

Project

Author

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Subject

ATLAS Stave Upgrade

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Report Created

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Software Used

[ANSYS 10.0](#)

Database

C:\ATLASUPGRADE\modelstave\STAVEFOAM.dsd

Summary

Stave dimensions

1m long, 0.06 m wide, 0.007 m high

Material	Thickness m
Si	3.00E-04
BeO	4.00E-04
aluminum 6061 T6	3.00E-04
Epoxy cast unreinforced	1.50E-04
kapton	1.00E-04
carbon fiber Thornel T-40	2.50E-04
peek	1.00E-04
rohacell	2.00E-03

Stave loads

Gravity

200 gr electronics (D.Lynn) applied as pressure $0.2 \times 10 / (1 \times 0.06) = 33.33$ Pa

100 W applied as heat flux $100 / (1 \times 0.06) = 1666.7$ W/m² on top and bottom faces

-15 C applied inside channel walls

20 atm applied in the case of CF for CO₂ cooling

Model assumptions

½ model with fixed-frictionless supports

no coolant weight

contact tolerance 1.25e-6 m (except for the 2 thermal models foam2 1.24 e-4 m)

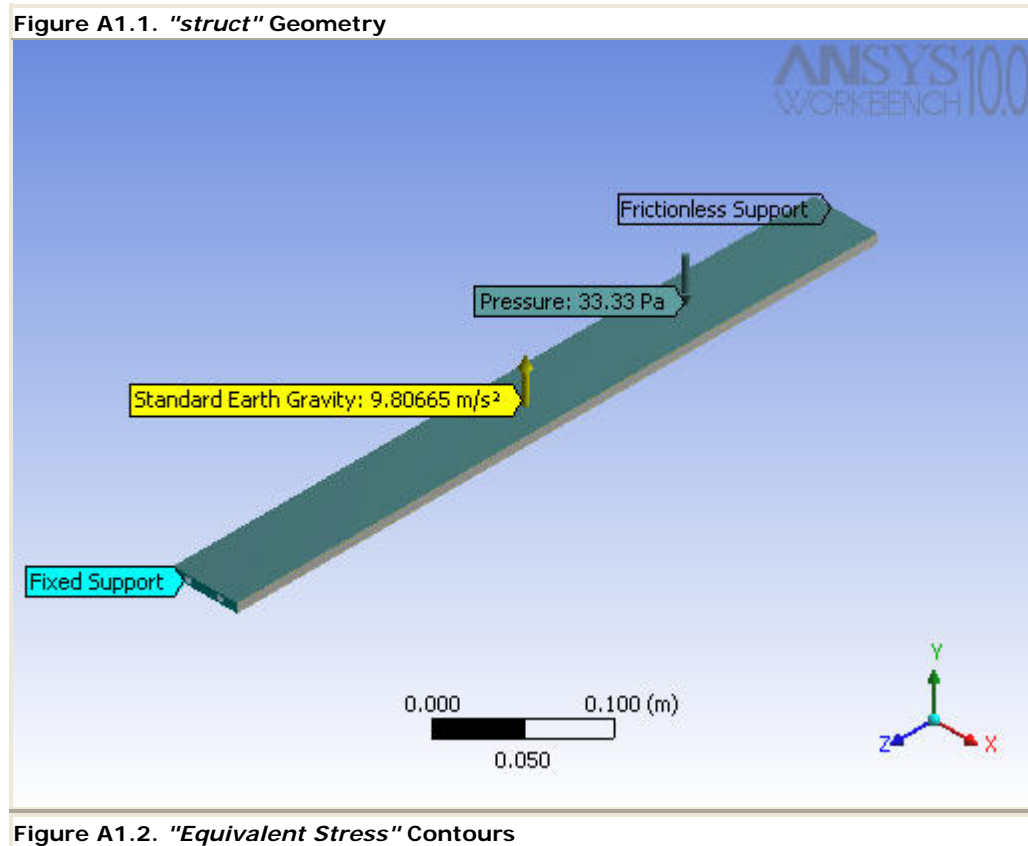
sizing of Kapton for thermal models only 0.01 m except for foam 2 0.0005

Results

	Structural		thermal
	Deflection um	stressMPa	DT
Foam 2	55	8	7
Foam 4	55	7.5	4
CF	40	7	1.5
Ears	56	9	4

FIGURES

A1. Foam 2 Channels Structural Figures



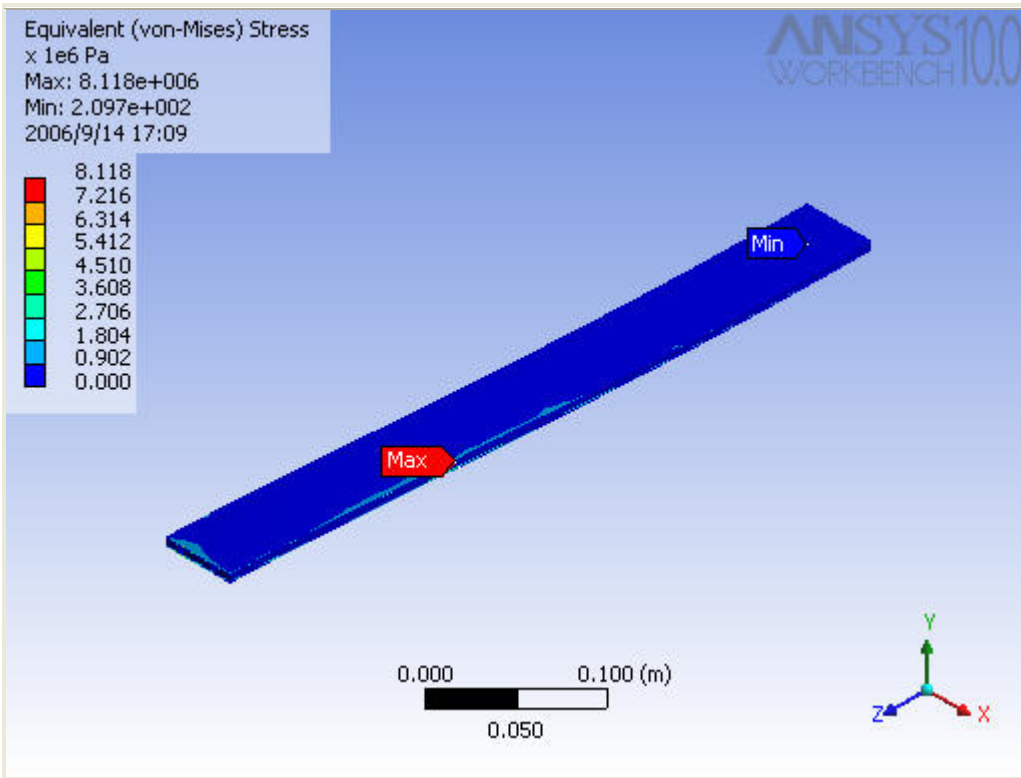
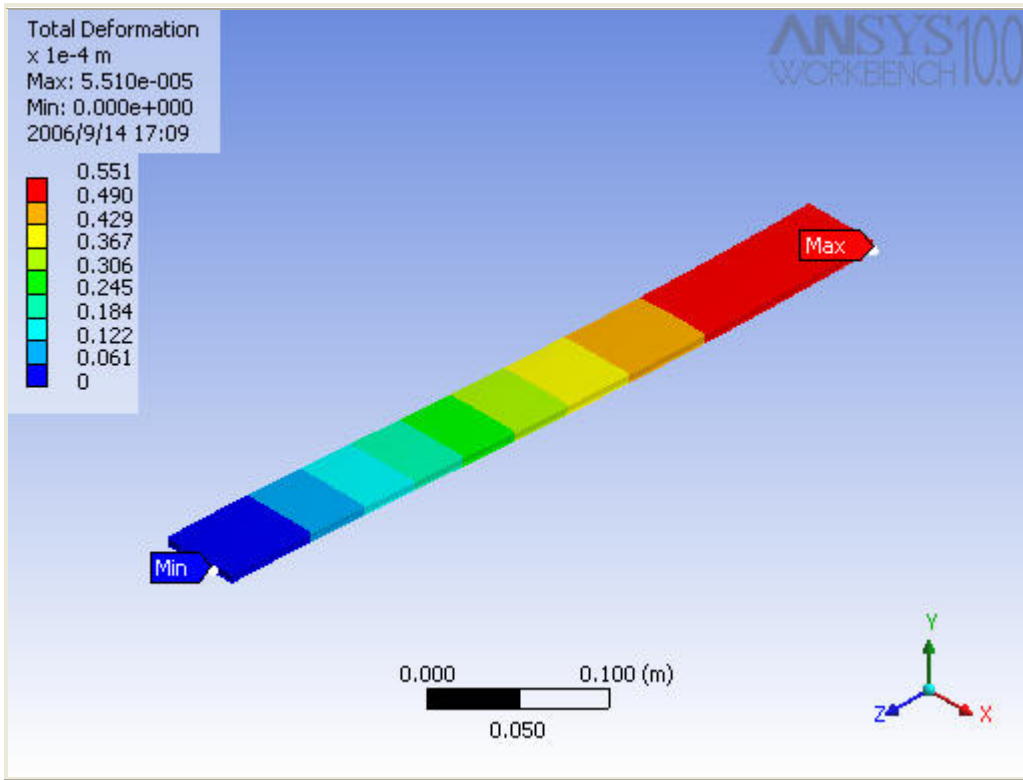


Figure A1.3. "Total Deformation" Contours



A2. Foam 2 Channels Thermal Figures

Figure A2.1. "Environment" Geometry

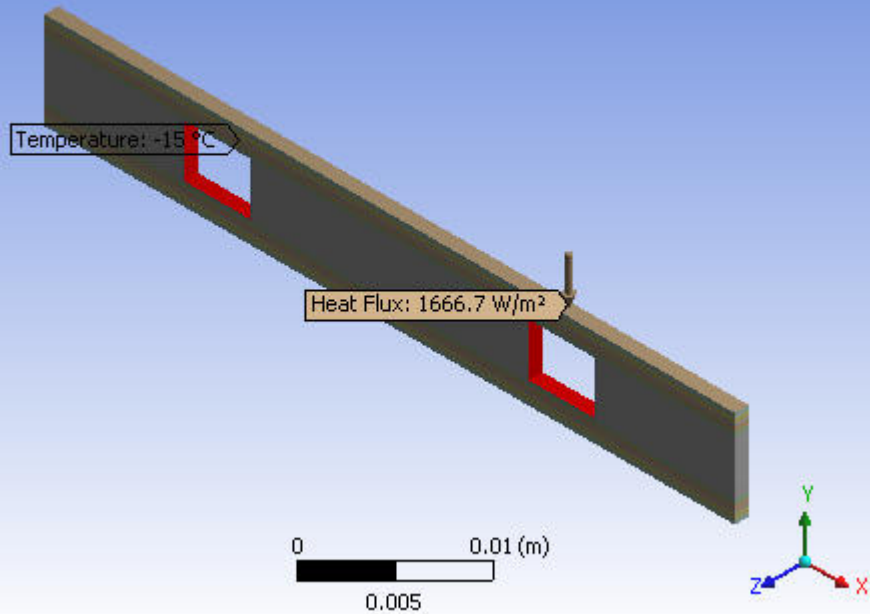
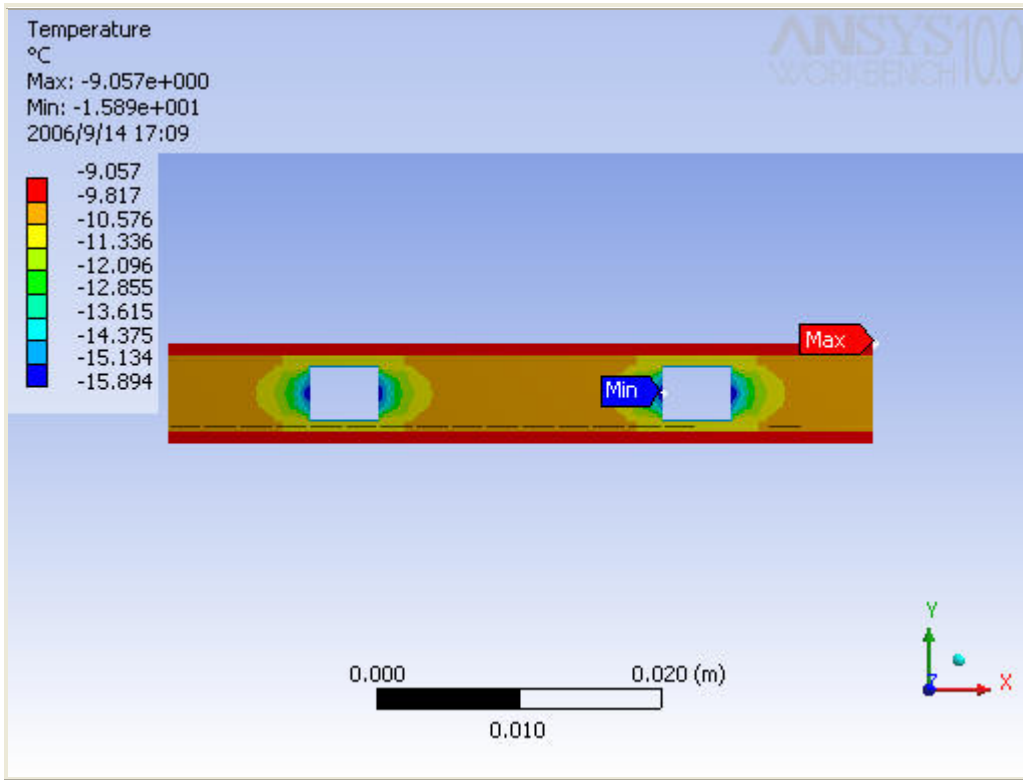


Figure A2.2. "Temperature" Contours



A7. Foam 4 Channels Structural Figures

Figure A7.1. "Environment" Geometry

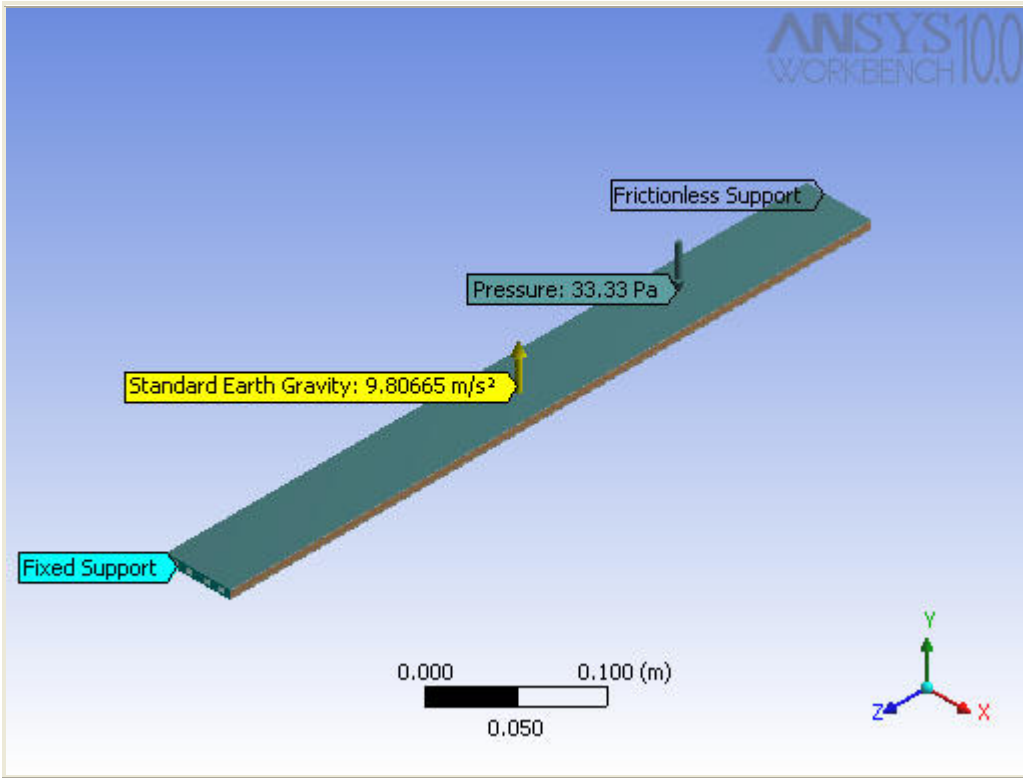


Figure A7.2. "Equivalent Stress" Contours

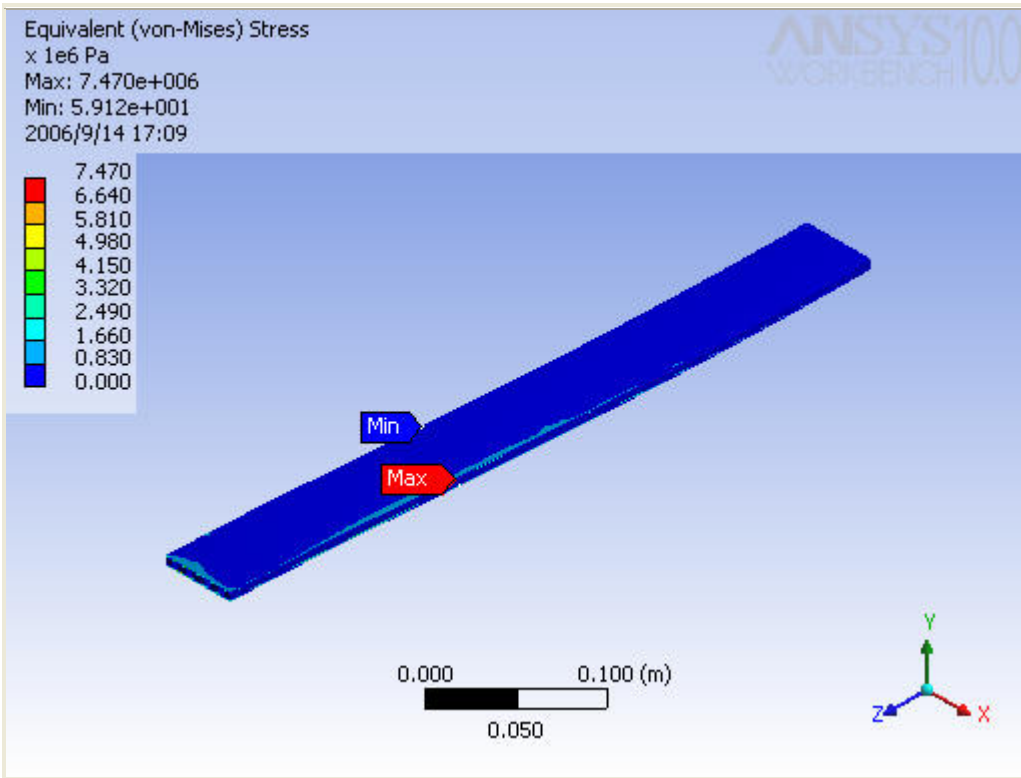
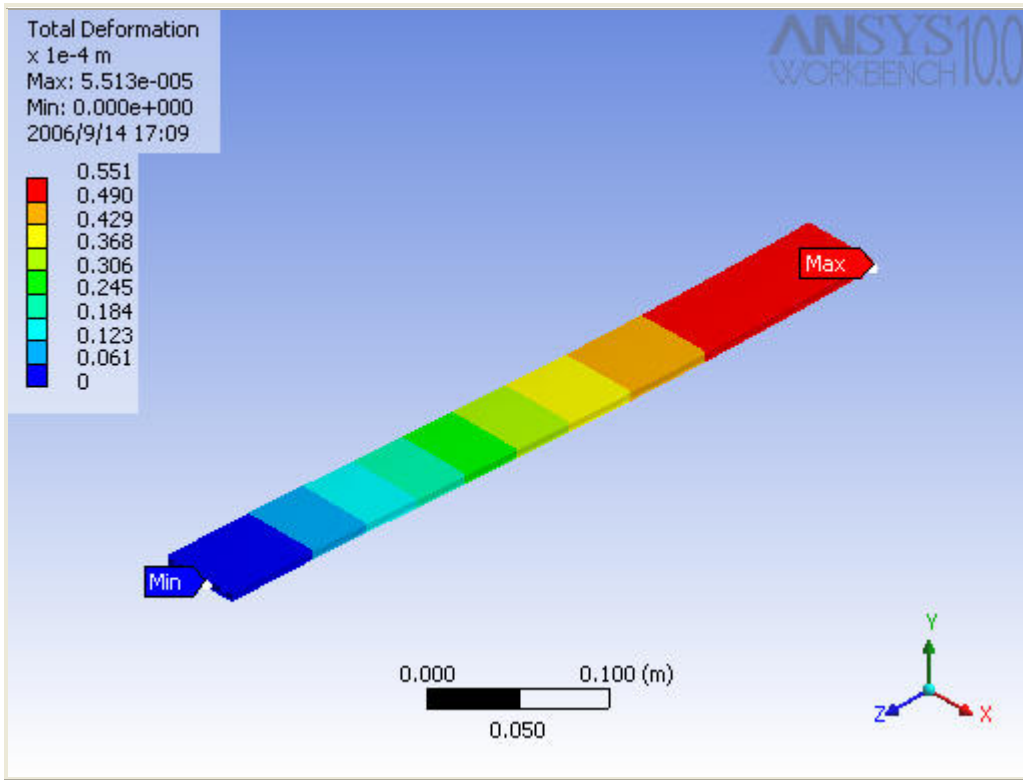


Figure A7.3. "Total Deformation" Contours



A3. Foam 4 Channels Thermal Figures

Figure A3.1. "Environment" Geometry

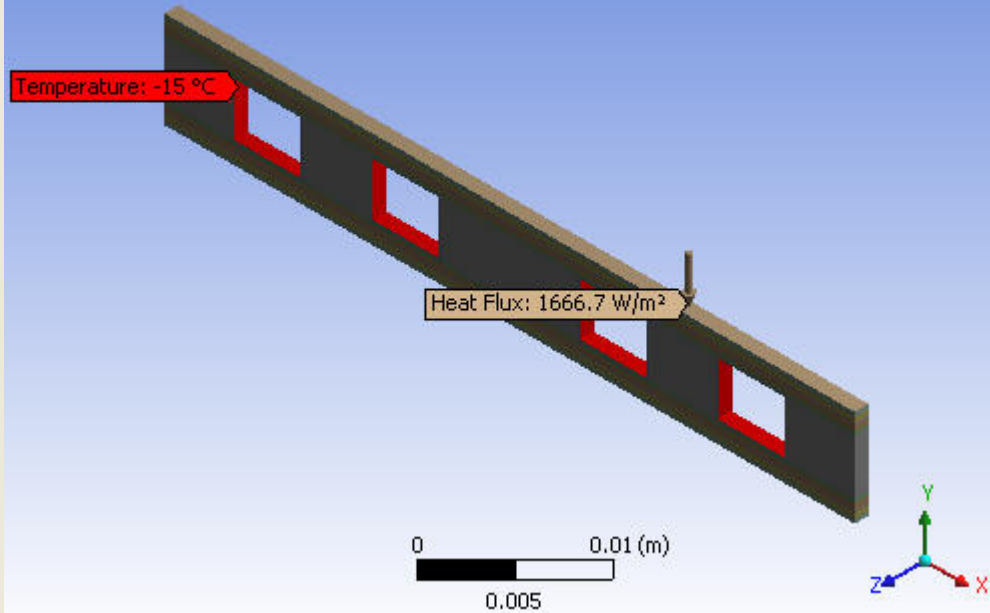
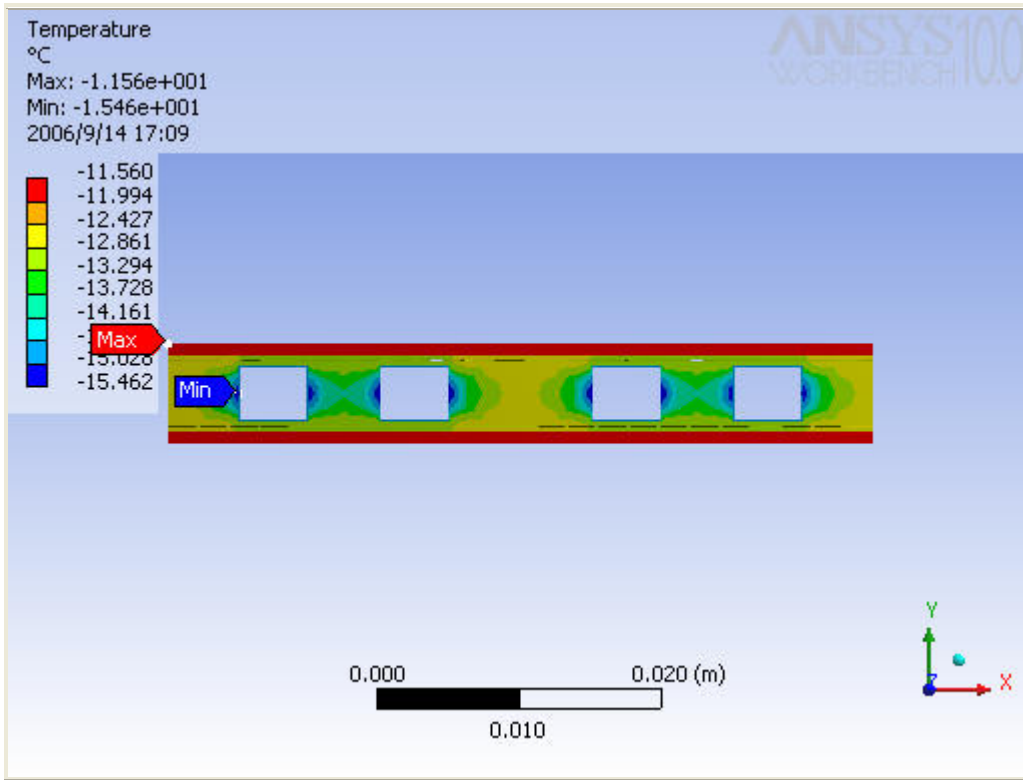


Figure A3.2. "Temperature" Contours



A6. Carbon Fiber Structural Figures

Figure A6.1. "Environment 2" Geometry

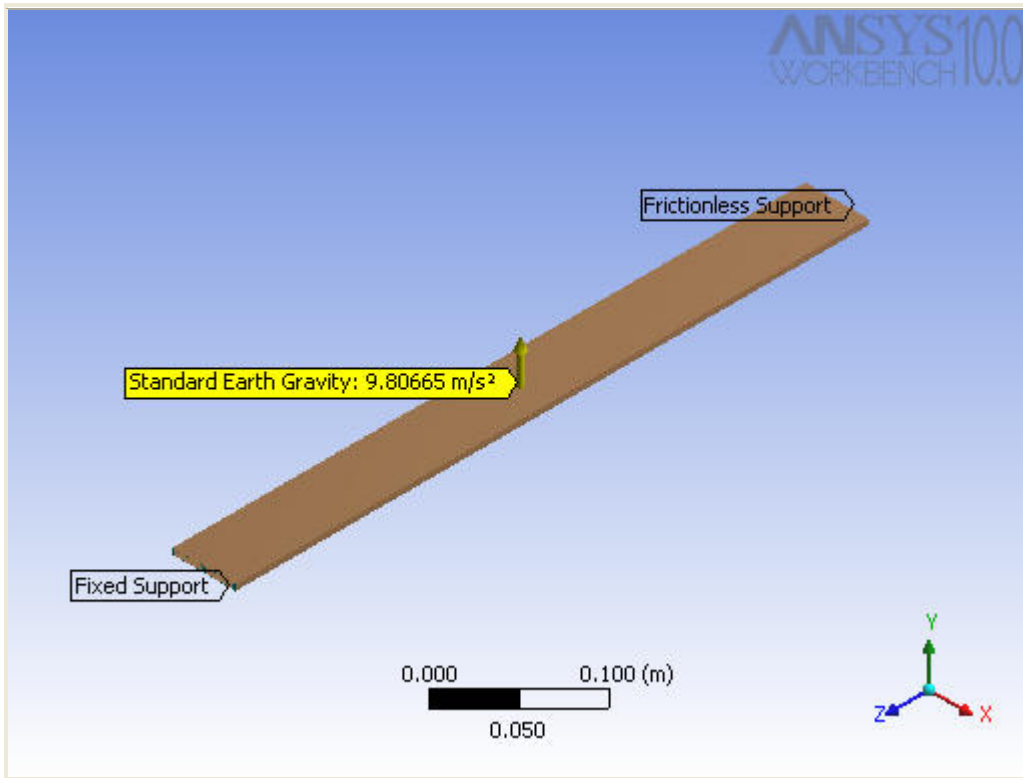


Figure A6.2. "Equivalent Stress" Contours

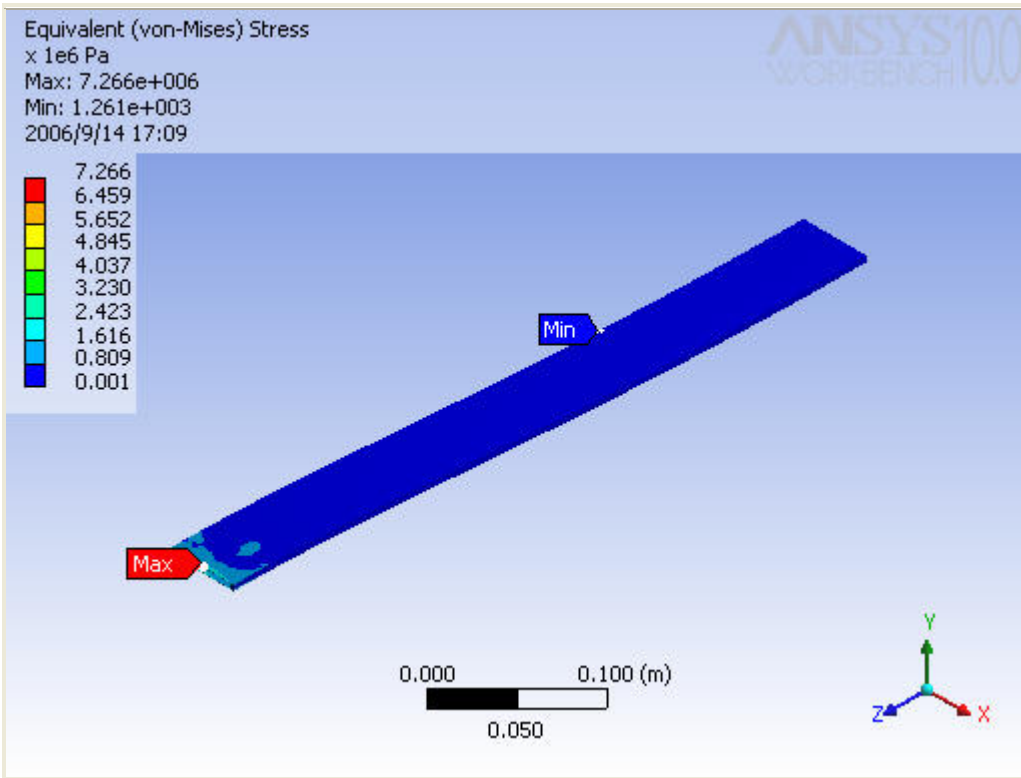
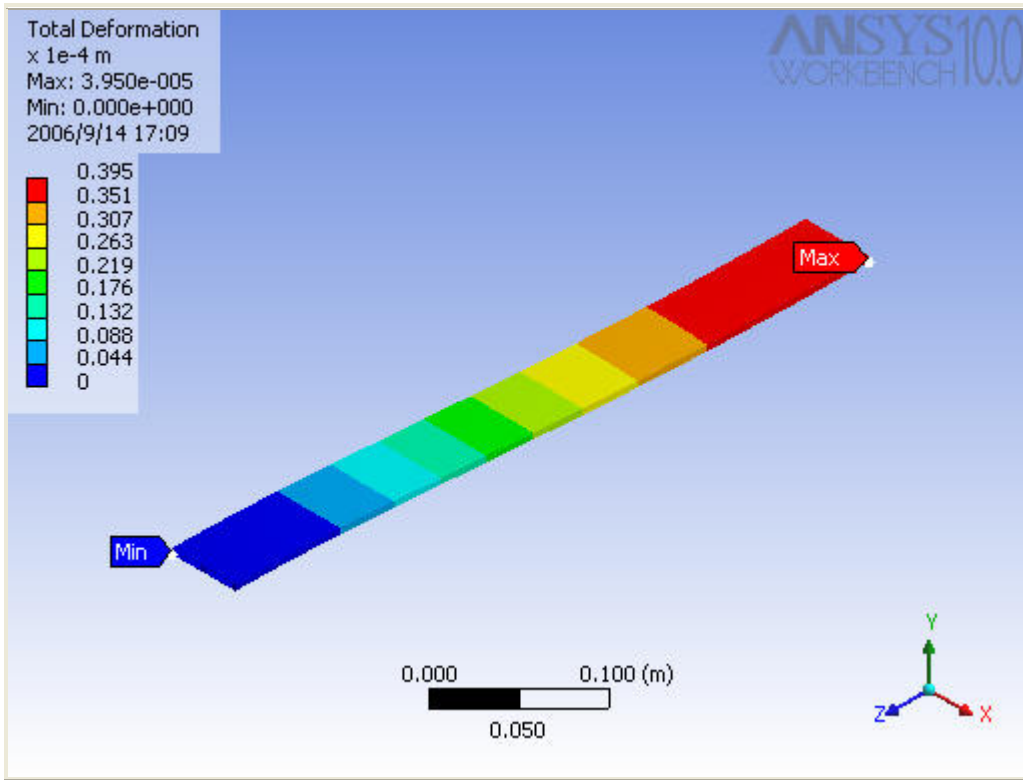


Figure A6.3. "Total Deformation" Contours



A4. Carbon Fiber Thermal Figures

Figure A4.1. "Environment" Geometry

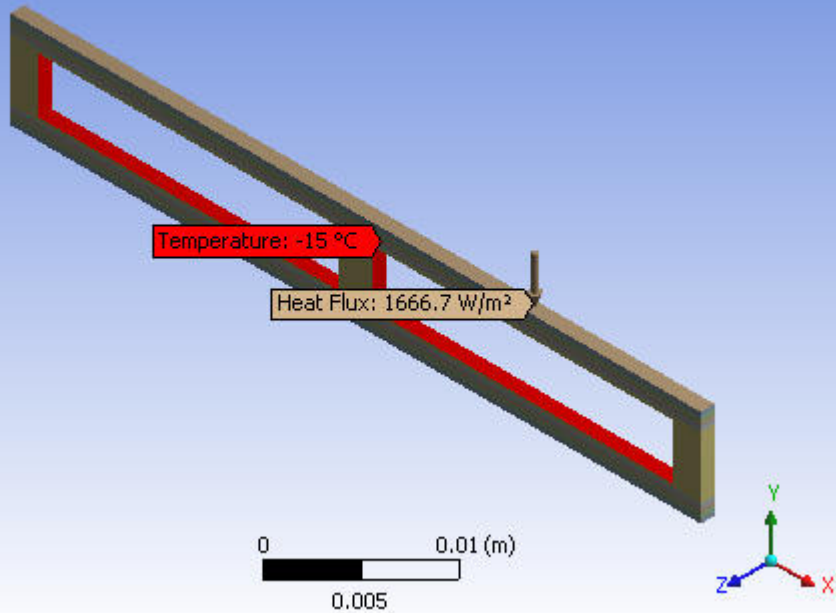
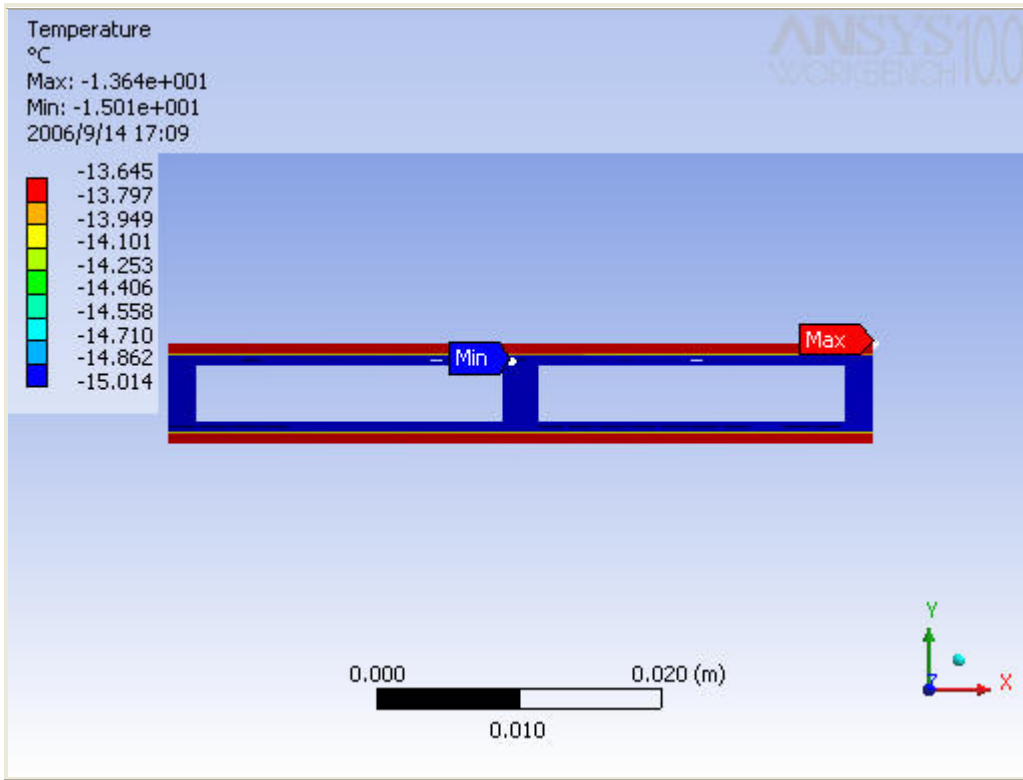


Figure A4.2. "Temperature" Contours



A8. Ear Structural Figures

Figure A8.1. "Environment" Geometry

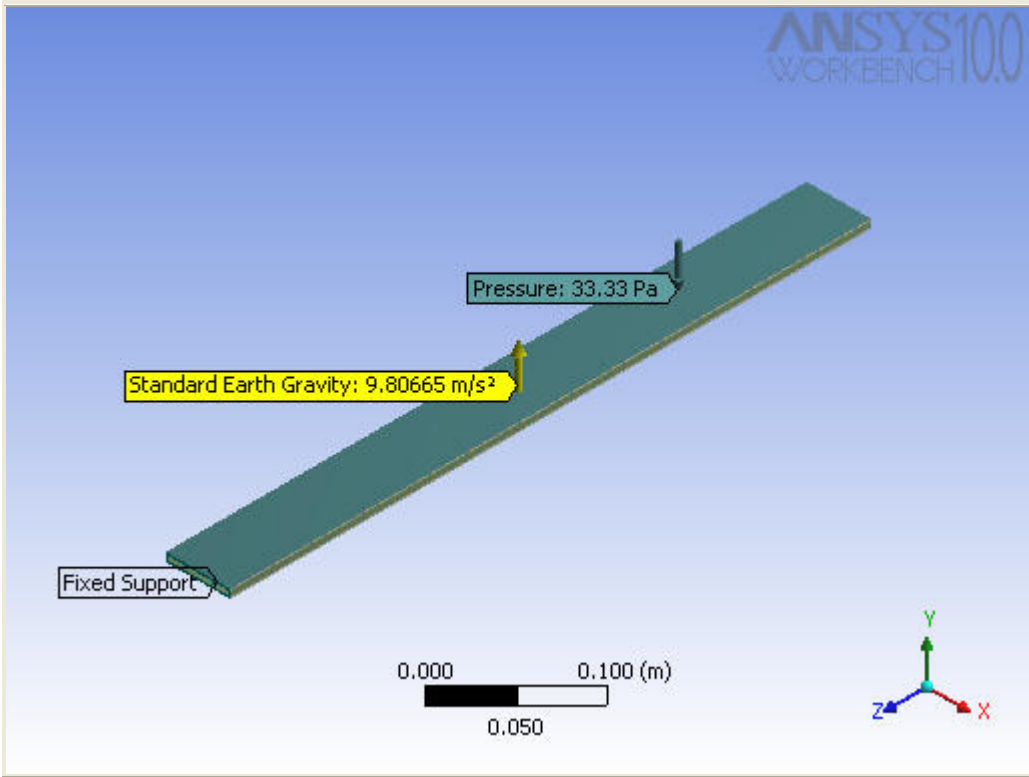


Figure A8.2. "Equivalent Stress" Contours

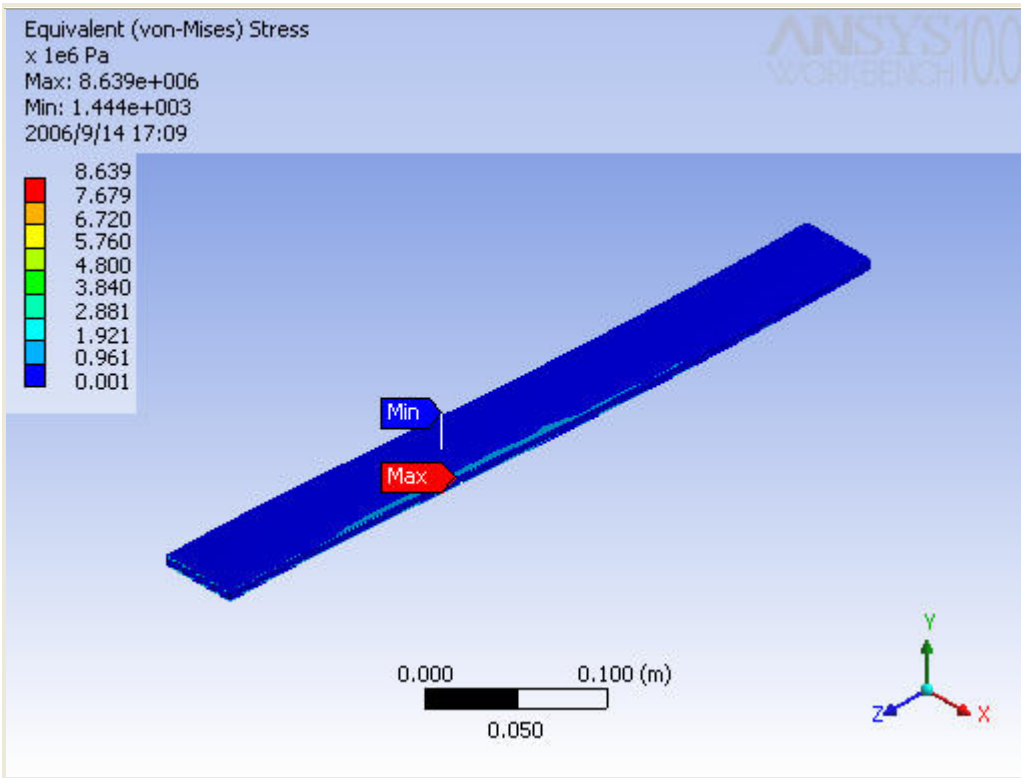
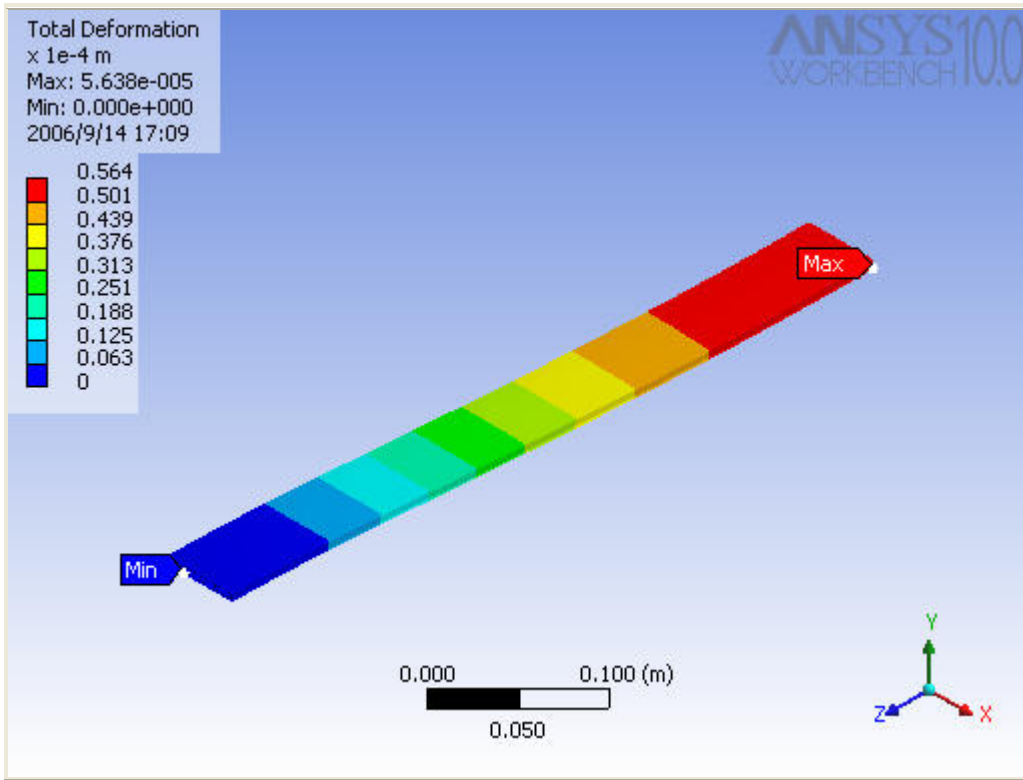


Figure A8.3. "Total Deformation" Contours



A9. Ear Thermal Figures

Figure A9.1. "Environment" Geometry

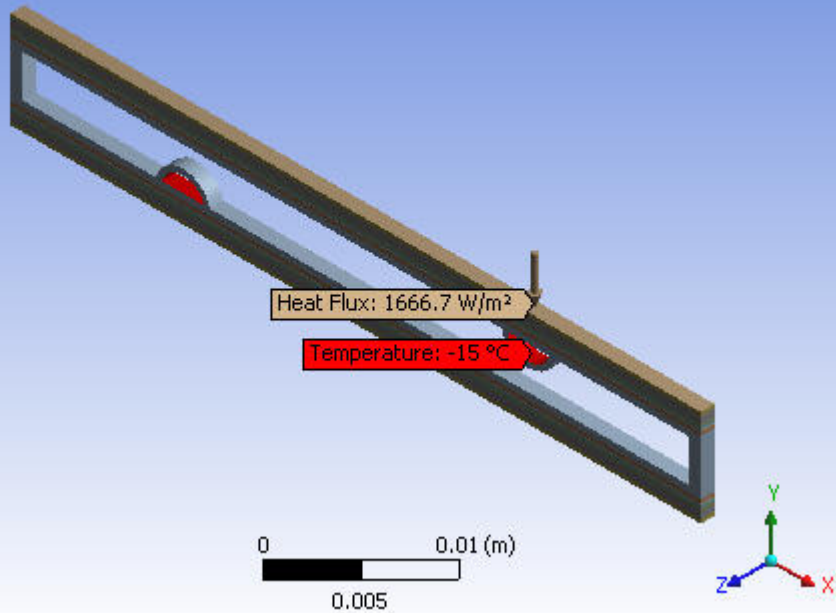


Figure A9.2. "Temperature" Contours

Temperature

°C

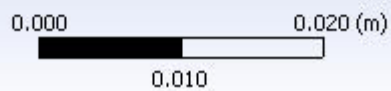
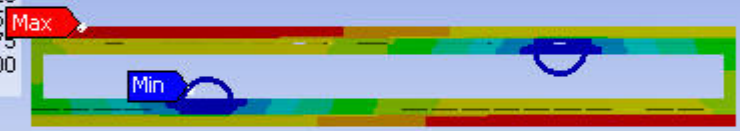
Max: -1.117e+001

Min: -1.500e+001

2006/9/14 17:09

ANSYS 10.0
WORKBENCH

- 11.174
- 11.599
- 12.024
- 12.449
- 12.874
- 13.300
- 13.725
- 14.150
- 14.575
- 15.000



1. Summary

This report documents design and analysis information created and maintained using the ANSYS® engineering software program. Each scenario listed below represents one complete engineering simulation.

Scenario 1

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVEHALF.ASM.4"](#).
- Considered the effect of [body-to-body contact](#), [acceleration](#), [structural loads](#) and [structural supports](#).
- Calculated [structural](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 1](#) below for supporting details and [Appendix A1](#) for corresponding figures.

Scenario 2

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVEHALFTH.ASM.1"](#).
- Considered the effect of [body-to-body contact](#) and [thermal loads](#).
- Calculated [thermal](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 2](#) below for supporting details and [Appendix A2](#) for corresponding figures.

Scenario 3

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVE4HALF.ASM.1"](#).
- Considered the effect of [body-to-body contact](#) and [thermal loads](#).
- Calculated [thermal](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 3](#) below for supporting details and [Appendix A3](#) for corresponding figures.

Scenario 4

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVEHALFCFTH.ASM.2"](#).
- Considered the effect of [body-to-body contact](#) and [thermal loads](#).
- Calculated [thermal](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 4](#) below for supporting details and [Appendix A4](#) for corresponding figures.

Scenario 5

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVEHALFCF.ASM.4"](#).
- Considered the effect of [body-to-body contact](#), [acceleration](#), [structural loads](#) and [structural supports](#).
- Calculated [structural](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 5](#) below for supporting details and [Appendix A5](#) for corresponding figures.

Scenario 6

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVEHALFCF.ASM.4"](#).
- Considered the effect of [body-to-body contact](#), [acceleration](#), [structural loads](#) and [structural supports](#).
- Calculated [structural](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 6](#) below for supporting details and [Appendix A6](#) for corresponding figures.

Scenario 7

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\stave4halfstr.asm.1"](#).
- Considered the effect of [body-to-body contact](#), [acceleration](#), [structural loads](#) and [structural supports](#).
- Calculated [structural](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 7](#) below for supporting details and [Appendix A7](#) for corresponding figures.

Scenario 8

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVEARS.ASM.1"](#).
- Considered the effect of [body-to-body contact](#), [acceleration](#), [structural loads](#) and [structural supports](#).
- Calculated [structural](#) results.
- No [convergence criteria](#) defined.
- No [alert criteria](#) defined.
- See [Scenario 8](#) below for supporting details and [Appendix A8](#) for corresponding figures.

Scenario 9

- Based on the Pro/ENGINEER® 2; assembly 2; ["C:\ATLASUPGRADE\modelstave\STAVEARSTH.ASM.1"](#).
 - Considered the effect of [body-to-body contact](#) and [thermal loads](#).
 - Calculated [thermal](#) results.
 - No [convergence criteria](#) defined.
 - No [alert criteria](#) defined.
 - See [Scenario 9](#) below for supporting details and [Appendix A9](#) for corresponding figures.
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2. Scenario 1

2.1. Foam 2 Channels Structural"foam2chstr"

"foam2chstr" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVEHALF.ASM.4".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 7.0×10^{-3} by 0.5 m along the global x, y and z axes, respectively.
- The model has a total mass of 0.18 kg.
- The model has a total volume of 1.57×10^{-4} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STFO[39]"	"Rohacell"	Yes	5.0×10^{-2} , 4.0×10^{-3} , 0.5	8.8×10^{-3}	8.0×10^{-5}	889	80
"STCH[40]"	"Peek"	Yes	3.0×10^{-2} , 4.0×10^{-3} , 0.5	2.36×10^{-3}	1.76×10^{-6}	22750	11518
"STCF[51]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 0.5	0.02	1.25×10^{-5}	6889	3040
"STBU[121]"	"AL6061"	Yes	5.0×10^{-2} , 5.3×10^{-3} , 0.5	0.04	1.5×10^{-5}	6407	2879
"STSI[127]"	"Silicon"	Yes	5.0×10^{-2} , 7.0×10^{-3} , 0.5	3.49×10^{-2}	1.5×10^{-5}	6130	2677
"STBO[132]"	"Beryllia"	Yes	5.0×10^{-2} , 6.4×10^{-3} , 0.5	0.06	2.0×10^{-5}	4180	1818
"STEP[133]"	"Epoxy"	Yes	5.0×10^{-2} , 5.6×10^{-3} , 0.5	9.0×10^{-3}	7.5×10^{-6}	16283	9046
"STKA[134]"	"Kapton 2"	Yes	5.0×10^{-2} , 4.7×10^{-3} , 0.5	6.7×10^{-3}	5.0×10^{-6}	7606	3232

2.1.1. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	"STFO[39]" and "STCH[40]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 22"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 23"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 26"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 29"	Bonded	"STCH[40]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 30"	Bonded	"STCF[51]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 31"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

2.1.2. Mesh

- "Mesh", associated with "foam2chstr" has an overall relevance of 0.
- "Mesh" contains 71134 nodes and 34290 elements.

No mesh controls specified.

2.2. "struct"

Simulation Type is set to Static

Analysis Type is set to Static Structural

"struct"(Figure [A1.1](#)) contains all loading conditions defined for "foam2chstr" in this scenario.

Standard Earth Gravity - Standard Earth Gravity

- Magnitude: 9.81 m/s²
- Vector: [0.0 m/s² x, 9.81 m/s² y, 0.0 m/s² z] in the Global Coordinate System

2.2.1. Structural Loading

Name	Type	Magnitude	Vector	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Pressure"	Pressure	33.33 Pa	N/A	N/A	N/A	N/A	N/A	"STSI[127]"

2.2.2. Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Fixed Support"	Fixed Surface	0.45 N	[1.35 × 10 ⁻³ N x, 0.42 N y, -0.16 N z]	0.18 N·m	[0.18 N·m x, -1.97 × 10 ⁻³ N·m y, -3.73 × 10 ⁻² N·m z]	"STFO[39]", "STCH[40]", "STCF[51]", "STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]" and "STKA[134]"
"Frictionless Support"	Frictionless Support	1.55 × 10 ⁻² N	[0.0 N x, -9.51 × 10 ⁻¹⁹ N y, 1.55 × 10 ⁻² N z]	7.87 × 10 ⁻² N·m	[7.86 × 10 ⁻² N·m x, 3.18 × 10 ⁻³ N·m y, 1.95 × 10 ⁻¹⁹ N·m z]	"STFO[39]", "STCH[40]", "STCF[51]", "STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]" and "STKA[134]"

NOTE: If a body contains two or more supports that share an edge or vertex, use caution in evaluating the listed reaction forces at those supports. Calculation of reaction forces includes the forces acting along bounding edges and vertices. When supports share edges or vertices the global summation of forces may not appear to balance.

2.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for "foam2chstr" given loading conditions defined in "struct".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "foam2chstr". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

2.3.1. Structural Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Equivalent Stress"	A1.2	All Bodies In "foam2chstr"	209.73 Pa	8.12×10^6 Pa	STFO[39]	STSI[127]	None
"Total Deformation"	A1.3	All Bodies In "foam2chstr"	0.0 m	5.51×10^{-5} m	STFO[39]	STSI[127]	None

- Convergence tracking not enabled.
-

3. Scenario 2

3.1. Foam 2 Channels Thermal "foam2chth"

"foam2chth" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVEHALFTH.ASM.1".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 7.0×10^{-3} by 1.0×10^{-3} m along the global x, y and z axes, respectively.
- The model has a total mass of 3.64×10^{-4} kg.
- The model has a total volume of 3.14×10^{-7} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STFO[39]"	"Rohacell"	Yes	5.0×10^{-2} , 4.0×10^{-3} , 1.0×10^{-3}	1.76×10^{-5}	1.6×10^{-7}	343	32
"STCH[40]"	"Peek"	Yes	3.0×10^{-2} , 4.0×10^{-3} , 1.0×10^{-3}	4.72×10^{-6}	3.52×10^{-9}	451	160
"STCF[51]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 1.0×10^{-3}	4.53×10^{-5}	2.5×10^{-8}	851	321
"STBU[121]"	"AL6061"	Yes	5.0×10^{-2} , 5.3×10^{-3} , 1.0×10^{-3}	8.1×10^{-5}	3.0×10^{-8}	926	378
"STSI[127]"	"Silicon"	Yes	5.0×10^{-2} , 7.0×10^{-3} , 1.0×10^{-3}	6.99×10^{-5}	3.0×10^{-8}	919	373
"STBO[132]"	"Beryllia"	Yes	5.0×10^{-2} , 6.4×10^{-3} , 1.0×10^{-3}	1.14×10^{-4}	4.0×10^{-8}	858	326
"STEP[133]"	"Epoxy"	Yes	5.0×10^{-2} , 5.6×10^{-3} , 1.0×10^{-3}	1.8×10^{-5}	1.5×10^{-8}	844	286
"STKA[134]"	"Kapton 2"	Yes	5.0×10^{-2} , 4.7×10^{-3} , 1.0×10^{-3}	1.34×10^{-5}	10.0×10^{-9}	2340	723

3.1.1. Named Selections

- "Named Selections"

Name	Figures	Comments
"Problematic Geometry"	None	None

3.1.2. Contact

- "Contact" uses a tolerance of 1.26×10^{-4} m for automatic detection.

Table 3.1.2.1. Contact Conditions										
Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region 1"	Bonded	"STFO[39]" and "STCH[40]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	"STFO[39]" and "STCH[40]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 3"	Bonded	"STFO[39]" and "STCH[40]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	"STFO[39]" and "STCH[40]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 8"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 10"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 11"	Bonded	"STCH[40]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	"STCH[40]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 13"	Bonded	"STCH[40]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 14"	Bonded	"STCH[40]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 15"	Bonded	"STCF[51]" and "STBU[121]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 16"	Bonded	"STCF[51]" and "STBU[121]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

"Contact Region 17"	Bonded	"STCF[51]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 18"	Bonded	"STCF[51]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 19"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 20"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 21"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 22"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 23"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 24"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 25"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 26"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

3.1.3. Mesh

- "Mesh", associated with "foam2chth" has an overall relevance of 0.
- "Mesh" contains 7532 nodes and 2599 elements.

Name	Type	Element Size	Hard	Edge Behavior	Associated Bodies
"Sizing"	Face Sizing	5.0×10 ⁻⁴ m	N/A	No Curv/Proximity Refinement	"STKA[134]"

3.2. "Environment"

Simulation Type is set to Static

Analysis Type is set to Static Thermal

"Environment"(Figure [A2.1](#)) contains all loading conditions defined for "foam2chth" in this scenario.

3.2.1. Thermal Loading

Name	Description	Value	Reaction	Associated Bodies
"Temperature"	Surface Temperature	-15.0 °C	-0.17 W	"STCH[40]"
"Heat Flux"	Surface Heat Flux	1,666.7 W/m ²		"STSI[127]"

3.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

Result File Name Selection is set to Program Controlled

Result File Name is C:\ATLASUPGRADE\modelstave\STAVEFOAM.rth

"Solution" contains the calculated response for "foam2chth" given loading conditions defined in "Environment".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "foam2chth". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

3.3.1. Thermal Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Temperature"	A2.2	All Bodies In "foam2chth"	-15.89 °C	-9.06 °C	STCH[40]	STSI[127]	None

- Convergence tracking not enabled.
-

4. Scenario 3

4.1. Foam 4 Channels Thermal "foam4chth"

"foam4chth" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVE4HALF.ASM.1".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 7.0×10^{-3} by 1.0×10^{-3} m along the global x, y and z axes, respectively.
- The model has a total mass of 3.64×10^{-4} kg.
- The model has a total volume of 2.77×10^{-7} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STFO[39]"	"Rohacell"	Yes	5.0×10^{-2} , 4.0×10^{-3} , 1.0×10^{-3}	1.32×10^{-5}	1.2×10^{-7}	293	24
"STCH[40]"	"Peek"	Yes	4.0×10^{-2} , 4.0×10^{-3} , 1.0×10^{-3}	9.43×10^{-6}	7.04×10^{-9}	1056	408
"STCF[51]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 1.0×10^{-3}	4.53×10^{-5}	2.5×10^{-8}	851	321
"STBU[121]"	"AL6061"	Yes	5.0×10^{-2} , 5.3×10^{-3} , 1.0×10^{-3}	8.1×10^{-5}	3.0×10^{-8}	926	378
"STSI[127]"	"Silicon"	Yes	5.0×10^{-2} , 7.0×10^{-3} , 1.0×10^{-3}	6.99×10^{-5}	3.0×10^{-8}	919	373
"STBO[132]"	"Beryllia"	Yes	5.0×10^{-2} , 6.4×10^{-3} , 1.0×10^{-3}	1.14×10^{-4}	4.0×10^{-8}	858	326
"STEP[133]"	"Epoxy"	Yes	5.0×10^{-2} , 5.6×10^{-3} , 1.0×10^{-3}	1.8×10^{-5}	1.5×10^{-8}	844	286
"STKA[134]"	"Kapton 2"	Yes	5.0×10^{-2} , 4.7×10^{-3} , 1.0×10^{-3}	1.34×10^{-5}	10.0×10^{-9}	2283	844

4.1.1. Named Selections

- "Named Selections"

Name	Figures	Comments
"Problematic Geometry"	None	None
"Problematic Geometry 2"	None	None

4.1.2. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region 1"	Bonded	"STFO[39]" and "STCH[40]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 3"	Bonded	"STCH[40]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"STCF[51]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 8"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

4.1.3. Mesh

- "Mesh", associated with "foam4chth" has an overall relevance of 0.
- "Mesh" contains 8030 nodes and 2960 elements.

Name	Type	Element Size	Hard	Edge Behavior	Associated Bodies
"Sizing"	Face Sizing	0.01 m	N/A	No Curv/Proximity Refinement	"STKA[134]"

4.2. "Environment"

Simulation Type is set to Static

Analysis Type is set to Static Thermal

"Environment"(Figure [A3.1](#)) contains all loading conditions defined for "foam4chth" in this scenario.

4.2.1. Thermal Loading

Name	Description	Value	Reaction	Associated Bodies
"Temperature"	Surface Temperature	-15.0 °C	-0.17 W	"STCH[40]"
"Heat Flux"	Surface Heat Flux	1,666.7 W/m ²		"STSI[127]"

4.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

Result File Name Selection is set to Program Controlled

Result File Name is C:\ATLASUPGRADE\modelstave\STAVEFOAM_2.rth

"Solution" contains the calculated response for "foam4chth" given loading conditions defined in "Environment".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "foam4chth". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

4.3.1. Thermal Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Temperature"	A3.2	All Bodies In "foam4chth"	-15.46 °C	-11.56 °C	STCH[40]	STSI[127]	None

- Convergence tracking not enabled.
-

5. Scenario 4

5.1. Carbon Fiber Thermal "cfth"

"cfth" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVEHALFCFTH.ASM.2".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 7.0×10^{-3} by 1.0×10^{-3} m along the global x, y and z axes, respectively.
- The model has a total mass of 3.89×10^{-4} kg.
- The model has a total volume of 1.76×10^{-7} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STBU[121]"	"AL6061"	Yes	5.0×10^{-2} , 5.3×10^{-3} , 1.0×10^{-3}	8.1×10^{-5}	3.0×10^{-8}	926	378
"STSI[127]"	"Silicon"	Yes	5.0×10^{-2} , 7.0×10^{-3} , 1.0×10^{-3}	6.99×10^{-5}	3.0×10^{-8}	919	373
"STBO[132]"	"Beryllia"	Yes	5.0×10^{-2} , 6.4×10^{-3} , 1.0×10^{-3}	1.14×10^{-4}	4.0×10^{-8}	858	326
"STEP[133]"	"Epoxy"	Yes	5.0×10^{-2} , 5.6×10^{-3} , 1.0×10^{-3}	1.8×10^{-5}	1.5×10^{-8}	844	286
"STKA[134]"	"Kapton 2"	Yes	5.0×10^{-2} , 4.7×10^{-3} , 1.0×10^{-3}	1.34×10^{-5}	10.0×10^{-9}	2283	844
"STFCO[149]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 1.0×10^{-3}	9.23×10^{-5}	5.1×10^{-8}	1155	109

5.1.1. Named Selections

- "Named Selections"

Name	Figures	Comments
"Problematic Geometry"	None	None

5.1.2. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Table 5.1.2.1. Contact Conditions

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 3"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"STKA[134]" and "STCFCO[149]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

5.1.3. Mesh

- "Mesh", associated with "cfth" has an overall relevance of 0.
- "Mesh" contains 6985 nodes and 2316 elements.

Table 5.1.3.1. Mesh Sizing Controls

Name	Type	Element Size	Hard	Edge Behavior	Associated Bodies
"Sizing"	Face Sizing	0.01 m	N/A	No Curv/Proximity Refinement	"STKA[134]"

5.2. "Environment"

Simulation Type is set to Static

Analysis Type is set to Static Thermal

"Environment"(Figure [A4.1](#)) contains all loading conditions defined for "cfth" in this scenario.

5.2.1. Thermal Loading

Name	Description	Value	Reaction	Associated Bodies
"Heat Flux"	Surface Heat Flux	1,666.7 W/m ²		"STSI[127]"
"Temperature"	Surface Temperature	-15.0 °C	-0.17 W	"STCFCO[149]"

5.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

Result File Name Selection is set to Program Controlled

Result File Name is C:\ATLASUPGRADE\modelstave\STAVEFOAM_1.rth

"Solution" contains the calculated response for "cfth" given loading conditions defined in "Environment".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "cfth". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

5.3.1. Thermal Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Temperature"	A4.2	All Bodies In "cfth"	-15.01 °C	-13.64 °C	STCFCO[149]	STSI[127]	None

- Convergence tracking not enabled.
-

6. Scenario 5

6.1. "cfstr"

"cfstr" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVEHALFCF.ASM.4".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 4.5×10^{-3} by 0.5 m along the global x, y and z axes, respectively.
- The model has a total mass of 0.19 kg.
- The model has a total volume of 8.8×10^{-5} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STBU[121]"	"AL6061"	Yes	0.0, 0.0, 0.0	0.04	1.5×10^{-5}	6407	2879
"STSI[127]"	"Silicon"	Yes	0.0, 0.0, 0.0	3.49×10^{-2}	1.5×10^{-5}	6130	2677
"STBO[132]"	"Beryllia"	Yes	0.0, 0.0, 0.0	0.06	2.0×10^{-5}	4180	1818
"STEP[133]"	"Epoxy"	Yes	0.0, 0.0, 0.0	9.0×10^{-3}	7.5×10^{-6}	16283	9046
"STKA[134]"	"Kapton 2"	Yes	0.0, 0.0, 0.0	6.7×10^{-3}	5.0×10^{-6}	7606	3232
"STFCO[149]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 0.5	4.62×10^{-2}	2.55×10^{-5}	8457	4421

6.1.1. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 3"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"STKA[134]" and "STCFCO[149]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

6.1.2. Mesh

- "Mesh", associated with "cfstr" has an overall relevance of 0.
- "Mesh" contains 49063 nodes and 24073 elements.

No mesh controls specified.

6.2. "Environment"

Simulation Type is set to Static

Analysis Type is set to Static Structural

"Environment" contains all loading conditions defined for "cfstr" in this scenario.

Standard Earth Gravity - Standard Earth Gravity

- Magnitude: 9.81 m/s²
- Vector: [0.0 m/s² x, 9.81 m/s² y, 0.0 m/s² z] in the Global Coordinate System

6.2.1. Structural Loading

Name	Type	Magnitude	Vector	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Pressure"	Pressure	33.33 Pa	N/A	N/A	N/A	N/A	N/A	"STSI[127]"
"Pressure 2"	Pressure	2.0×10 ⁷ Pa	N/A	N/A	N/A	N/A	N/A	"STCFCO[149]"

6.2.2. Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Fixed Support"	Fixed Surface	475.9 N	[-0.49 N x, 58.19 N y, 472.33 N z]	1.36 N·m	[0.19 N·m x, -1.0 N·m y, -0.91 N·m z]	"STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]", "STKA[134]" and "STCFCO[149]"
"Frictionless Support"	Frictionless Support	475.18 N	[0.0 N x, 2.91×10^{14} N y, -475.18 N z]	0.14 N·m	[3.55×10^{-3} N·m x, 0.14 N·m y, 8.3×10^{18} N·m z]	"STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]", "STKA[134]" and "STCFCO[149]"

NOTE: If a body contains two or more supports that share an edge or vertex, use caution in evaluating the listed reaction forces at those supports. Calculation of reaction forces includes the forces acting along bounding edges and vertices. When supports share edges or vertices the global summation of forces may not appear to balance.

6.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for "cfstr" given loading conditions defined in "Environment".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "cfstr". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

6.3.1. Structural Results

Name	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Equivalent Stress"	All Bodies In "cfstr"	243,085.48 Pa	1.05×10^9 Pa	STEP[133]	STCFCO[149]	None
"Total Deformation"	All Bodies In "cfstr"	0.0 m	3.9×10^{-5} m	STBU[121]	STSI[127]	None

7. Scenario 6

7.1. Carbon Fiber Structural "cfstr"

"cfstr" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVEHALFCF.ASM.4".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 4.5×10^{-3} by 0.5 m along the global x, y and z axes, respectively.
- The model has a total mass of 0.19 kg.
- The model has a total volume of 8.8×10^{-5} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STBU[121]"	"AL6061"	Yes	0.0, 0.0, 0.0	0.04	1.5×10^{-5}	6407	2879
"STSI[127]"	"Silicon"	Yes	0.0, 0.0, 0.0	3.49×10^{-2}	1.5×10^{-5}	6130	2677
"STBO[132]"	"Beryllia"	Yes	0.0, 0.0, 0.0	0.06	2.0×10^{-5}	4180	1818
"STEP[133]"	"Epoxy"	Yes	0.0, 0.0, 0.0	9.0×10^{-3}	7.5×10^{-6}	16283	9046
"STKA[134]"	"Kapton 2"	Yes	0.0, 0.0, 0.0	6.7×10^{-3}	5.0×10^{-6}	7606	3232
"STFCO[149]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 0.5	4.62×10^{-2}	2.55×10^{-5}	8457	4421

7.1.1. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 3"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"STKA[134]" and "STFCO[149]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

7.1.2. Mesh

- "Mesh", associated with "cfstr" has an overall relevance of 0.
- "Mesh" contains 49063 nodes and 24073 elements.

No mesh controls specified.

7.2. "Environment 2"

Simulation Type is set to Static

Analysis Type is set to Static Structural

"Environment 2"(Figure [A6.1](#)) contains all loading conditions defined for "cfstr" in this scenario.

Standard Earth Gravity - Standard Earth Gravity

- Magnitude: 9.81 m/s²
- Vector: [0.0 m/s² x, 9.81 m/s² y, 0.0 m/s² z] in the Global Coordinate System

7.2.1. Structural Loading

Name	Type	Magnitude	Vector	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Pressure"	Pressure	33.33 Pa	N/A	N/A	N/A	N/A	N/A	"STSI[127]"
"Pressure 2"	Pressure (Suppressed)	2.0×10^7 Pa	N/A	N/A	N/A	N/A	N/A	"STCFCO[149]"

7.2.2. Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Fixed Support"	Fixed Surface	1.93 N	$[-1.93 \times 10^{-3}$ N x, 1.91 N y, 0.21 N z]	0.24 N·m	[0.23 N·m x, 2.22×10^{-3} N·m y, -1.72×10^{-2} N·m z]	"STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]", "STKA[134]" and "STCFCO[149]"
"Frictionless Support"	Frictionless Support	0.29 N	[0.0 N x, 1.75×10^{-17} N y, -0.29 N z]	8.5×10^{-2} N·m	[8.5×10^{-2} N·m x, -1.14×10^{-3} N·m y, -7.0×10^{-20} N·m z]	"STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]", "STKA[134]" and "STCFCO[149]"

NOTE: If a body contains two or more supports that share an edge or vertex, use caution in evaluating the listed reaction forces at those supports. Calculation of reaction forces includes the forces acting along bounding edges and vertices. When supports share edges or vertices the global summation of forces may not appear to balance.

7.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for "cfstr" given loading conditions defined in "Environment 2".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "cfstr". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

7.3.1. Structural Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Equivalent Stress"	A6.2	All Bodies In "cfstr"	1,260.52 Pa	7.27×10^6 Pa	STEP[133]	STSI[127]	None
"Total Deformation"	A6.3	All Bodies In "cfstr"	0.0 m	3.95×10^{-5} m	STBU[121]	STBU[121]	None

- Convergence tracking not enabled.
-

8. Scenario 7

8.1. Foam 4 Channels Structural "foam4chstr"

"foam4chstr" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\stave4halfstr.asm.1".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 7.0×10^{-3} by 0.5 m along the global x, y and z axes, respectively.
- The model has a total mass of 0.18 kg.
- The model has a total volume of 1.39×10^{-4} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STFO[39]"	"Rohacell"	Yes	5.0×10^{-2} , 4.0×10^{-3} , 0.5	6.6×10^{-3}	6.0×10^{-5}	1240	100
"STCH[40]"	"Peek"	Yes	4.0×10^{-2} , 4.0×10^{-3} , 0.5	4.72×10^{-3}	3.52×10^{-6}	43500	22001
"STCF[51]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 0.5	0.02	1.25×10^{-5}	6889	3040
"STBU[121]"	"AL6061"	Yes	5.0×10^{-2} , 5.3×10^{-3} , 0.5	0.04	1.5×10^{-5}	6407	2879
"STSI[127]"	"Silicon"	Yes	5.0×10^{-2} , 7.0×10^{-3} , 0.5	3.49×10^{-2}	1.5×10^{-5}	6130	2677
"STBO[132]"	"Beryllia"	Yes	5.0×10^{-2} , 6.4×10^{-3} , 0.5	0.06	2.0×10^{-5}	4180	1818
"STEP[133]"	"Epoxy"	Yes	5.0×10^{-2} , 5.6×10^{-3} , 0.5	9.0×10^{-3}	7.5×10^{-6}	16283	9046
"STKA[134]"	"Kapton 2"	Yes	5.0×10^{-2} , 4.7×10^{-3} , 0.5	6.7×10^{-3}	5.0×10^{-6}	7606	3232

8.1.1. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	"STFO[39]" and "STCH[40]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	"STFO[39]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 22"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 23"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 26"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 29"	Bonded	"STCH[40]" and "STCF[51]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 30"	Bonded	"STCF[51]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 31"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

8.1.2. Mesh

- "Mesh", associated with "foam4chstr" has an overall relevance of 0.
- "Mesh" contains 92235 nodes and 44793 elements.

No mesh controls specified.

8.2. "Environment"

Simulation Type is set to Static

Analysis Type is set to Static Structural

"Environment"(Figure [A7.1](#)) contains all loading conditions defined for "foam4chstr" in this scenario.

Standard Earth Gravity - Standard Earth Gravity

- Magnitude: 9.81 m/s²
- Vector: [0.0 m/s² x, 9.81 m/s² y, 0.0 m/s² z] in the Global Coordinate System

8.2.1. Structural Loading

Name	Type	Magnitude	Vector	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Pressure"	Pressure	33.33 Pa	N/A	N/A	N/A	N/A	N/A	"STSI[127]"

8.2.2. Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Fixed Support"	Fixed Surface	2.65 N	$[-9.53 \times 10^{-3} \text{ N x}, 2.65 \text{ N y}, -0.11 \text{ N z}]$	0.18 N·m	$[0.18 \text{ N·m x}, -2.6 \times 10^{-4} \text{ N·m y}, 1.55 \times 10^{-2} \text{ N·m z}]$	"STFO[39]", "STCH[40]", "STCF[51]", "STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]" and "STKA[134]"
"Frictionless Support"	Frictionless Support	$4.53 \times 10^{-2} \text{ N}$	$[0.0 \text{ N x}, 2.77 \times 10^{-18} \text{ N y}, -4.53 \times 10^{-2} \text{ N z}]$	$7.93 \times 10^{-2} \text{ N·m}$	$[7.93 \times 10^{-2} \text{ N·m x}, 8.81 \times 10^{-4} \text{ N·m y}, 5.4 \times 10^{-20} \text{ N·m z}]$	"STFO[39]", "STCH[40]", "STCF[51]", "STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]" and "STKA[134]"

NOTE: If a body contains two or more supports that share an edge or vertex, use caution in evaluating the listed reaction forces at those supports. Calculation of reaction forces includes the forces acting along bounding edges and vertices. When supports share edges or vertices the global summation of forces may not appear to balance.

8.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for "foam4chstr" given loading conditions defined in "Environment".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "foam4chstr". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

8.3.1. Structural Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Equivalent Stress"	A7.2	All Bodies In "foam4chstr"	59.12 Pa	7.47×10^6 Pa	STFO[39]	STSI[127]	None
"Total Deformation"	A7.3	All Bodies In "foam4chstr"	0.0 m	5.51×10^{-5} m	STFO[39]	STBU[121]	None

- Convergence tracking not enabled.
-

9. Scenario 8

9.1. Ear Structural "earstr"

"earstr" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVEARS.ASM.1".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 7.0×10^{-3} by 0.5 m along the global x, y and z axes, respectively.
- The model has a total mass of 0.25 kg.
- The model has a total volume of 1.03×10^{-4} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STCF[51]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 0.5	0.02	1.25×10^{-5}	6889	3040
"STBU[121]"	"AL6061"	Yes	5.0×10^{-2} , 5.3×10^{-3} , 0.5	0.04	1.5×10^{-5}	6407	2879
"STSI[127]"	"Silicon"	Yes	5.0×10^{-2} , 7.0×10^{-3} , 0.5	3.49×10^{-2}	1.5×10^{-5}	6130	2677
"STBO[132]"	"Beryllia"	Yes	5.0×10^{-2} , 6.4×10^{-3} , 0.5	0.06	2.0×10^{-5}	4180	1818
"STEP[133]"	"Epoxy"	Yes	5.0×10^{-2} , 5.6×10^{-3} , 0.5	9.0×10^{-3}	7.5×10^{-6}	16283	9046
"STKA[134]"	"Kapton 2"	Yes	5.0×10^{-2} , 4.7×10^{-3} , 0.5	6.7×10^{-3}	5.0×10^{-6}	7606	3232
"SEARS[150]"	"AL6061"	Yes	5.0×10^{-2} , 4.0×10^{-3} , 0.5	7.64×10^{-2}	2.83×10^{-5}	30714	16635

9.1.1. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region 10"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 16"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 22"	Bonded	"STCF[51]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 23"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	"STCF[51]" and "SEARS[150]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

9.1.2. Mesh

- "Mesh", associated with "earstr" has an overall relevance of 0.
- "Mesh" contains 78209 nodes and 39327 elements.

No mesh controls specified.

9.2. "Environment"

Simulation Type is set to Static

Analysis Type is set to Static Structural

"Environment"(Figure [A8.1](#)) contains all loading conditions defined for "earstr" in this scenario.

Standard Earth Gravity - Standard Earth Gravity

- Magnitude: 9.81 m/s²
- Vector: [0.0 m/s² x, 9.81 m/s² y, 0.0 m/s² z] in the Global Coordinate System

9.2.1. Structural Loading

Name	Type	Magnitude	Vector	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Pressure"	Pressure	33.33 Pa	N/A	N/A	N/A	N/A	N/A	"STSI[127]"

9.2.2. Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Fixed Support"	Fixed Surface	2.77 N	[-2.53 × 10 ⁻³ N x, 2.76 N y, 0.15 N z]	0.25 N·m	[0.25 N·m x, 3.36 × 10 ⁻³ N·m y, -1.83 × 10 ⁻² N·m z]	"STCF[51]", "STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]", "STKA[134]" and "SEARS[150]"
"Frictionless Support"	Frictionless Support	0.26 N	[0.0 N x, 1.56 × 10 ⁻¹⁷ N y, -0.26 N z]	8.37 × 10 ⁻² N·m	[8.37 × 10 ⁻² N·m x, -1.61 × 10 ⁻³ N·m y, -9.83 × 10 ⁻²⁰ N·m z]	"STCF[51]", "STBU[121]", "STSI[127]", "STBO[132]", "STEP[133]" and "STKA[134]"

NOTE: If a body contains two or more supports that share an edge or vertex, use caution in evaluating the listed reaction forces at those supports. Calculation of reaction forces includes the forces acting along bounding edges and vertices. When supports share edges or vertices the global summation of forces may not appear to balance.

9.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for "earstr" given loading conditions defined in "Environment".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "earstr". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

9.3.1. Structural Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Equivalent Stress"	A8.2	All Bodies In "earstr"	1,444.38 Pa	8.64×10^6 Pa	STEP[133]	STSI[127]	None
"Total Deformation"	A8.3	All Bodies In "earstr"	0.0 m	5.64×10^{-5} m	STCF[51]	STBU[121]	None

- Convergence tracking not enabled.
-

10. Scenario 9

10.1. Ear Thermal "earsth"

"earsth" obtains geometry from the Pro/ENGINEER® 32; assembly 32; "C:\ATLASUPGRADE\modelstave\STAVEARSTH.ASM.1".

- The bounding box for all positioned bodies in the model measures 5.0×10^{-2} by 7.0×10^{-3} by 1.0×10^{-3} m along the global x, y and z axes, respectively.
- The model has a total mass of 4.94×10^{-4} kg.
- The model has a total volume of 2.07×10^{-7} m³.

Name	Material	Nonlinear Material Effects	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"STCF[51]"	"CarbonFiber"	Yes	5.0×10^{-2} , 4.5×10^{-3} , 1.0×10^{-3}	4.53×10^{-5}	2.5×10^{-8}	851	321
"STBU[121]"	"AL6061"	Yes	5.0×10^{-2} , 5.3×10^{-3} , 1.0×10^{-3}	8.1×10^{-5}	3.0×10^{-8}	926	378
"STSI[127]"	"Silicon"	Yes	5.0×10^{-2} , 7.0×10^{-3} , 1.0×10^{-3}	6.99×10^{-5}	3.0×10^{-8}	919	373
"STBO[132]"	"Beryllia"	Yes	5.0×10^{-2} , 6.4×10^{-3} , 1.0×10^{-3}	1.14×10^{-4}	4.0×10^{-8}	858	326
"STEP[133]"	"Epoxy"	Yes	5.0×10^{-2} , 5.6×10^{-3} , 1.0×10^{-3}	1.8×10^{-5}	1.5×10^{-8}	844	286
"STKA[134]"	"Kapton 2"	Yes	5.0×10^{-2} , 4.7×10^{-3} , 1.0×10^{-3}	1.34×10^{-5}	10.0×10^{-9}	2283	844
"SEARS[150]"	"AL6061"	Yes	5.0×10^{-2} , 4.0×10^{-3} , 1.0×10^{-3}	1.53×10^{-4}	5.66×10^{-8}	1237	109

10.1.1. Named Selections

- "Named Selections"

Name	Figures	Comments
"Problematic Geometry"	None	None

10.1.2. Contact

- "Contact" uses a tolerance of 1.26×10^{-6} m for automatic detection.

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Update Stiffness	Formulation	Thermal Conductance	Pinball Region
"Contact Region 2"	Bonded	"STCF[51]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 3"	Bonded	"STCF[51]" and "SEARS[150]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	"STBU[121]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"STBU[121]" and "STKA[134]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	"STSI[127]" and "STBO[132]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	"STBO[132]" and "STEP[133]"	Face, Face	Program Controlled	Automatic	Symmetric	Never	Pure Penalty	Program Controlled	Program Controlled

10.1.3. Mesh

- "Mesh", associated with "earsth" has an overall relevance of 0.
- "Mesh" contains 7918 nodes and 2637 elements.

Name	Type	Element Size	Hard	Edge Behavior	Associated Bodies
"Sizing"	Face Sizing	0.01 m	N/A	No Curv/Proximity Refinement	"STKA[134]"

10.2. "Environment"

Simulation Type is set to Static

Analysis Type is set to Static Thermal

"Environment"(Figure [A9.1](#)) contains all loading conditions defined for "earsth" in this scenario.

10.2.1. Thermal Loading

Name	Description	Value	Reaction	Associated Bodies
"Temperature"	Surface Temperature	-15.0 °C	-0.17 W	"SEARS[150]"
"Heat Flux"	Surface Heat Flux	1,666.7 W/m ²		"STSI[127]"

10.3. "Solution"

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

Result File Name Selection is set to Program Controlled

Result File Name is C:\ATLASUPGRADE\modelstave\STAVEFOAM_4.rth

"Solution" contains the calculated response for "earsth" given loading conditions defined in "Environment".

- Thermal expansion calculations use a constant reference temperature of 22.0 °C for all bodies in "earsth". Theoretically, at a uniform temperature of 22.0 °C no strain results from thermal expansion or contraction.

10.3.1. Thermal Results

Name	Figure	Scope	Minimum	Maximum	Minimum Occurs On	Maximum Occurs On	Alert Criteria
"Temperature"	A9.2	All Bodies In "earsth"	-15.0 °C	-11.17 °C	SEARS[150]	STSI[127]	None

- Convergence tracking not enabled.

A10. Definition of "Rohacell"

Name	Value
Density	110.0 kg/m ³
Poisson's Ratio	0.0
Young's Modulus	1.57 × 10 ⁸ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	0.03 W/m·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	4.41 × 10 ⁶ Pa

A11. Definition of "Peek"

Name	Value
Density	1,340.0 kg/m ³
Poisson's Ratio	0.44
Young's Modulus	7.6 × 10 ⁹ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	0.2 W/m·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	1.79 × 10 ⁸ Pa

A12. Definition of "CarbonFiber"

Name	Value
Density	1,810.0 kg/m ³
Poisson's Ratio	0.0
Young's Modulus	2.9 × 10 ¹¹ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	15.0 W/m·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	5.65 × 10 ⁹ Pa

A13. Definition of "AL6061"

Name	Value
Density	2,700.0 kg/m ³
Poisson's Ratio	0.33
Young's Modulus	6.9×10 ¹⁰ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	167.0 W/m·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	2.76×10 ⁸ Pa

A14. Definition of "Silicon"

Name	Value
Density	2,330.0 kg/m ³
Poisson's Ratio	0.28
Young's Modulus	1.12×10 ¹¹ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	1.2×10 ⁸ Pa

Table A14.2. Thermal Conductivity

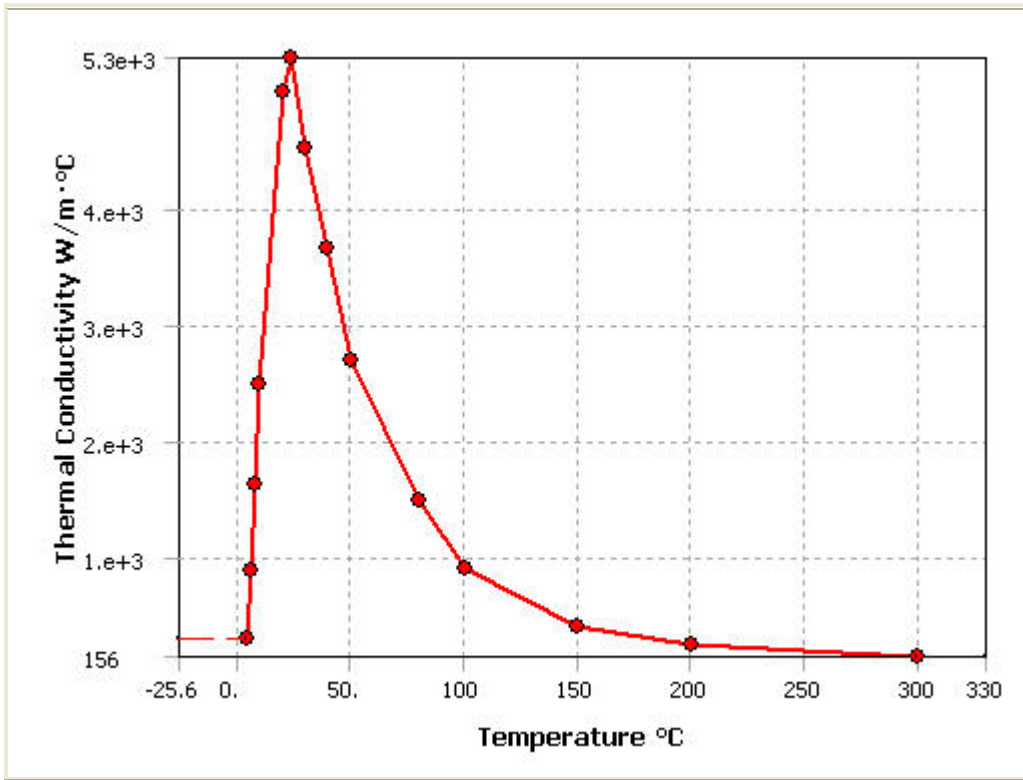


Table A14.3. "Thermal Conductivity"

Temperature °C	Thermal Conductivity W/m·°C
4.0	311.0
6.0	899.0
8.0	1,640.0
10.0	2,500.0
20.0	5,000.0
24.0	5,300.0
30.0	4,520.0
40.0	3,660.0
50.0	2,700.0
80.0	1,500.0

100.0	913.0
150.0	410.0
200.0	266.0
300.0	156.0

A15. Definition of "Beryllia"

Name	Value
Density	2,850.0 kg/m ³
Poisson's Ratio	0.26
Young's Modulus	3.45 × 10 ¹¹ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	248.0 W/m·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	1.38 × 10 ⁸ Pa

A16. Definition of "Epoxy"

Name	Value
Density	1,200.0 kg/m ³
Poisson's Ratio	0.0
Young's Modulus	2.6 × 10 ⁹ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	0.2 W/m·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	6.0 × 10 ⁷ Pa

A17. Definition of "Kapton 2"

Name	Value
Density	1,340.0 kg/m ³
Poisson's Ratio	0.34
Young's Modulus	2.9 × 10 ⁹ Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	0.37 W/m·°C
Relative Permeability	0.0
Resistivity	0.0 Ohm·m
Tensile Yield Strength	1.79 × 10 ⁸ Pa

A18. Distributing This Report

The following table lists the files that you need to include for posting this report to an Internet or Intranet web server or for moving this report to a different location. Store all files in the same folder as the HTML page.

This report was originally generated in the folder "C:\ATLASUPGRADE\pics\".

Table A18.1. Files Included In This Report	
File Name	Description
"STAVE.htm"	This HTML page.
"StyleSheet.css"	The Cascading Style Sheet used to format the HTML page.
"AnsCompanyLogo.gif"	The ANSYS image displayed at the top of the title page.
"DS0001.jpg"	Figure A1.1. "struct" Geometry
"DS0002.jpg"	Figure A1.2. "Equivalent Stress" Contours
"DS0003.jpg"	Figure A1.3. "Total Deformation" Contours
"DS0004.jpg"	Figure A2.1. "Environment" Geometry
"DS0005.jpg"	Figure A2.2. "Temperature" Contours
"DS0006.jpg"	Figure A3.1. "Environment" Geometry
"DS0007.jpg"	Figure A3.2. "Temperature" Contours
"DS0008.jpg"	Figure A4.1. "Environment" Geometry
"DS0009.jpg"	Figure A4.2. "Temperature" Contours
"DS0010.jpg"	Figure A6.1. "Environment 2" Geometry
"DS0011.jpg"	Figure A6.2. "Equivalent Stress" Contours
"DS0012.jpg"	Figure A6.3. "Total Deformation" Contours
"DS0013.jpg"	Figure A7.1. "Environment" Geometry
"DS0014.jpg"	Figure A7.2. "Equivalent Stress" Contours
"DS0015.jpg"	Figure A7.3. "Total Deformation" Contours
"DS0016.jpg"	Figure A8.1. "Environment" Geometry
"DS0017.jpg"	Figure A8.2. "Equivalent Stress" Contours
"DS0018.jpg"	Figure A8.3. "Total Deformation" Contours

"DS0019.jpg"	Figure A9.1. "Environment" Geometry
"DS0020.jpg"	Figure A9.2. "Temperature" Contours
"Table0001.jpg"	Table A14.2. "Thermal Conductivity" Thermal Conductivity