ANSYS

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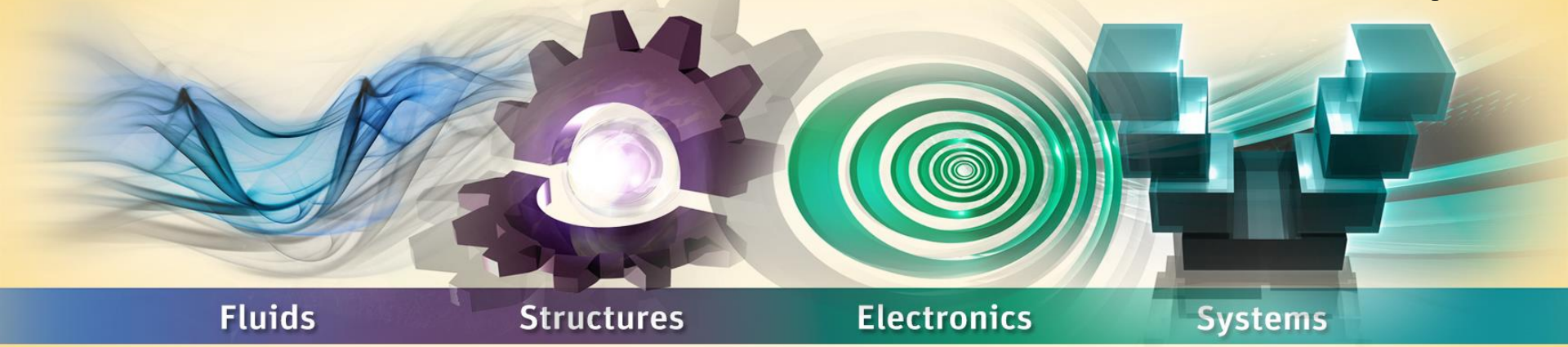
BGA Solder Joint Reliability Sensitivity Simulations Using ANSYS ACT Extension RBF Morph



Prof. Marco Evangelos Biancolini and Dr. Corrado Groth (University of Rome Tor Vergata)

Metin Ozen, Ph.D., (Ozen Engineering, Inc.)

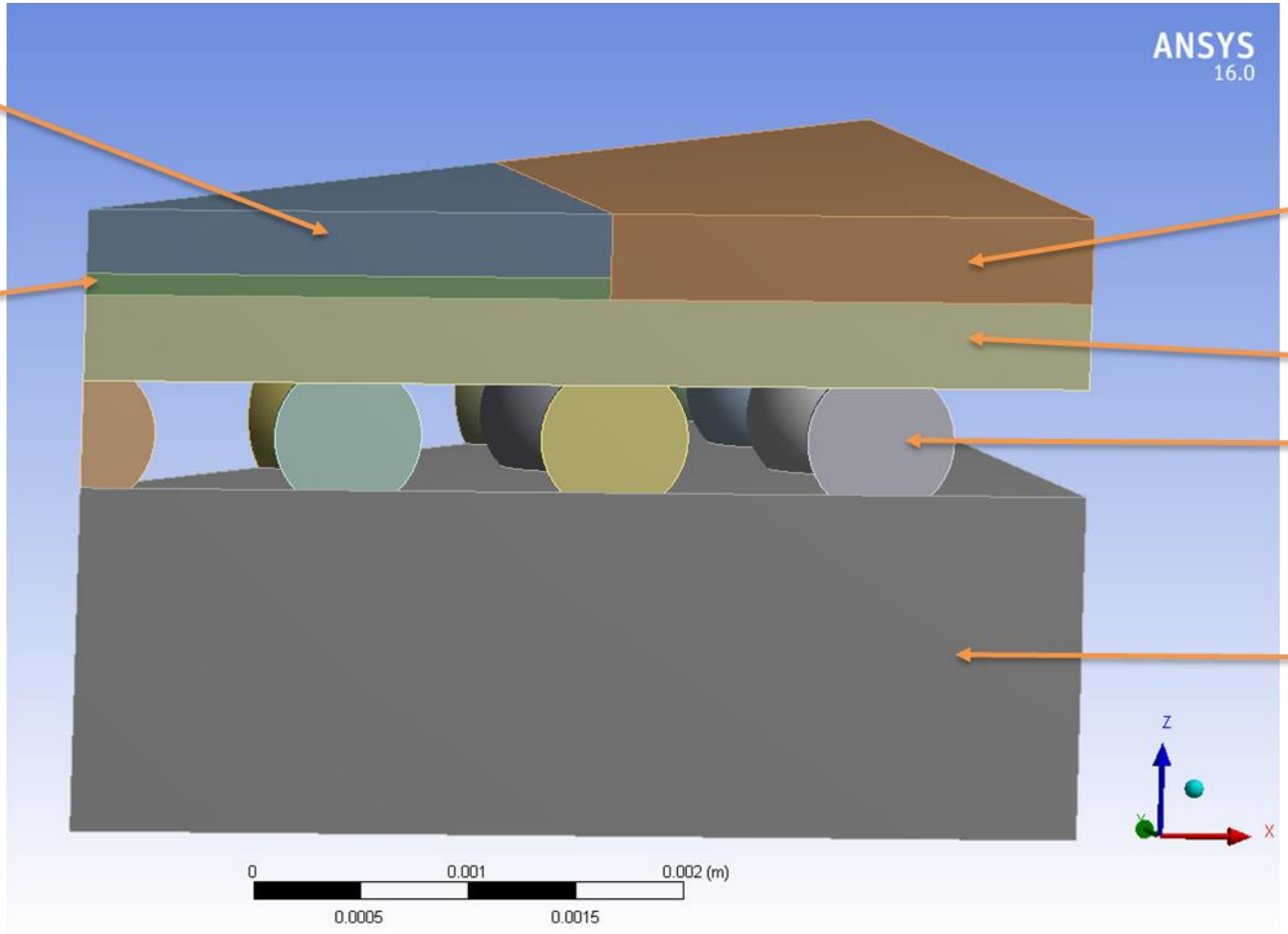
Ozen

OBJECTIVE

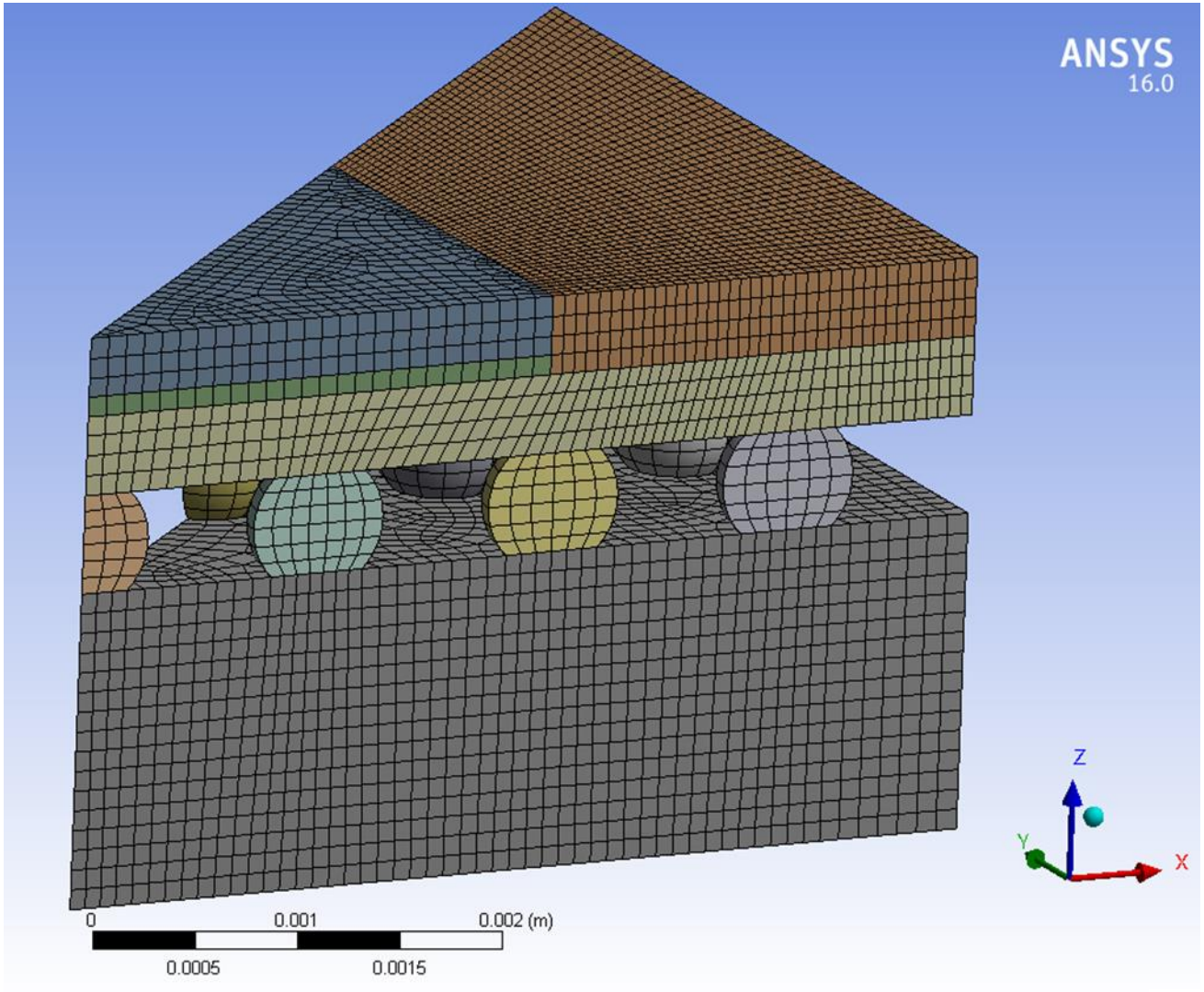
The objective here is to show how

1. **RBF Morph ACT can be used in BGA Solder Joint Reliability sensitivity simulations,**
2. **Geometric parameters can be converted to mesh morphing without regenerating the geometry and remeshing, and**
3. **Ball shape affects the stresses in a solder joint.**

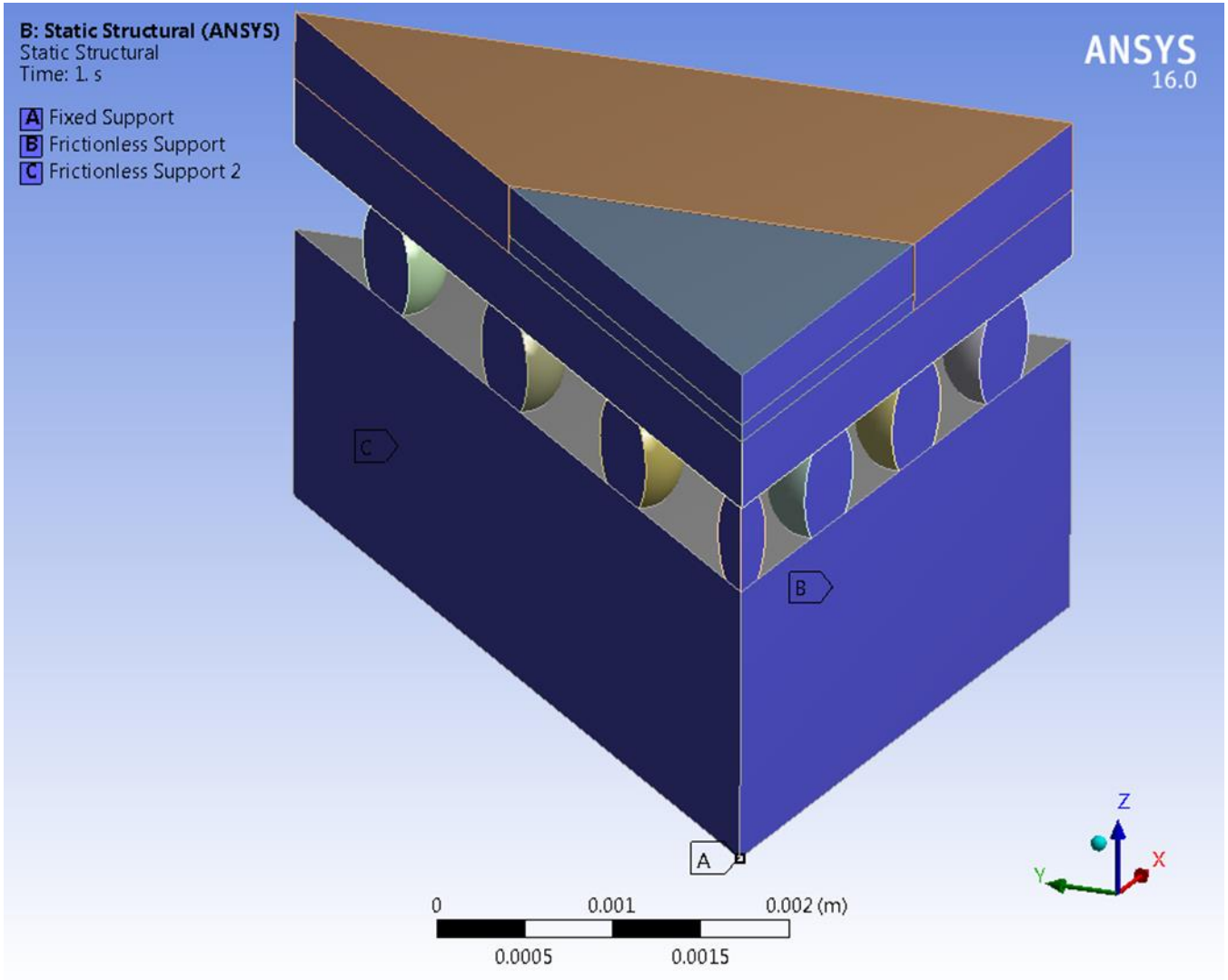
GEOMETRY



MESH

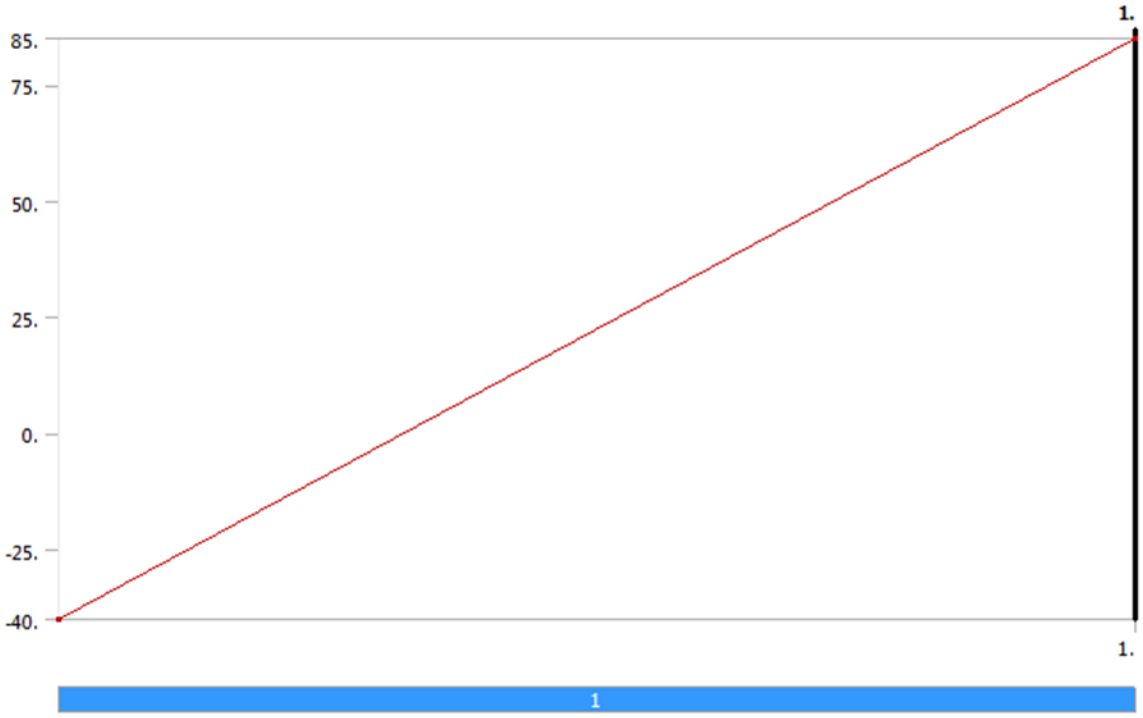


BOUNDARY CONDITIONS



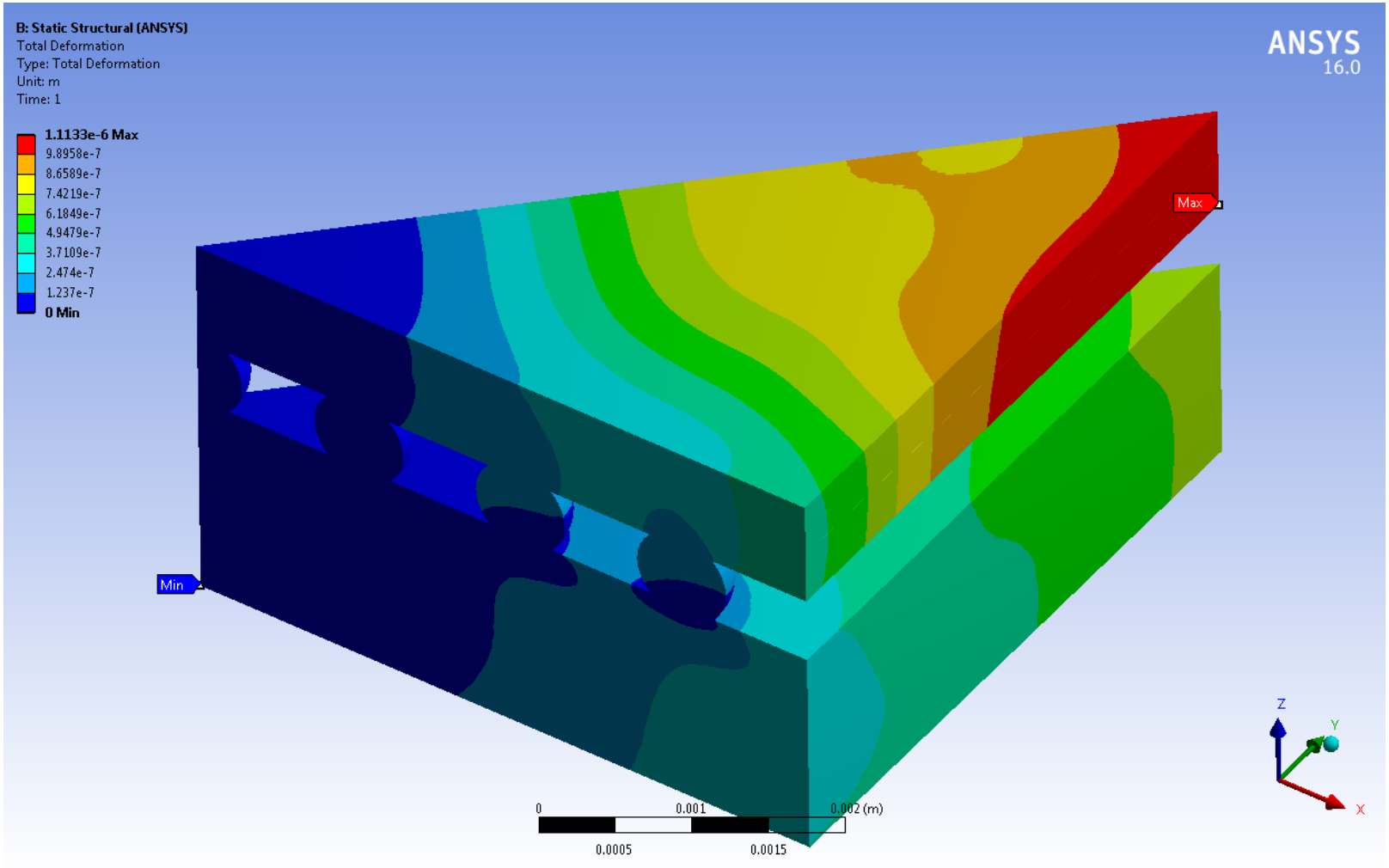
BOUNDARY CONDITIONS

Thermal Condition: -40 deg C to 85 deg. C

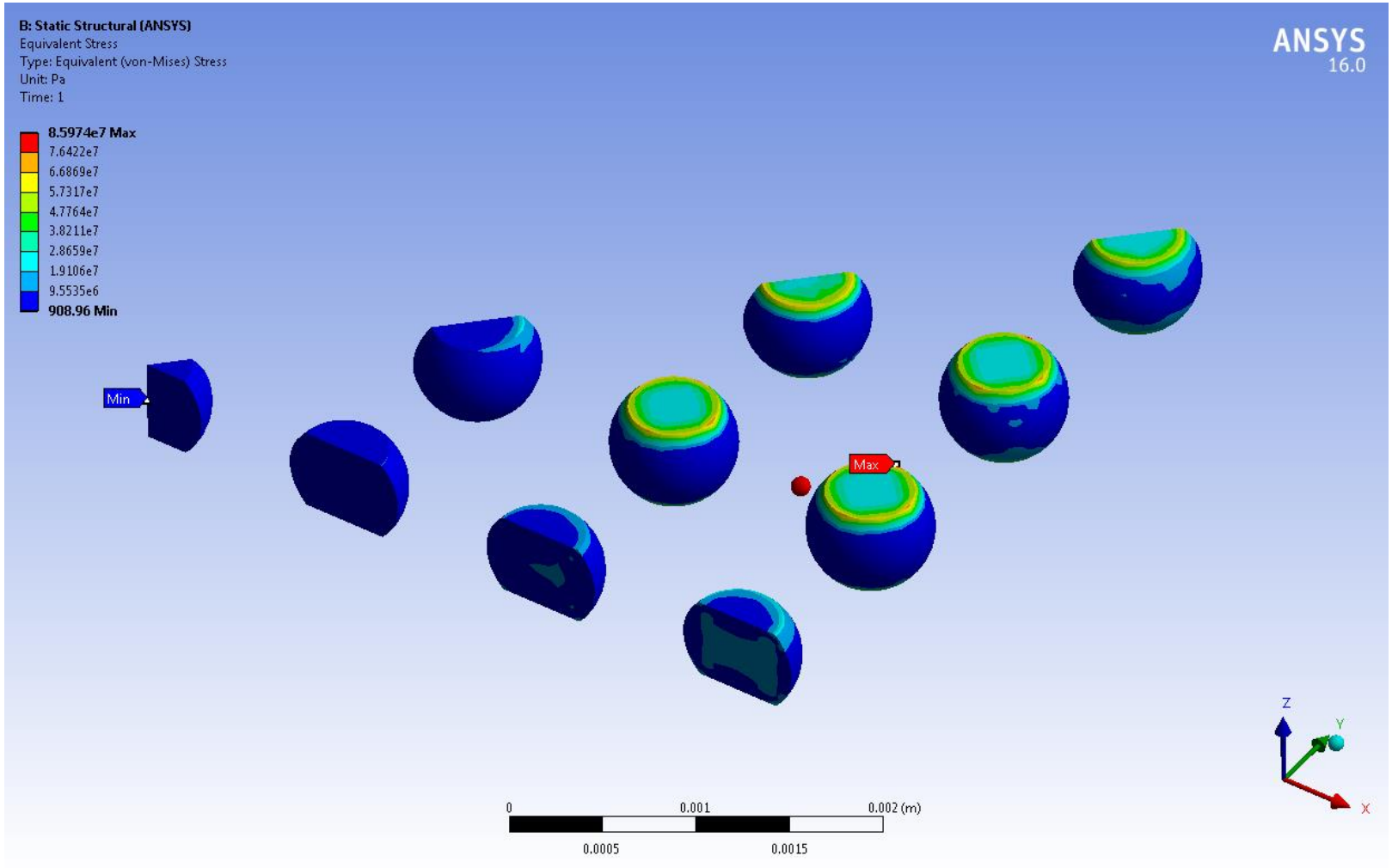


	Steps	Time [s]	Temperature [°C]
1	1	0.	-40.
2	1	1.	85.
*			

RESULTS

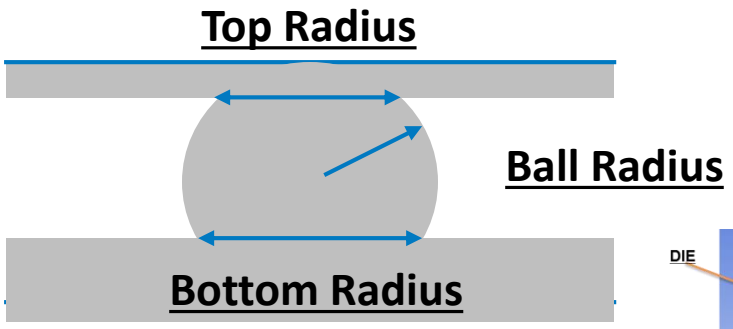


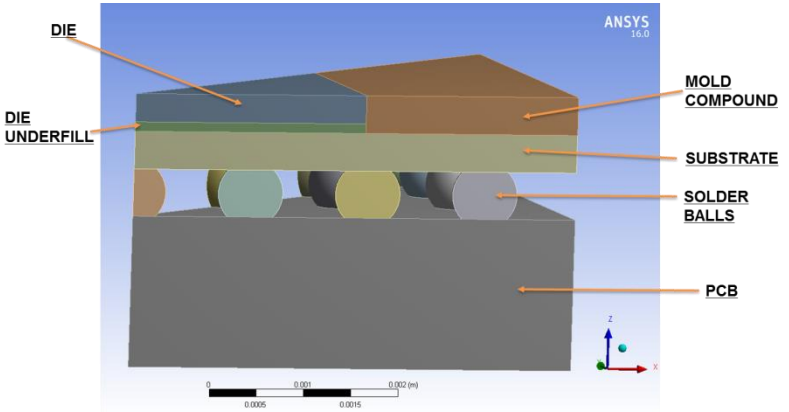
RESULTS



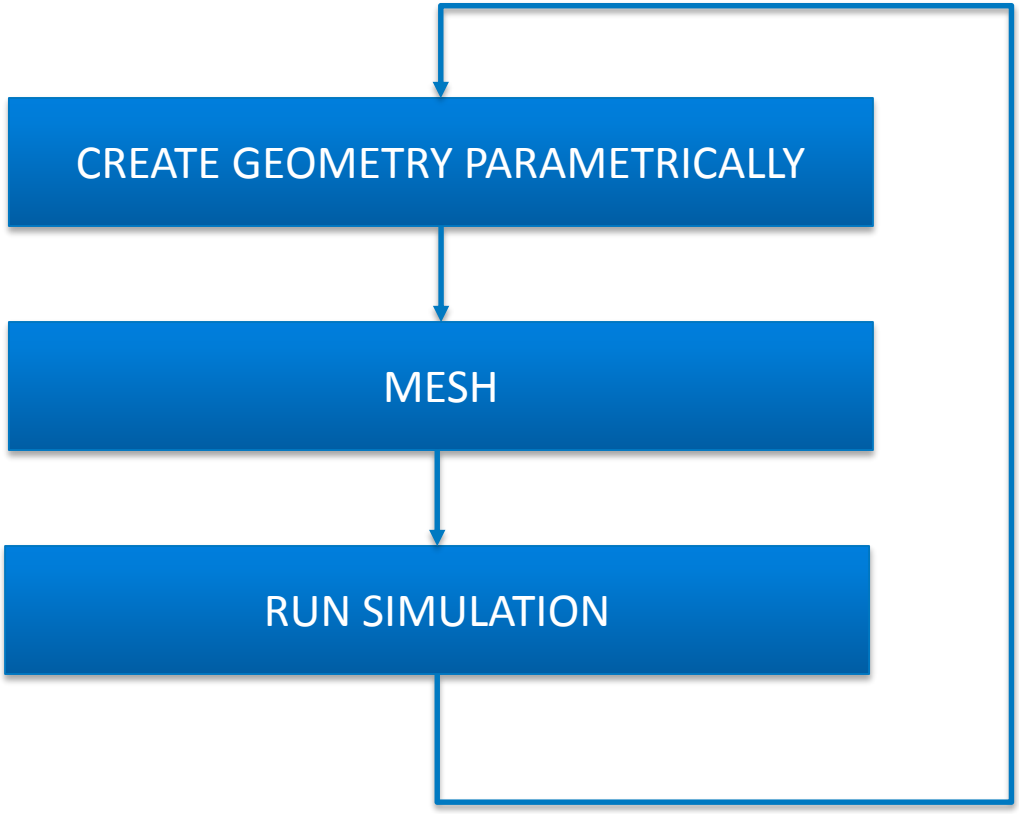
OBJECTIVE

- **Minimize the maximum value of Equivalent (von-Mises) Stress on "Solder Balls" by looking at a variation of:**
  - **Solder Ball Radius**
  - **Different radii at the top of the ball than the bottom of the ball**

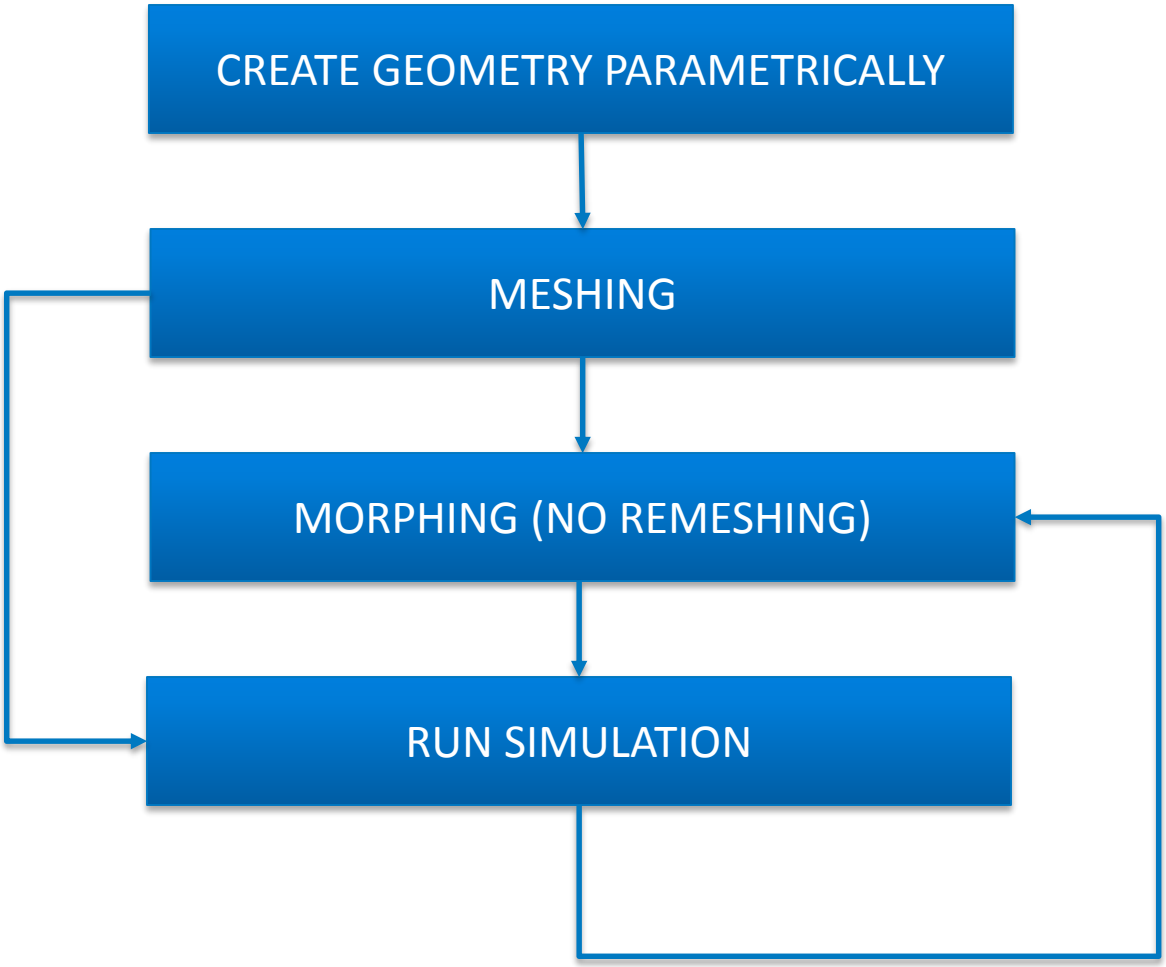




CURRENT PROCEDURE

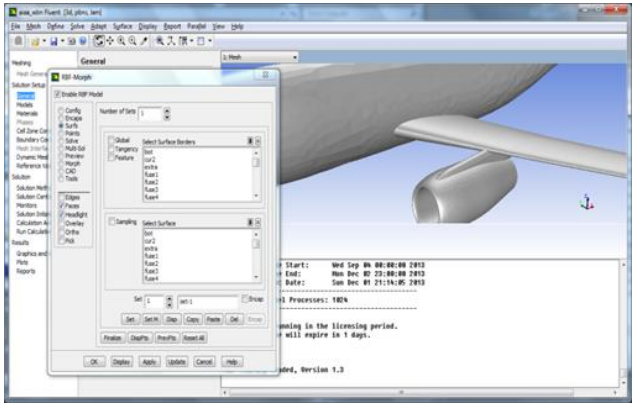


PROCEDURE USING RBF MORPH ACT



WHAT IS RBF-MORPH?

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.

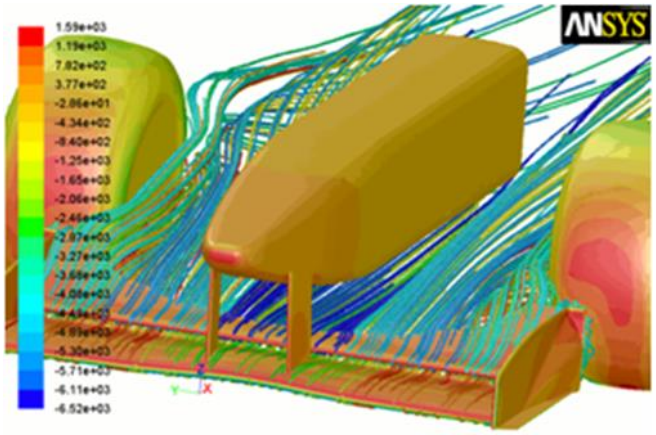


RBF Morph is an independent software-house and vendor. Their main product is RBF Morph™, that is a unique morpher that combines a very accurate control of the geometrical parameters with an extremely fast mesh smoothing properly designed to be integrated in advanced computational optimization procedures.

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

WHAT IS RBF-MORPH?

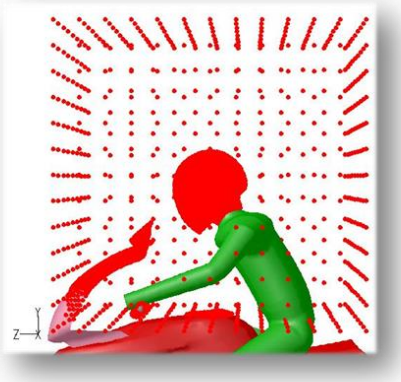
The RBF Morph tool had its inception in 2008 as on-demand solution for a Formula 1 top team. The need was a novel technology able to change the shape of large CFD numerical models as fast as possible. The final result had been so good that the technology was packaged in a commercial software product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



MESH MORPHING WITH RBF

- A system of Radial Basis Functions is used to fit a solution for the mesh movement/Morphing, from a list of source points and their displacements.
- Radial Basis Function interpolation is used to derive the displacement in any location in the space, each component of the displacement is interpolated:

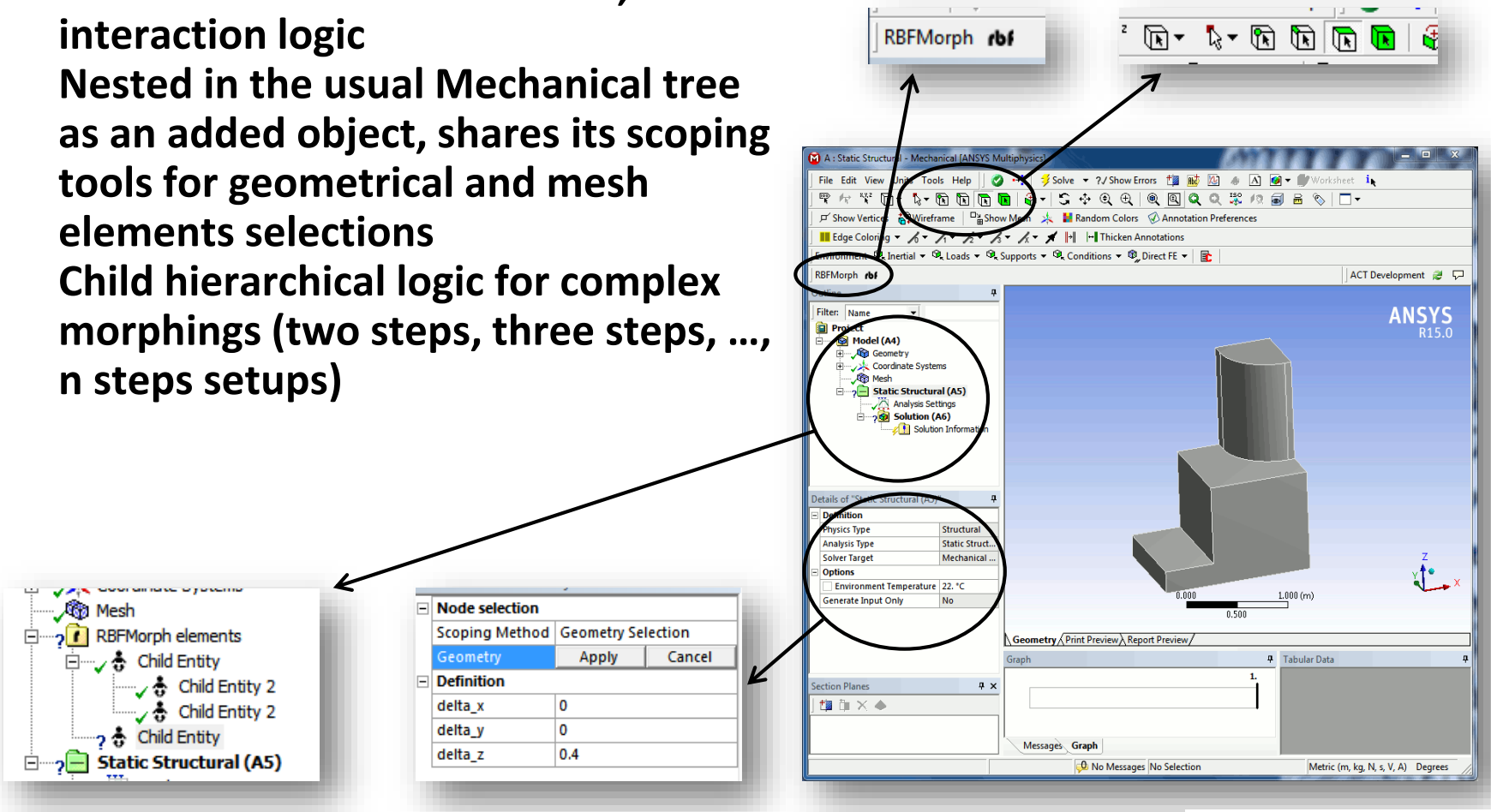
$$\begin{cases} v_x = s_x(\mathbf{x}) = \sum_{i=1}^{N} \gamma_i^x \phi\left(\left\|\mathbf{x}-\mathbf{x}_{k_i}\right\|\right) + \beta_1^x + \beta_2^x x + \beta_3^x y + \beta_4^x z \\ v_y = s_y(\mathbf{x}) = \sum_{i=1}^{N} \gamma_i^y \phi\left(\left\|\mathbf{x}-\mathbf{x}_{k_i}\right\|\right) + \beta_1^y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



- RBF are recognized as one of the best mathematical tool for mesh morphing. The main issue is about performances required for the solution of large dataset.

ACT EXTENSION FOR MECHANICAL

- **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**
- **Child hierarchical logic for complex morphings (two steps, three steps, …, n steps setups)**

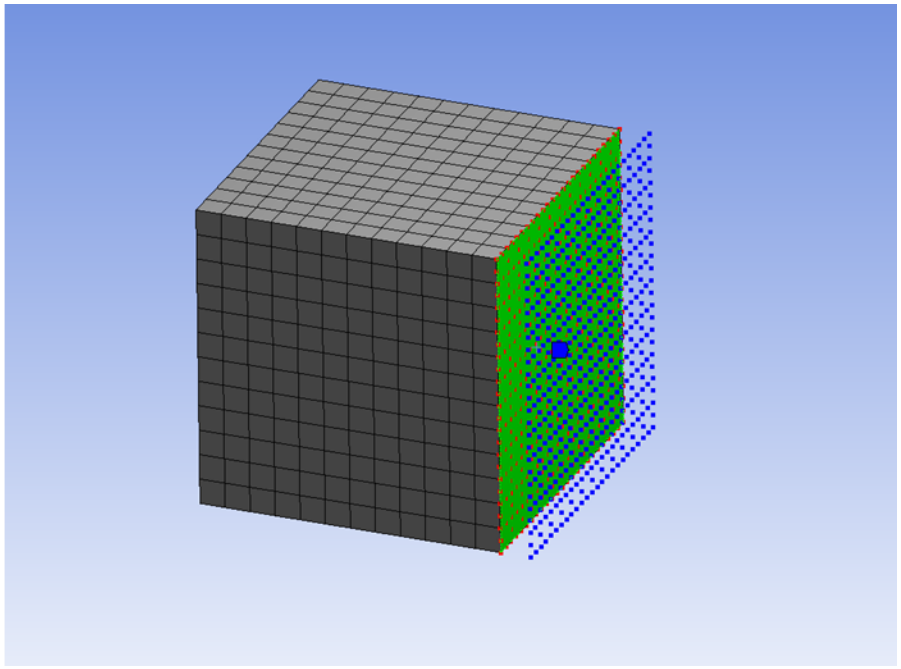


WHY MESH MORPHING?

- 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.

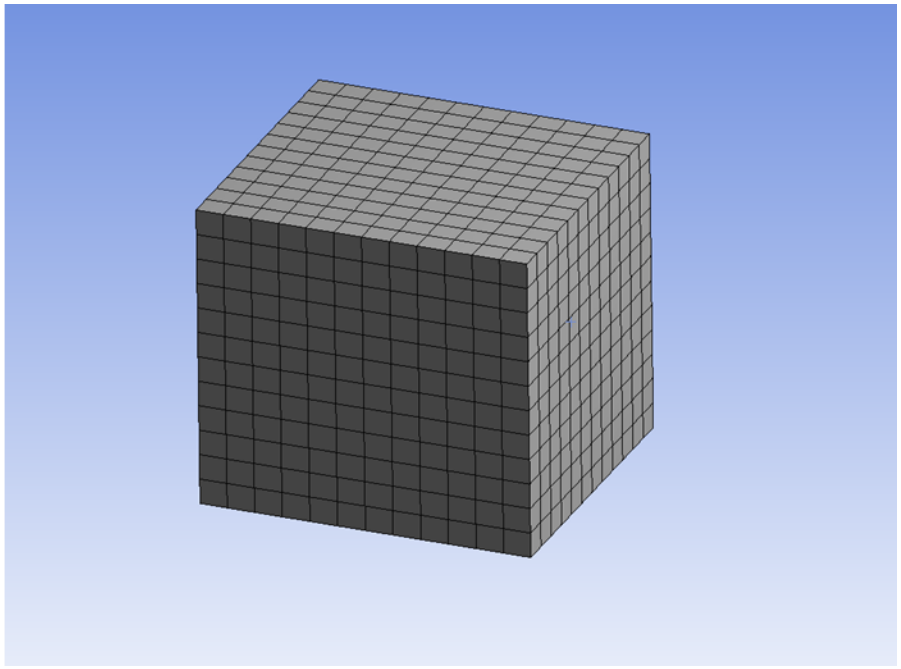
MORPHING OPTIONS: TRANSLATION

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Translation
Delta x	0.1 [m]
Delta y	0 [m]
Delta z	0 [m]
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



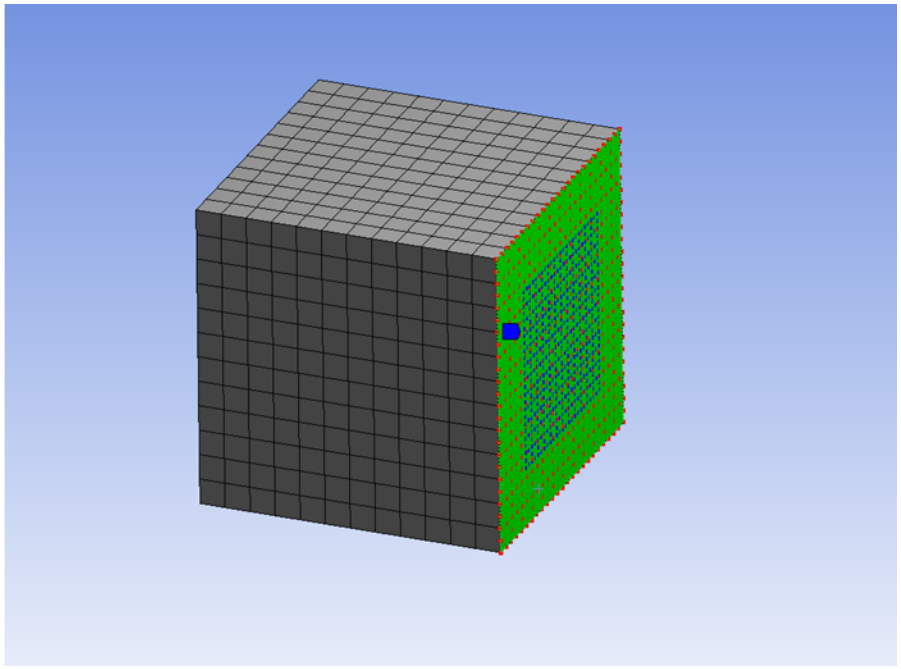
MORPHING OPTIONS: TRANSLATION

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Translation
Delta x	0.1 [m]
Delta y	0 [m]
Delta z	0 [m]
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



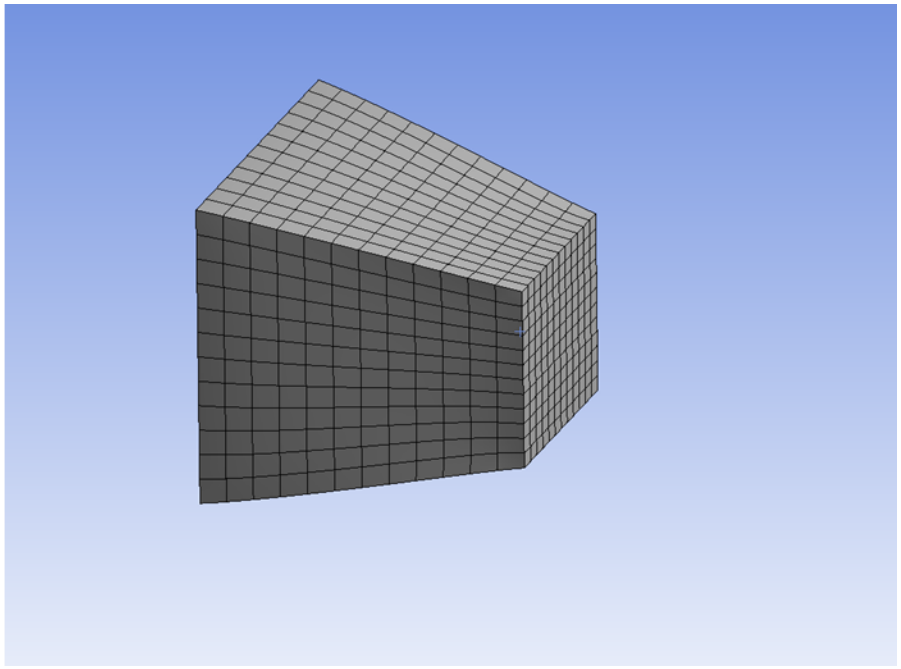
MORPHING OPTIONS: SCALING

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Scaling
Scaling System Definition	By Coordinate System
Scaling x	0.6
Scaling y	0.6
Scaling z	1
Coordinate System	face_center
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



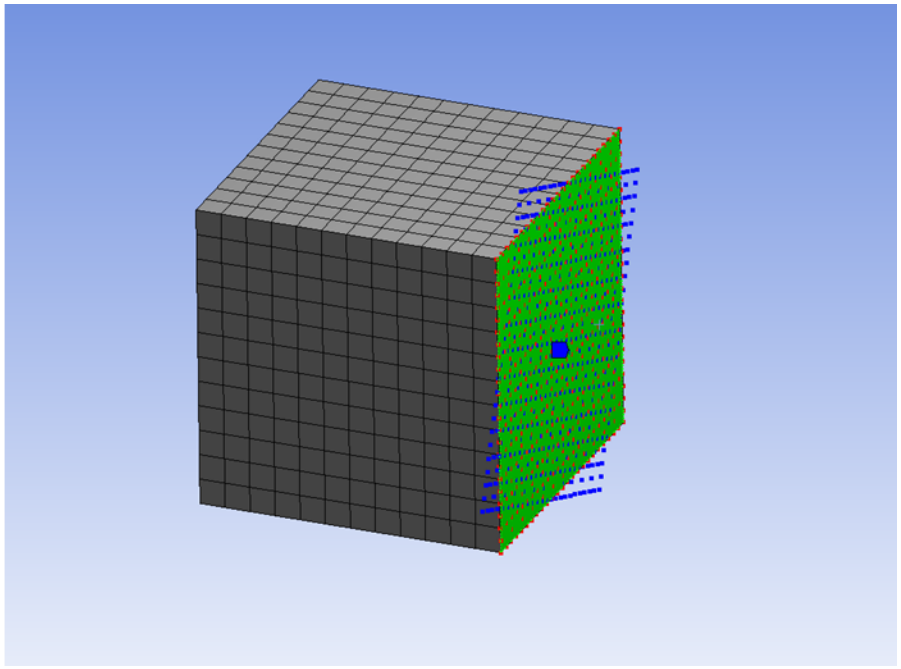
MORPHING OPTIONS: SCALING

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Scaling
Scaling System Definition	By Coordinate System
Scaling x	0.6
Scaling y	0.6
Scaling z	1
Coordinate System	face_center
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



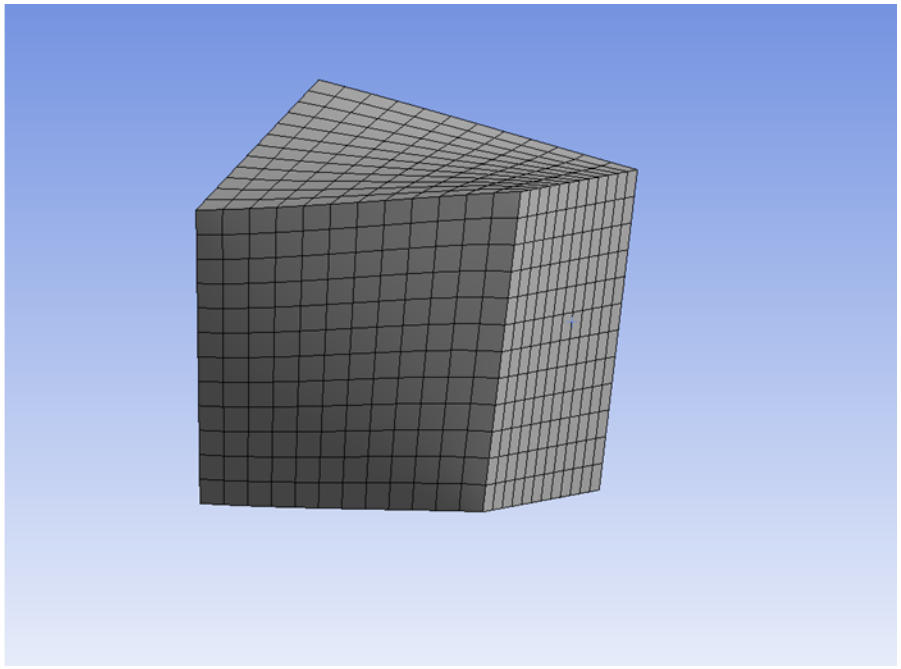
MORPHING OPTIONS: ROTATION

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Rotation
Rotation System Definition	By Coordinate System
Angle	20 [°]
Coordinate System	face_center
Axis Used	z
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



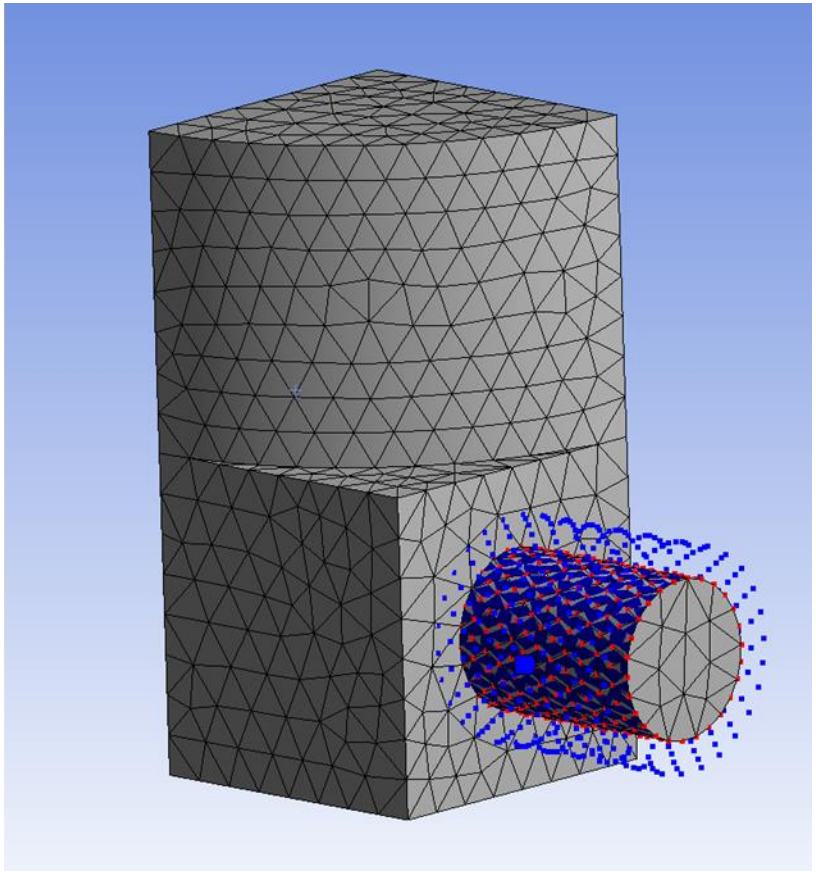
MORPHING OPTIONS: ROTATION

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Rotation
Rotation System Definition	By Coordinate System
Angle	20 [°]
Coordinate System	face_center
Axis Used	z
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



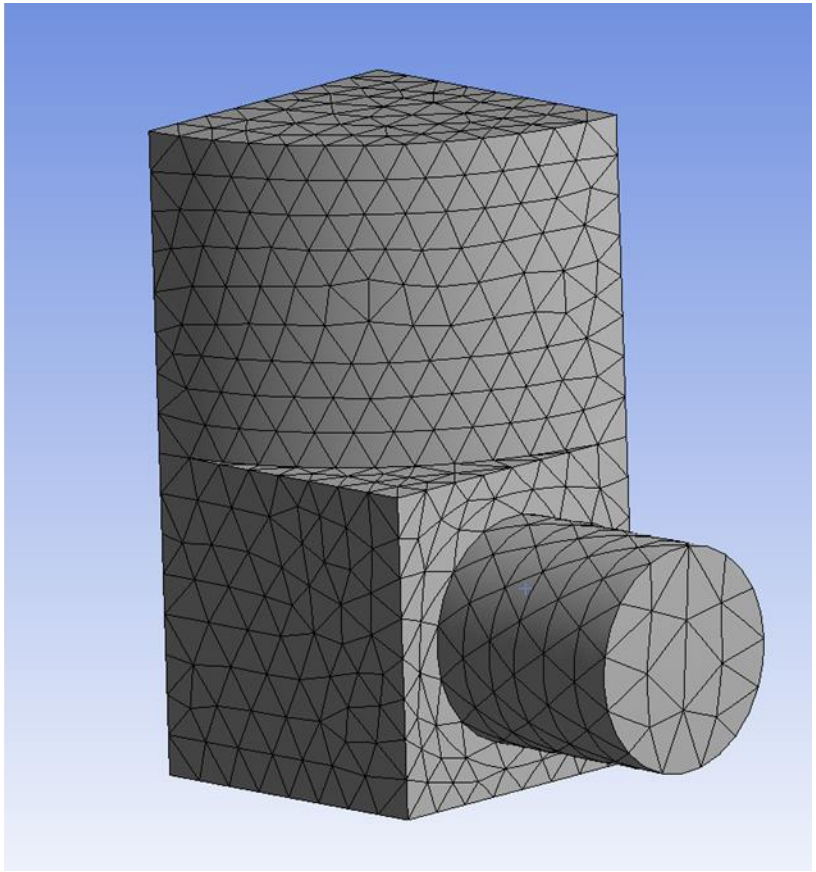
MORPHING OPTIONS: SURFACE OFFSET

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Surface Offset
Surface Offset	0.1 [m]
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



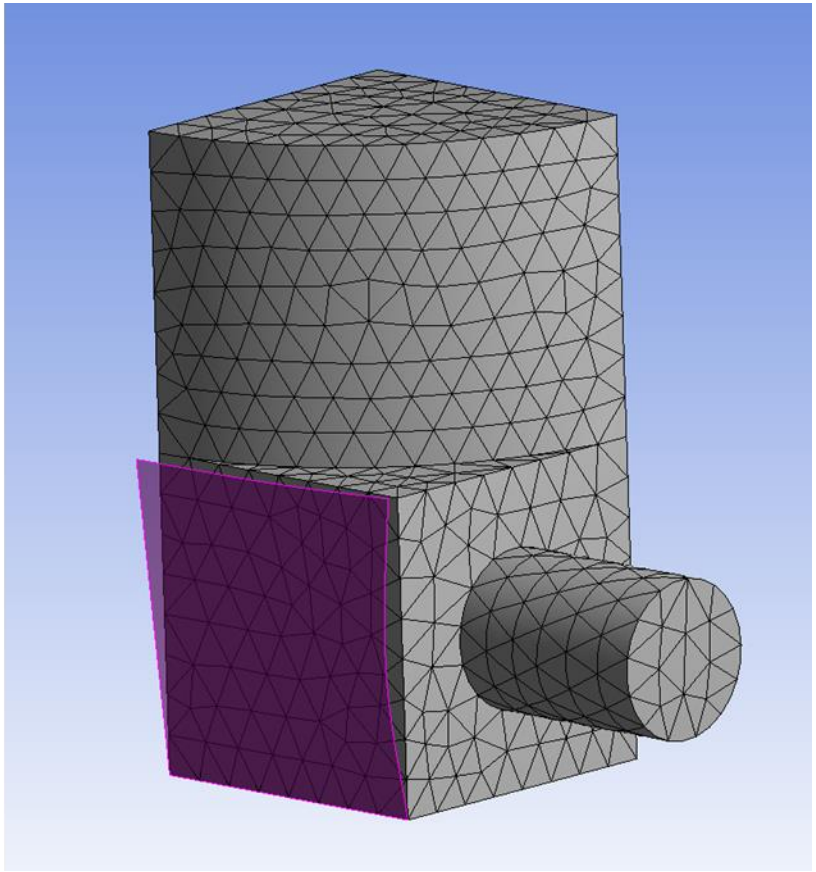
MORPHING OPTIONS: SURFACE OFFSET

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Surface Offset
Surface Offset	0.1 [m]
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



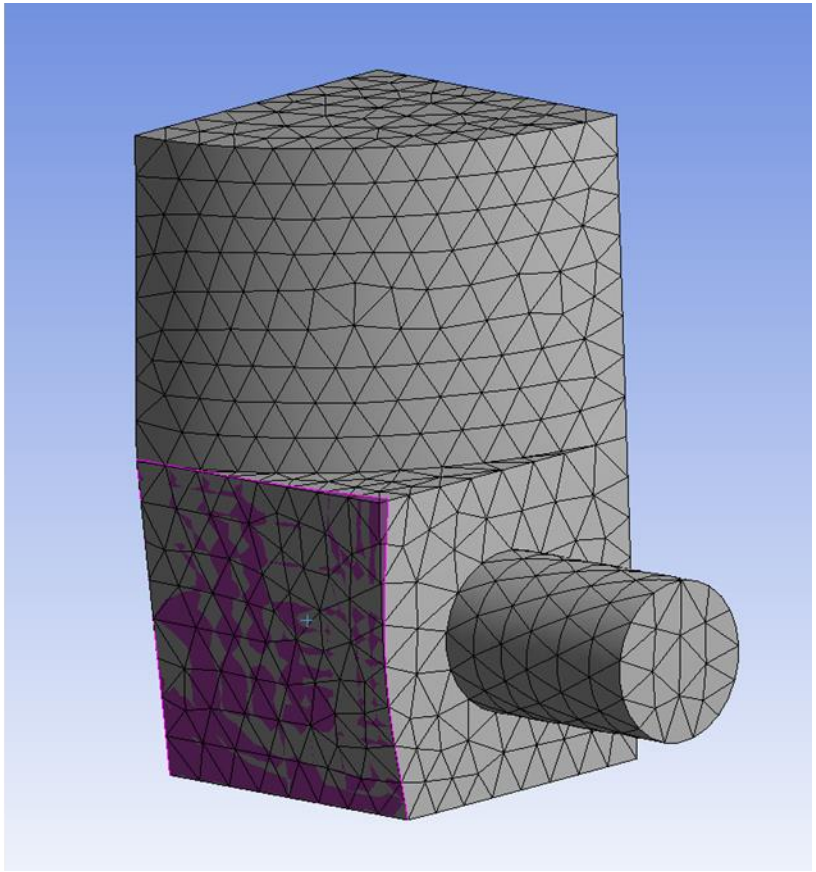
MORPHING OPTIONS: SURFACE TARGET

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Surface Targeting
Percentage	1
Geometry Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override

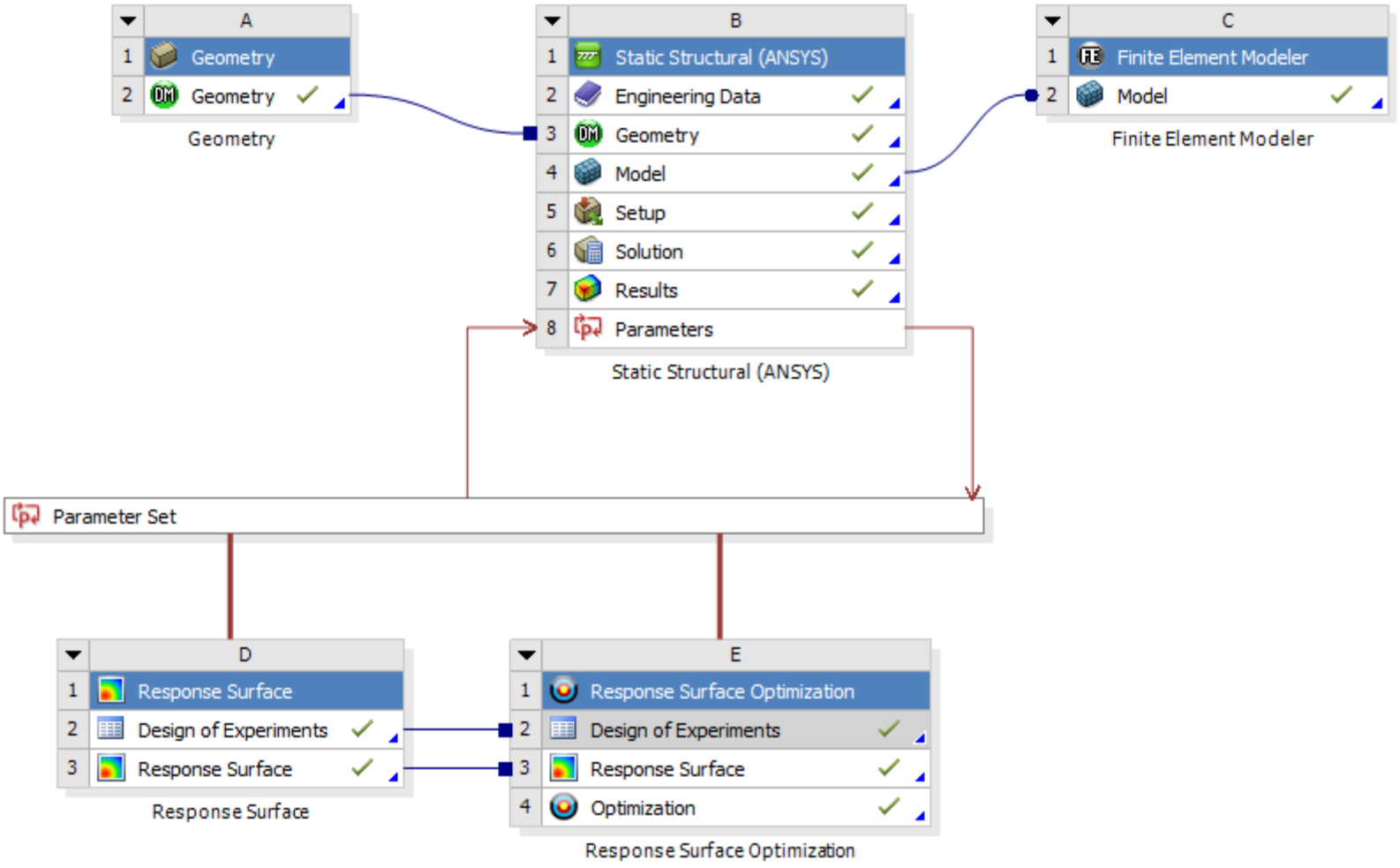


MORPHING OPTIONS: SURFACE TARGET

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Transformation	Surface Targeting
Percentage	1
Geometry Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override



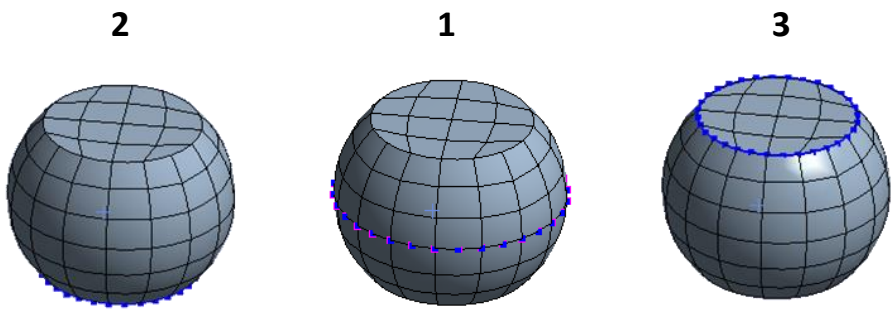
PROJECT SCHEMATIC

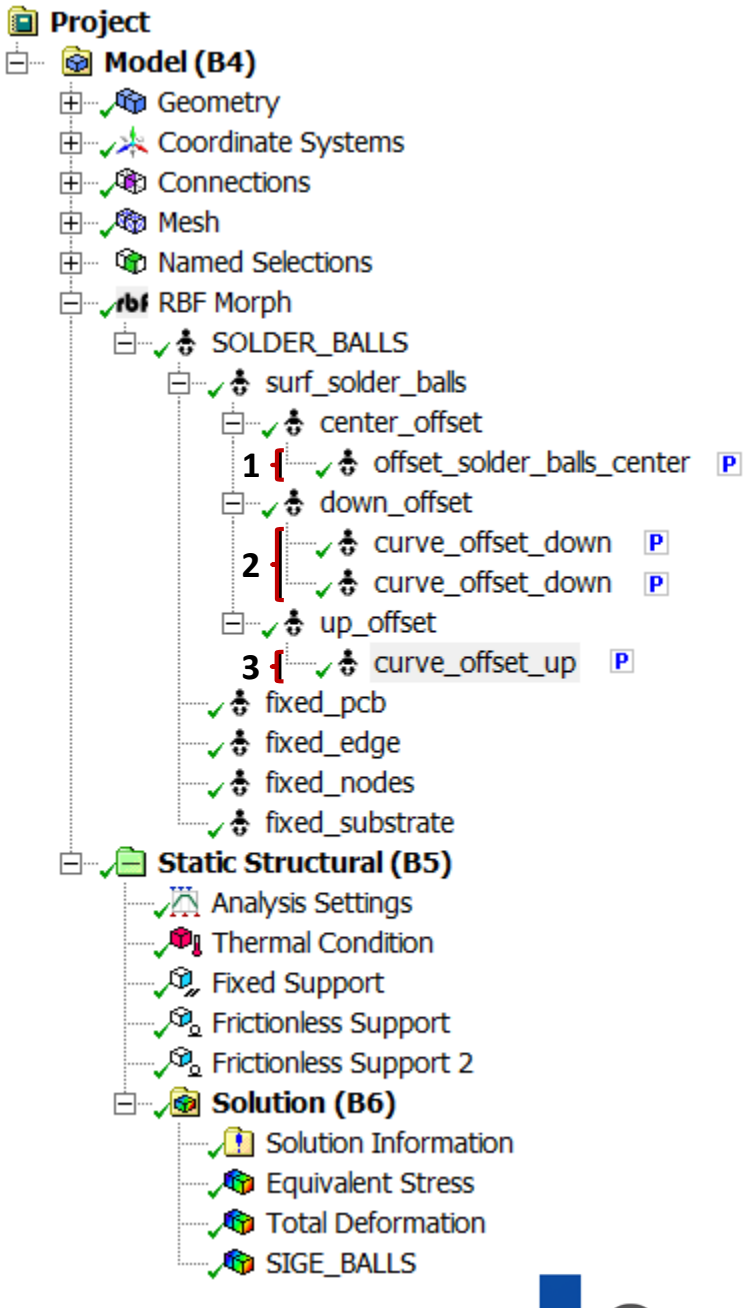


PROJECT TREE

Action Commands:

- **Preview**
- **Morph**





PARAMETERS

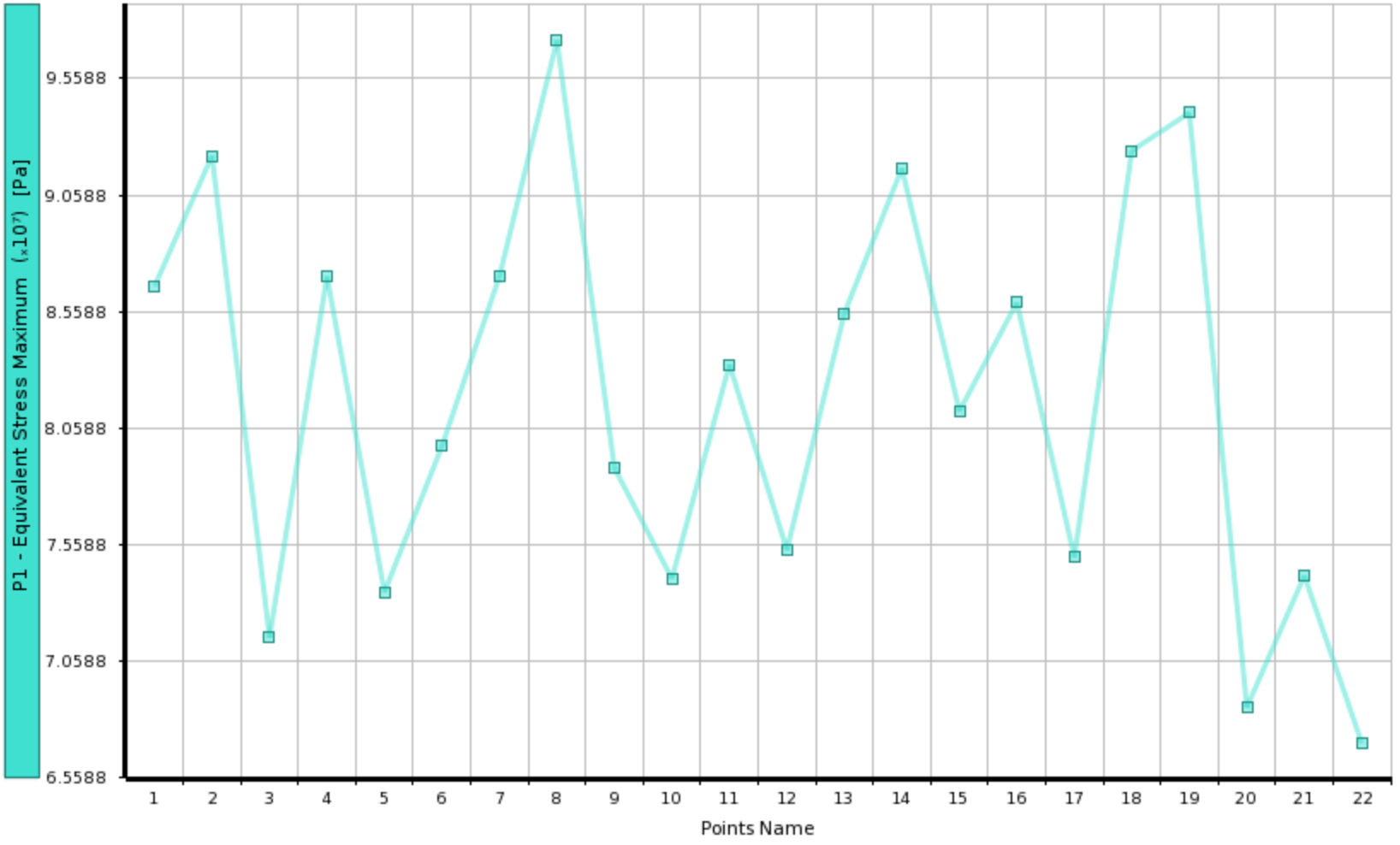
	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	Static Structural (ANSYS) (B1)			
4	P2	offset_solder_balls_center Surface Offset	0	m
5	P3	curve_offset_up Curve Offset	0	m
6	P4	curve_offset_down Curve Offset	0	m
7	P5	curve_offset_down Curve Offset	0	m
*	New input parameter	New name	New expression	
9	Output Parameters			
10	Static Structural (ANSYS) (B1)			
11	P1	Equivalent Stress Maximum	8.5974E+07	Pa
*	New output parameter		New expression	
13	Charts			

Expression	- P4
Usage	Input

TABLE OF DESIGN POINTS

	A	B	C	D	E	F
1	Name	P2 - offset_solder_balls_center Surface Offset (m)	P3 - curve_offset_up Curve Offset (m)	P4 - curve_offset_down Curve Offset (m)	P1 - Equivalent Stress Maximum (Pa)	P5 - curve_offset_down Curve Offset (m)
2	1 DP 13	1E-05	4E-05	1E-05	8.6673E+07	-1E-05
3	2 DP 16	4E-05	0	2E-05	9.2266E+07	-2E-05
4	3 DP 5	-7E-05	1E-05	-5E-05	7.1617E+07	5E-05
5	4 DP 15	3E-05	-7E-05	6E-05	8.7096E+07	-6E-05
6	5 DP 6	-6E-05	-5E-05	-4E-05	7.3565E+07	4E-05
7	6 DP 19	7E-05	-6E-05	-6E-05	7.9826E+07	6E-05
8	7 DP 14	2E-05	6E-05	5E-05	8.7099E+07	-5E-05
9	8 DP 18	6E-05	3E-05	4E-05	9.7219E+07	-4E-05
10	9 DP 9	-3E-05	-4E-05	0	7.8883E+07	0
11	10 DP 8	-4E-05	2E-05	7E-05	7.4147E+07	-7E-05
12	11 DP 11	-1E-05	-2E-05	-2E-05	8.3329E+07	2E-05
13	12 DP 7	-5E-05	5E-05	-3E-05	7.5369E+07	3E-05
14	13 DP 12	0	-1E-05	-1E-05	8.552E+07	1E-05
15	14 DP 17	5E-05	7E-05	-7E-05	9.1734E+07	7E-05
16	15 DP 10	-2E-05	-3E-05	3E-05	8.1323E+07	-3E-05
17	16 DP 0	0	0	0	8.5974E+07	0
18	17 DP 1	-5E-05	0	0	7.5055E+07	0
19	18 DP 2	5E-05	0	0	9.2486E+07	0
20	19 DP 3	7.5E-05	0	0	9.4107E+07	0
21	20 DP 4	-7.5E-05	0	0	6.8627E+07	0
22	21 DP 20	-7.431E-05	7.4128E-05	6.5215E-05	7.427E+07	-6.5215E-05
23	22 DP 21	-7.3075E-05	-7.3524E-05	6.1283E-05	6.7094E+07	-6.1283E-05

TABLE OF DESIGN POINTS



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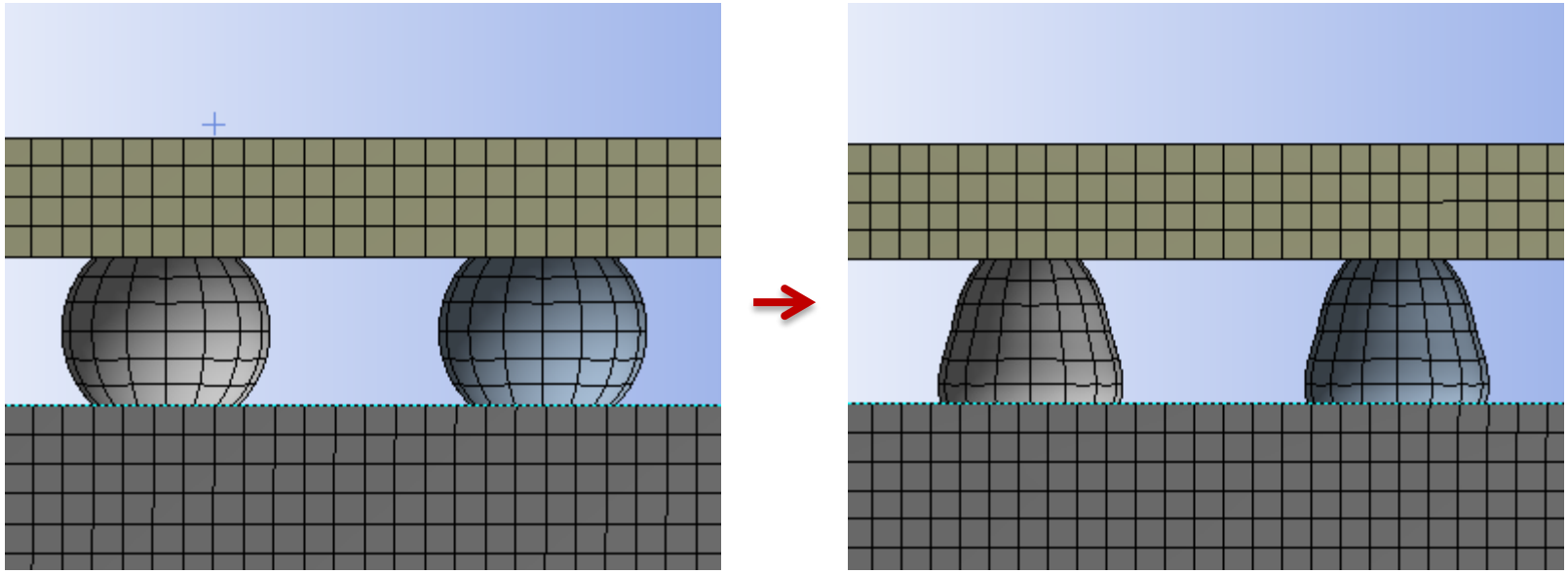
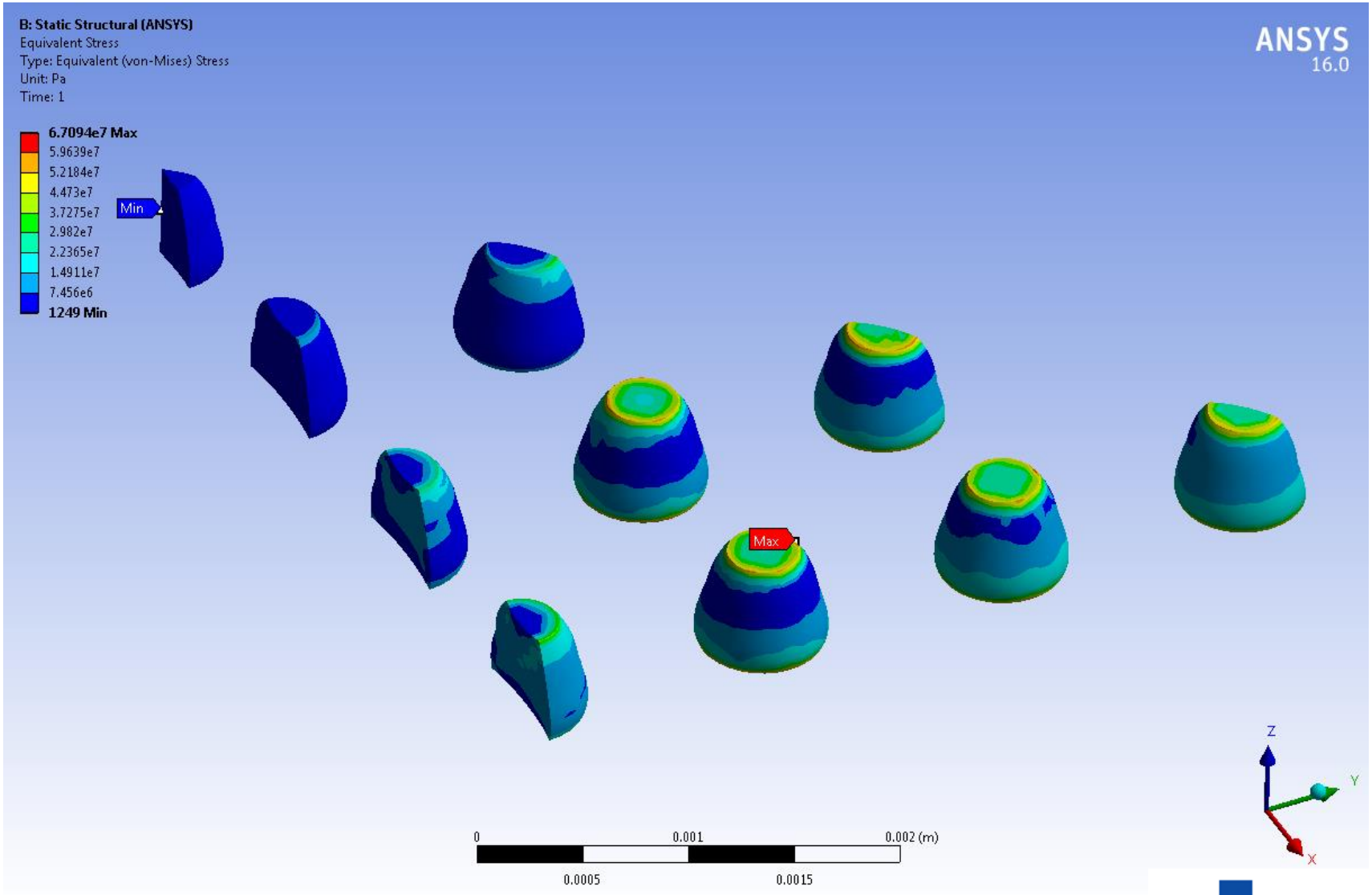


Baseline

Optimum

TABLE OF DESIGN POINTS



CONCLUSIONS

- 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)
- Basic capability of the first software prototype are demonstrated on a BGA Solder Joint Reliability Sensitivity Simulation

THANK YOU!

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- **Dr. Corrado Groth – University of Rome**
  - corrado.groth@uniroma2.it
- **Metin Ozen, Ph.D. – Ozen Engineering, Inc.**
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