



CLV Upper Stage Common Bulkhead Sizing with HyperFEA

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Corporation
Hampton, VA**

Spherical Common Bulkhead Geometry



- Three Load Cases:

- Internal (outward)

$P = 50 \text{ psi}$

$T = -293 \text{ F}$

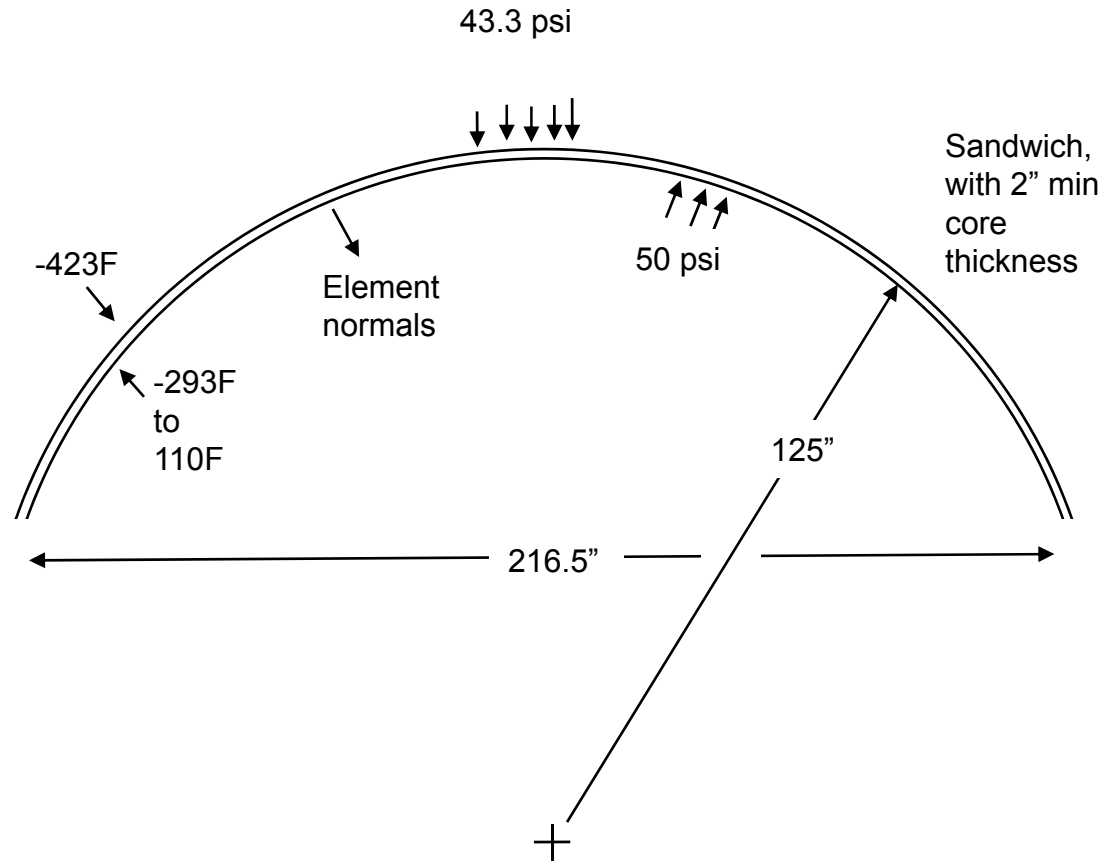
- External (crushing)

$P = 43.3 \text{ psi}$

$T = -423 \text{ F}$

- Combined

$\Delta G = -423 \text{ to } -293$



Assumptions

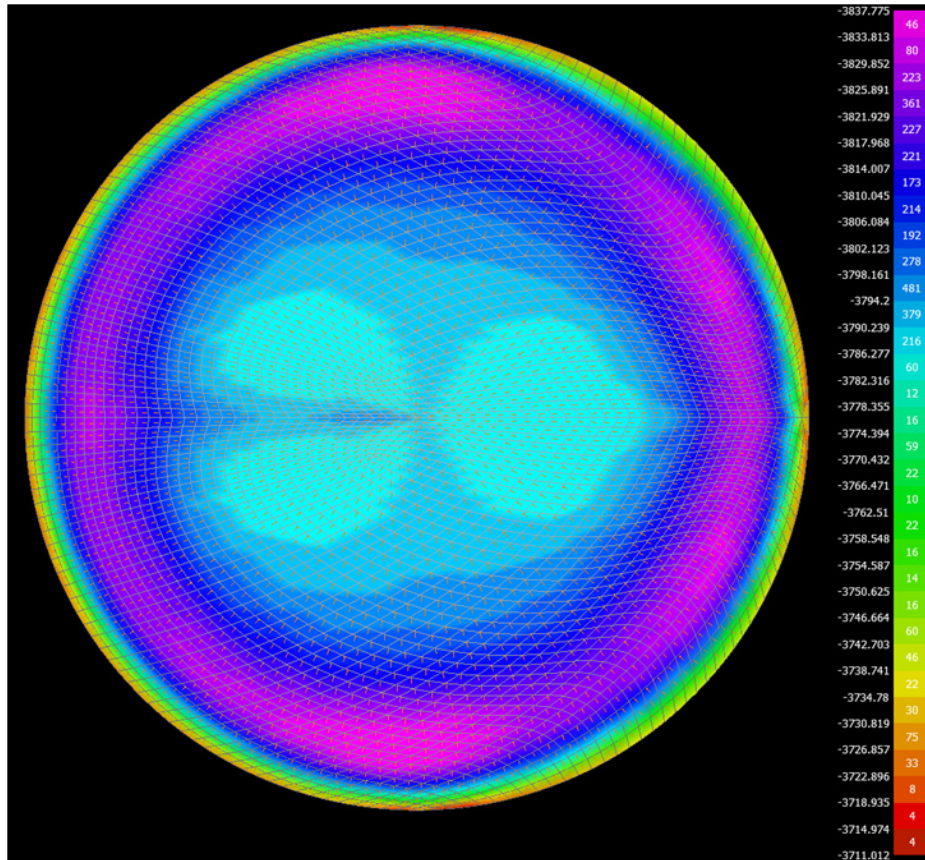


- Only using what is perceived to be the most severe load case: Hydrogen Crushing Pressure = 43.3 psi
- Temperature of wall assumed to be -423 F
- Boundaries of bulkhead are pinned ($u = v = w = 0$)
- Bulkhead is represented as a single large shell component where shell properties represent the entire sandwich (i.e. no solid elements)
- Reference plane is midplane of honeycomb panel
- Minimum gages of 2" Core and 0.04" facesheets not used for current sizing study

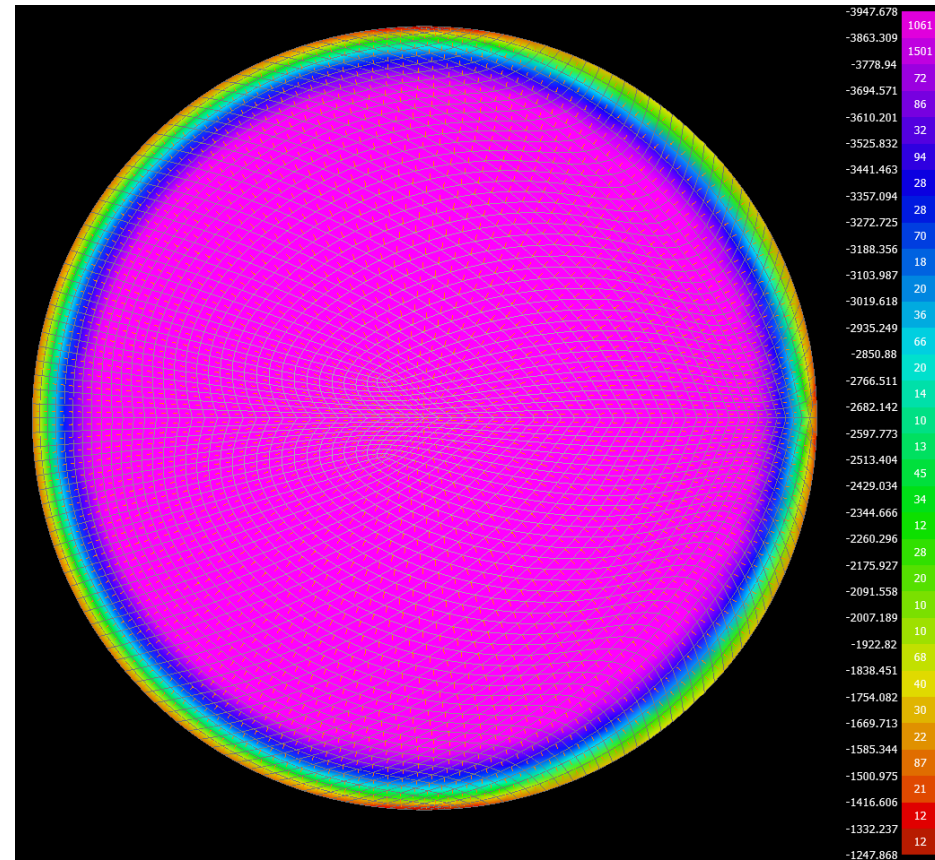
Nx and Ny Static Loads



Static Solution, Nx Contours



Static Solution, Ny Contours



Static Displacements and Buckling Modes (Nastran)



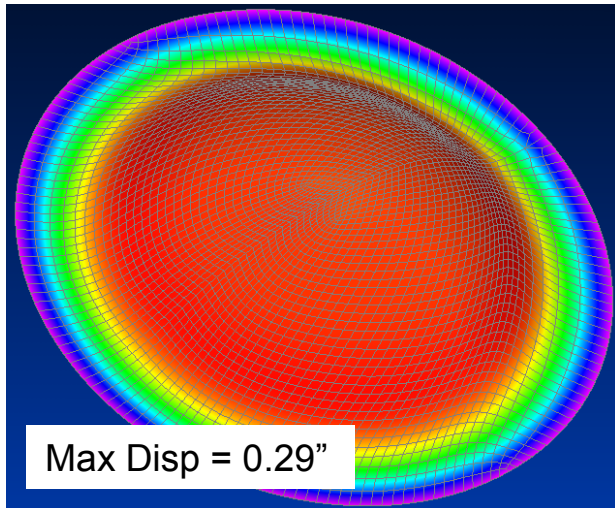
Facesheets:

Al 2219, $t = 0.06''$

Core:

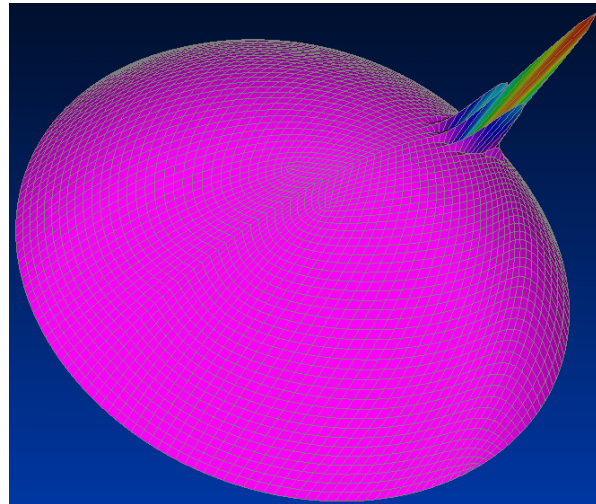
Hexcel HRH 10-1/8-4.0, $t=1''$

Static Solution (Displacement)

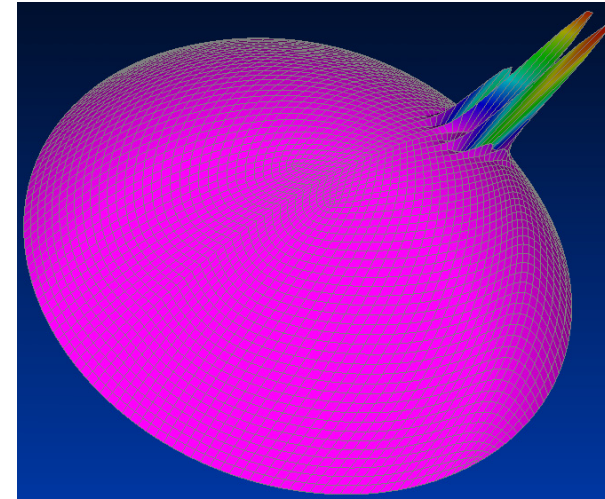


Buckling mode shapes show tendency for short wavelength buckling (i.e. crimping) in areas of high Q_x due to soft core material

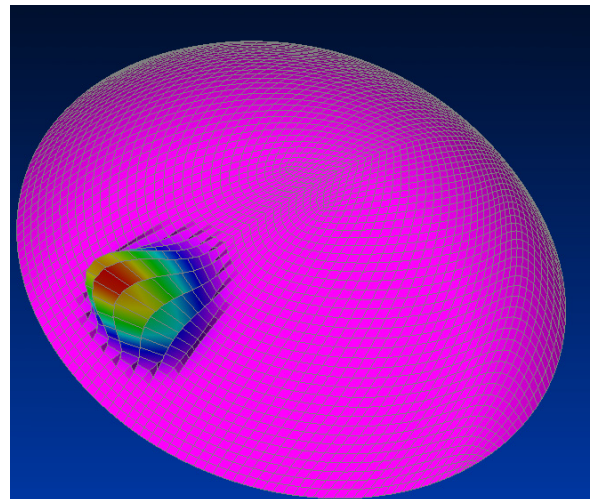
Mode 1



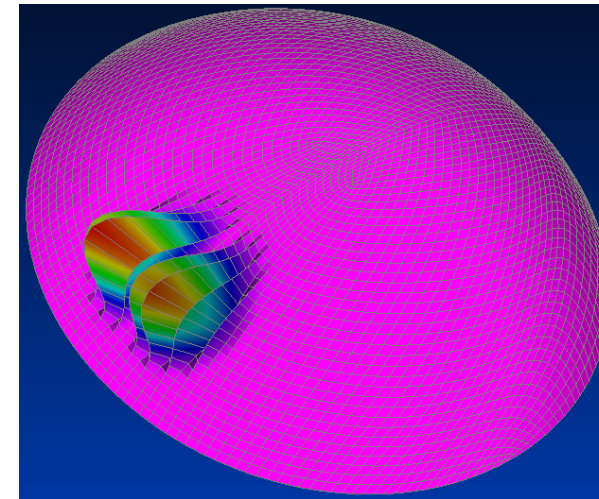
Mode 2



Mode 3



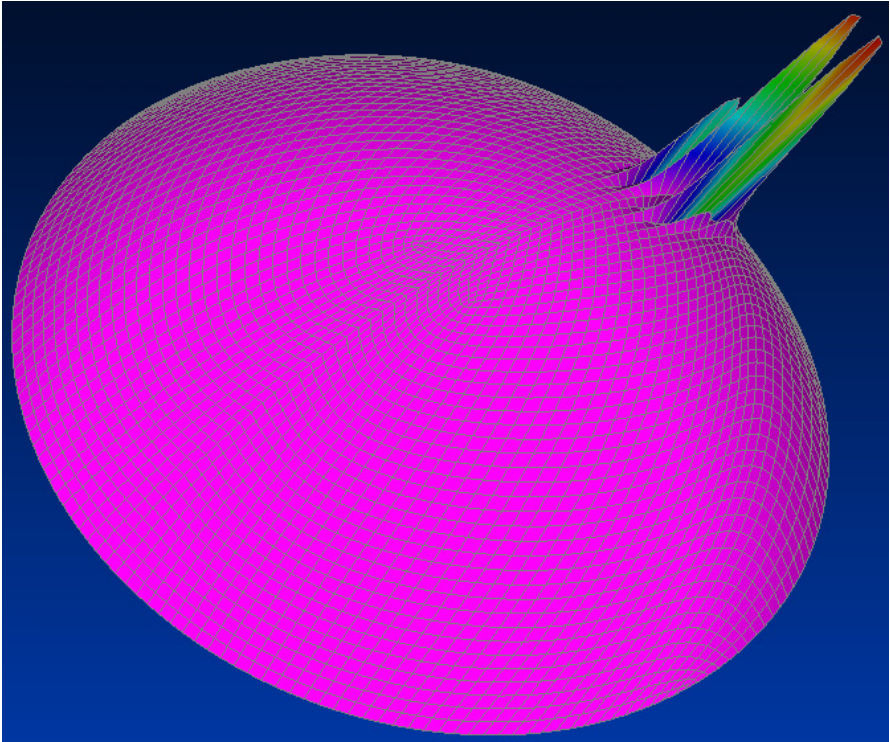
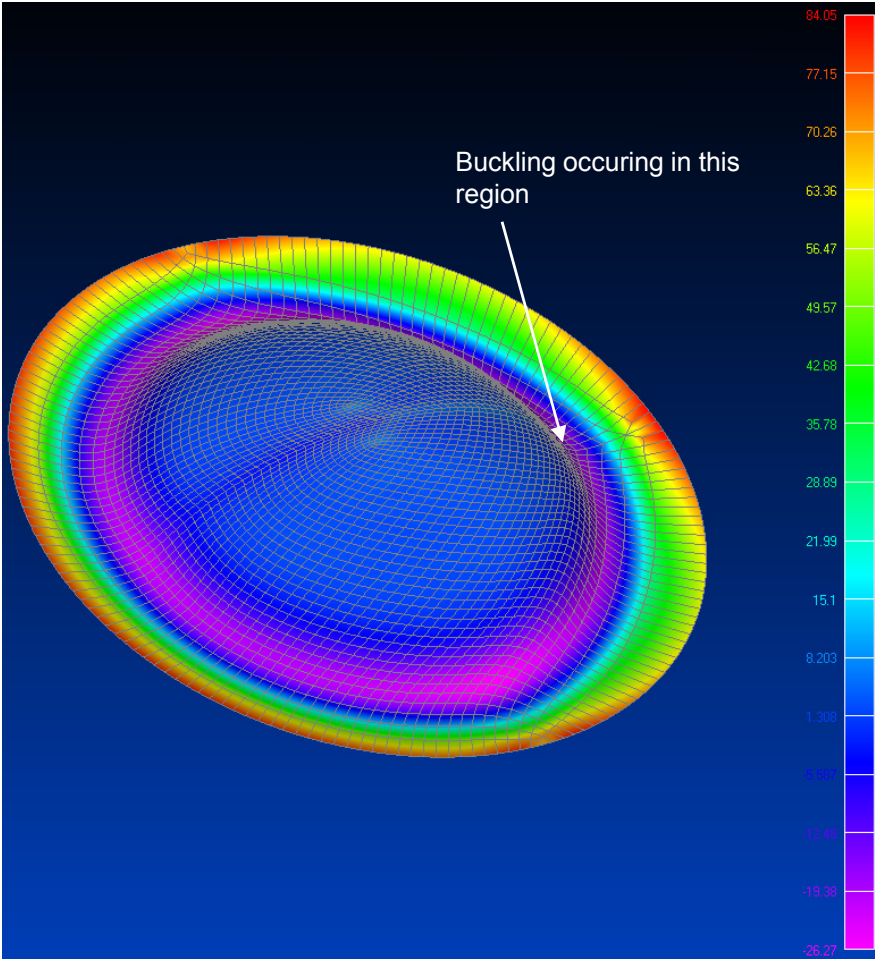
Mode 5



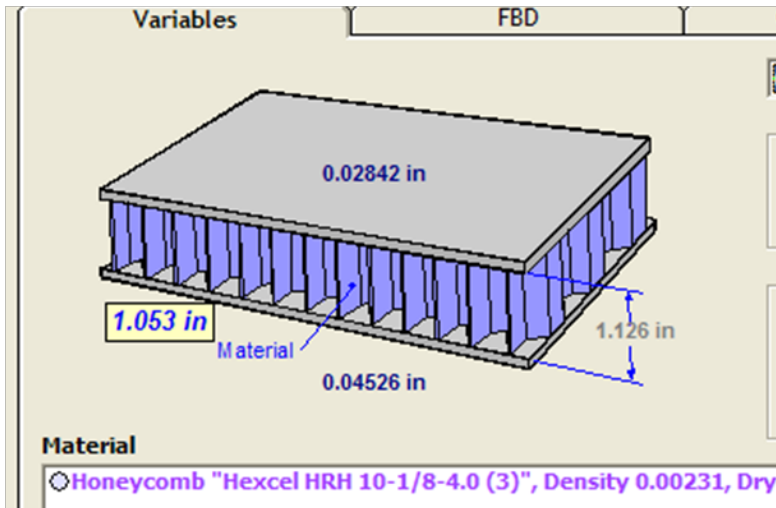
Short Wavelength Buckling in areas of high out-of-plane shear



Static Qx



Start with HyperSizer standard sizing



Setup

X Span: 20

Y Span: 20 (348.9926 max)

Panel Knockdown: 0.5

Initial Imperfection: 0

Local Knockdown: 1

Panel is Curved:

- Panel knockdown factor assumed to be 0.5 – solution also includes 1.4 ultimate factor
- Sizing controlled by facesheet wrinkling and Shear Crimping (i.e. short wavelength buckling)

Available Failure Analyses

Limit MS	Ultimate MS	γ	Location - Analysis Description
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (1
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	1.037 (0)		Honeycomb Panel Buckling, Curved or Flat, All BC
			Honeycomb Panel Buckling, Curved or Flat, NASA SP-8007
0.4441 (0)	0.1346 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honey
0.4107 (0)	0.1084 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
26.46 (0)	20.58 (0)		Top Honeycomb Face Intracell Dimpling, X, Y & Interaction
			Honeycomb Core Crushing, Concentrated Load
471.9 (0)	290.9 (0)		Honeycomb Core Crushing, Flexural Bending Load
			Honeycomb Core Crushing, Joint Support Load
0.3341 (0)	0.04822 (0)		Honeycomb Core Shear Crimping, X, Y & Interaction (Hexc
14.04 (0)	10.82 (0)		Honeycomb Core Shear Strength, x (Longitudinal) direction
28.04 (0)	21.81 (0)		Honeycomb Core Shear Strength, Y (Transverse) direction
			Honeycomb Core Shear Strength, Interaction
0.2984 (0)	0.0202 (0)		Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or H
0.5731 (0)	0.236 (0)		Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb C
60.55 (0)	47.36 (0)		Bottom Honeycomb Face Intracell Dimpling, X, Y & Intera

After converging with standard HyperSizer HyperFEA sizing, activate eigenvalue sizing



HyperFEA
sizing without
FEA
eigenvalue
calculation

The screenshot shows the HyperFEA software interface. The main window displays a progress window on the left and a graph on the right. The progress window shows the current iteration (4) and the FEM format (NEINastran). The graph plots Weight (Y-axis) against iterations (X-axis). The weight starts at 644.4 and converges to 490.2 after 4 iterations. The Options dialog box is open, showing the Iteration Control Options section with the 'Run Eigenvalue analysis every' checkbox checked and set to 1 iteration, and the Minimum Eigenvalue set to 2.8. The Wing Displacement Limits section is also visible, showing limits for Wing tip displacement (in), Wing tip twist (deg), and Control Nodes.

Iteration	Total	Panel	Beam	Eigv	Tip Defl.	Twist	C.Lift
0	644.4	644.4	.0				
1	511.4	511.4	.0				
2	490.2	490.2	.0				
2	490.2	490.2	.0				
3	490.2	490.2	.0				
4	490.2	490.2	.0				

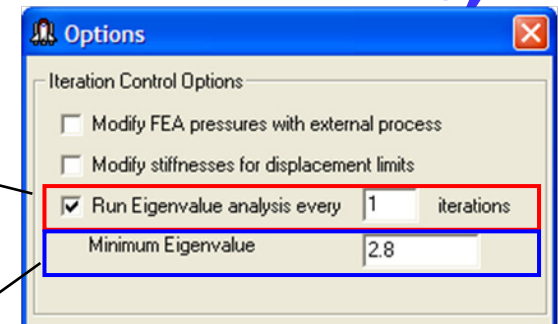
Options dialog box settings:

- Iteration Control Options:
 - Modify FEA pressures with external process:
 - Modify stiffnesses for displacement limits:
 - Run Eigenvalue analysis every: 1 iterations
 - Minimum Eigenvalue: 2.8
- Wing Displacement Limits:

	Limit	Current
Wing tip displacement (in)	0	
Wig tip twist (deg)	0	
Control Nodes	0	0

HyperFEA Eigenvalue Sizing

- Using HyperFEA, at user specified intervals, execute an FEA eigenvalue solution
- If minimum eigenvalue is below the required minimum, apply a required stiffness in HyperSizer

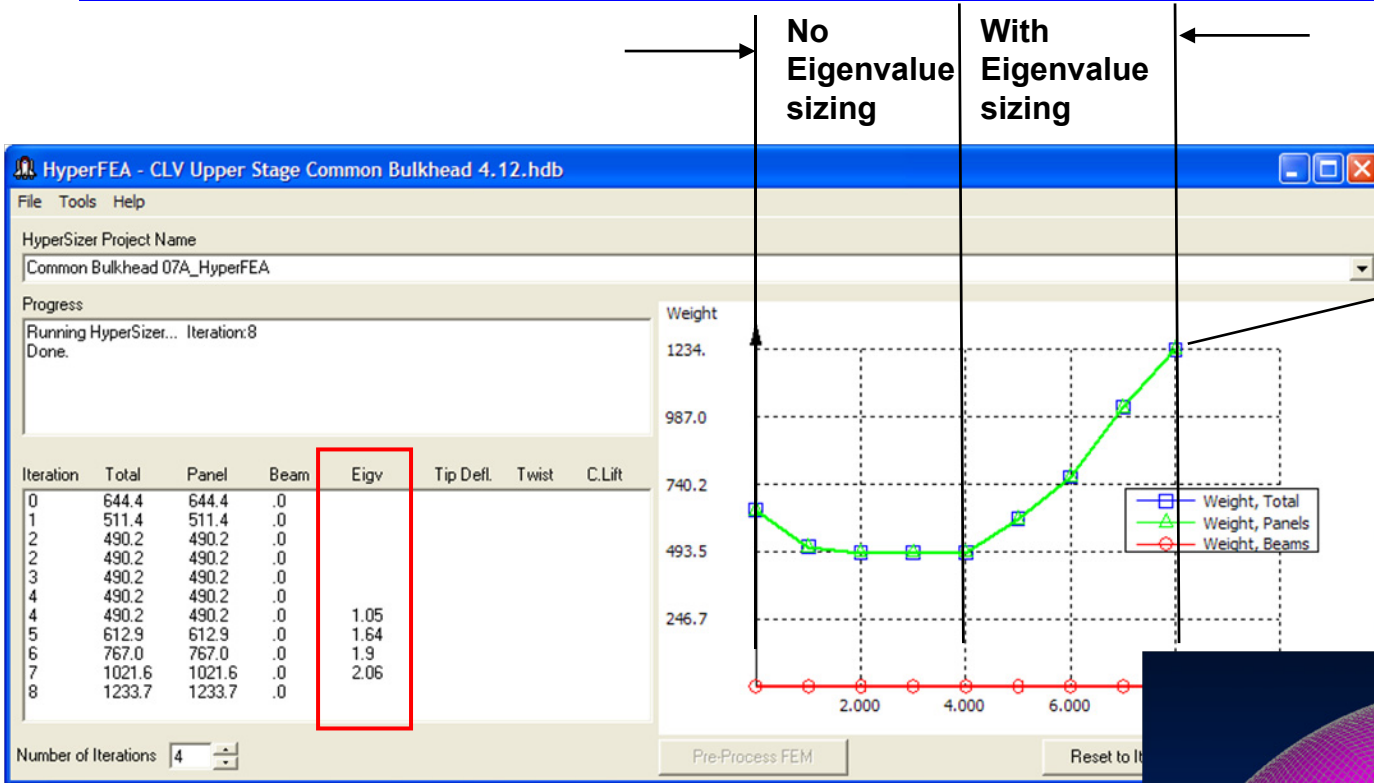


$$D_{ij, reqd} = D_{ij, result} * Eigv_{reqd} / Eigv_{result}$$

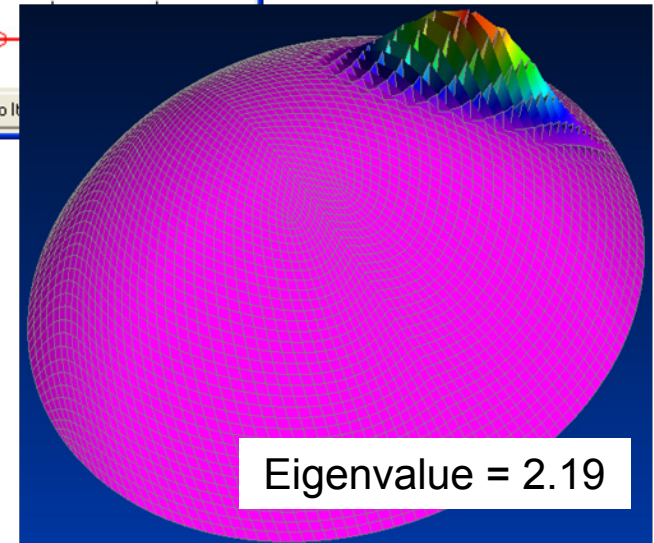
Optimization Requirements

	Required Value	Computed Value
Symmetric Stiffness Terms		
A11		813711.5
A22		813711.5
A33		266021.1
D11	307157.2	329475.9
D22	307157.2	329475.9
D33	105339.2	112993.3

HyperFEA Sizing with Eigenvalue leads to oversize with soft nomex/phenolic core



Oversize:
Max gage on all dimensions
Therefore required Eigv=2.8 cannot be reached



Facesheets:

Al 2219, $t = 0.06''$

Core:

Hexcel HRH 10-1/8-4.0, $t=1''$

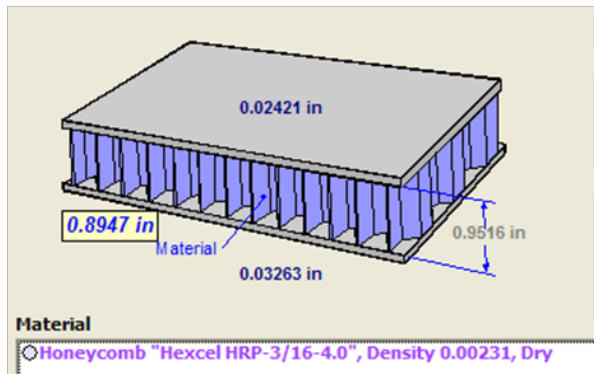
To prevent short wavelength buckling, use stiffer Aluminum Core Material



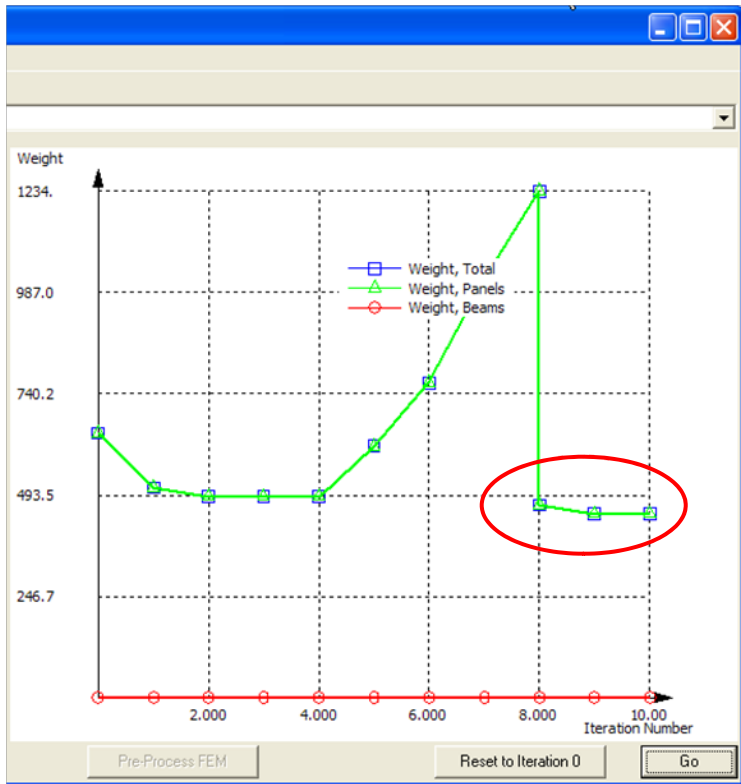
Hexcel HRH 10-1/8-4.0 Hexcel 1/8-5052-.0015

Material	Nomex/Phenolic	Al 5052
Density (pcf)	4	6.1
Et (ksi)	28	240
GW (ksi)	4.7	41
GL (ksi)	9.2	98
Ftu (ksi)	0.47	0.68
FsuW (ksi)	0.11	0.27
FsuL (ksi)	0.23	0.46

HyperSizer Sizing using stiffer core without eigenvalue analysis

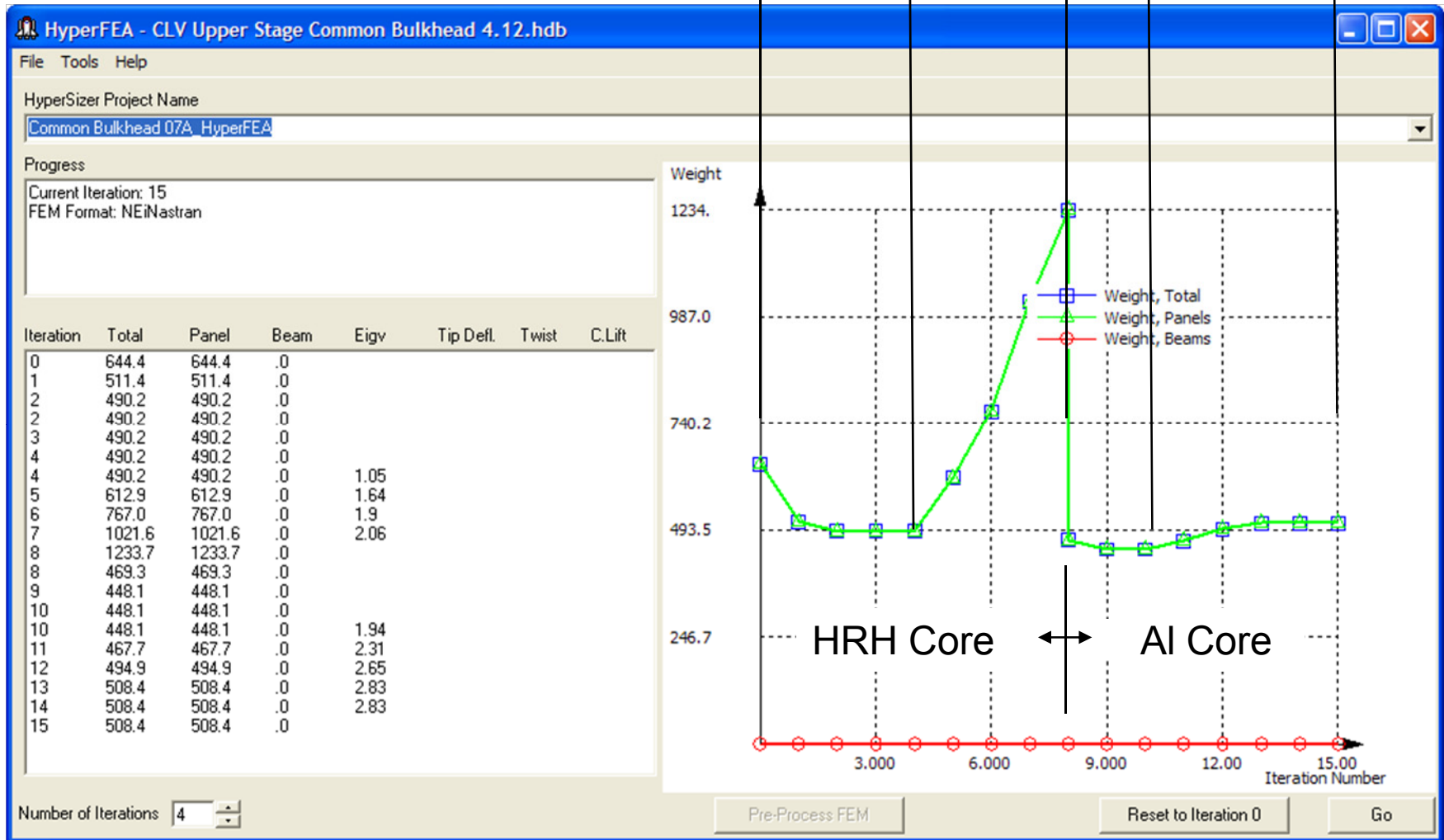


Available Failure Analyses			Location - Analysis Description
Limit MS	Ultimate MS	γ	
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (1
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	0.07855 (0)		Honeycomb Panel Buckling, Curved or Flat, All BC
			Honeycomb Panel Buckling, Curved or Flat, NASA SP-8007
4.119 (0)	3.022 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honey
2.972 (0)	2.121 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
22.25 (0)	17.27 (0)		Top Honeycomb Face Intracell Dimpling, X, Y & Interaction
			Honeycomb Core Crushing, Concentrated Load
Very High	710.4 (0)		Honeycomb Core Crushing, Flexural Bending Load
			Honeycomb Core Crushing, Joint Support Load
7.992 (0)	6.065 (0)		Honeycomb Core Shear Crimping, X, Y & Interaction (Hexc
11.64 (0)	8.928 (0)		Honeycomb Core Shear Strength, X (Longitudinal) direction
32.28 (0)	25.15 (0)		Honeycomb Core Shear Strength, Y (Transverse) direction
			Honeycomb Core Shear Strength, Interaction
3.526 (0)	2.556 (0)		Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or H
2.538 (0)	1.78 (0)		Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb C
24.48 (0)	19.02 (0)		Bottom Honeycomb Face Intracell Dimpling, X, Y & Intera

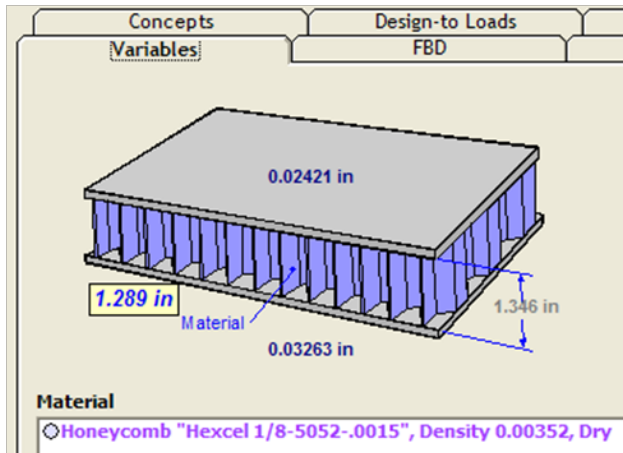


- Controlled by panel buckling
- Short wavelength phenomena (crimping, wrinkling) are no longer a factor

Activate Eigenvalue Sizing

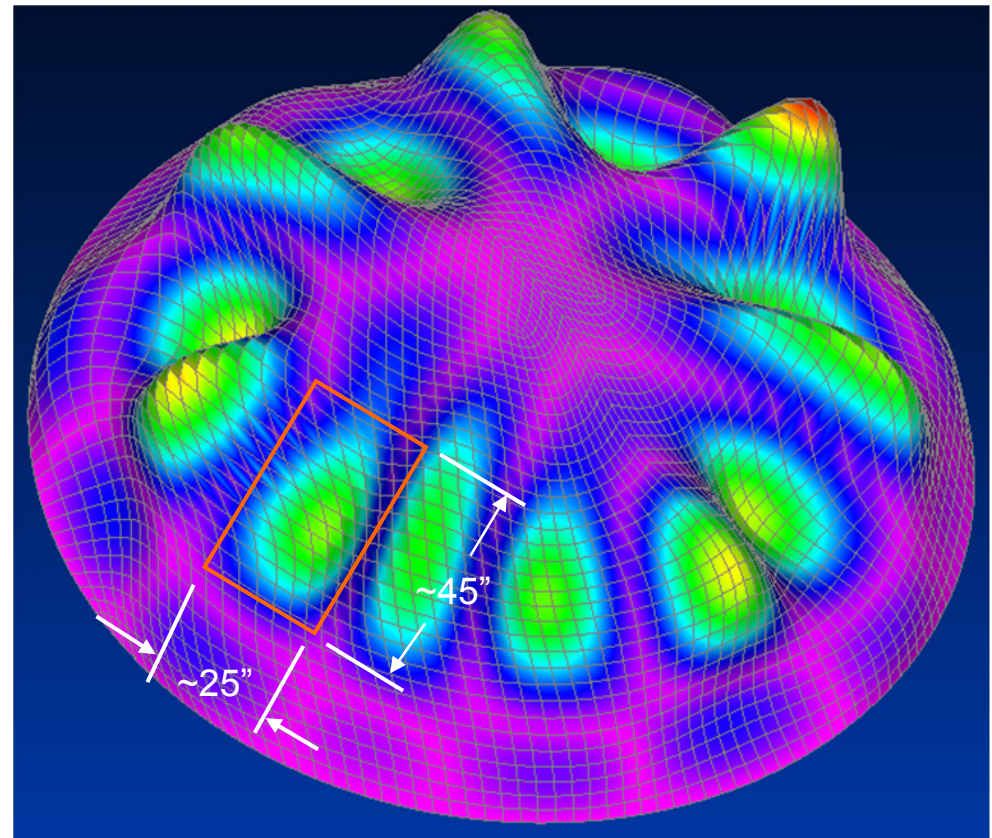


HyperSizer buckling solution shows substantial positive margin, use FEA Eign solution to determine more appropriate buckling lengths



Unit Weight = 1.50 psf
 FEA Eigenvalue = 2.82

Available Failure Analyses			Location - Analysis Description
Limit MS	Ultimate MS	γ	
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (T
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	1.362 (0)		Honeycomb Panel Buckling, Curved or Flat, All BC
			Honeycomb Panel Buckling, Curved or Flat, NASA SP-8007
3.63 (0)	2.637 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honey
1.666 (0)	1.094 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
14.42 (0)	11.12 (0)		Top Honeycomb Face Intracell Dimpling, X, Y & Interaction
			Honeycomb Core Crushing, Concentrated Load
Very High	647.9 (0)		Honeycomb Core Crushing, Flexural Bending Load
			Honeycomb Core Crushing, Joint Support Load
12.98 (0)	9.986 (0)		Honeycomb Core Shear Crimping, X, Y & Interaction (Hexc
16.48 (0)	12.74 (0)		Honeycomb Core Shear Strength, X (Longitudinal) direction
51.27 (0)	40.07 (0)		Honeycomb Core Shear Strength, Y (Transverse) direction
			Honeycomb Core Shear Strength, Interaction
3.219 (0)	2.315 (0)		Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or H
1.625 (0)	1.062 (0)		Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb C
22.77 (0)	17.67 (0)		Bottom Honeycomb Face Intracell Dimpling, X, Y & Intera



HyperSizer buckling solution shows substantial positive margin, use FEA Eigv solution to determine more appropriate buckling lengths



Original Buckling lengths

Setup

X Span: 20

Y Span: 20 (348.9926 max)

Panel Knockdown: 0.5

Initial Imperfection: 0

Local Knockdown: 1

Panel is Curved:



Available Failure Analyses

Limit MS	Ultimate MS	γ	Location - Analysis Description
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (T
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	1.362 (0)		Honeycomb Panel Buckling, Curved or Flat, All BC
3.63 (0)	2.637 (0)		Honeycomb Panel Buckling, Curved or Flat, NASA SP-8007
1.666 (0)	1.094 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honey
14.42 (0)	11.12 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
			Top Honeycomb Face Intracell Dimpling, X, Y & Interactor
			Honeycomb Core Crushing, Concentrated Load
Very High	647.9 (0)		Honeycomb Core Crushing, Flexural Bending Load
			Honeycomb Core Crushing, Joint Support Load
12.98 (0)	9.986 (0)		Honeycomb Core Shear Crimping, X, Y & Interaction {Hexc
16.48 (0)	12.74 (0)		Honeycomb Core Shear Strength, X (Longitudinal) director
51.27 (0)	40.07 (0)		Honeycomb Core Shear Strength, Y (Transverse) direction
			Honeycomb Core Shear Strength, Interaction
3.219 (0)	2.315 (0)		Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or H
1.625 (0)	1.062 (0)		Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb C
22.77 (0)	17.67 (0)		Bottom Honeycomb Face Intracell Dimpling, X, Y & Intera

Modified buckling lengths based on FEA solution

Setup

X Span: 45

Y Span: 25 (348.9926 max)

Panel Knockdown: 0.5

Initial Imperfection: 0

Local Knockdown: 1

Panel is Curved:



Available Failure Analyses

Limit MS	Ultimate MS	γ	Location - Analysis Description
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (T
	N/A		Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
	0.007994 (0)		Honeycomb Panel Buckling, Curved or Flat, All BC
			Honeycomb Panel Buckling, Curved or Flat, NASA SP-8007
3.63 (0)	2.637 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honey
1.666 (0)	1.094 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
14.42 (0)	11.12 (0)		Top Honeycomb Face Intracell Dimpling, X, Y & Interactor
			Honeycomb Core Crushing, Concentrated Load
Very High	647.9 (0)		Honeycomb Core Crushing, Flexural Bending Load
			Honeycomb Core Crushing, Joint Support Load
12.98 (0)	9.986 (0)		Honeycomb Core Shear Crimping, X, Y & Interaction {Hexc
16.48 (0)	12.74 (0)		Honeycomb Core Shear Strength, X (Longitudinal) director
51.27 (0)	40.07 (0)		Honeycomb Core Shear Strength, Y (Transverse) direction
			Honeycomb Core Shear Strength, Interaction
3.219 (0)	2.315 (0)		Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or H
1.625 (0)	1.062 (0)		Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb C
22.77 (0)	17.67 (0)		Bottom Honeycomb Face Intracell Dimpling, X, Y & Intera