

Analysis of Elastomeric Components & Assemblies: Some Practical Considerations

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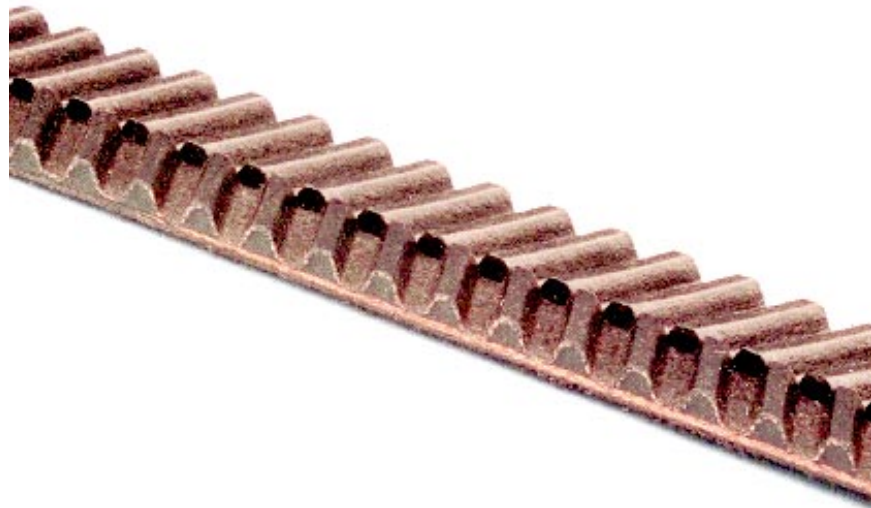
ACE Profile

- W. Lafayette, Indiana
- Started in 1985
- 15 employees
- ABAQUS Rep. since 1988.
- Business profile:
 - 1/4 support usage of ABAQUS
 - 3/4 engineering services
 - Solution of mechanical design problems with ABAQUS

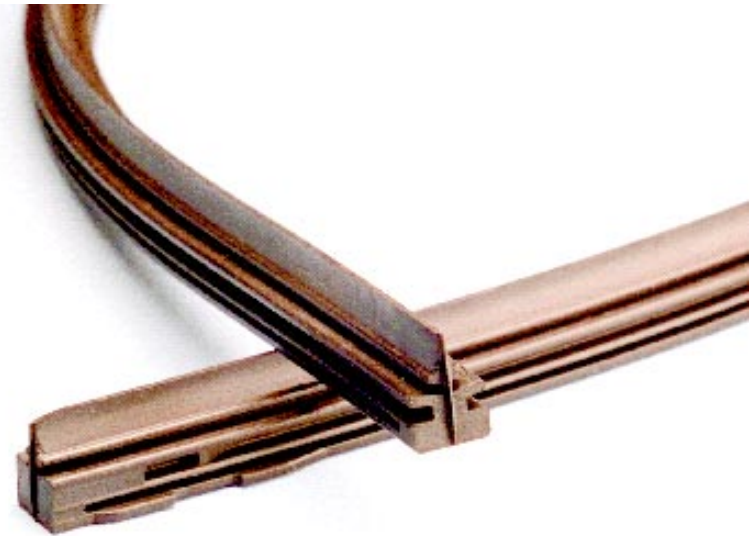




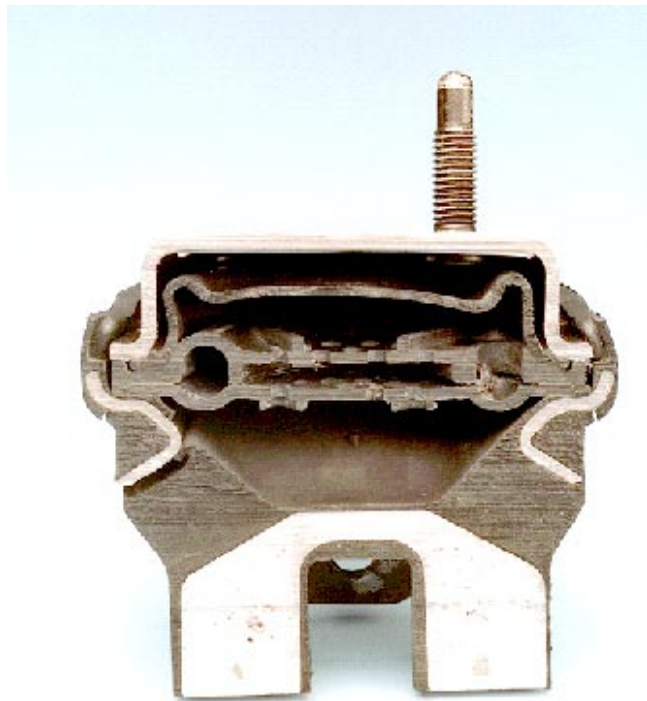
Staple/Nail Gun - Timing Belt



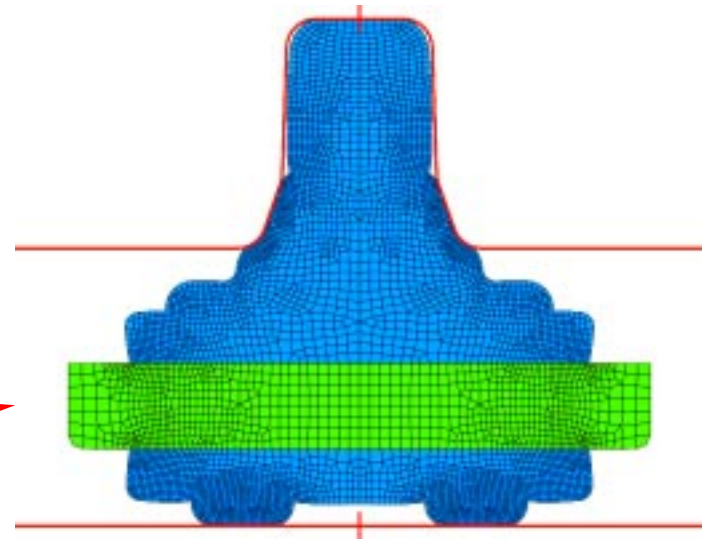
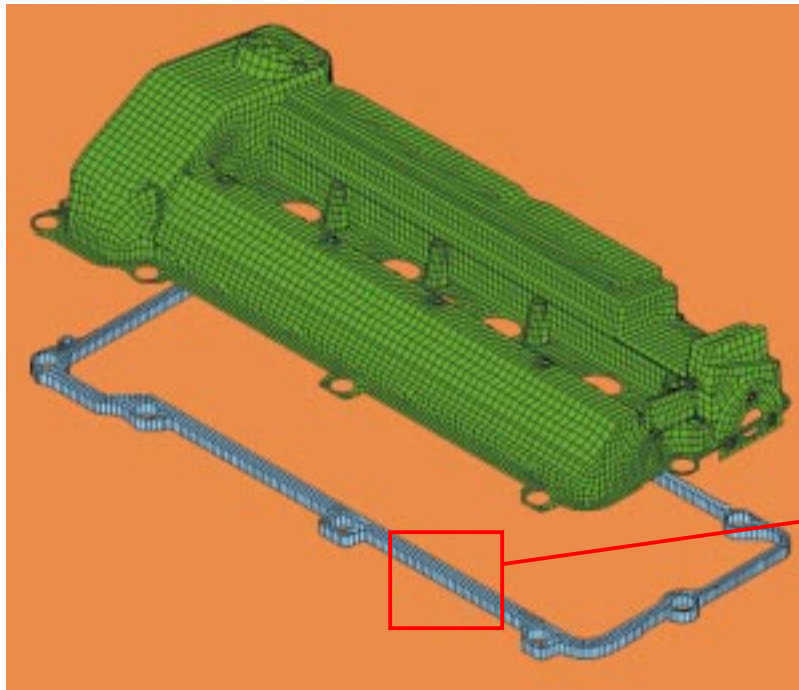
Tires - Wiper Blades



Engine/Transmission Mounts



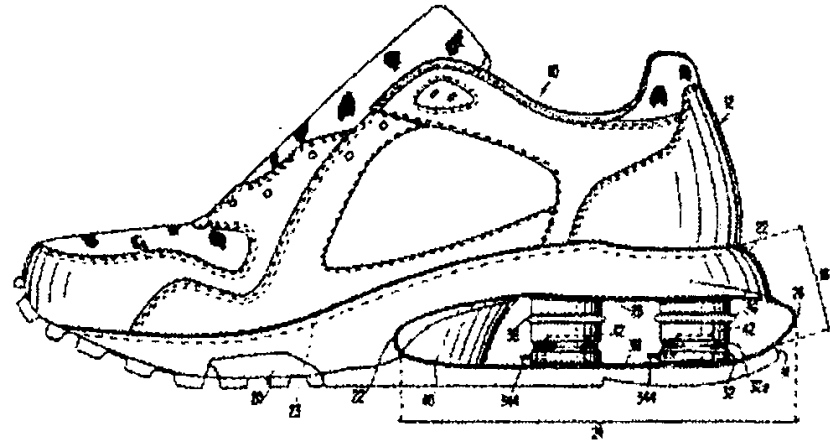
Valve Cover Gasket



Hospital Products

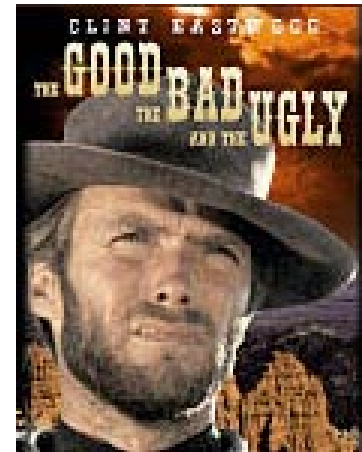


Agriculture - Athletic



ABAQUS Tips and Tricks for Rubber Problems

- Material Properties
- "Rubber Turbulence"
- The "Silver Bullet" for Rubber Problems
- Rubber Parts in Contact





AC ENGINEERING, INC.

Engineering **Not** Science

- Engineering Design & Analysis is Approximate
 - idealization
 - physical to FEA
 - geometry, manufacturing tolerances, use, mechanics
 - FEA
 - numerical procedure
 - discrete vs continuum
 - mechanics available in software
 - material models
 - post processing
 - interpretation
 - impact on design
 - practical constraints
 - incomplete information
 - very tight time frame
 - limited cooperation
 - *outcome significantly affected by expertise of engineer*
 - corporate culture

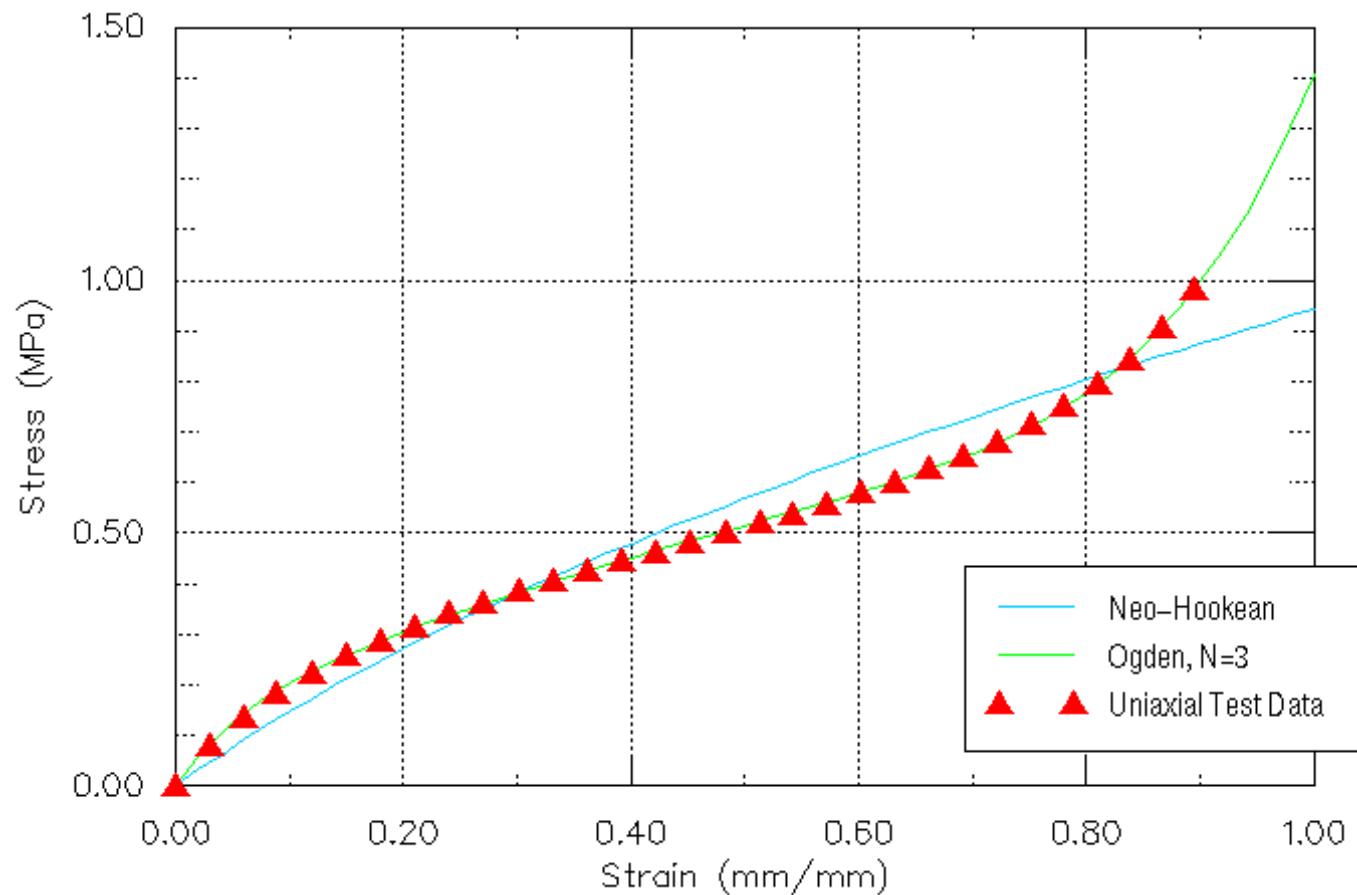


Material Properties

- A poor material model will prevent your model from running or could give you **misleading** results.
- The off axis modes in rubber are significantly more complex than most other materials.
- Given uniaxial data only ABAQUS will **sacrifice** the biaxial and shear behavior to fit your data.

Uniaxial Tension

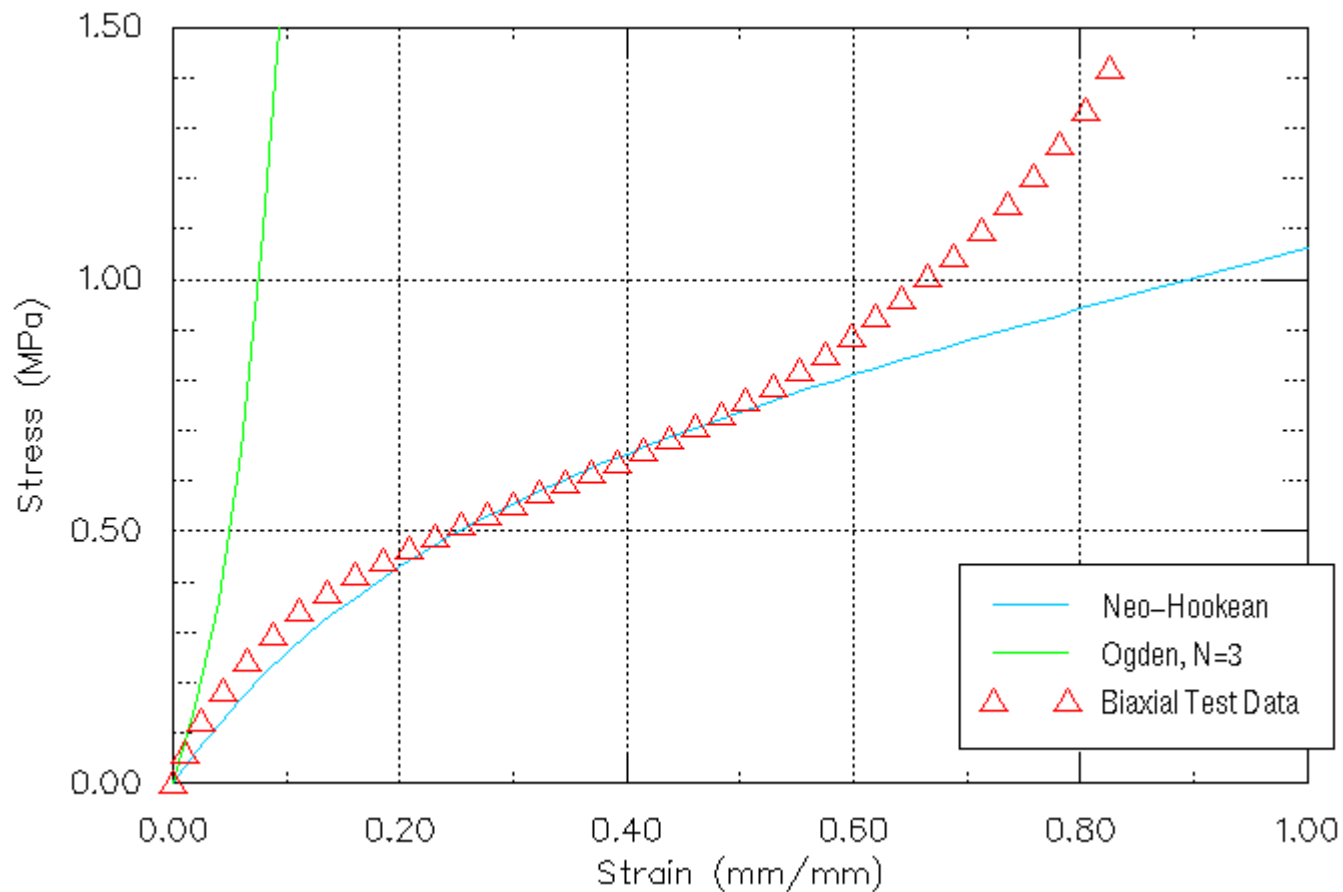
- Given only uniaxial tension data a good fit is achieved in this mode.





Biaxial Tension

- Without test data you will run into problems with high order models!

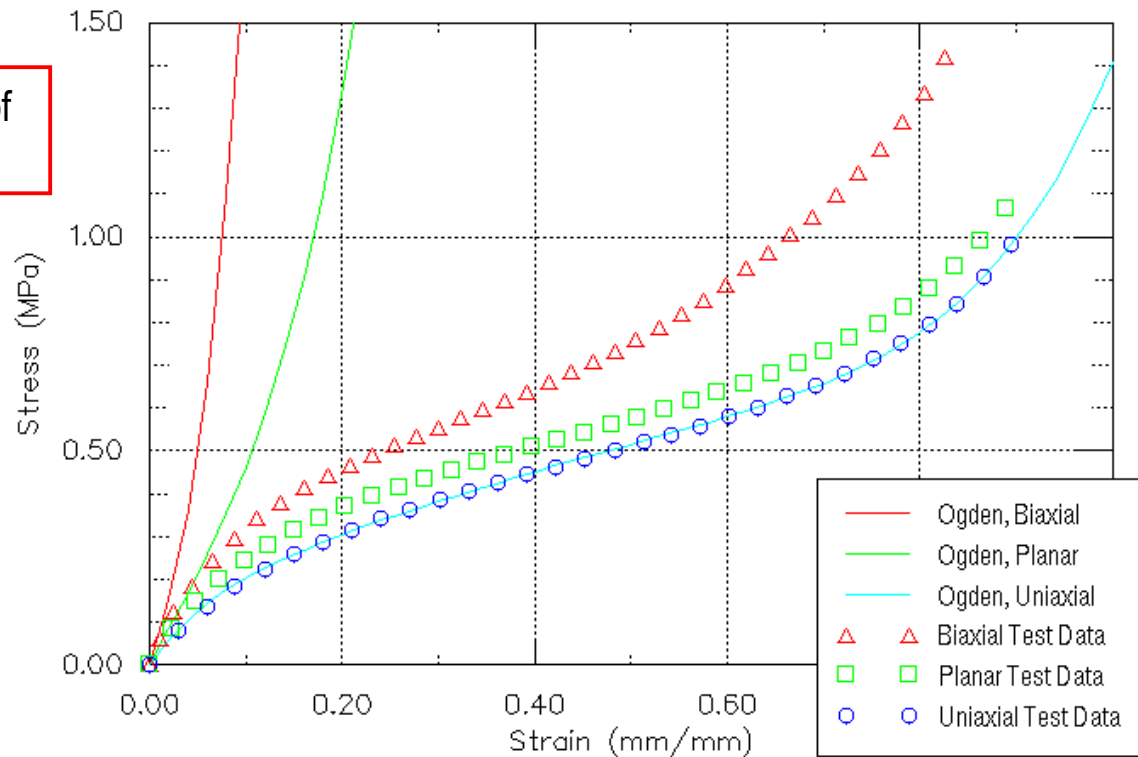




Always verify your material model

- Plot uniaxial, biaxial, and pure shear on the same graph

Test Data Courtesy of Axel Products, Inc.



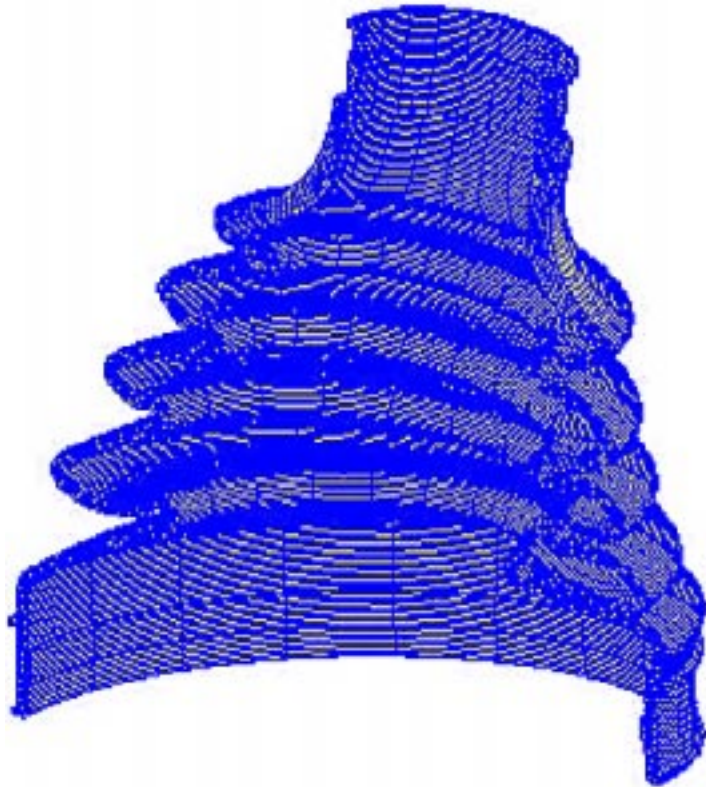
- Use `abaqus fetch job=2020301` to retrieve a simple one element model for testing.

How to Fix your Material Model

- Get all the test data!
- Use a lower order model if you are missing data.
- If you must use a higher order model and do not have test data, then it is better to make up off-axis data than to not have it!
 - If you are uncomfortable making up data, then do the test.

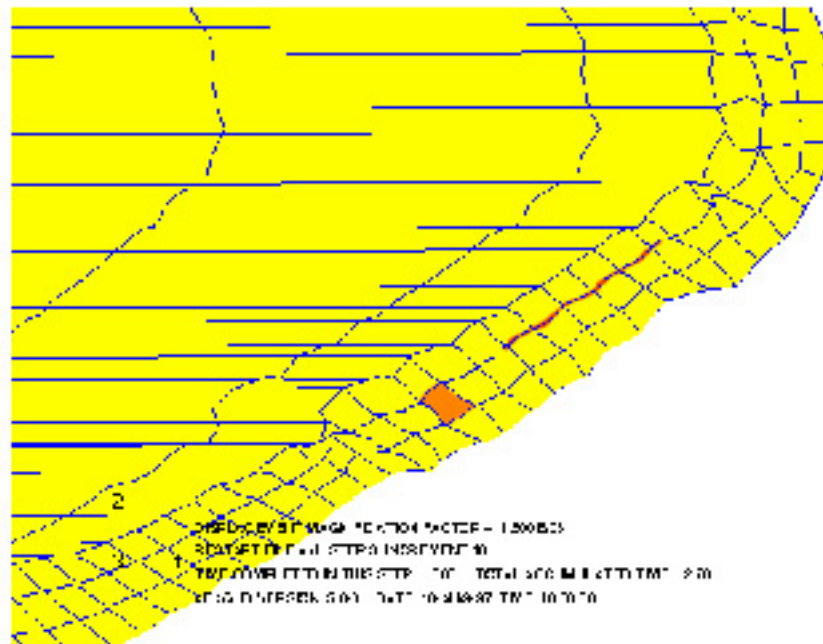
Rubber Turbulence, Ugly

- Have you ever had a mesh blow up?



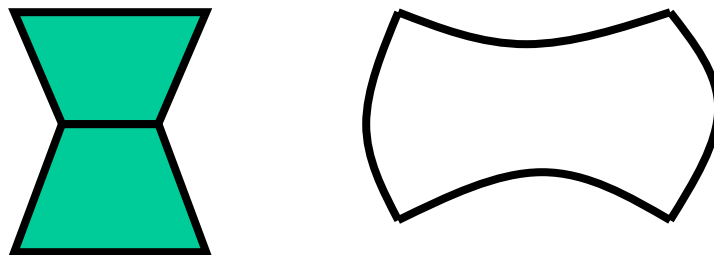
Rubber Turbulence - Demystified

- Turn down the displacement magnification and you will see:
 - *Hourglassing?*



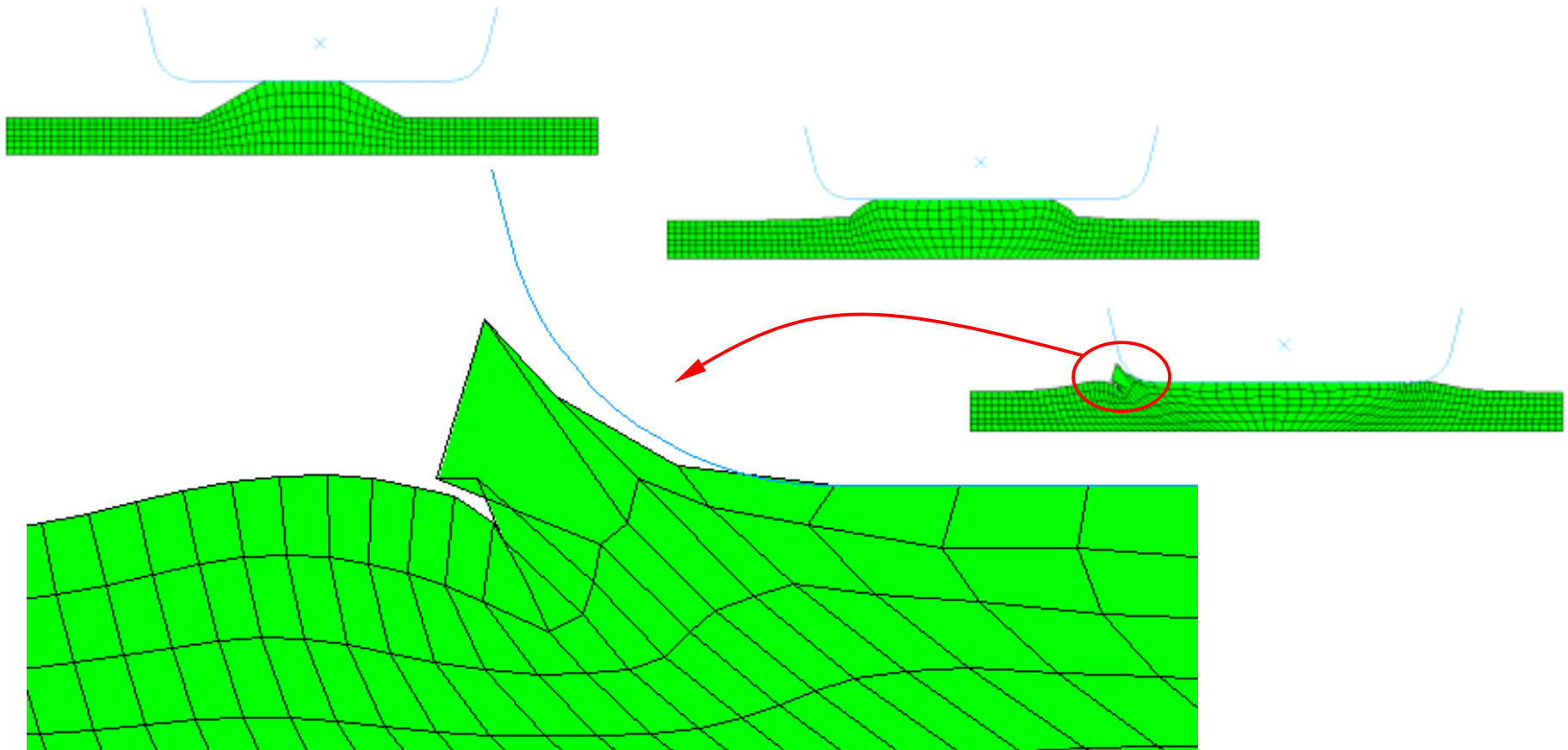
Hourglassing, Bad

- Hourglassing occurs when there is compression in the material
- Hourglassing is NOT restricted to low order reduced integration elements
- This shape can propagate through your mesh
- Elements can snap **violently** into this shape causing “Rubber Turbulence”
- Theorists will argue, but if it looks like hourglassing then we call it hourglassing



Fully Integrated Elements Hourglass

- Fully Integrated elements can go into the hourglass shape!





The Silver Bullet, Good

- Physically this is not real - If you drew a grid on a real part you will not see the grid hourglass!
- You can tell ABAQUS not to allow elements to go into the hourglass shape!

***HOURLASS STIFFNESS**

100,

**** default = 3.5E-3**

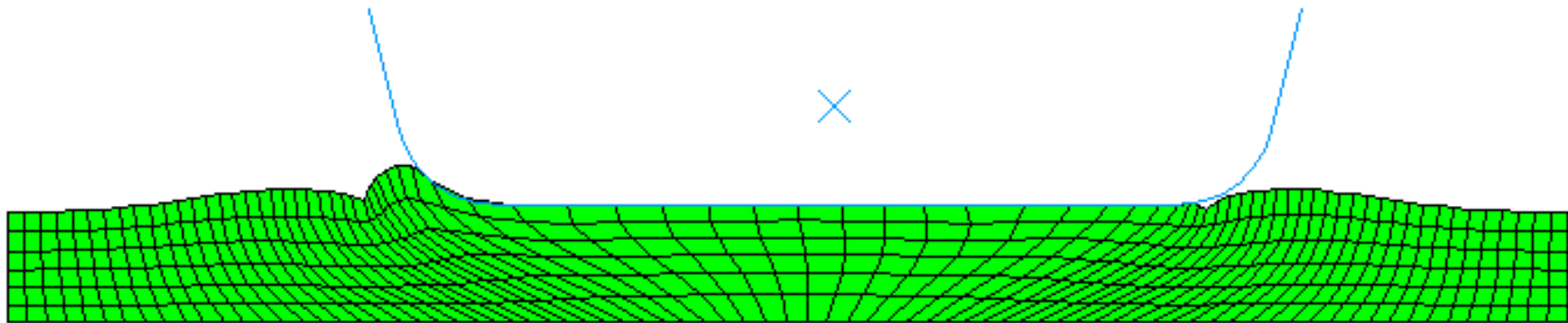
Make a Difference

- Don't just tweak the hourglass stiffness up 5 and 10% at a time!
- Crank the hourglass stiffness impossibly high then back off.
- ABAQUS will solve your problem fast and in fewer increments when the hourglass stiffness is too high rather than too low!



Gasket with "Silver Bullet"

- The analysis runs faster and farther using CPE4RH
- 87 Iterations, 108 Seconds, 86% with CPE4H
- 54 Iterations, 35 Seconds, 100% with CPE4RH

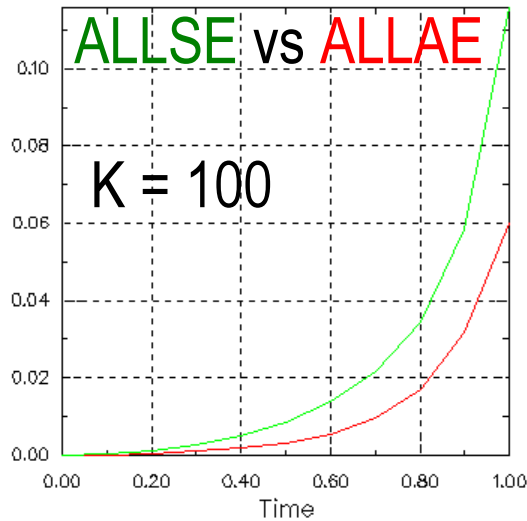




Caveat

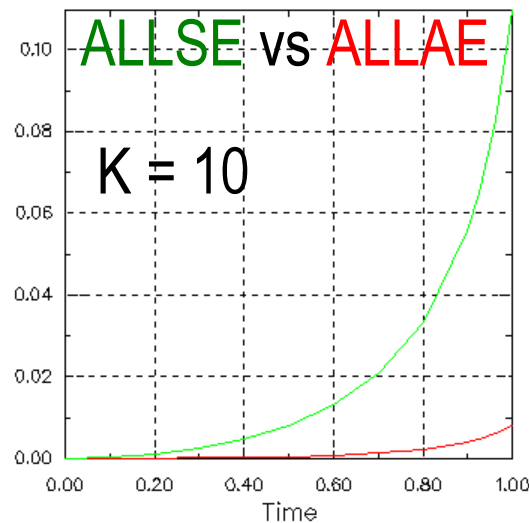
- Beware when you use this trick - you are changing the problem.
- The hourglass mode is the same shape needed for [bending](#).
- Plot the strain energy (ALLSE) and the artificial energy (ALLAE) on the same graph to see how much energy is absorbed by the hourglass stiffness.

NO!



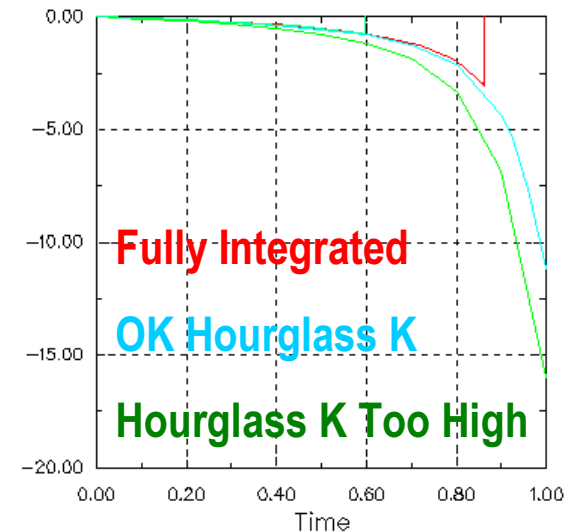
May 19, 1999

OK



Elastomer - Finite Element Analysis '99

RF Curves

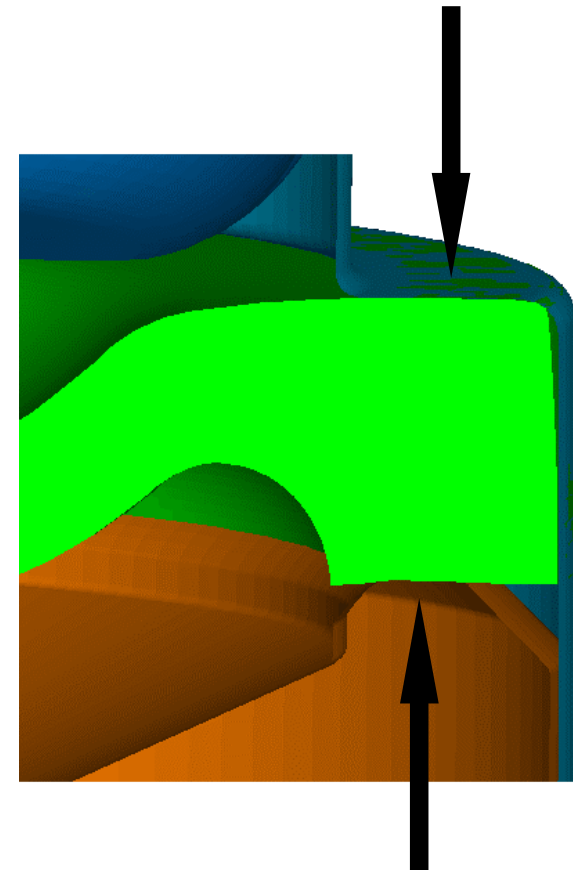
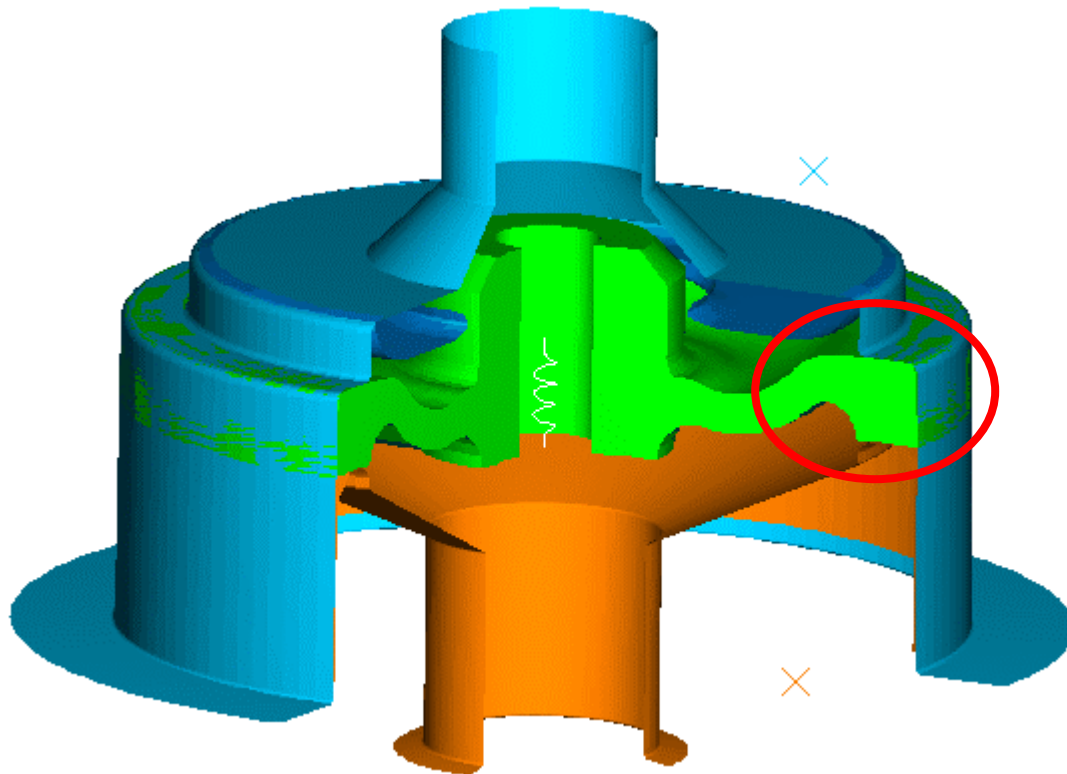


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Rubber in Contact

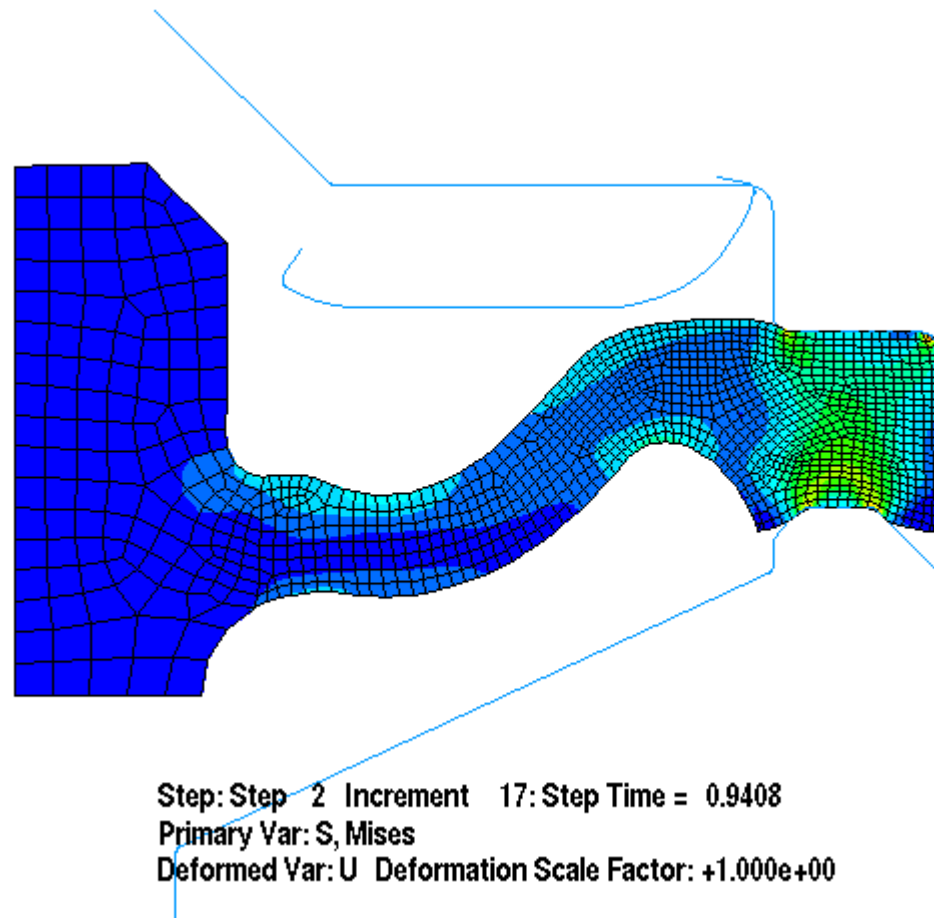
- Most rubber parts are involved in assemblies and contact with other parts.





Why didn't this problem run?

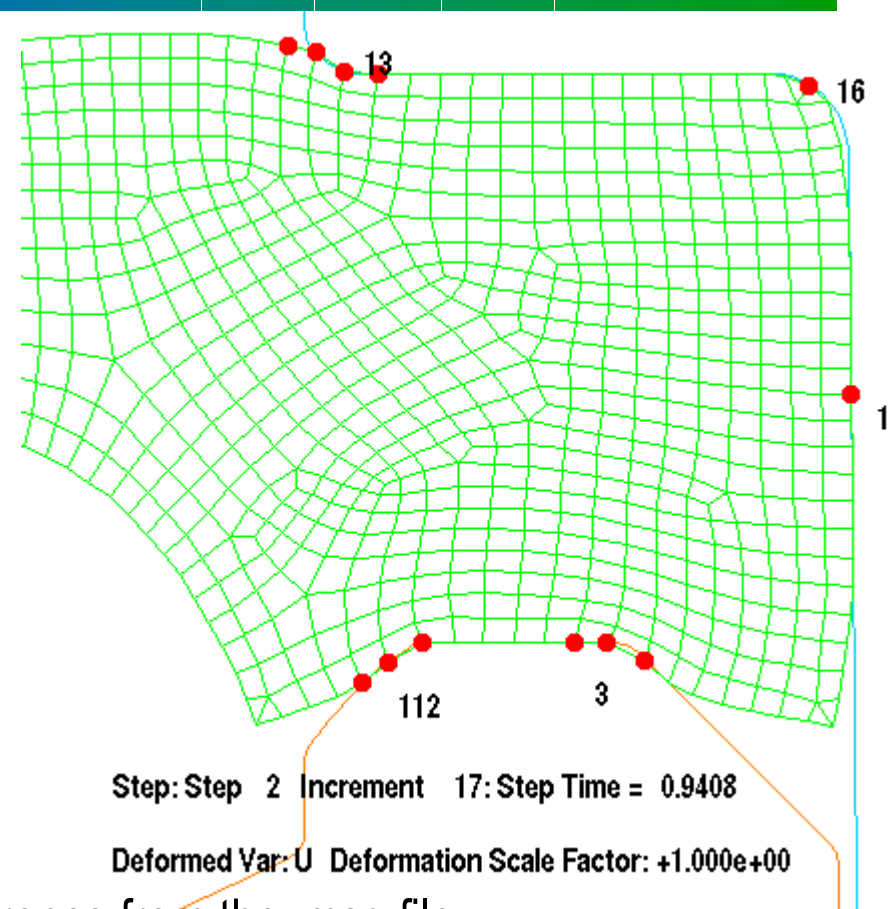
- This problem dies at about 94%, What would you do?
 - Add Compressibility
 - Softened Contact
 - Change the Friction to Rough
 - Hourglass Stiffness
 - RIKS
 - Refine the Mesh
 - Triangular Elements
 - Call it “close enough”





Locate the Problem

- The message file contains a wealth of information
- Find out at what nodes the maximum residuals occur
- What do most of the problem nodes have in common?



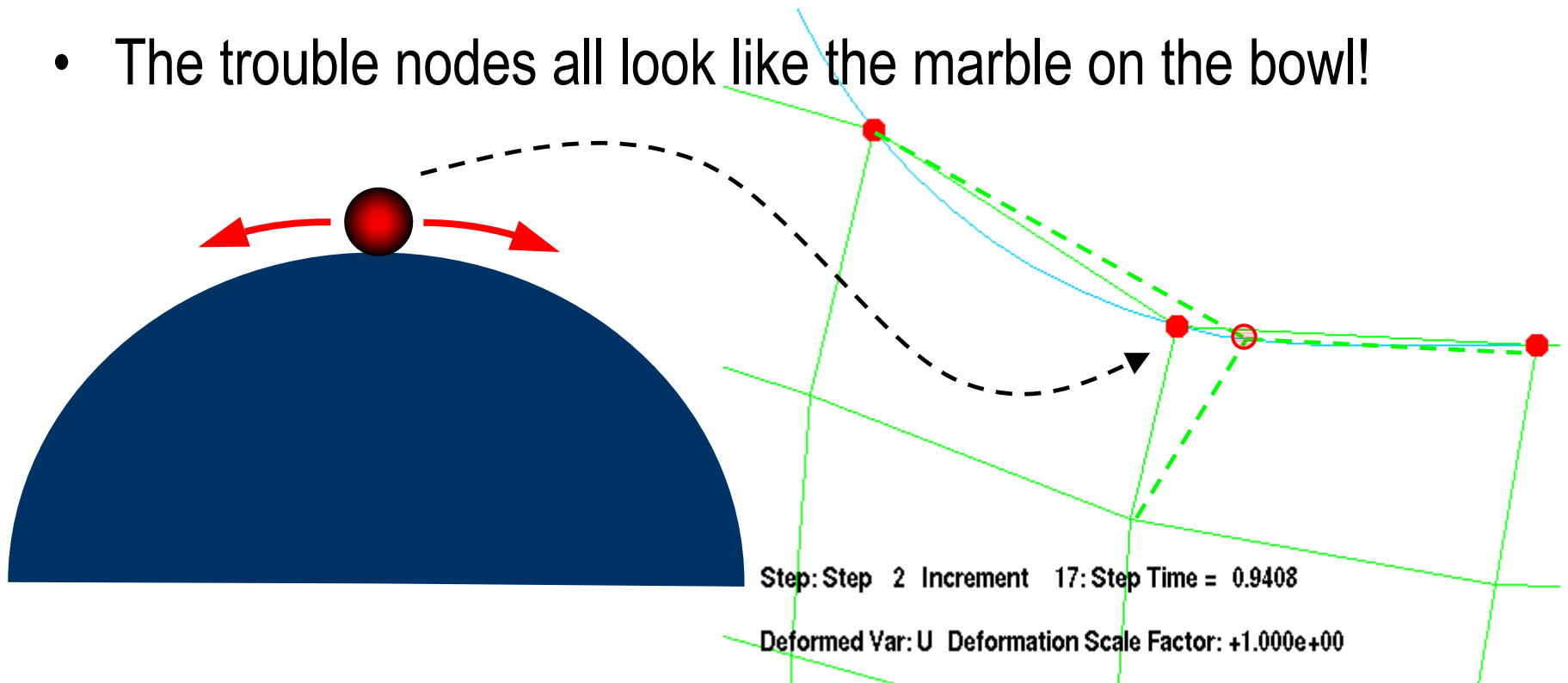
To extract these nodes and frequency of occurrence from the .msg file:

```
awk '/RESIDUAL FORCE/ {print $7}' deck.msg | sort | uniq -c | sort -n
```



Marble on the Bowl

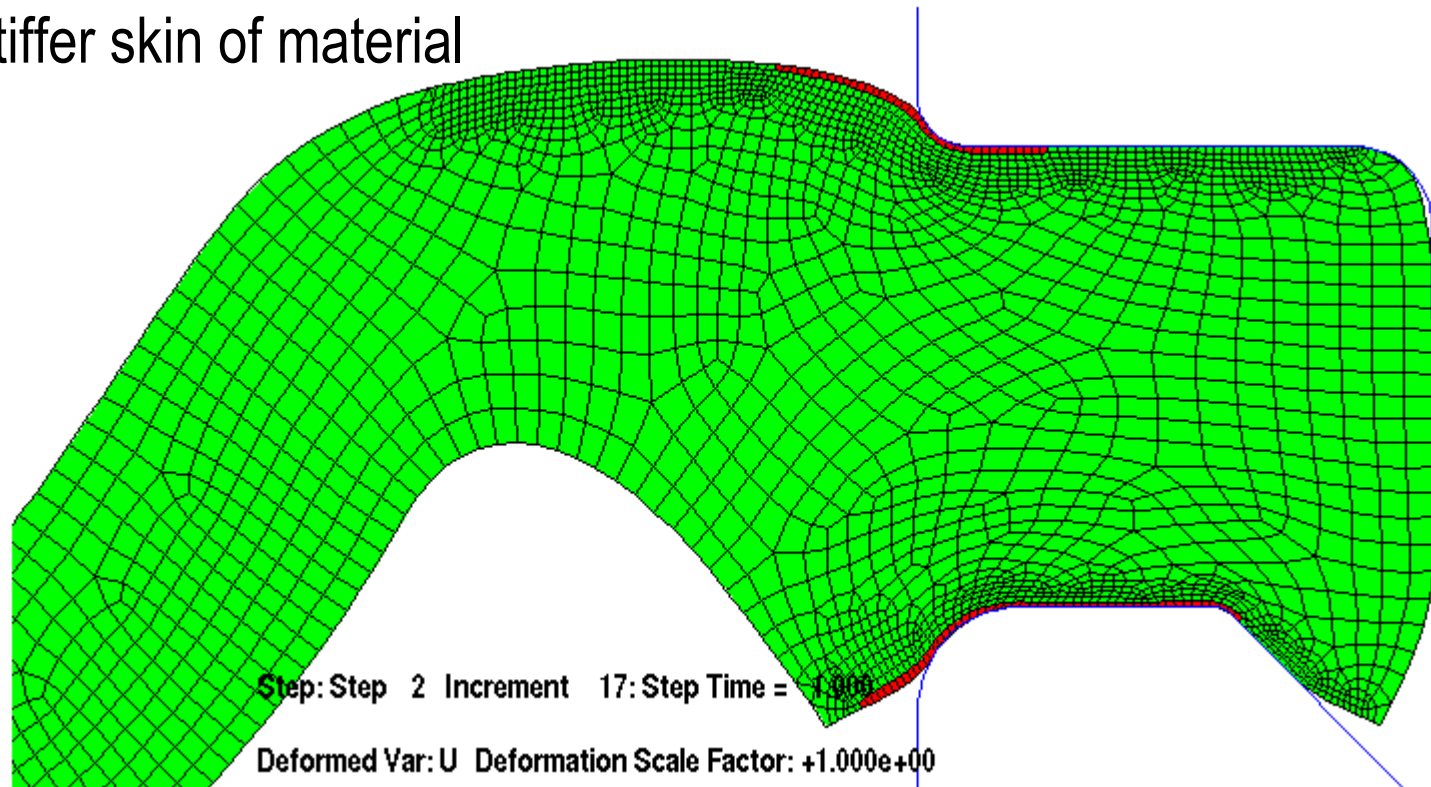
- If you turn a bowl upside down and place a marble on it, it will tend to roll off. This is unstable!
- The trouble nodes all look like the marble on the bowl!





Hang on to your Marbles

- Support the marble from rolling off the bowl
 - Axisymmetric membranes
 - Stiffer skin of material



Step: Step 2 Increment 17: Step Time = 1.000
Deformed Var: U Deformation Scale Factor: +1.000e+00



Summary

- Material Properties
 - thoroughly check your model
- "Rubber Turbulence"
 - dmag
- The "Silver Bullet"
 - hourglass stiffness
- Rubber Parts in Contact
 - hang on to your marbles
- Be an Engineer, **Not** a Scientist



For More Information

- You can download this presentation from our web site
 - www.aceng.com
- Get Advanced Training
 - Solving and Resolving Non Convergence
 - Contact Problems made Easy
 - Analysis of Rubber Components