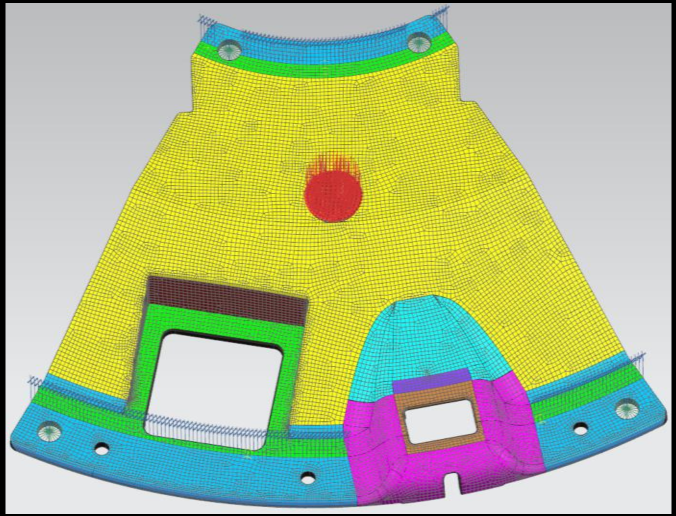
3D Printed Structures: Analysis Techniques



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Outline

- Background
- Structural Complexities
- Correlation Testing
- Three Approaches and Results
- Modeling the Covers
- Other Test Cases
- Changing Materials
- Acknowledgements
- Questions

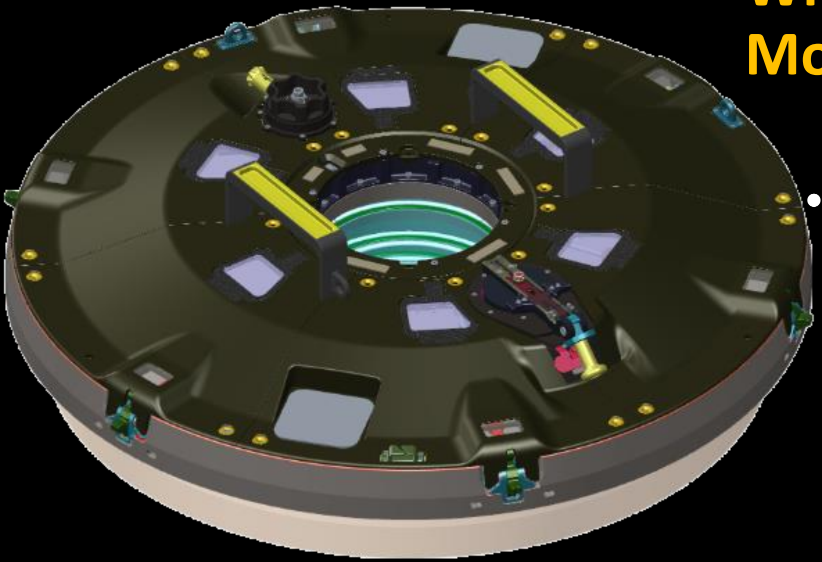
Project Background

- Orion EM-2 Docking Hatch Internal Covers
- Using Additive Manufacturing can save Weight, Manufacturing Time, and Cost
- Ultem and Pekk Do Not Have Properties as Well Defined As Aluminum and Analyzing them Becomes an Iterative Process
- Material Properties are Highly Process Dependent
- Changes in Material Due to Electrostatic Shock Build Up Concerns which Was Overkill Since it is Far From Electrical Components

Structural Complexities

What Made Analyzing the Covers Complex Apart from the Material Issues?

- The covers have regions of varying thickness. Portions are solid and other portions are constructed of sandwich structures which have a facesheet and core. Also part of the sandwich structure is printed at a 20 degree angle and part at a 0 degree orientation.



What Makes Analyzing Ultem More Difficult than Aluminum?

- A structure printed from Ultem can vary greatly in capability due to making simple changes such as fill, traces, and print direction. All of which necessitate testing of coupons for material properties and full scale part testing.

Model Correlation

What Testing was Done to Ascertain Material Properties for the FEM?

- Tensile Testing in a Sideways Print Orientation - Ultem
- Tensile Testing in a Vertical Print Orientation – Ultem
- Tensile Testing in a Sideways Print Orientation - Pekk
- Tensile Testing in a Vertical Print Orientation – Pekk
- 3-Point Bend of a Rectangular Sandwich Structure Specimen

What Other Testing was Done?

- Sandwich structure that had been printed in four different build configurations were tested. These tests were done in order to determine which printing techniques provide the best structural capability.

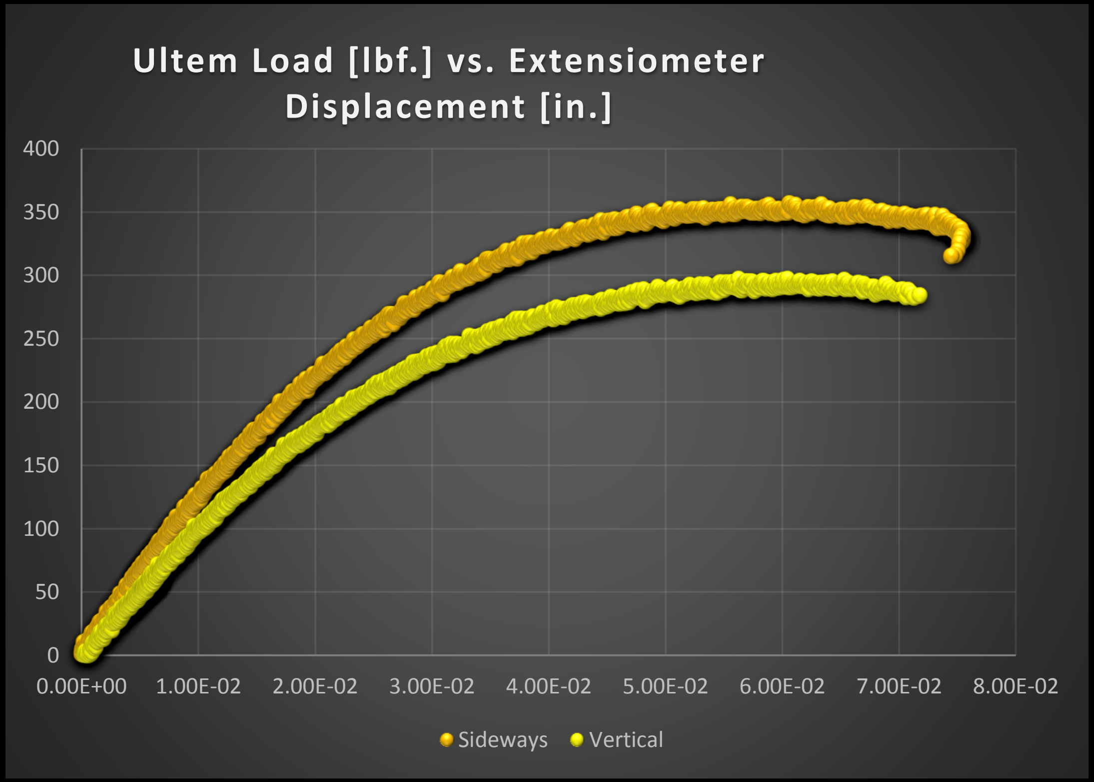
Ultem vs Pekk

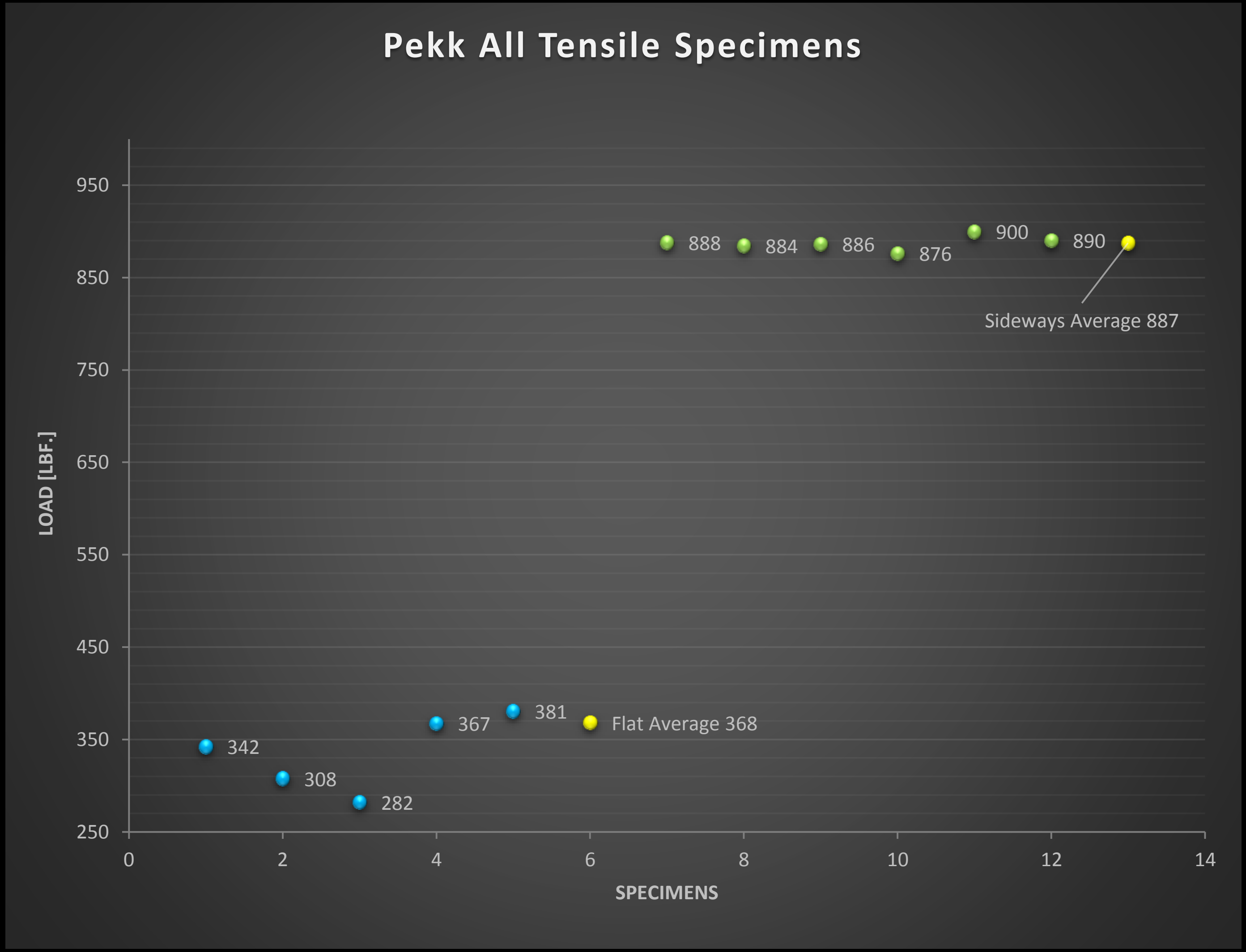
	Time *sec*	Load *lbf*	Extensometer *in*
			Ultem
7	Sideways	357	0.061
8	Flat	297	0.060

	Time *sec*	Load *lbf*	Extensometer *in*
			Vertical Pekk
9	77	342	0.013
10	64	308	0.012
11	64	282	0.010
12	68	367	0.014
13	83	381	0.015
14	83	368	0.013
Average	73	342	0.013
Standard Deviation	9	39	0.002
CV	**12%**	**11%**	**14%**

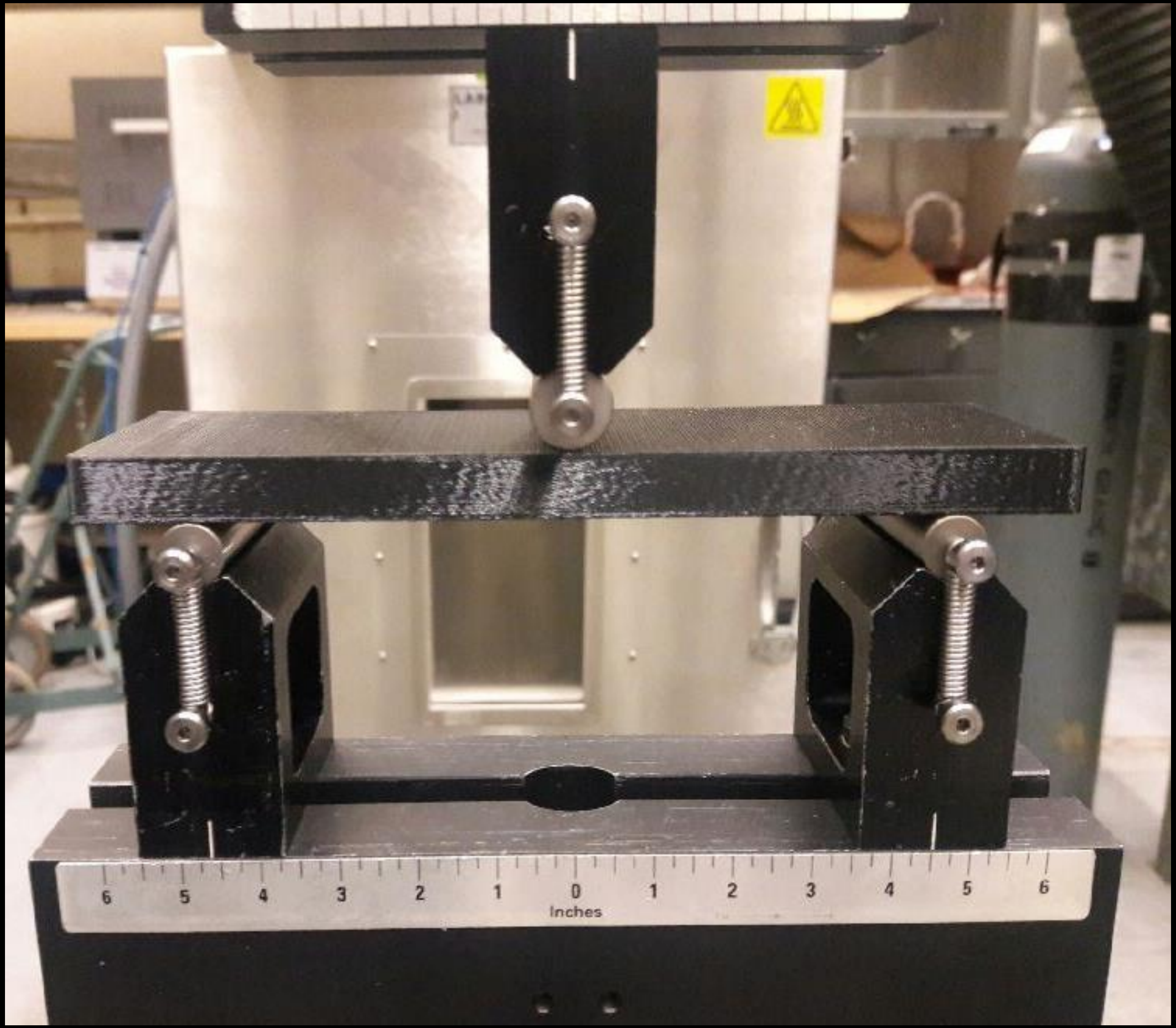
	Time *sec*	Load *lbf*	Extensometer *in*
			Sideways Pekk
15	170	888	0.042
16	168	884	0.039
17	163	886	0.042
18	167	876	0.044
19	165	900	0.044
20	162	890	0.042
Average	166	887	0.042
Standard Deviation	3	8	0.002
CV	**2%**	**1%**	**4%**

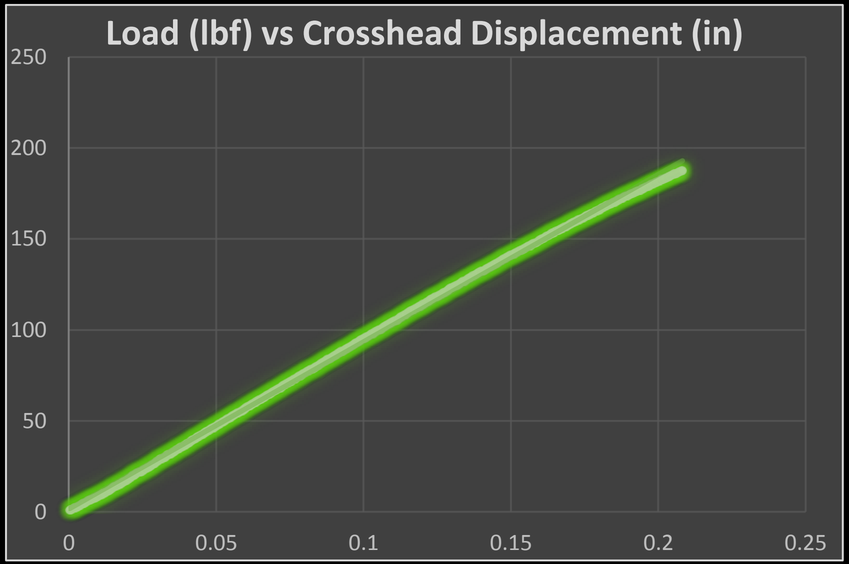
Ultem vs Pekk 2





3-Point Bending Test

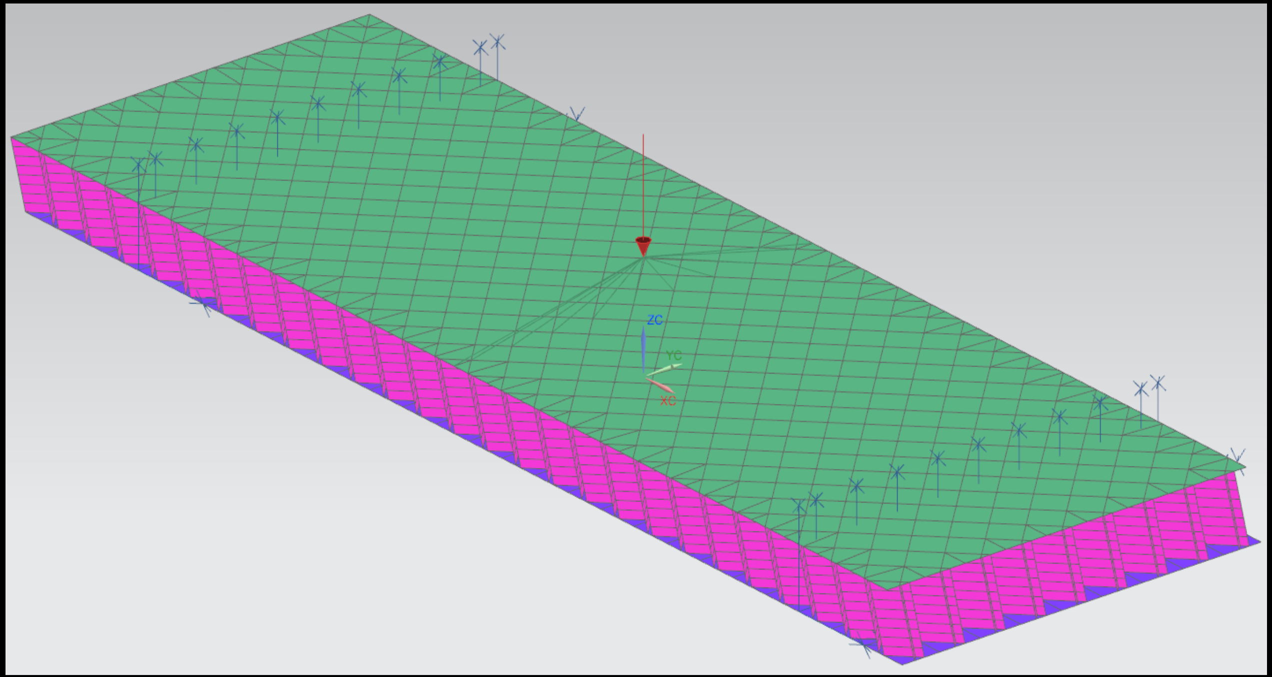


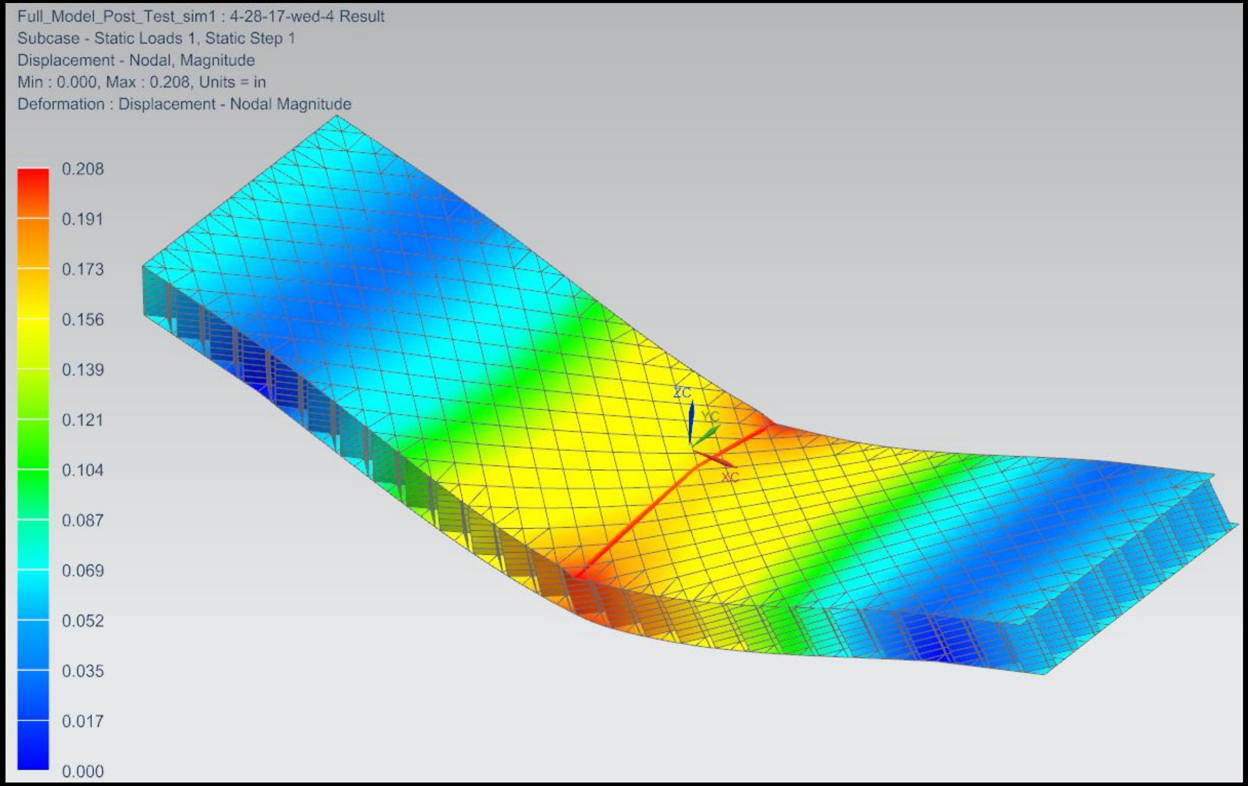


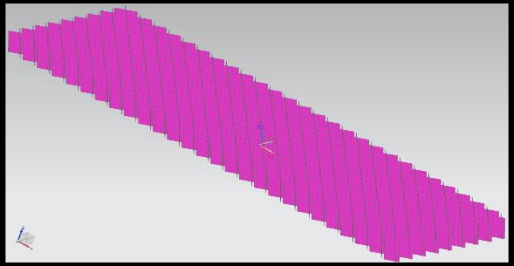
What Level Did the Specimen Fail At?

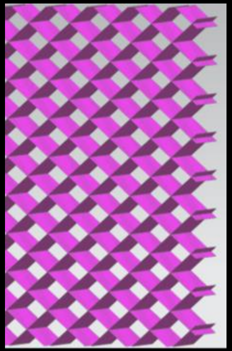
- The 3-point bend specimen failed at 188 pounds and reached a displacement of 0.208 inches.

Full Detailed Model

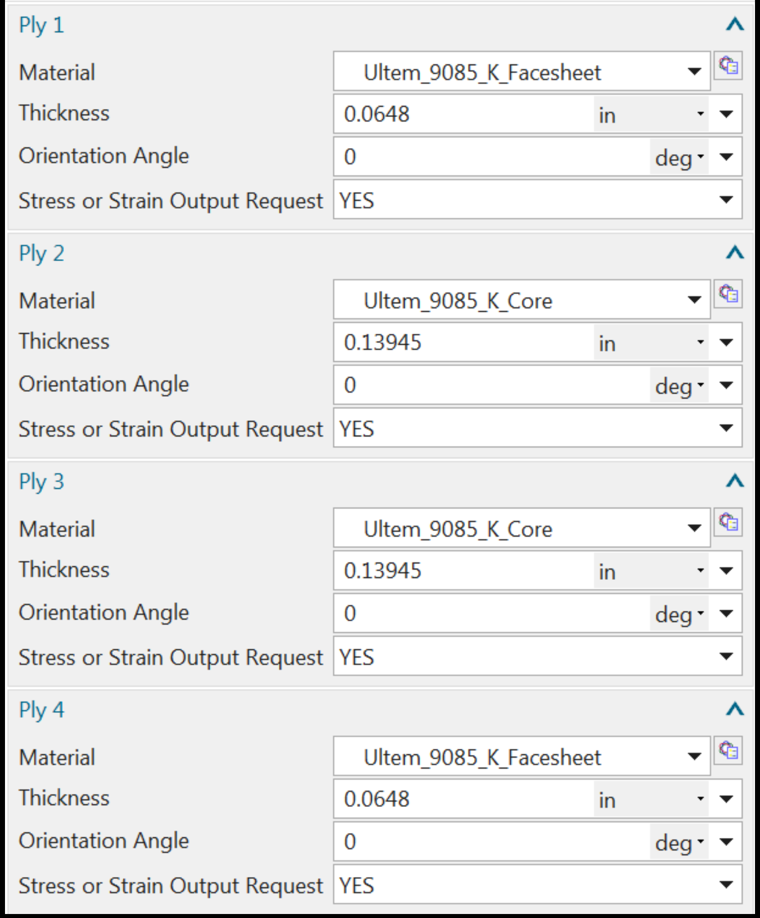


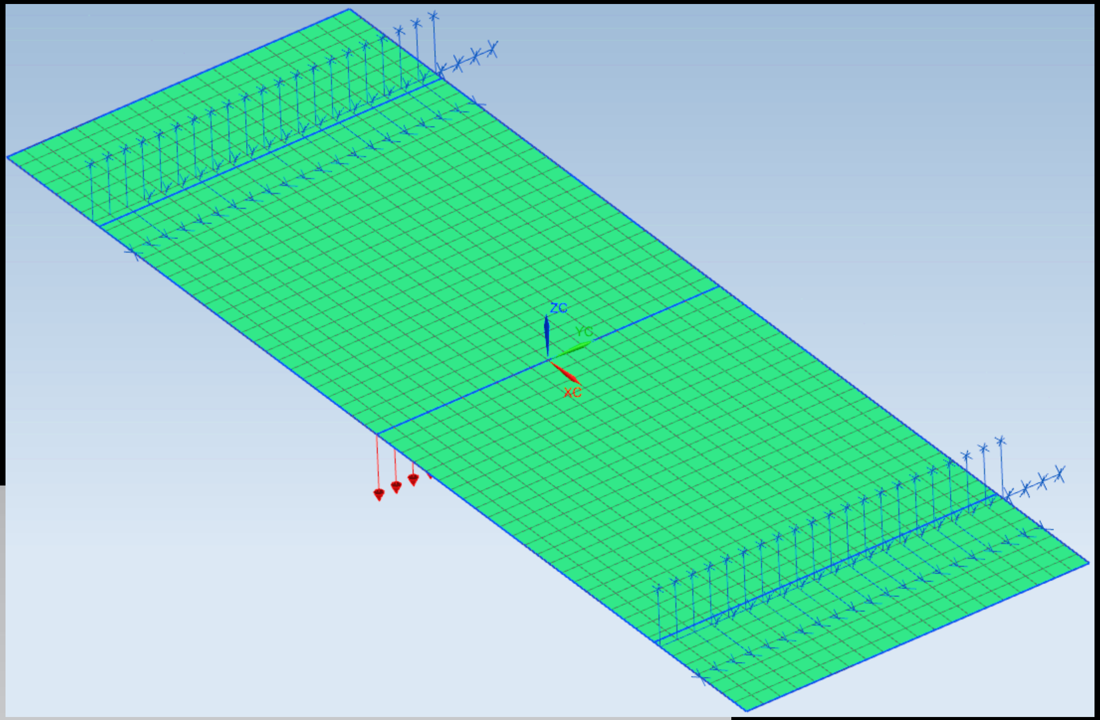


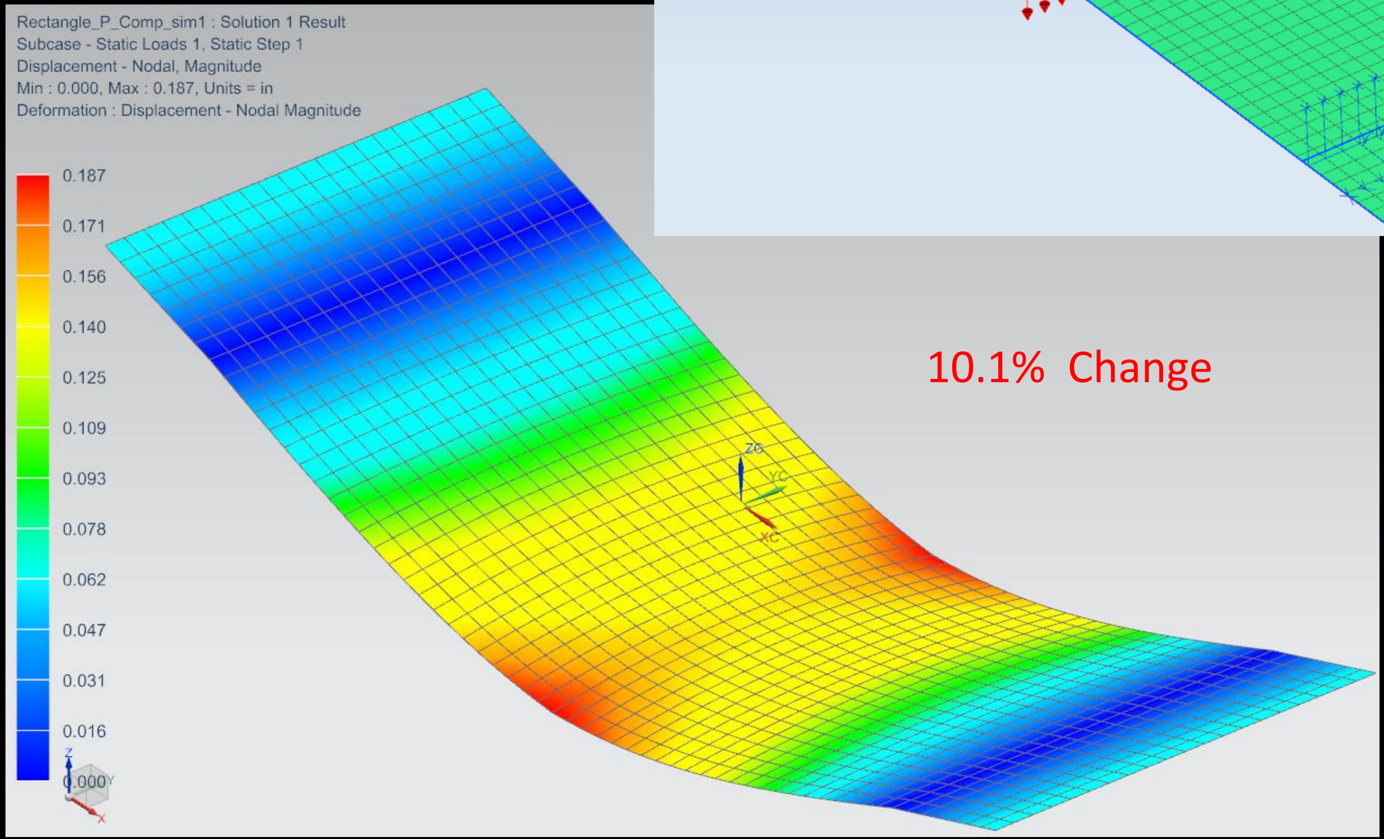




PComp Model

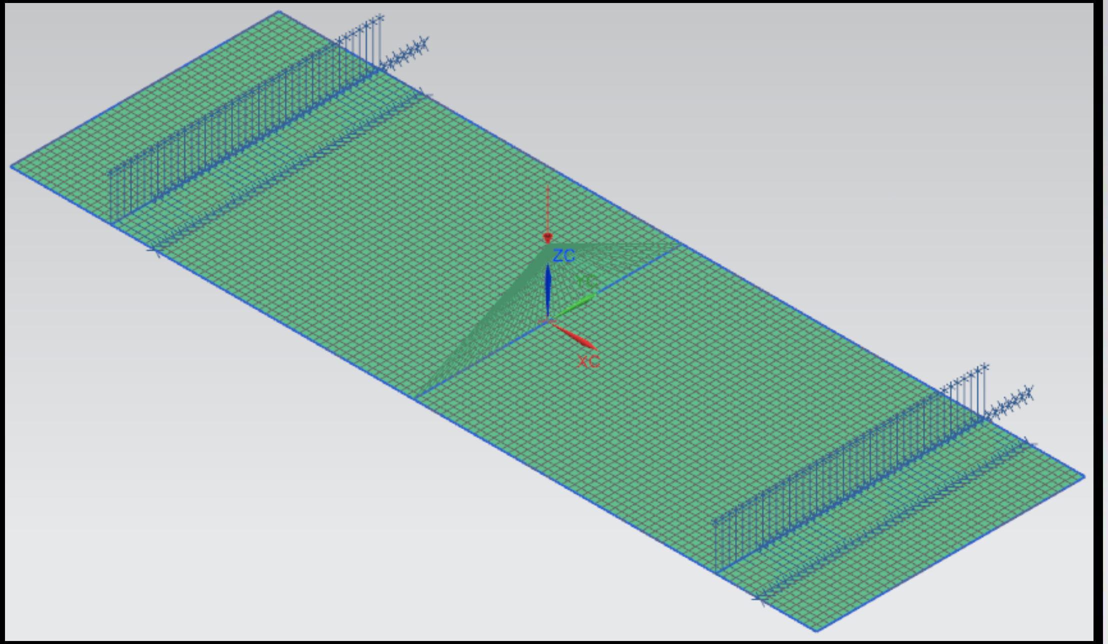


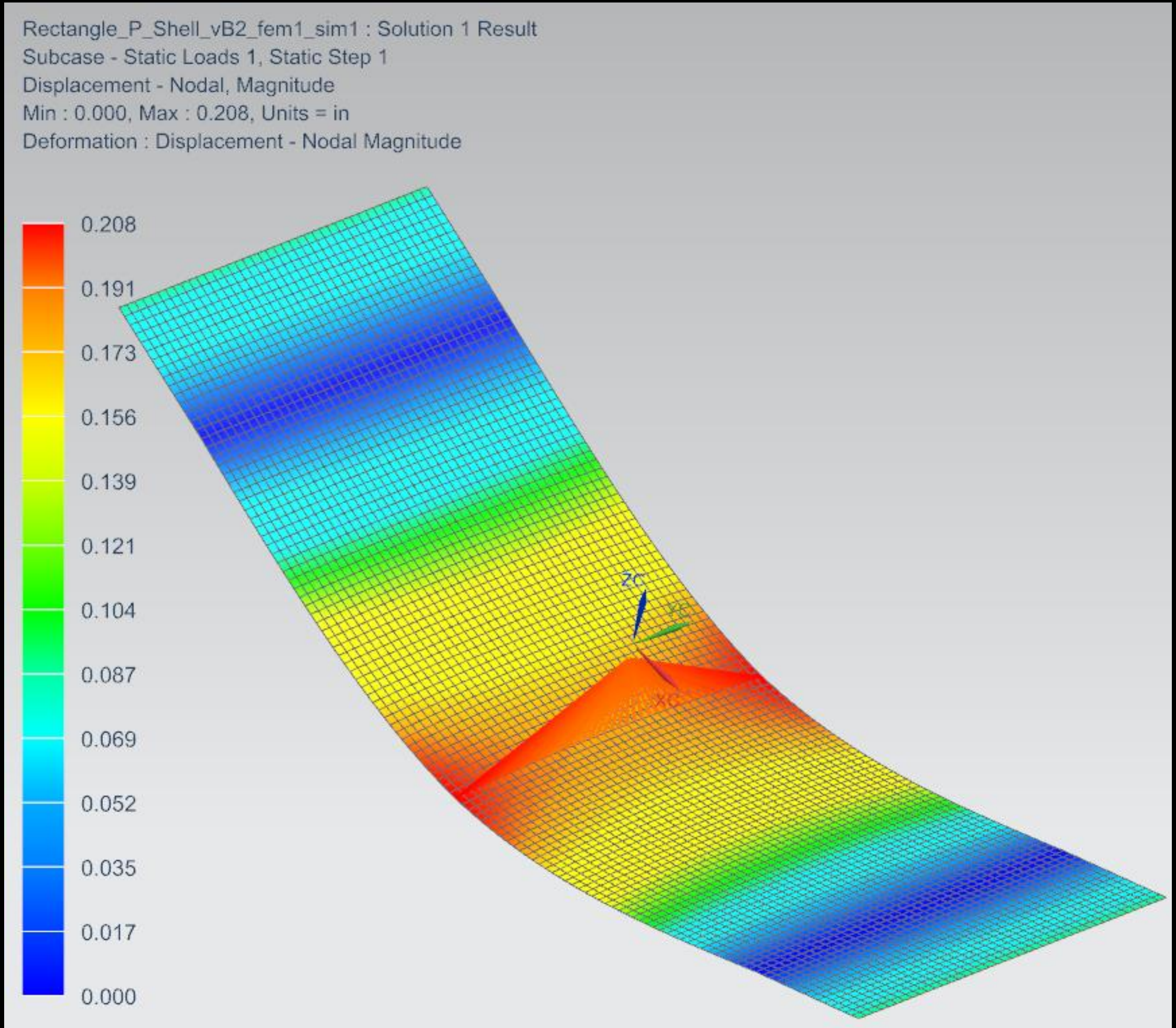




10.1% Change

PShell Model





Modeling Approaches

Which Modeling Approach Was Used for the Actual Covers?

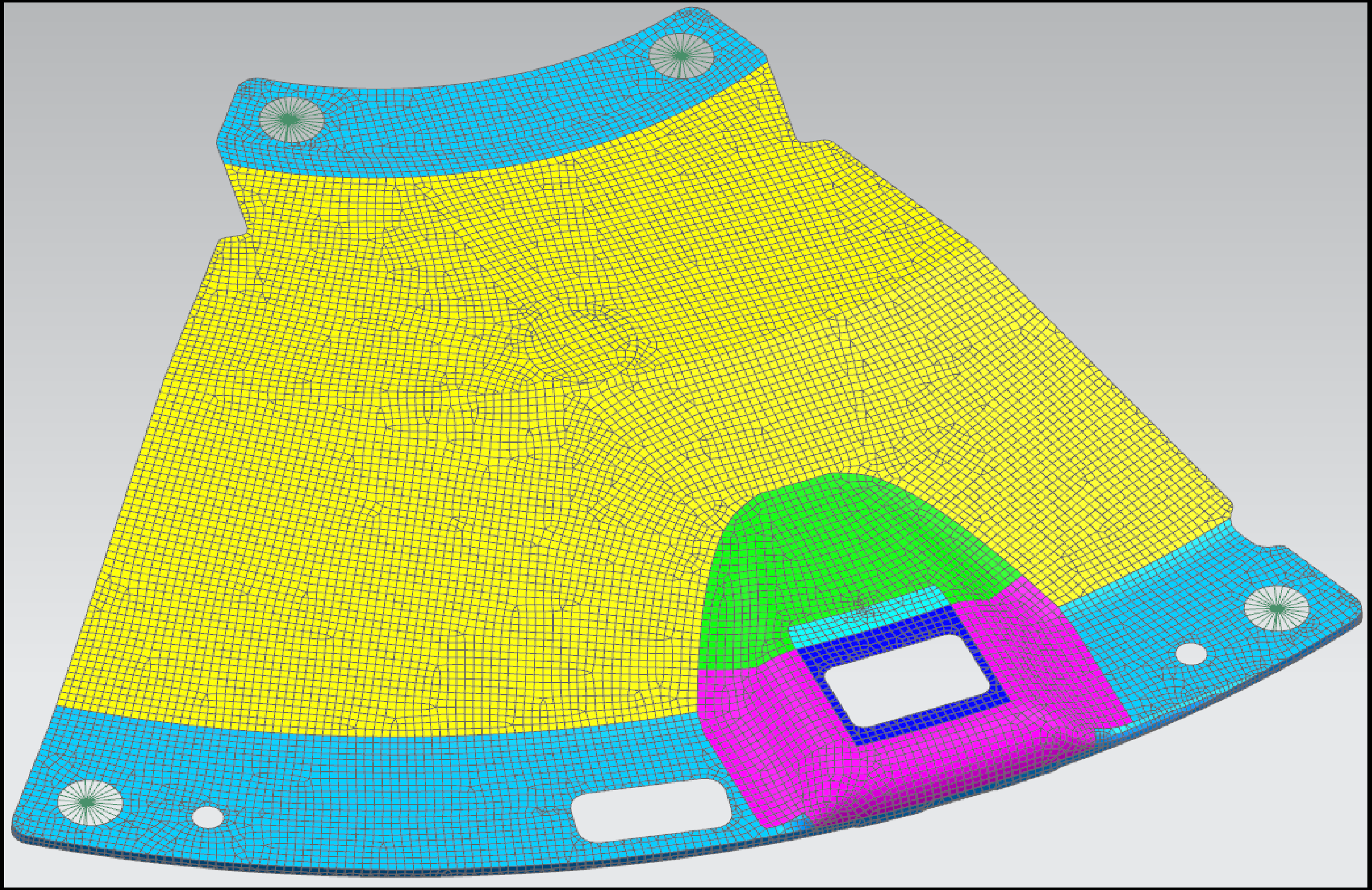
- The PComp modeling approach produced results that are 10.1% off of the value produced. This was a rectangular coupon. When the more complex geometry of the actual cover was employed the result were likely to shift by an even greater amount. There are regions of solid facesheets. There are also sandwich regions of facesheet and core. Both the detailed full modeled approach and the PShell modeling approach correlated with the rectangular test specimen. The decision was made to proceed with modeling the full sized cover as a PShell instead of a detailed model in order to save time while acknowledging that due to the complex geometry it is likely that the results would be more off of the tested result than if a full detailed model mas made.

Which Modeling Approach Was Used for the Actual Covers?

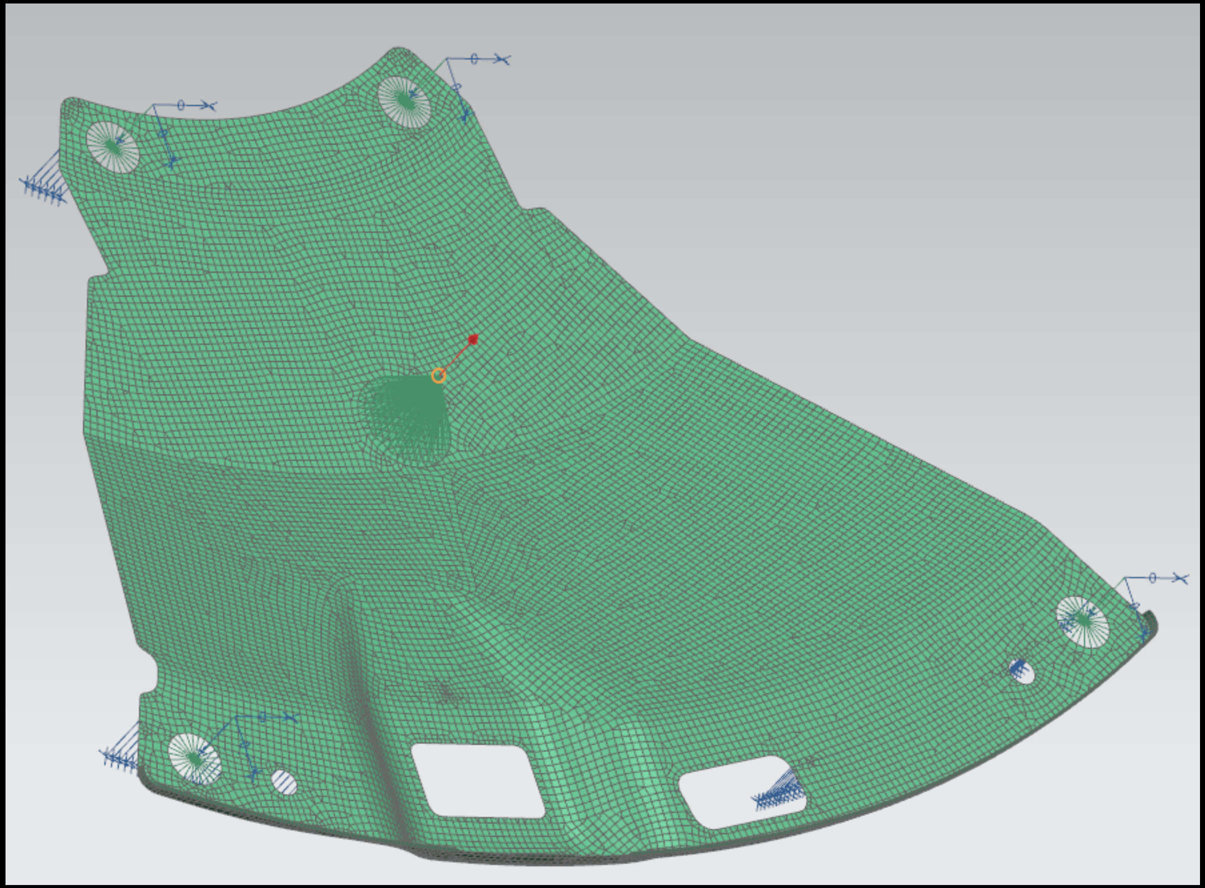
- The covers were exported from Creo into a parasolid (.x_t) file. The parasolid file was imported into MSC Apex Version Fossa in order to reduce geometric complexities. This was necessary in order to be able to mesh the top of the part's surface. This reduced part is then exported from Apex and imported into Siemens NX 11 for finite element model generation and analysis. Loads were applied through an RBE3 element. The constraints for the fastener were also applied through an RBE3. An assumption was made to represent the fastener as steel.

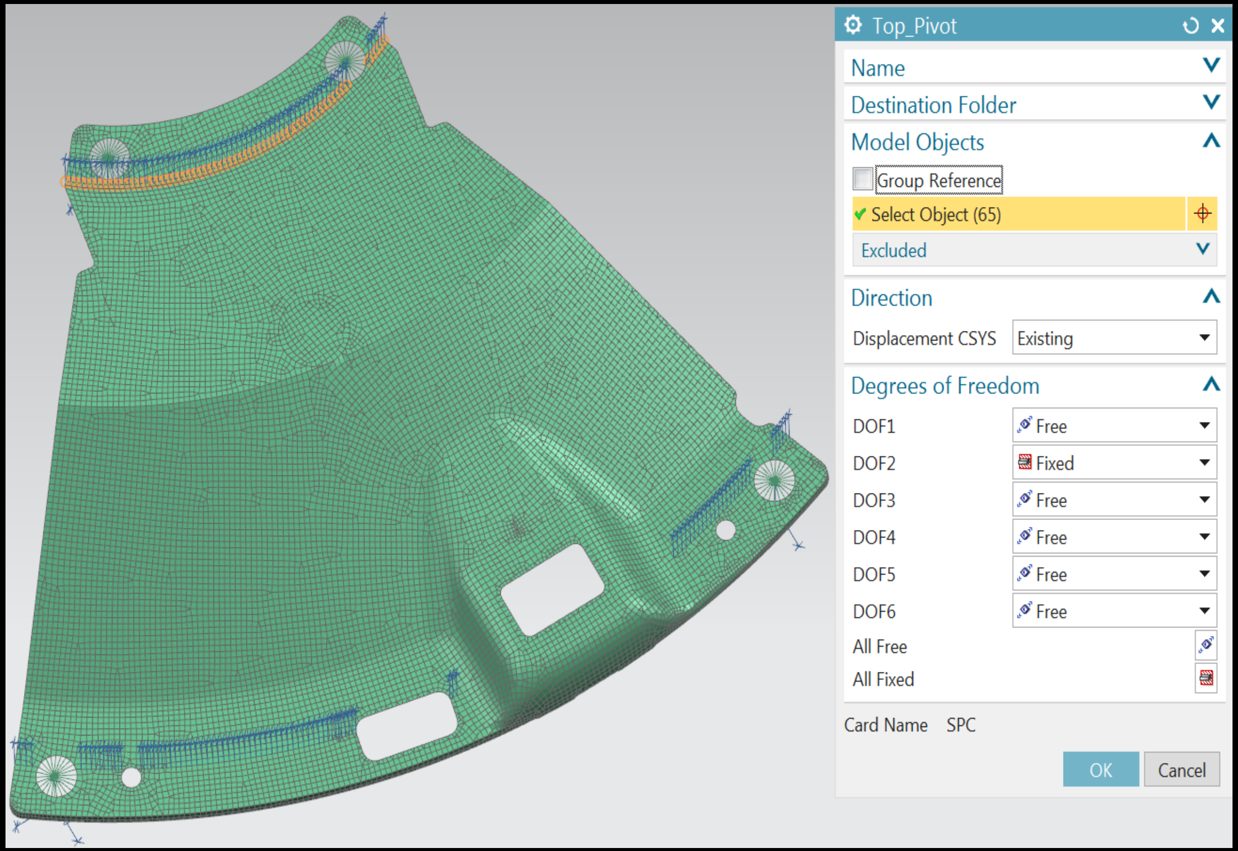
From Apex to NX

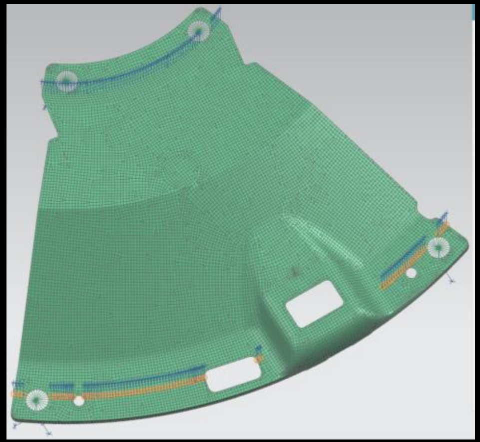
Shells by Thickness Solid Facesheets and Sandwich Structure



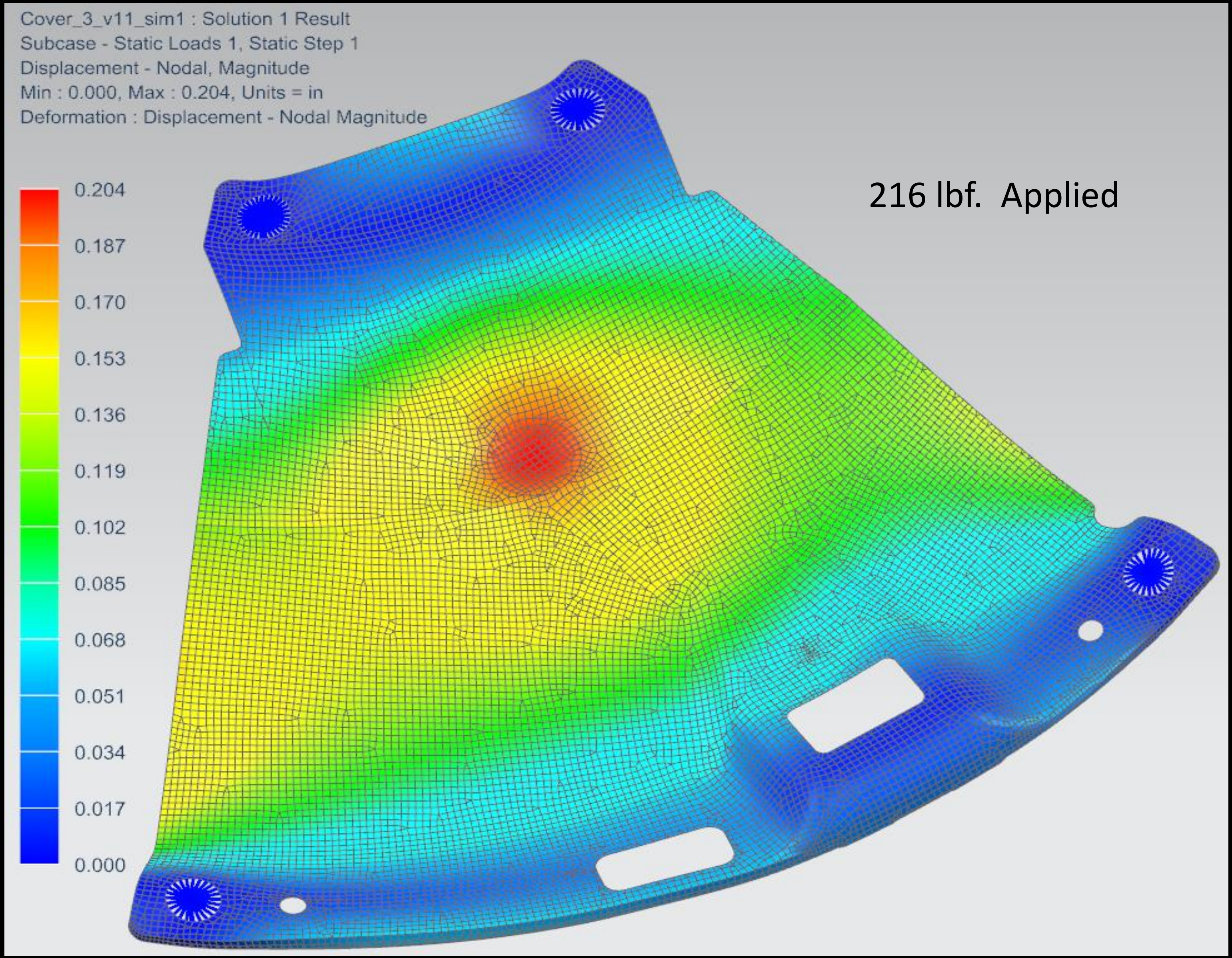
Constraints



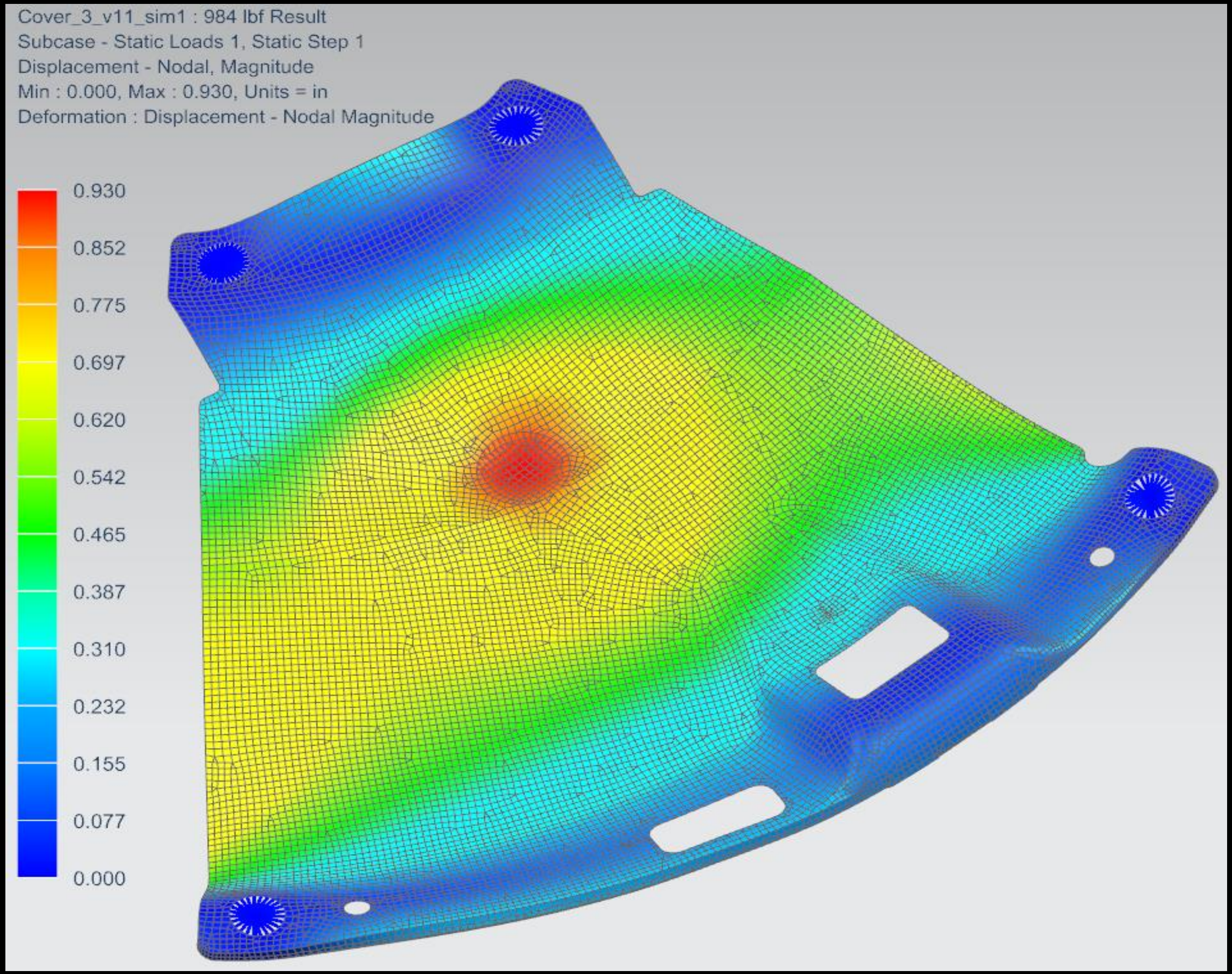


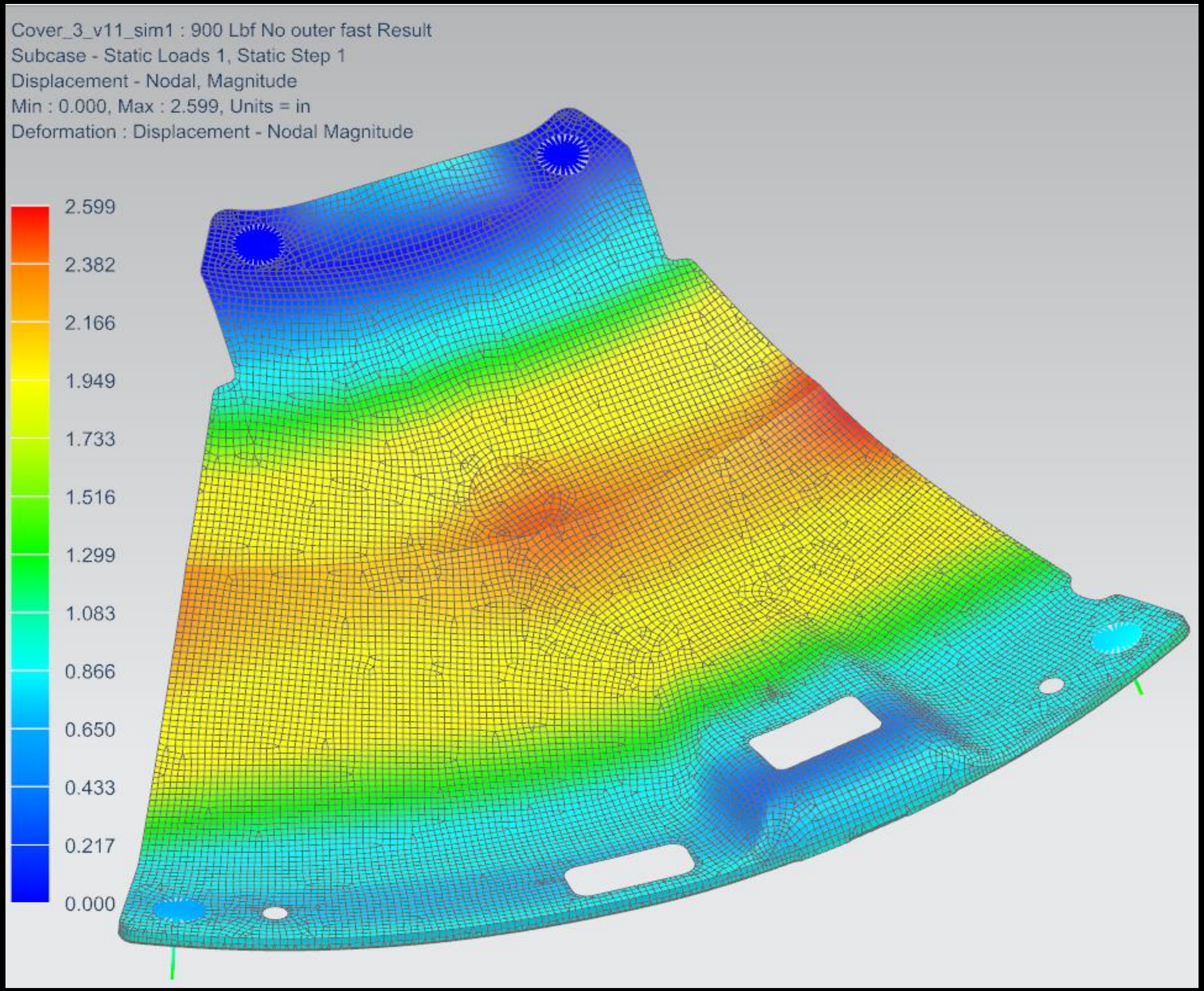


Results


Cover_3_v11_sim1 : Solution 1 Result
Subcase - Static Loads 1, Static Step 1
Displacement - Nodal, Magnitude
Min : 0.000, Max : 0.204, Units = in
Deformation : Displacement - Nodal Magnitude
0.204
0.187
0.170
0.153
0.136
0.119
0.102
0.085
0.068
0.051
0.034
0.017
0.000
216 lbf. Applied

Other Test Cases





%Change = ((Test – FEM) / (Test)) * 100

%Change = ((1.00 in – 0.93 in) / (1.00 in)) * 100

%Change = 7%

%Change = ((Test – FEM) / (Test)) * 100

%Change = ((0.94 in – 2.60 in) / (0.94 in)) * 100

%Change = 177%

Conclusion

- Correlation was good for the first two load cases.
- Using an iterative approach can allow for good model prediction.
- Using MSC Apex saved a lot of time in model preparation.
- Siemens NX 11 was a better analysis tool than MSC PATRAN in this case because it allows the user to easily change the geometry have those updates reflected in the mesh.
- The usage of shell elements saved time when compared to a detailed 3D shell model while having good correlation to physical tests.
- These models can be used to predict results of future test cases. Further testing needs to be done in order to switch from Ultem to Pekk.

Acknowledgments

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