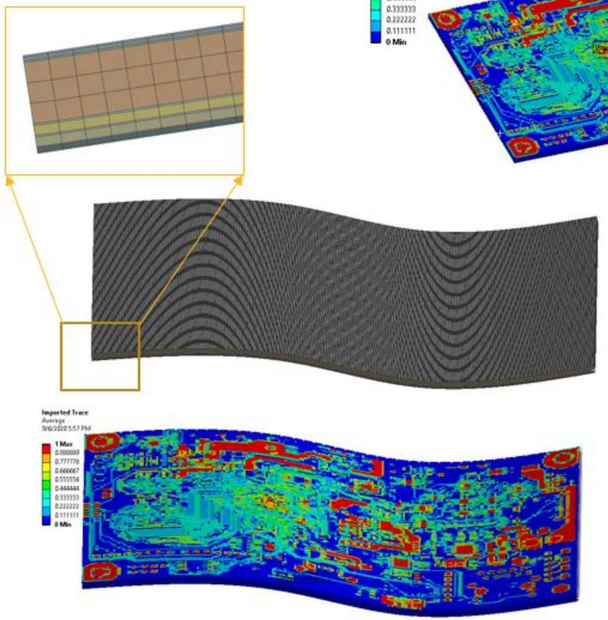
Case 1: Shell Trace Mapping (Results)



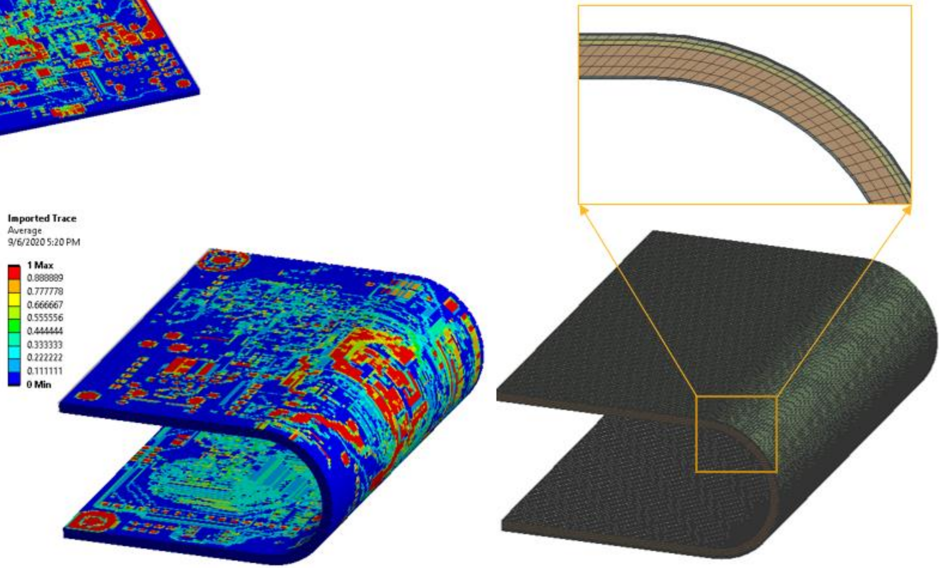
Case 1: Solid Trace Mapping (Results)

Trace Mapping on a Flat Board





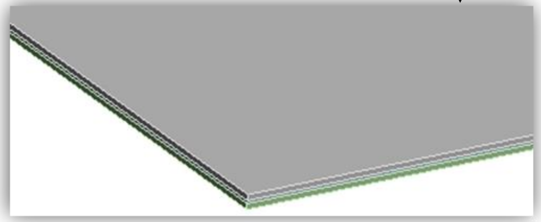
Trace Mapping & Morphed Mesh on the Wavy Structure

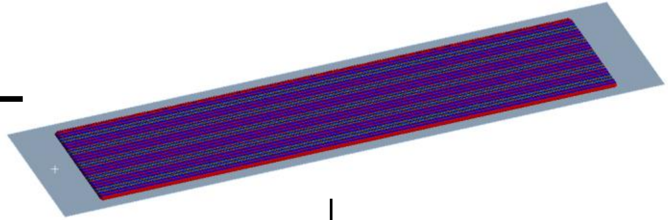


Trace Mapping & Morphed Mesh on the Wrap Structure

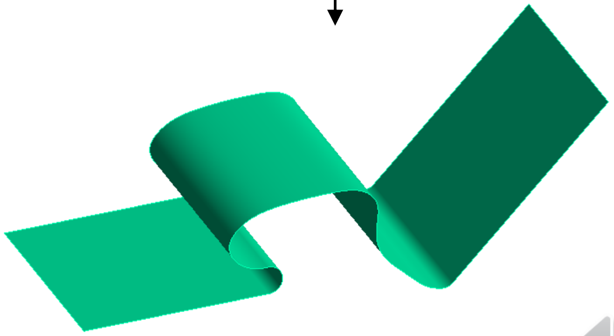
Case 2: Analysis of an FCB Cable

<u>PCB tested:</u> Flex PCB (Solid or Shell)





<u>Target Geometries:</u> Installed Shape in the consumer electronics product



<u>Objective</u>

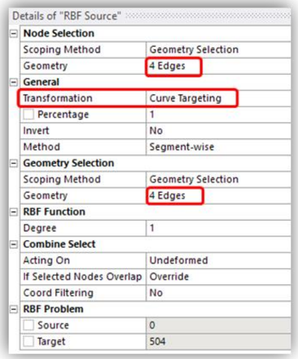
For the target geometry, wrapping should be possible for:

- Solid Trace Mapping
- Shell Trace Mapping

Case 2: FCB Cable (Shell – Morph Logic)

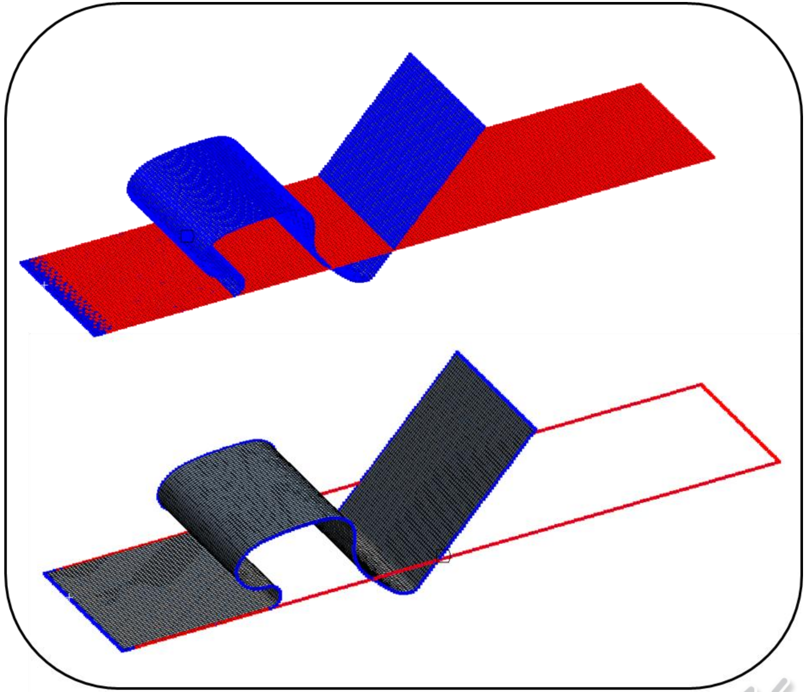
<u>Mesh morphing approach</u>:

- Boundary curves are connected to do a first morphing step
- The projection onto the target surface happens in the second and final morphing step



Details of "RBF Source"

Node Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
General	
Transformation	Curve Targeting
Percentage	1
Invert	No
Method	Segment-wise
Geometry Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	No
RBF Problem	
Source	0
Target	504



Case 2: FCB Cable (Solid – Morph Logic)

Mesh morphing approach:

- An auxiliary Surface/Solid is defined to drive 2d morphing
- Curves are connected
- The 2d morphing action is propagated on the complete solid mesh by turning on Coordinate Filtering

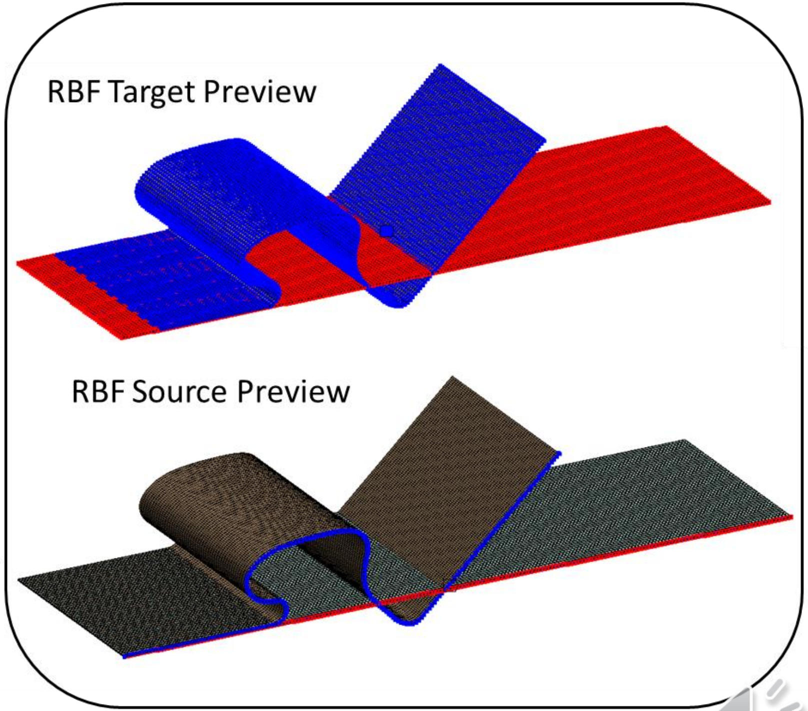
RBF Morph Set Up
RBF Target
RBF Source

Details of "RBF Target"

Node Selection	
Scoping Method	Geometry Selection
Geometry	3 Bodies
General	
Transformation	Translation
Translation Definition	Manual
Delta x	0 in
Delta y	0 in
Delta z	0 in
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	Yes
Coordinate System	Global Coordinate System
Locked Coordinate	x
Locked Coordinate Value	0 in
RBF Problem	
Source	408
Target	61506

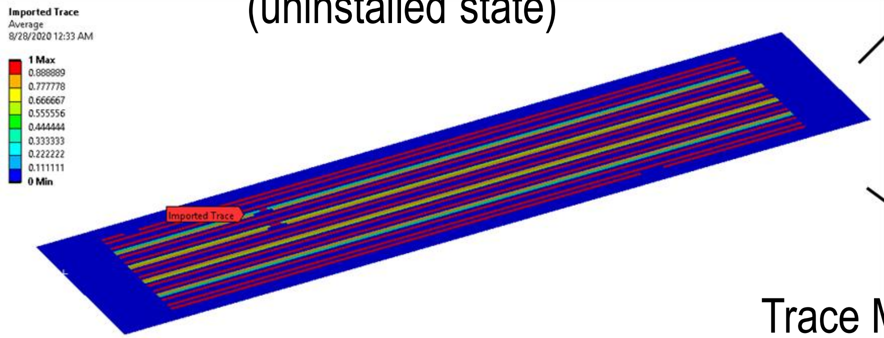
Details of "RBF Source"

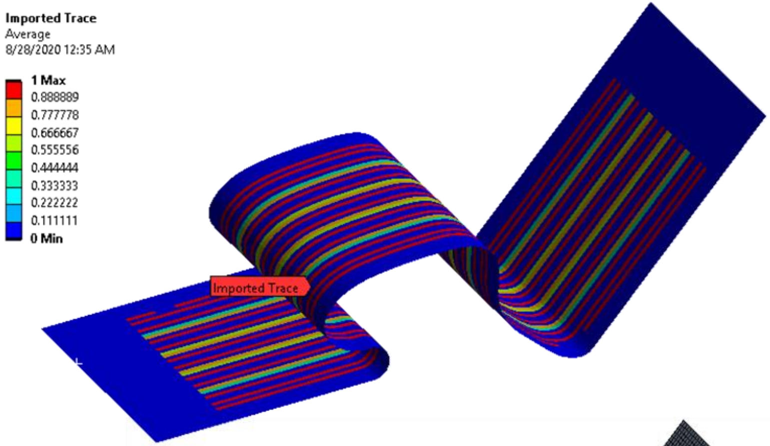
Node Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
General	
Transformation	Curve Targeting
Percentage	1
Invert	No
Method	Segment-wise
Geometry Selection	
Scoping Method	Geometry Selection
Geometry	4 Edges
RBF Function	
Degree	1



Case 2: FCB Cable (Shell Trace Mapping - Results)

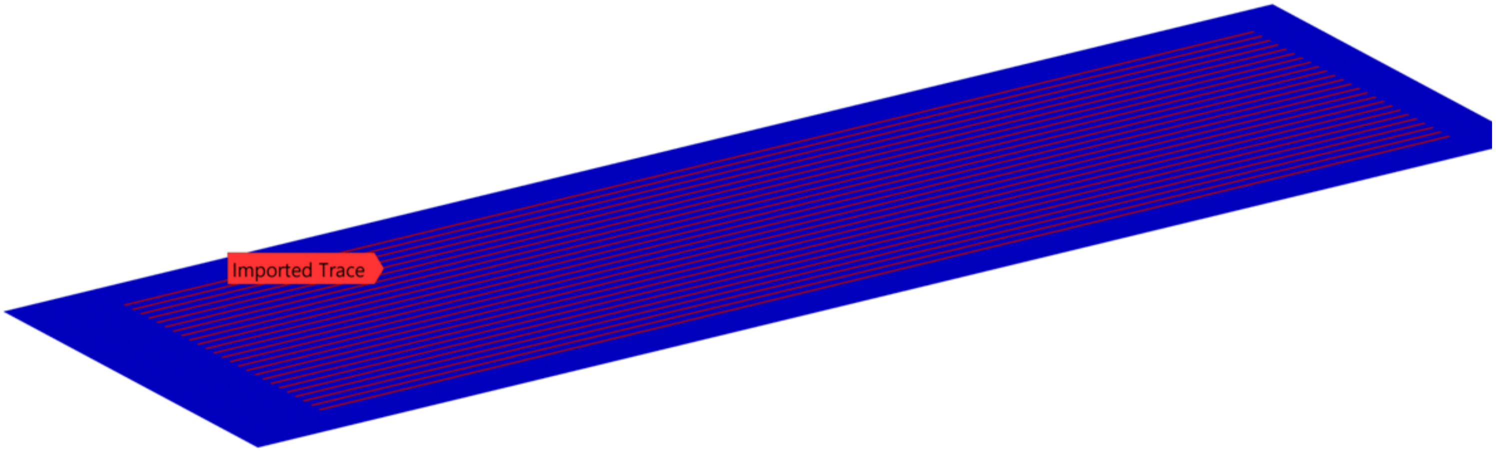
Trace Mapping on a flat Board (uninstalled state)



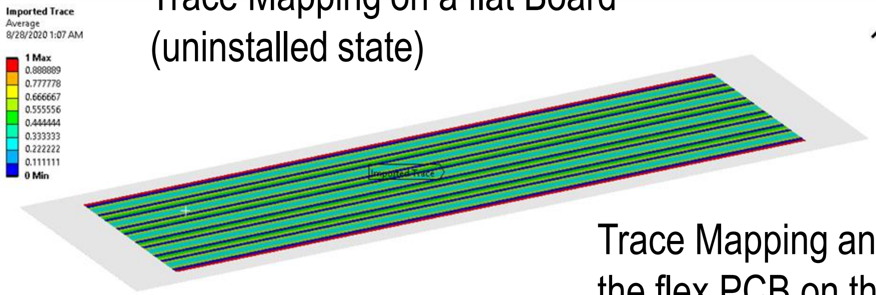


Trace Mapping and Morphed Mesh of the flex PCB on the installed structure

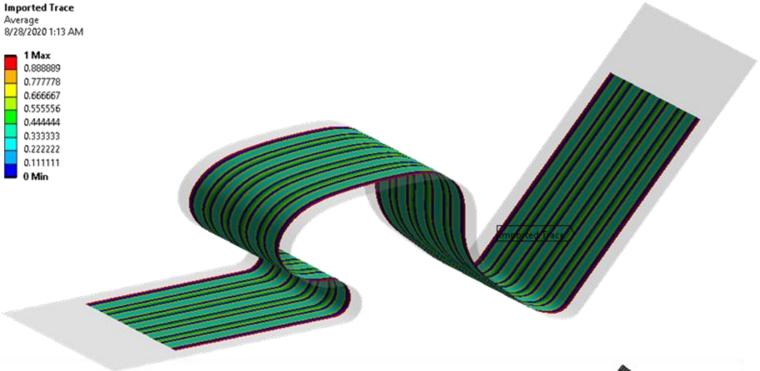
Case 2: FCB Cable (Shell Trace Mapping - Results)



Case 2: FCB Cable (Solid Trace Mapping - Results)



Trace Mapping on a flat Board (uninstalled state)

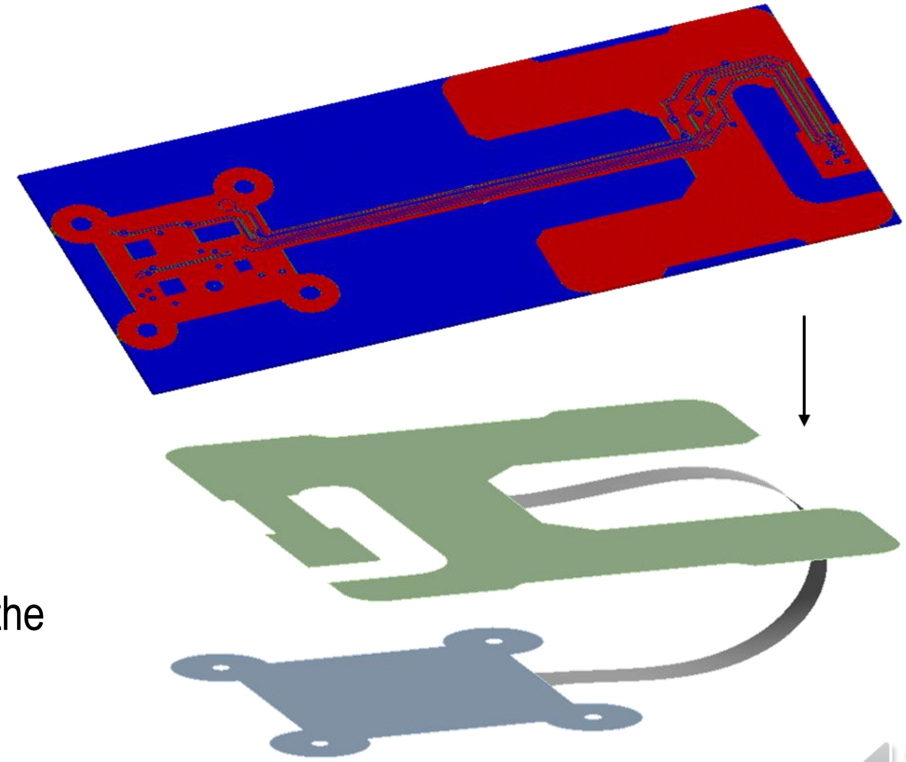


Trace Mapping and Morphed Mesh of the flex PCB on the installed structure

<u>Note:</u> For the Solid case, an averaging scheme was used for material representation which showcases the capability of the Trace Mapping technology

Case 3: Analysis of a Rigid-Flex PCB

PCB tested: Rigid-Flex PCB (Shell)



Target Geometries: Installed Shape in the consumer electronics product

Objective

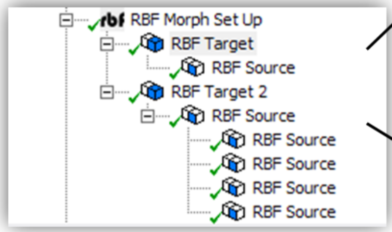
For the target geometry (a 180-degree bend) of the structure has been performed for:

- Shell Trace Mapping

Case 3: Analysis of a Rigid-Flex PCB (Morph Logic)

Morph Approach for Rigid- Flex PCB:

- A more complicated (full 3D) Morph strategy is employed here as we are dealing with multiple bodies.

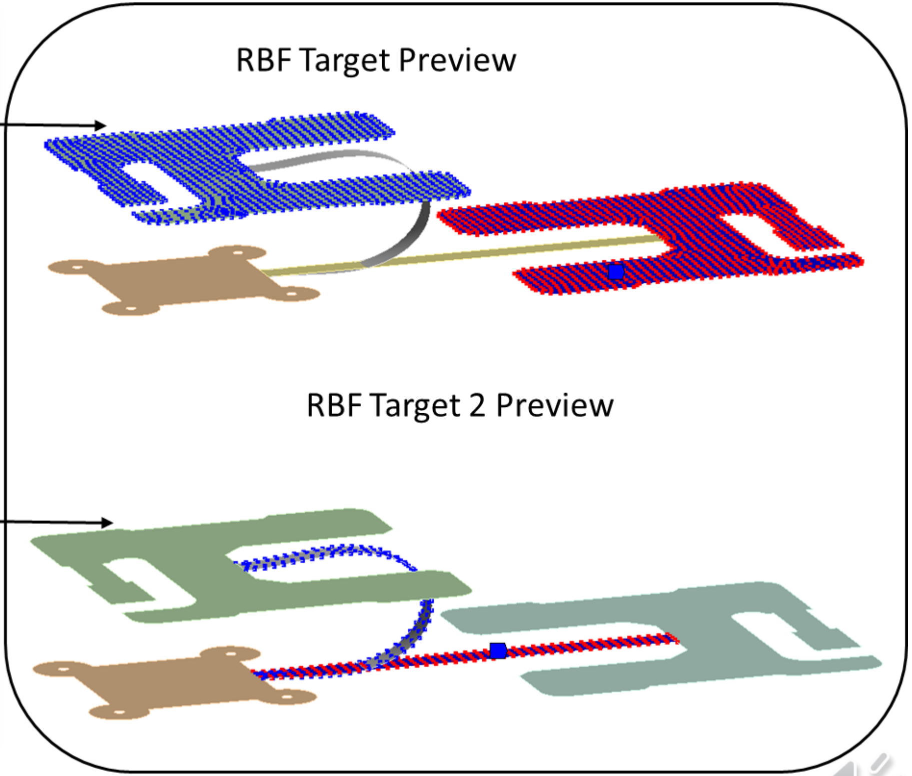


Details of "RBF Target"

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Body
General	
Transformation	Rotation
Rotation System Definition	By Coordinate System
Angle	180 °
Coordinate System	Coordinate System
Axis Used	y
RBF Function	
Degree	1
Combine Select	
Acting On	Deformed
If Selected Nodes Overlap	Override
Coord Filtering	No

Details of "RBF Target 2"

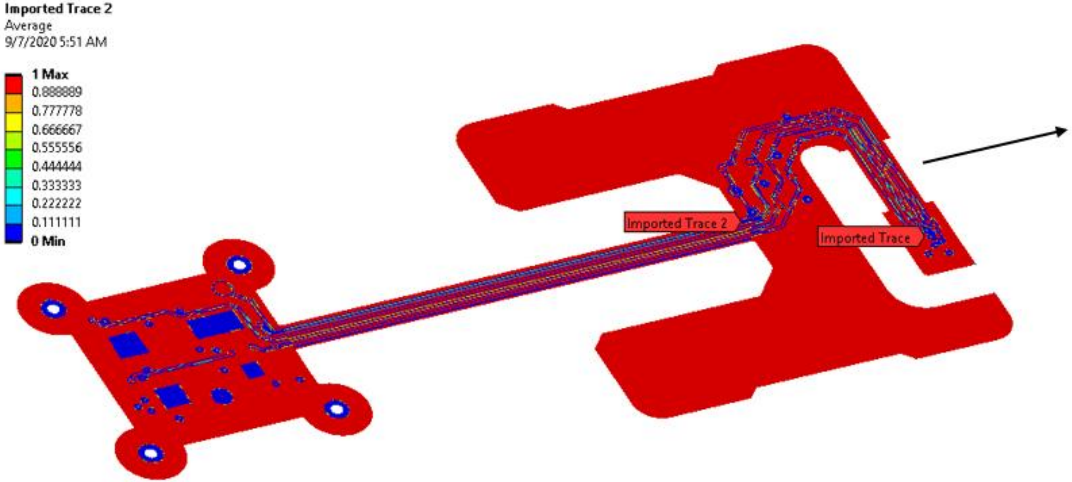
Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Body
General	
Transformation	Translation
Translation Definition	Manual
Delta x	0 in
Delta y	0 in
Delta z	0 in
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	No



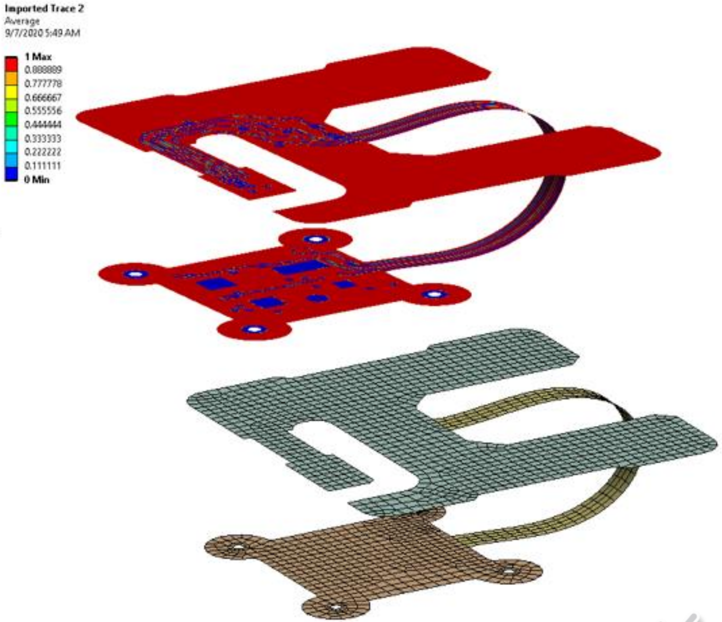
Note: The morphing is performed directly on the faces of the bodies with guides in the case of the flex (i.e., Sources along the edges)

Case 3: Analysis of a Rigid-Flex PCB (Results)

Trace Mapping on a flat PCB (uninstalled state)



Trace Mapping and Morphed Mesh of the Rigid-Flex PCB on the installed structure



Conclusions

- An advanced mesh morphing workflow based on radial basis function mesh morphing has been defined for curved/flexible PCB modelling
- Two strategies are considered
  - Use of **auxiliary 2d** geometry to guide the morphing process
  - **Full morphing** achieved by direct control of 3D shapes
- For all the geometries investigated the proposed approach gives good results both for the deformed shape and both for the traces representation
- The promising results observed in this initial study open to **further investigations** in this field:
  - Simplified **computation of strain and stress** by differentiating the RBF field.
  - Use of deformed configurations to **guide/restart full FEA structural** assessment.
- For more information:
  - marco.biancolini@rbf-morph.com
  - sandeep.medikonda@ansys.com

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