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Modeling Isogrid Buckling

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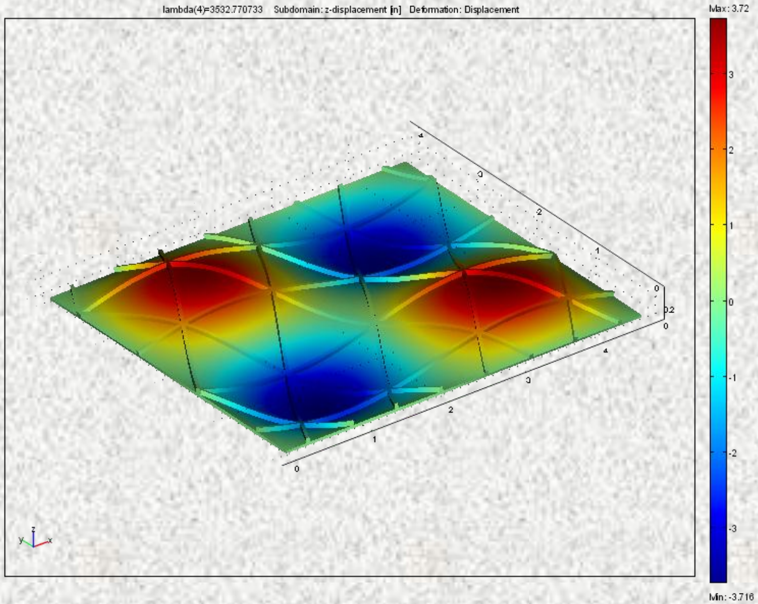
Topic Overview

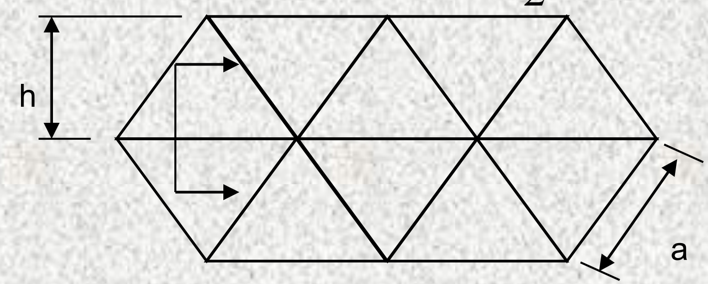
- Isogrid Geometry
- Analytical Solution
- Analysis Approach
- Model Creation And Meshing
- Modeling Results
- Mode Shape Verification
- Rib Buckling
- Conclusions



Isogrid Geometry

- Created by individual equilateral triangular panels
  - Triangle geometry defined by height (h) and side (s)
- Based on NASA report CR-124075
  - Geometry is reducible to unit width panel for all h and s
  - Maintain bending (D) and tensile (K) stiffness
  - E^* and t^* provide equivalent stiffness

$$h = a\frac{\sqrt{3}}{2}$$



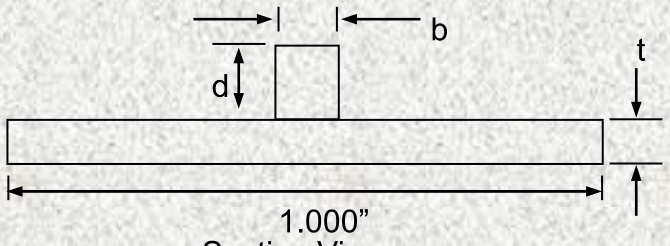
Stiffness Equations

$$D = \frac{E^* t^{*3}}{12(1-\nu^2)}$$

$$K = \frac{E^* t^*}{1-\nu^2}$$

$$t^* = \sqrt{\frac{12I}{A}} = t\,\frac{\beta}{1+\alpha+\mu}$$

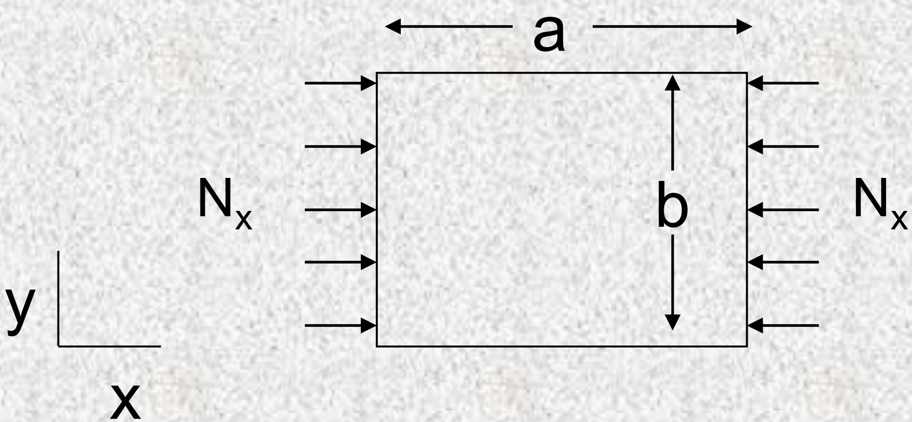
$$E^* = E_0 \frac{A}{t^*}$$



Section View

Analytical Solution

- Simple supported plate
  - Based on E^* and t^* calculations
- Calculate critical load required for elastic instability
  - Loads calculated for individual modes
  - M controls load direction half wave
  - N controls load perpendicular half wave
- 3 load cases capture geometry variation



$$N_x = b\frac{a^2\pi^2 D}{m^2}\left(\frac{m^2}{a^2}+\frac{n^2}{b^2}\right)^2$$

$$D = \frac{E^* t^{*3}}{12(1-\nu^2)}$$

$$a = 4.618''$$

$$b = 4.000''$$

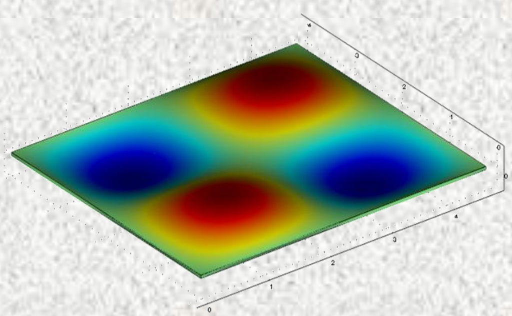
Analysis Approach

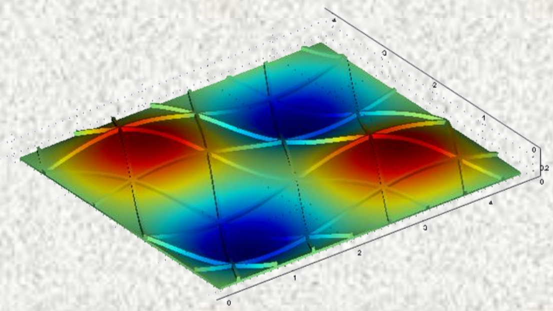
- Verify numerical approach with plate model
  - 4.618” (a) x 4.000” (b)
  - E^* and t^* used in analytical solution
- Model isogrid panel
  - 4.618” (a) x 4.000” (b)
  - Verify E^* and t^* methodology
  - Represents configuration specific geometry
- Verify predicted mode shapes match analytical solution

$$N_x = b\frac{a^2\pi^2 D}{m^2}\left(\frac{m^2}{a^2}+\frac{n^2}{b^2}\right)^2$$

$$a = 4.618'' \qquad m = 2$$

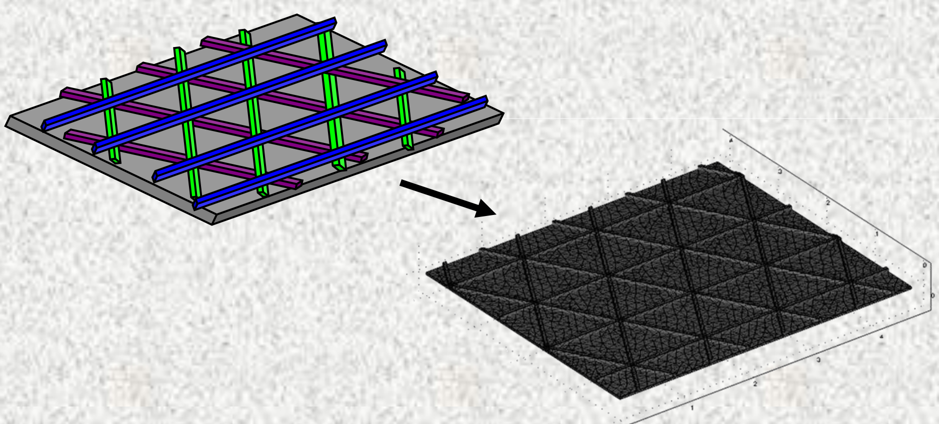
$$b = 4.000'' \qquad n = 2$$

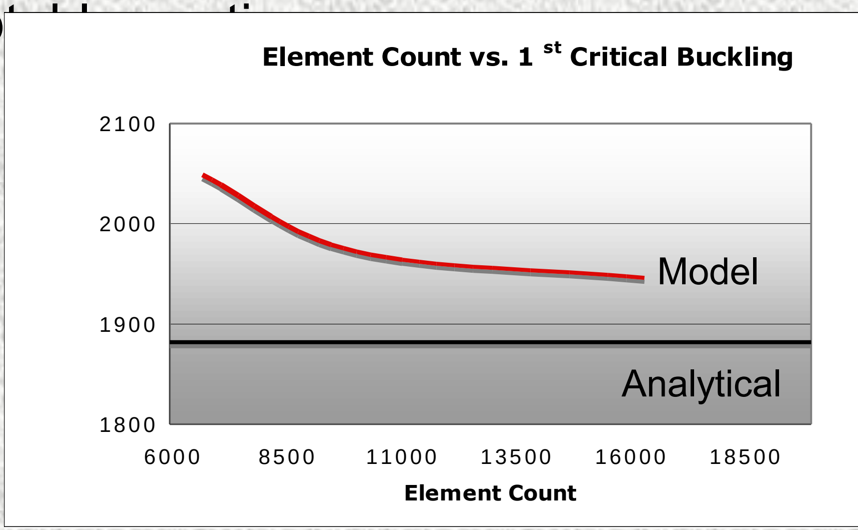




Model Creation And Meshing

- All geometry developed from simple blocks
  - Ribs rotated in specific locations to create triangular pattern
  - Arrays created to reduce rib modeling time
- Composite object created with ribs
  - Allowed simplified trimming
- Auto-mesh used to create rapid mesh study
  - Verify mesh density for complex mode shapes
  - “Coarser” mesh provided accept





Modeling Results

- Eigen-buckling analysis completed using unit load
  - Calculated eigenvalue is critical buckling load
- Analytical solution compares well with numerical analysis
  - Analytical plate calculated using E^*t^* properties
  - Numerical plate model compared using E^*t^* properties
  - Isogrid model comparison based on model geometry and E_0

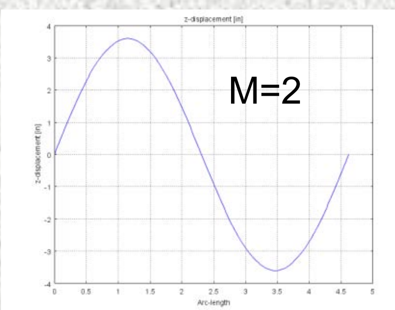
Increased Complexity

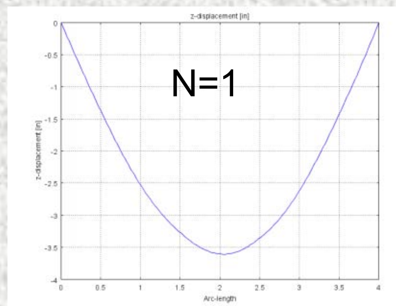
No increase in error

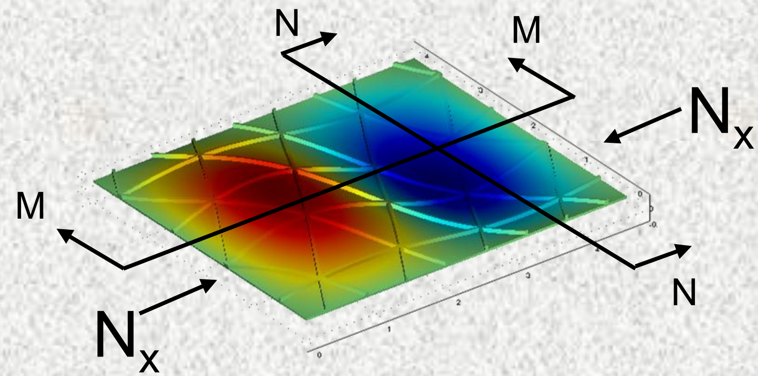
m	n	Calculated	Plate	Percent Error	Delta	Isogrid	Percent Error	Delta
1	1	1882	1858	-1.28	-24	1946	3.39	64
2	1	2458	2431	-1.11	-27	2543	3.44	85
3	1	4102	4063	-0.94	-39	4223	2.96	121
4	1	6492	6435	-0.87	-57	6568	1.18	76
2	2	7529	7433	-1.27	-96	7620	1.21	91
				Average	-48		Average	88

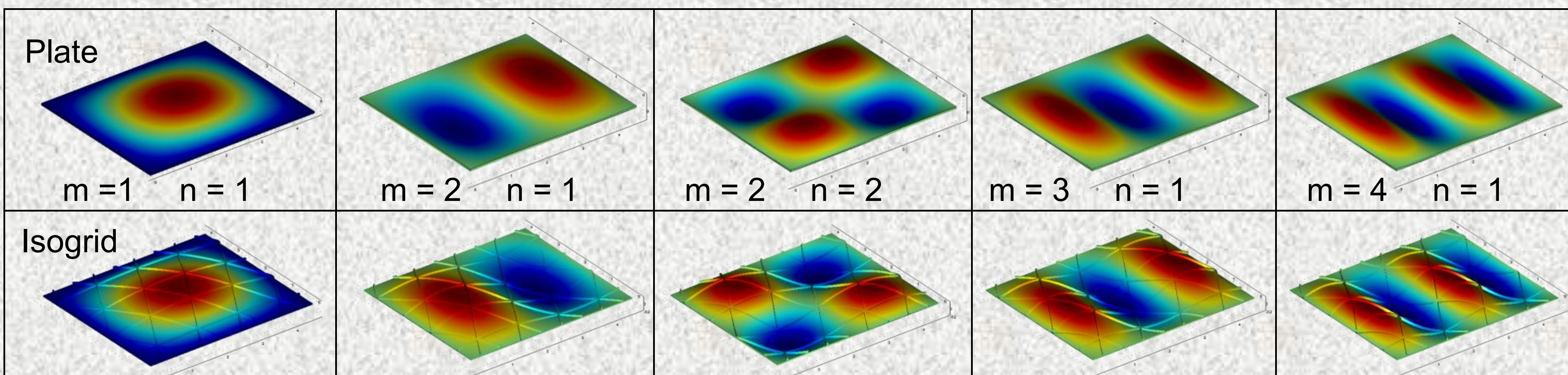
Mode Shape Verification

- First 5 mode shapes verified
  - Analytical solution compared to numerical prediction
  - Analytical shapes based on values of m and n



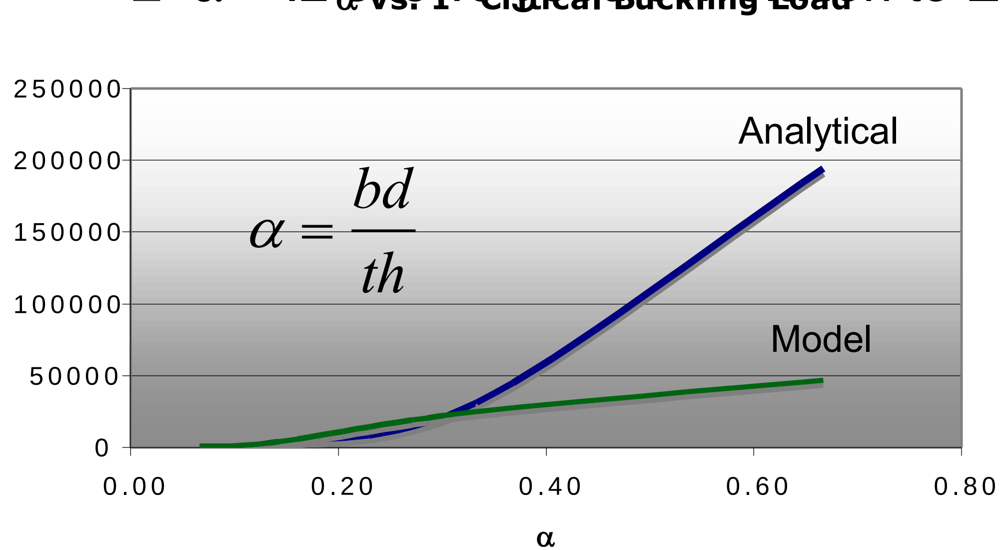


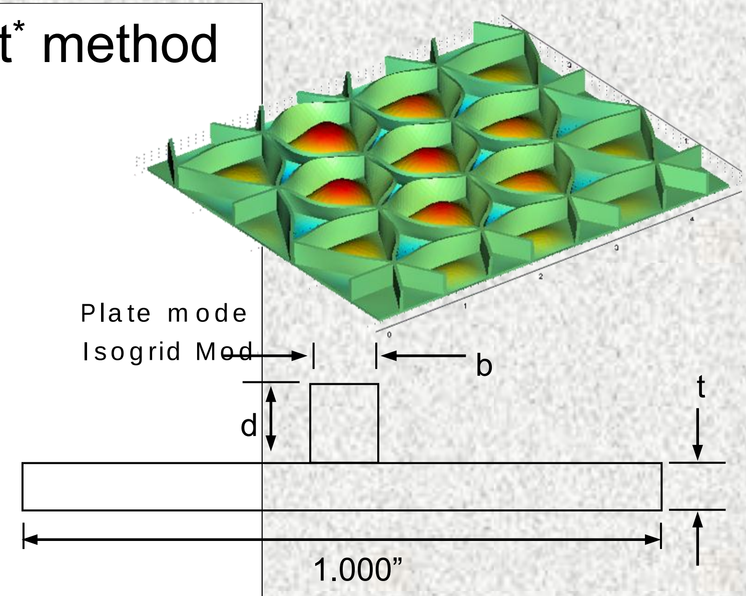




Rib Buckling

- Model created by scaling rib composite object
- Study completed for 4 different rib heights
  - Rib height (d) varied
  - Load applied to both edges a and b
- Parameter α used for comparison of E^*t^* applicability
  - α < .2 shows good correlation to E^*t^* method





Conclusions

- Analytical critical buckling load matches numerical approximation
  - Plate model critical buckling load off 1.3%
  - Isogrid model critical buckling load off 3.5%
- Model accuracy did not decrease with displacement complexity
  - Mesh density appropriate to calculate mode shape
- Correct buckling mode shapes produced
  - Verified with both plate and isogrid model
- Verified E^*t^* design approach for use on plate buckling
  - Design limitation defined based on non-dimensional parameter

Questions

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