Elastomer Analysis Using MARC

Prepared for: Elastomer - Fea Forum ‘99 3rd International Symposium on Finite Element Analysis of Rubber and Rubber-like Materials

May 19th and 20th, 1999
The University of Akron
E. J. Thomas Hall
Akron, Ohio USA

Organized by: Akron Rubber Development Laboratory, Inc. (ARDL)

Prepared by: Daniel S. Wolf
MARC Analysis Research Corp.
260 Sheridan Ave., Suite 309
Palo Alto, CA 94306

Vita for Dr. Daniel S. Wolf

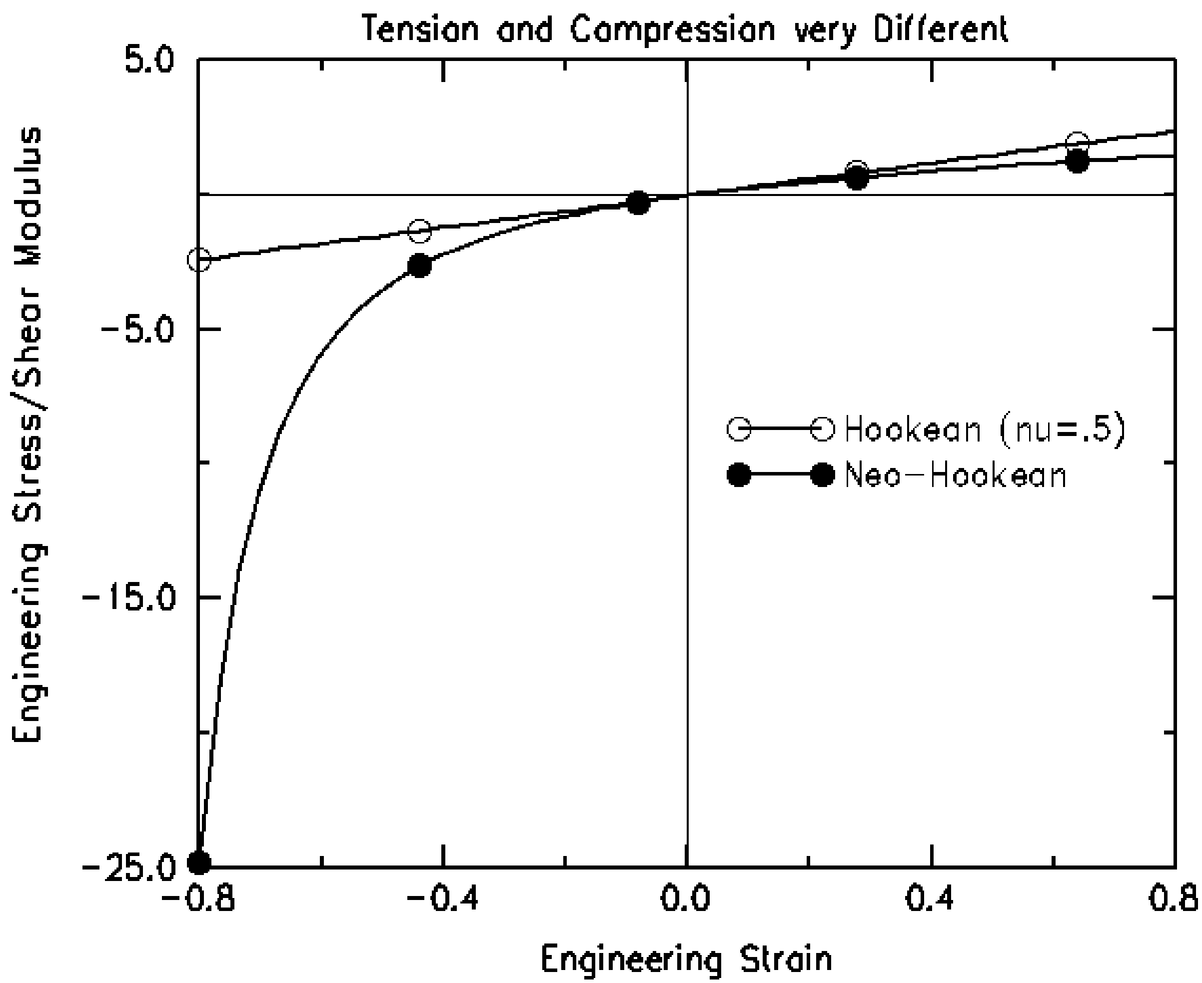
Daniel S. Wolf received his Ph. D., M.S. and B.S. in Aeronautical Engineering from the School of Aeronautics and Astronautics at Purdue University. As a graduate instructor he taught many undergraduate mechanics and laboratory courses. He studied under Professor C.T. Sun and specialized in continuum mechanics. His thesis title was “Some Problems on Interfacial Cracks”. Upon graduation in 1976, he became an assistant professor, responsible for teaching, research, and expanding laboratory and computing facilities in the department of Ocean Engineering at Florida Atlantic University in Boca Raton Florida. In 1979 he became a project engineer responsible for an advanced finite element group to insure the proper utilization of all structural analysis simulation programs used by many engineers at Pratt & Whitney. He has significant experience with finite element application programs and computing systems including nonlinear thermal/structural analysis of hot section engine components such as combustors and turbine airfoils. He was awarded patent 4,477,222 titled “Mounting Construction for Turbine Vane Assembly”, in 1984. In 1989 he moved on to MARC Analysis Research Corporation and became responsible for customer service, where he remains today in the service of MARC’s valued customers.

Contents

What Is New About Neo-Hookean?

Hookean (1660) $\sigma = 2(1+\upsilon)G\varepsilon$ $\tau = G\gamma$

Neo-Hookean (1940) $\sigma = G[(1+\varepsilon) - (1+\varepsilon)^{-2}]$ $\tau = G\gamma$



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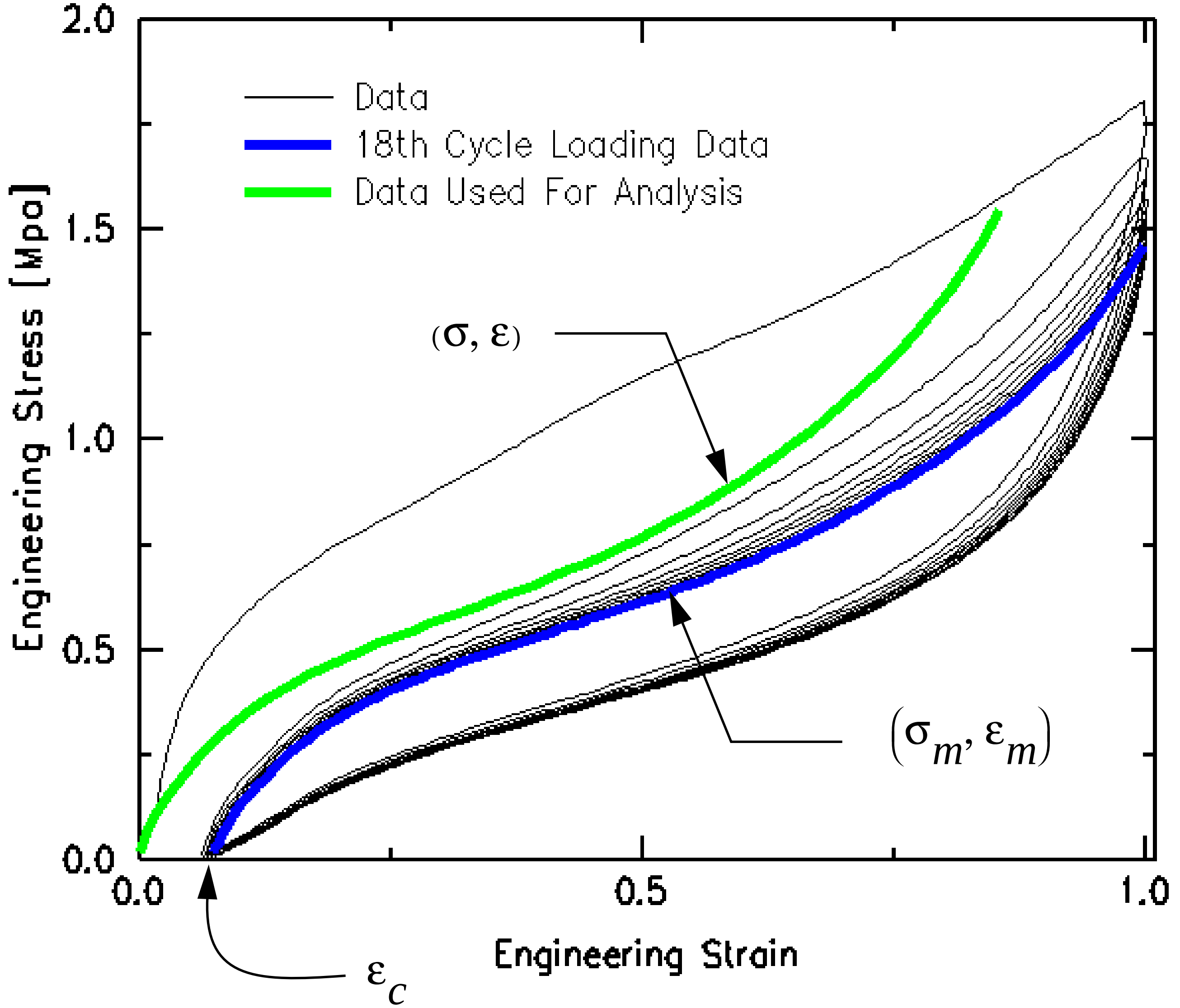
Reduce Measured Data And Fit For Analysis

Equal Biaxial Test



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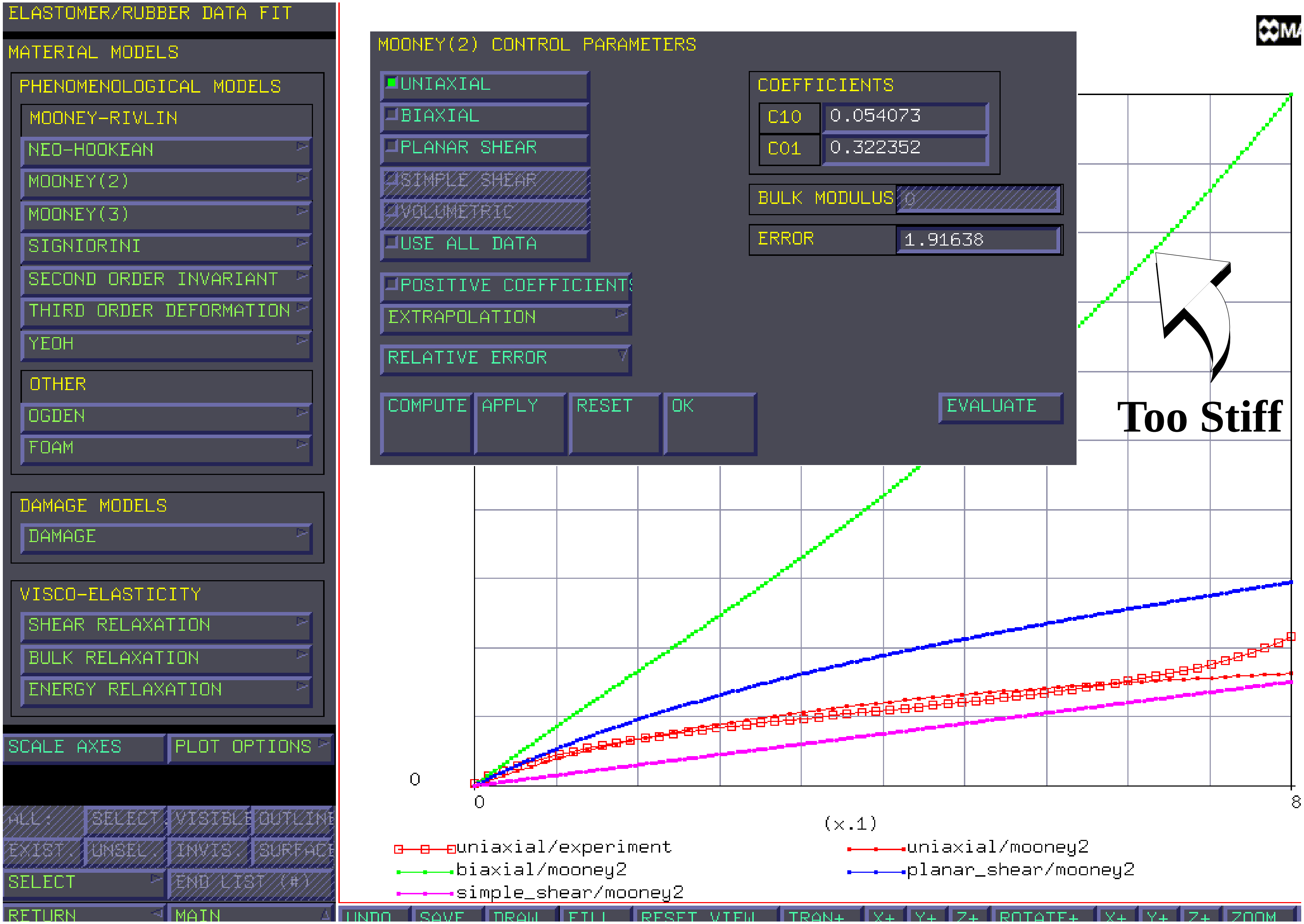
Fit Uniaxial Compression Data To 2 Term Mooney



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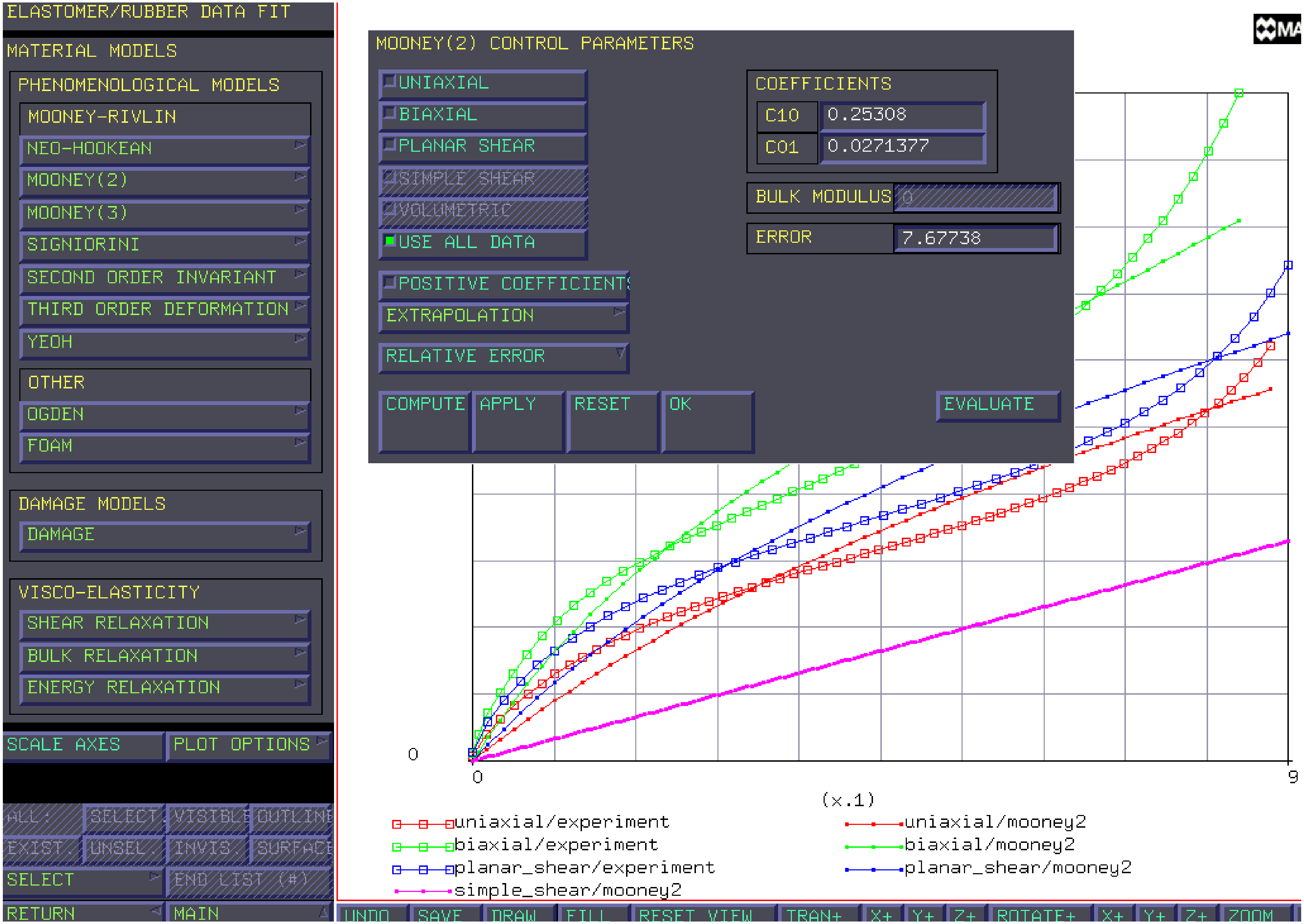
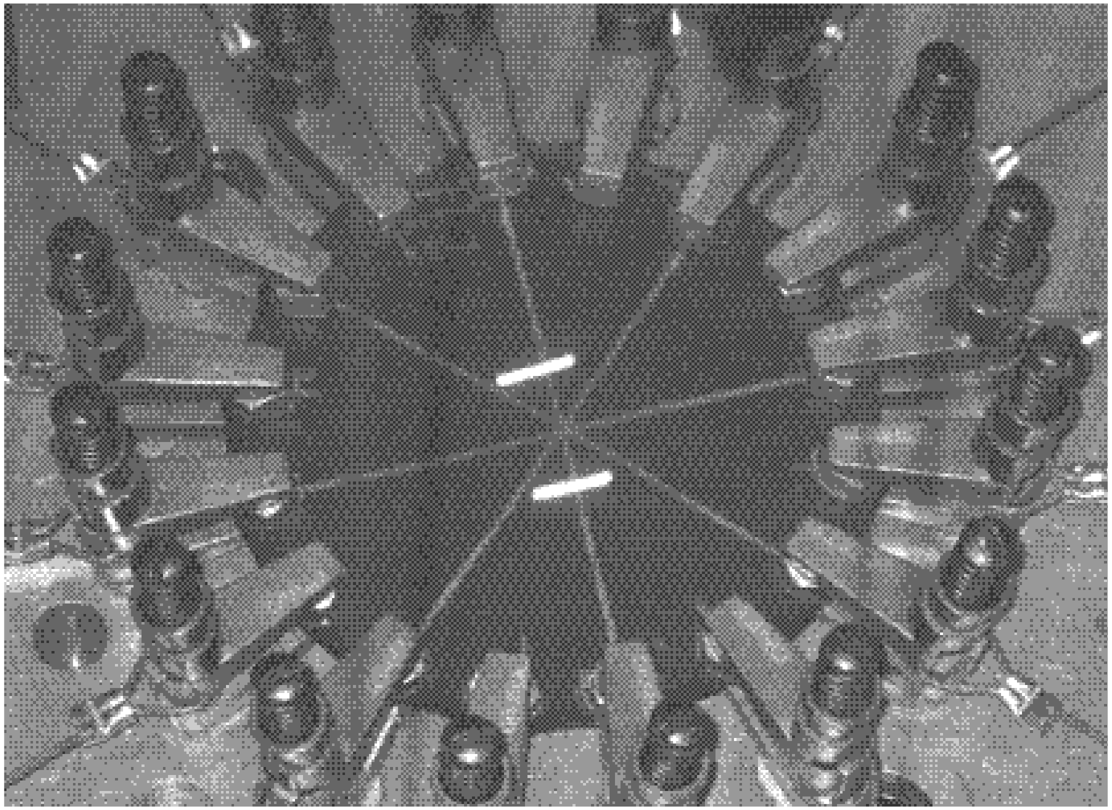
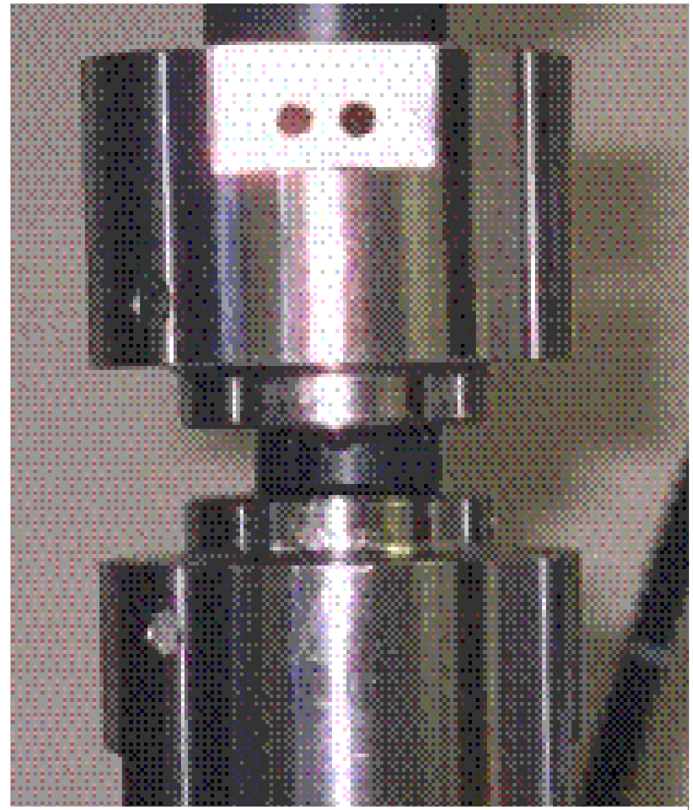
Fit Biaxial Data To 2 Term Mooney

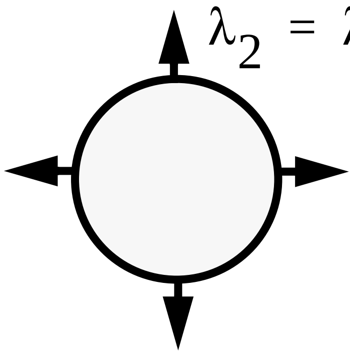


Biaxial Tension = Compression Strain State

Biaxial Tension is the same strain state as compression and is more reliable.





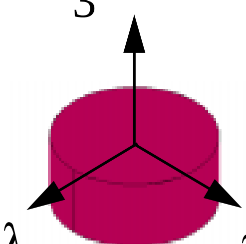


$\lambda_2 = \lambda$

$\lambda_1 = \lambda$

$\lambda_3 = \lambda^{-2}$

$\Lambda = \lambda^{-2}$



$\lambda_3 = \Lambda$

$\Lambda^{-\frac{1}{2}} = \lambda_2$

$\lambda_1 = \Lambda^{-\frac{1}{2}}$

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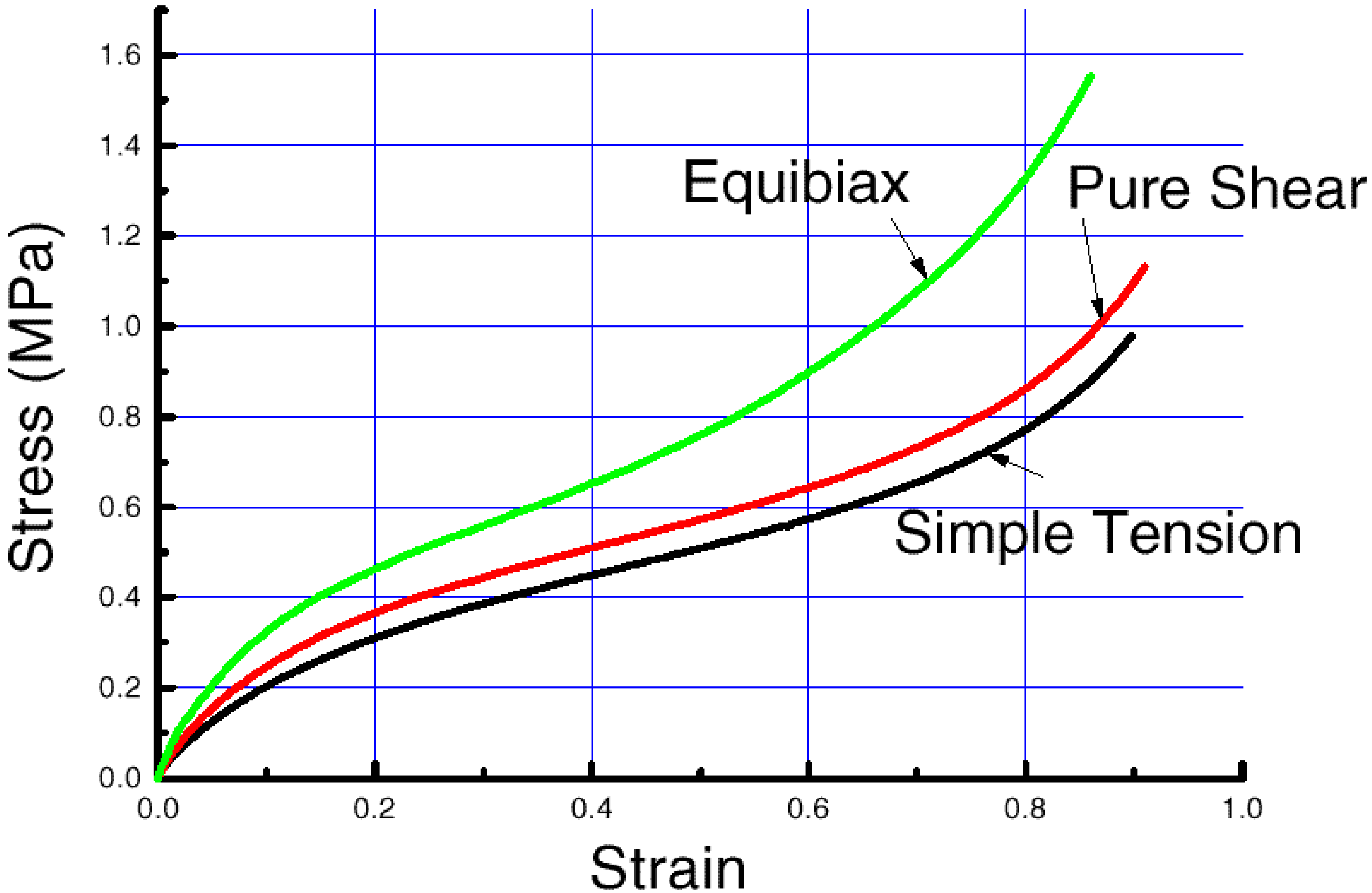
This Is A Reasonable Fit

Three Basic Strain States



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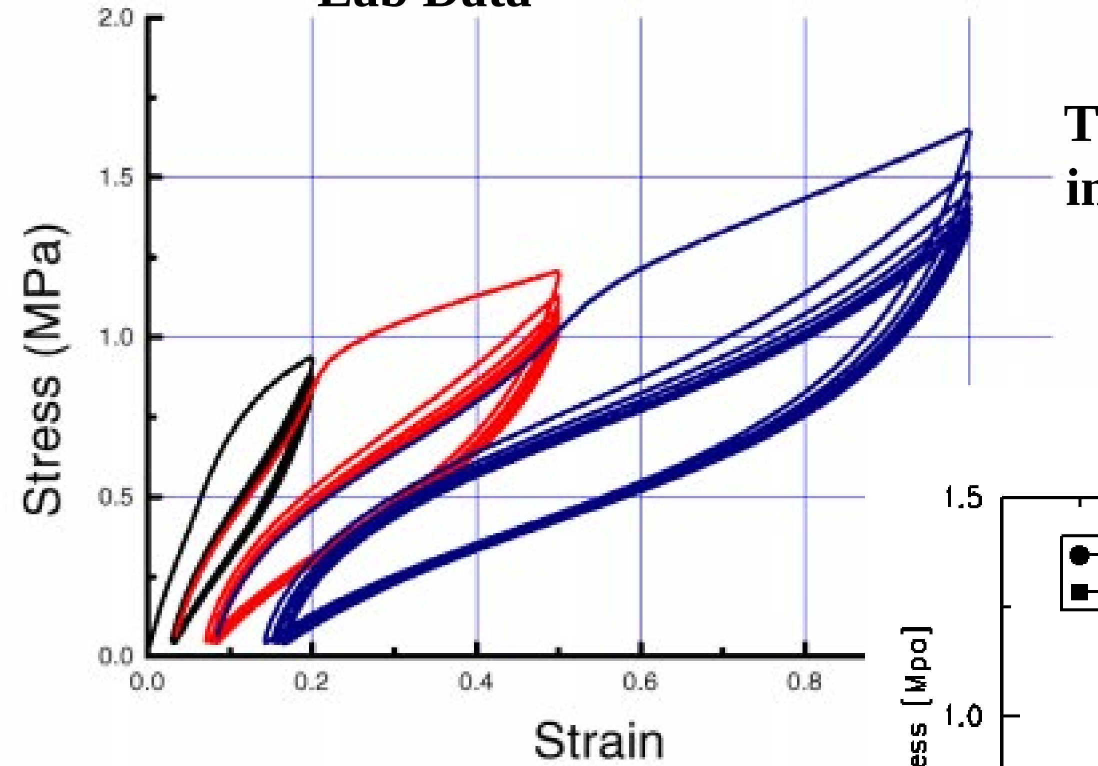
Mullins Effect

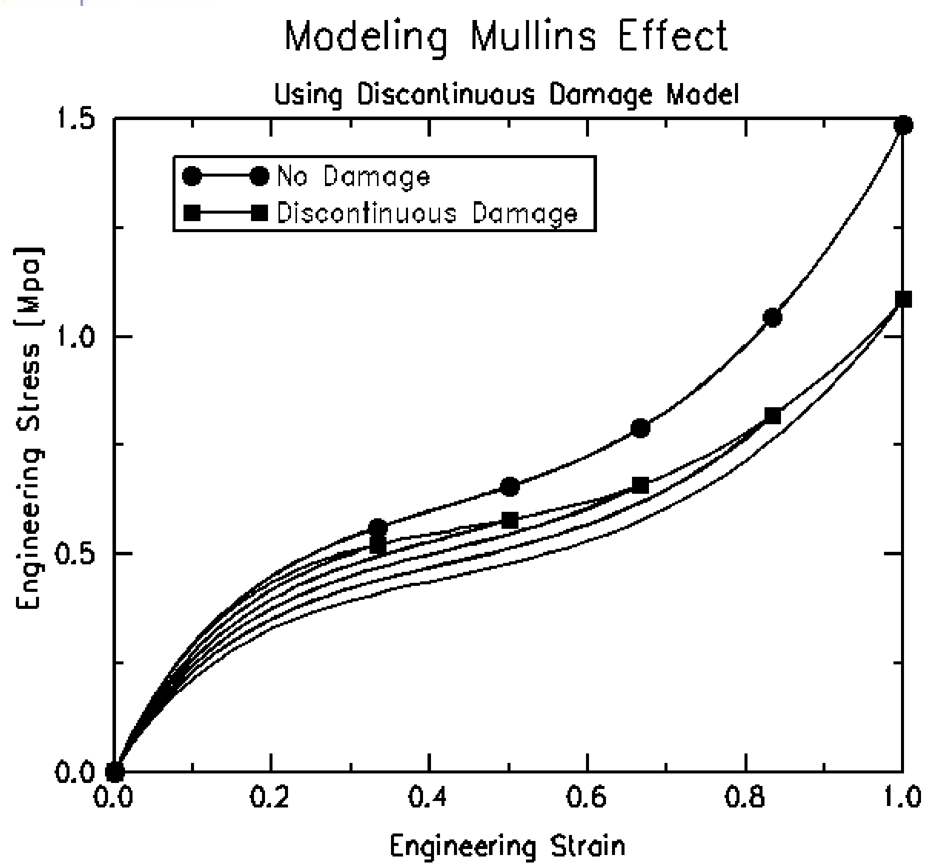
Lab Data



$$W = K(\alpha, \beta) W^{0}$$

The Kachanov factor, $K(\alpha, \beta)$, is implemented in MARC

Model Predictions



These factors can be entered directly or by fitting data in Mentat

DISCONTINUOUS (MULLINS) PARAMETERS

SCALAR FACTORS		RELAXATION PARAMETER	
1	0.9	1	3
2	0.1	2	10

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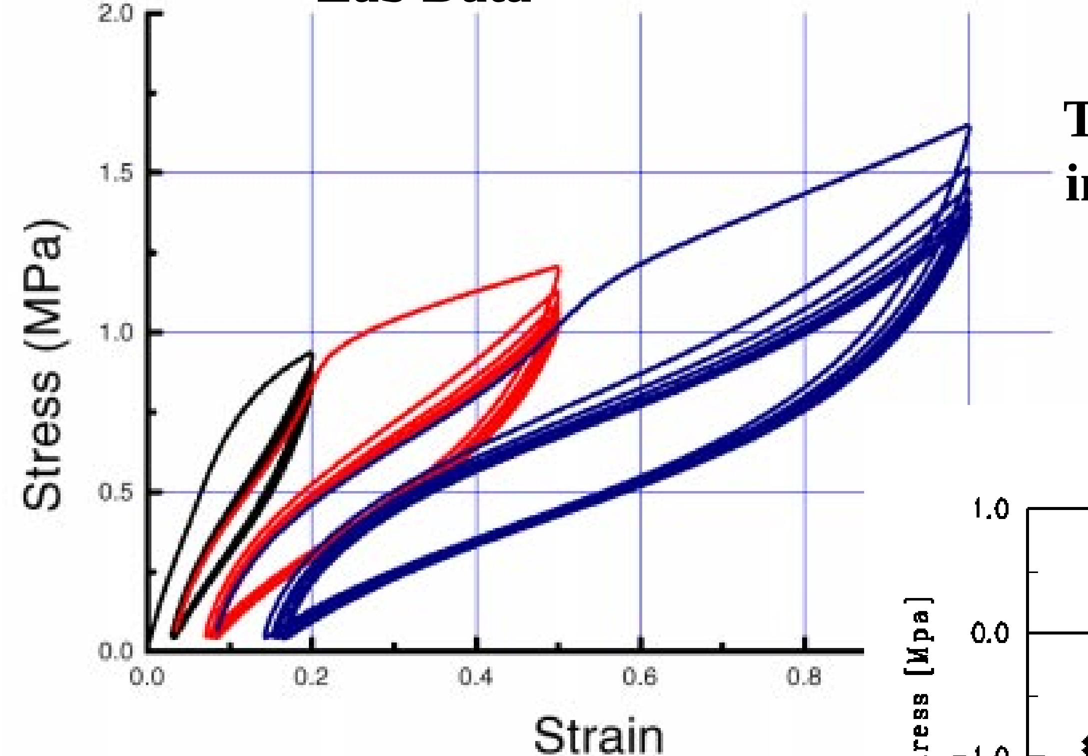
Miehe Effect

Lab Data



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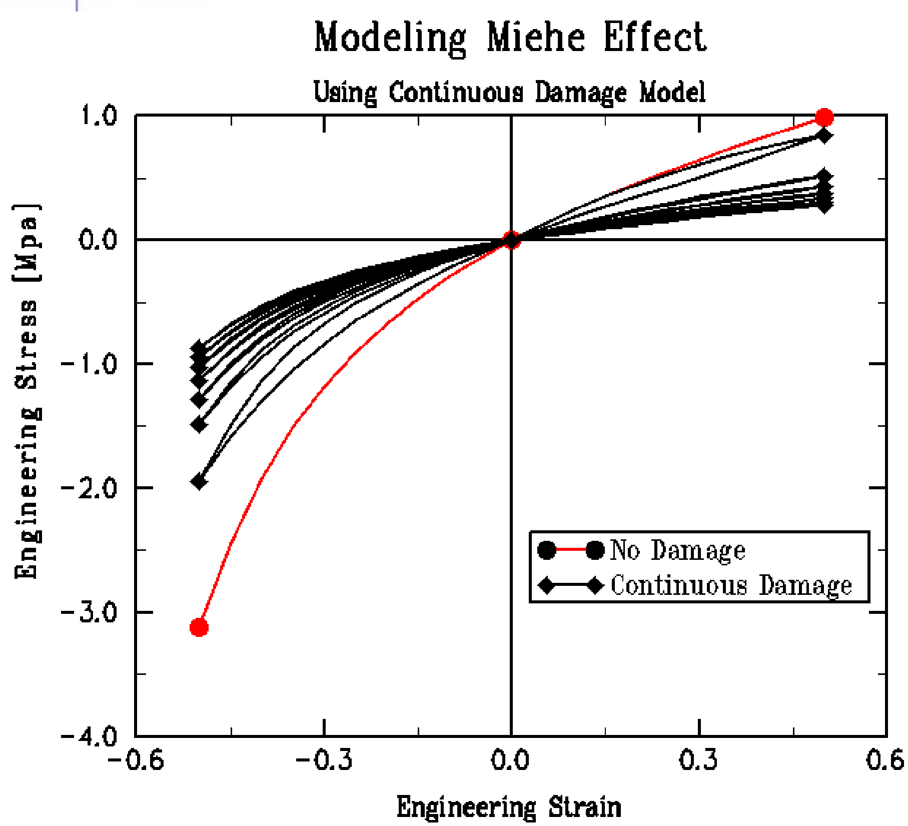

These factors can be entered directly or by fitting data in Mentat

CONTINUOUS (MIEHE) PARAMETERS

SCALAR FACTORS		RELAXATION PARAMETEF	
1	0	1	1
2	0	2	1

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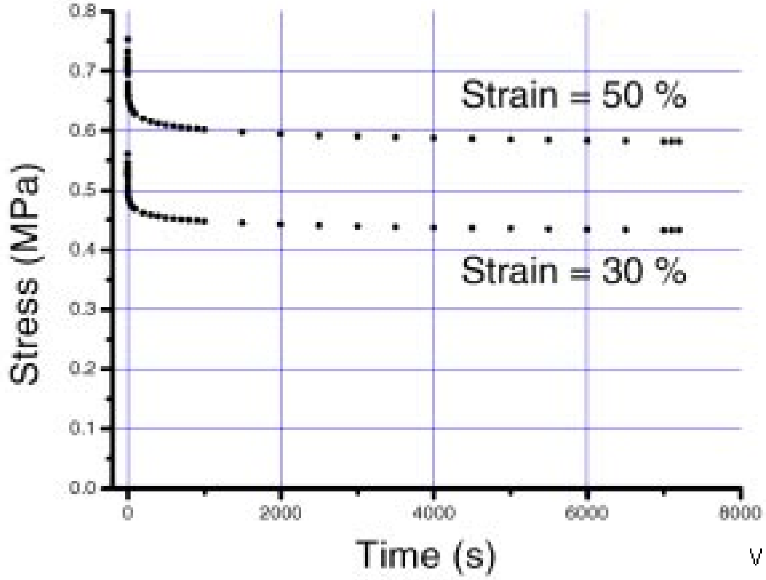
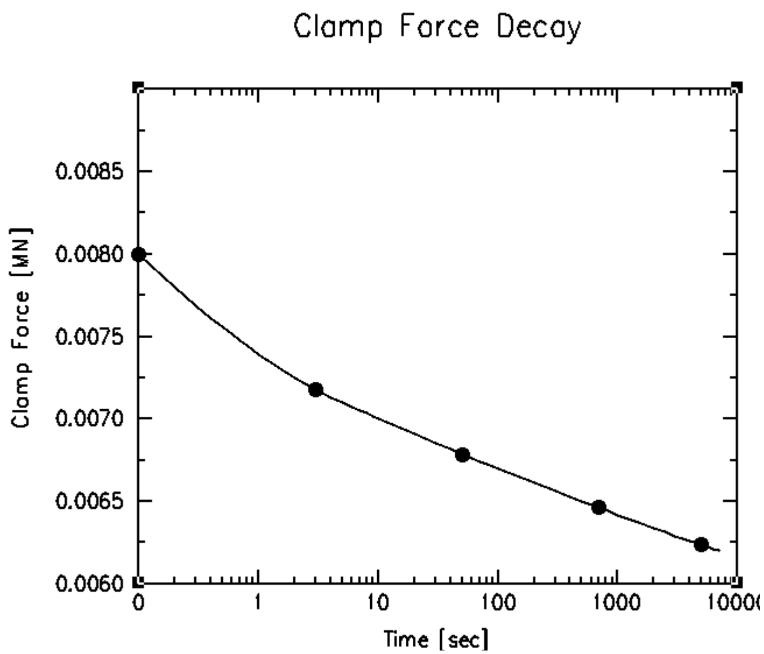
Viscoelastic Effects

Lab Data



$$W = W^{\infty} + \sum_{n=1}^{N} W^{n} \exp(-t/\lambda^{n})$$

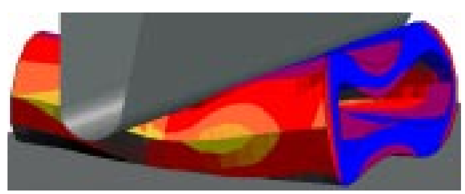
Prony series coefficients generated by Mentat



VISCO-ELASTICITY SHEAR RELAXATION CONTROL PARAMETERS

RELAXATION

NUMBER OF TERMS 3



COMPUTE APPLY RESET OK

COEFFICIENTS

	LINEAR	RELAXATION TI
1	0.111552	0.748714
2	0.0727897	41.4902
3	0.0638807	1441.73
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0

LONG 0.908593

SHOR 1.15682

ERROR 0.000715663

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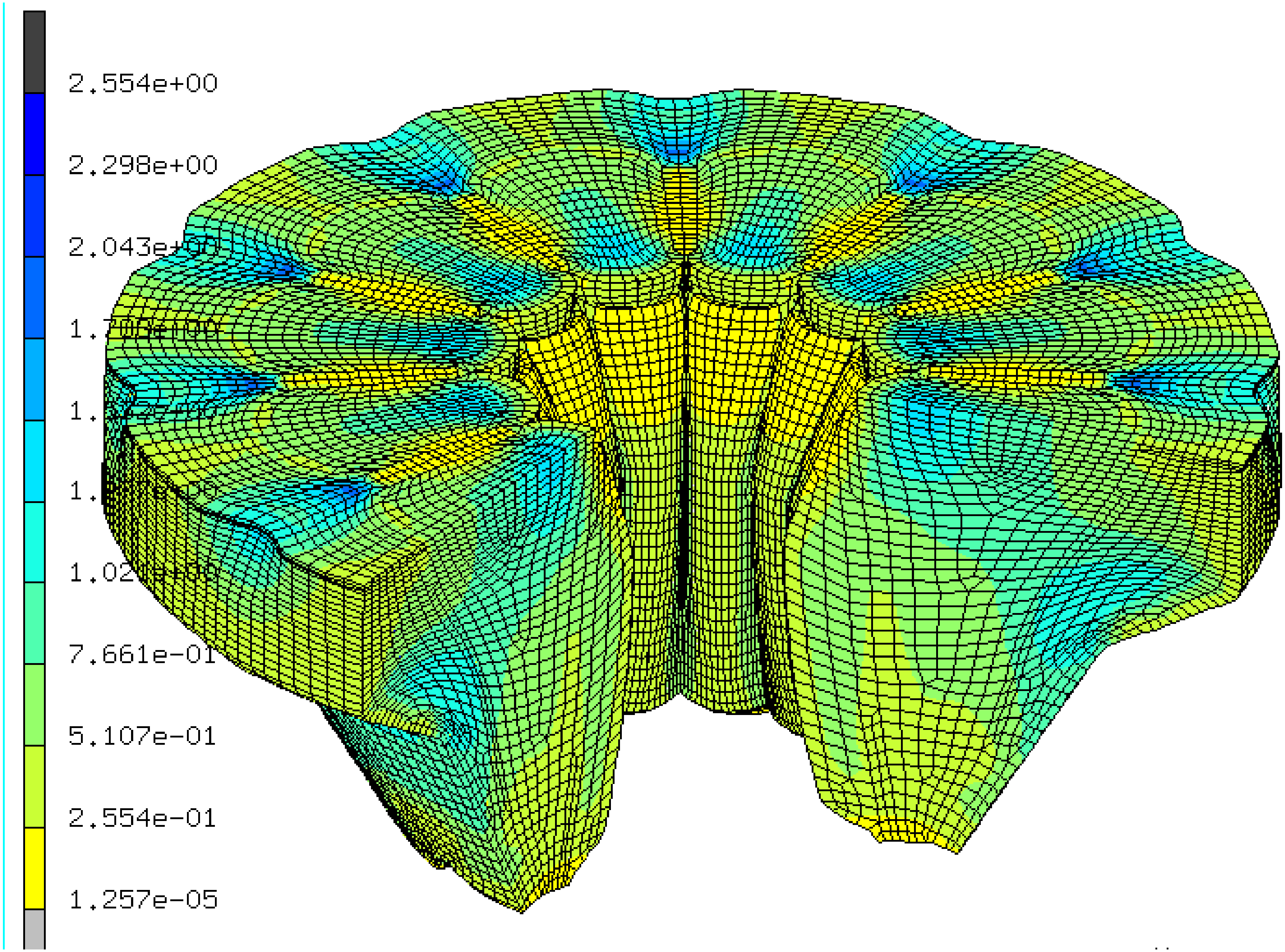
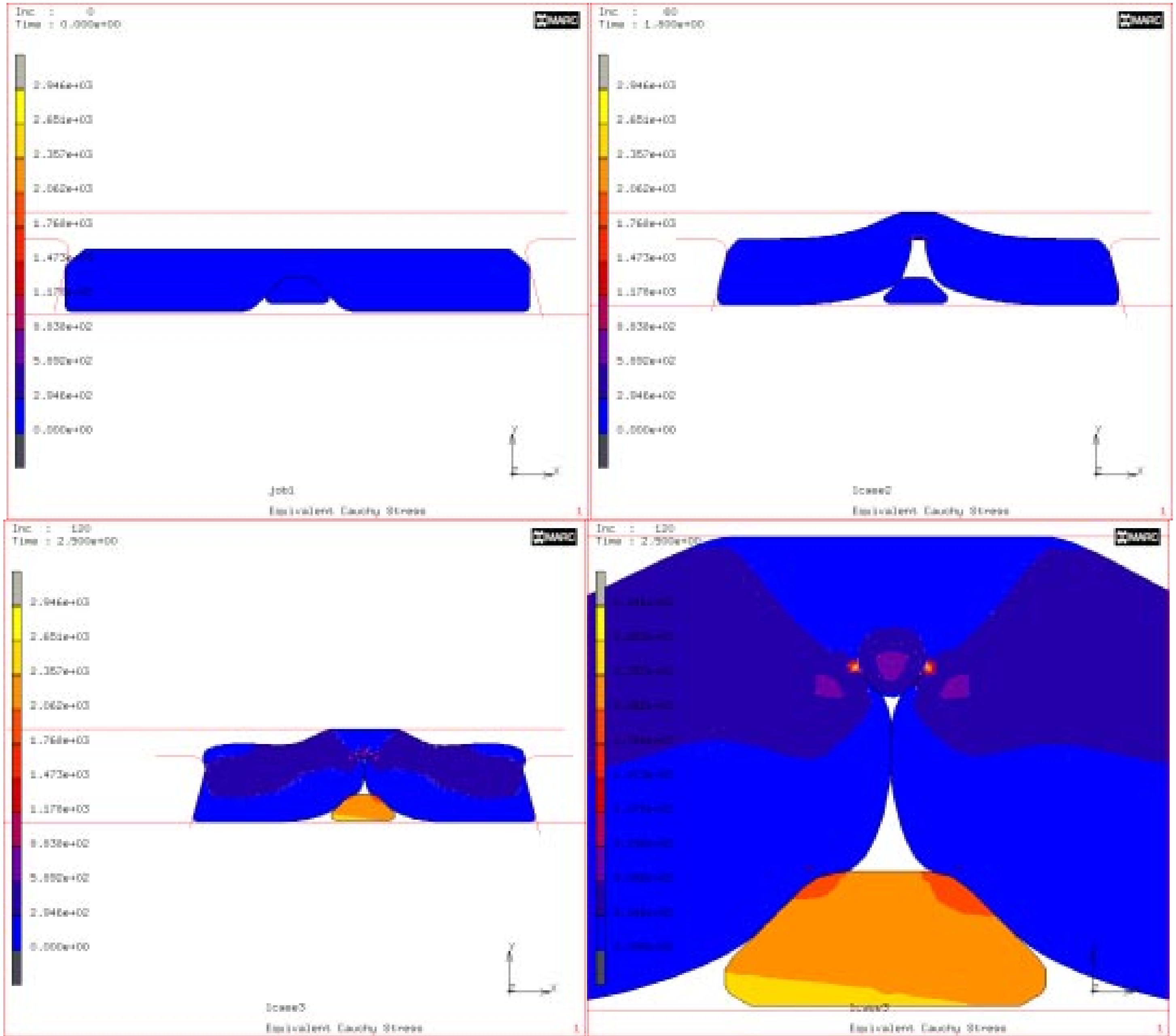
3D Packer Seal



Axisymmetric Packer Seal

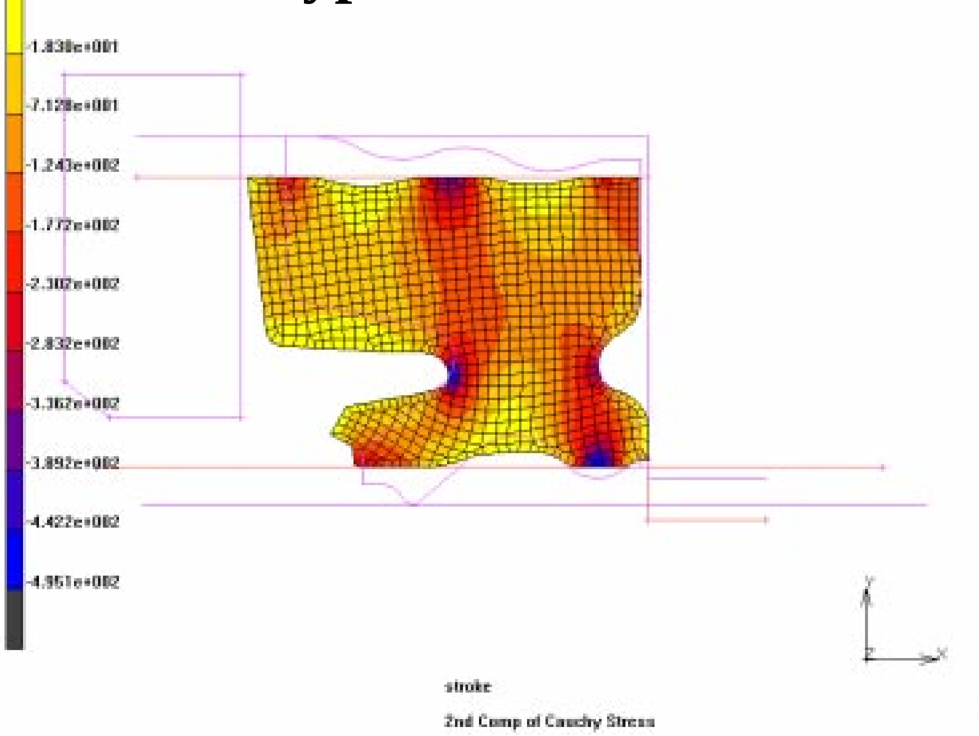


Zero Leak ABS Piston Seal

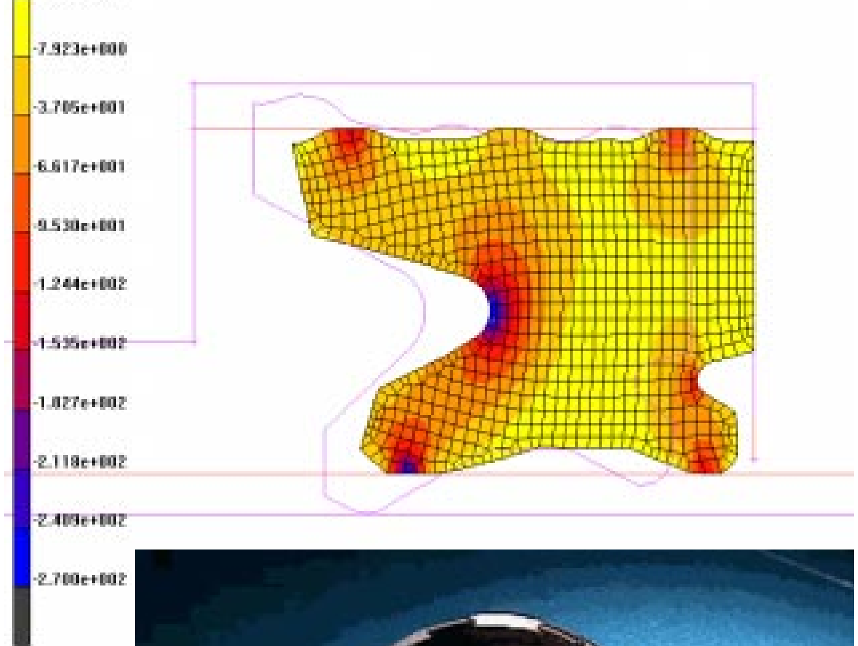
Acushnet Rubber Company, Inc.

Prototypes for testing were required in 6 weeks

Typical Seal



New Seal



See Customer Profile: Acushnet Rubber Company, On The MARC Newsletter, Spring 1999 (PDF, 591 KB) at www.marc.com

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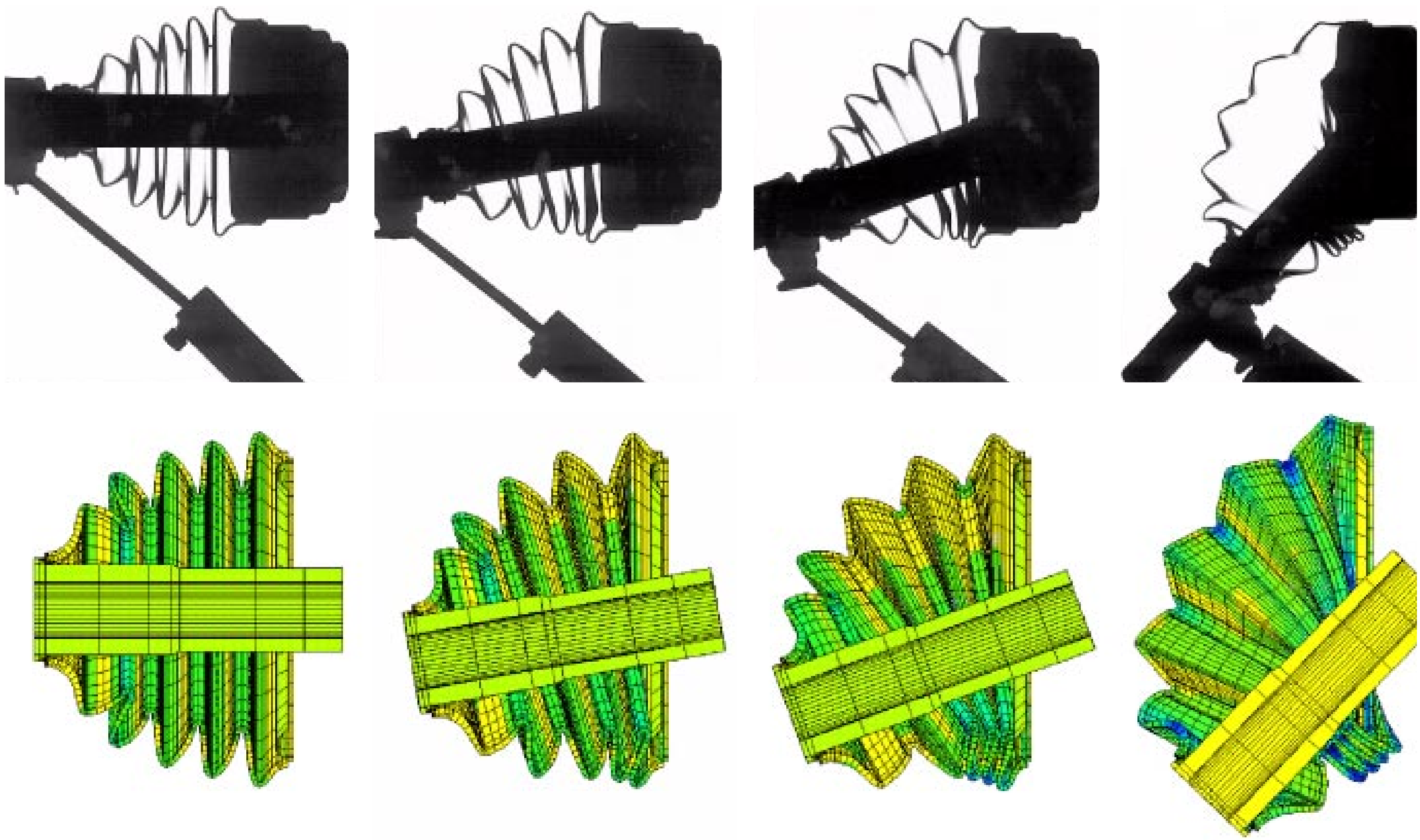
Constant Velocity Boot



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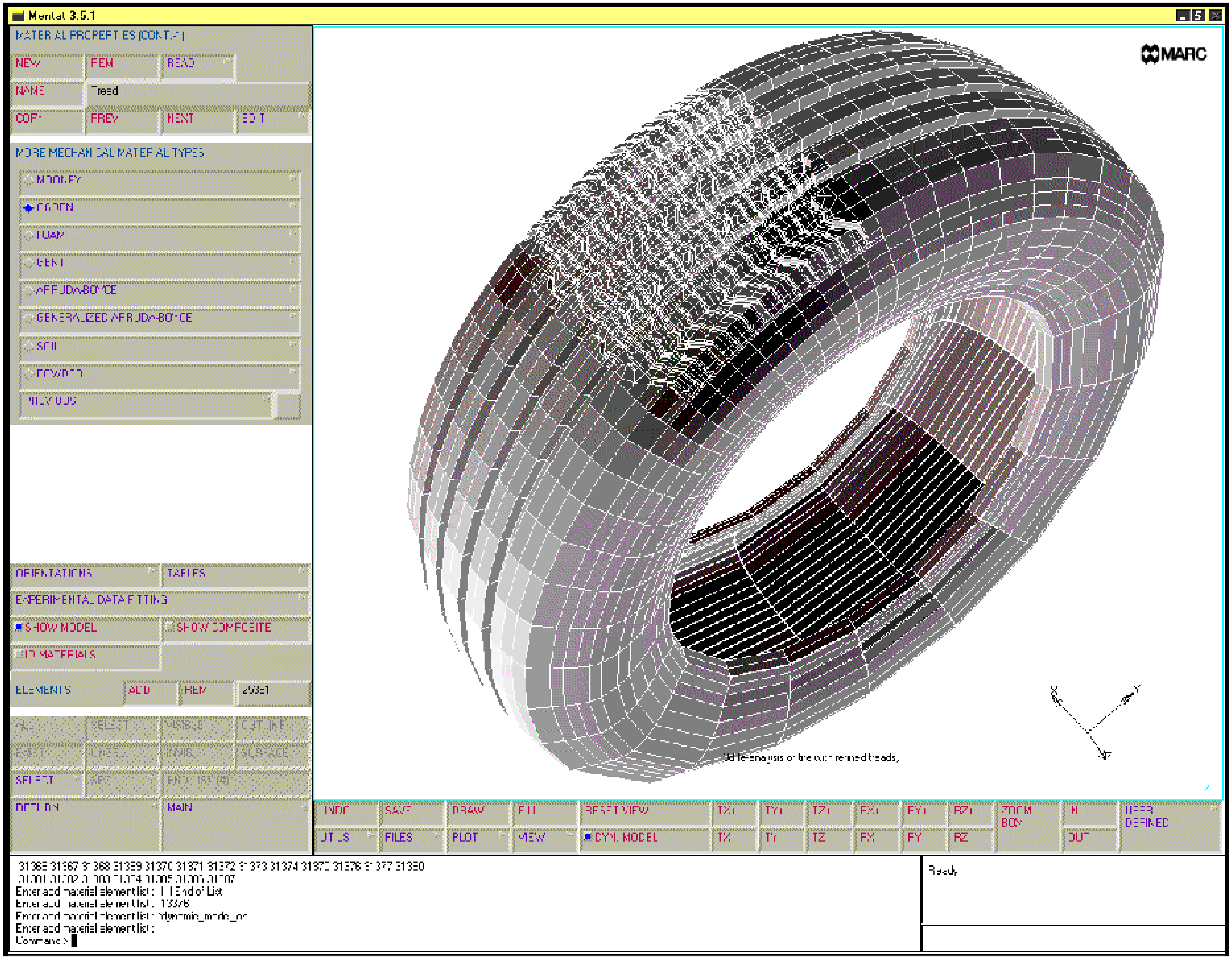
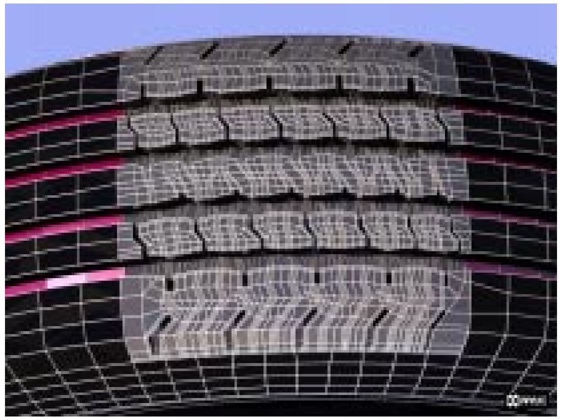
Tires


Mentat 3.5.1
NEW
NAME
Tread
SHOW MODEL
ELEMENTS
SAVE
FILES
PLOT
Ready
MARC

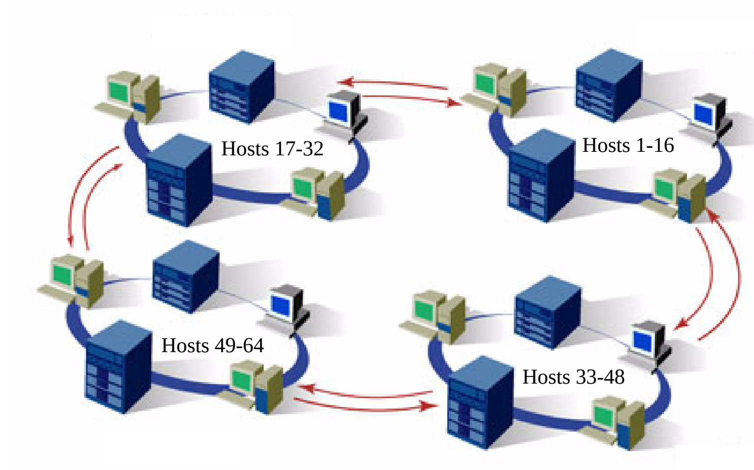
Tire Model Running MARC K73 Parallel

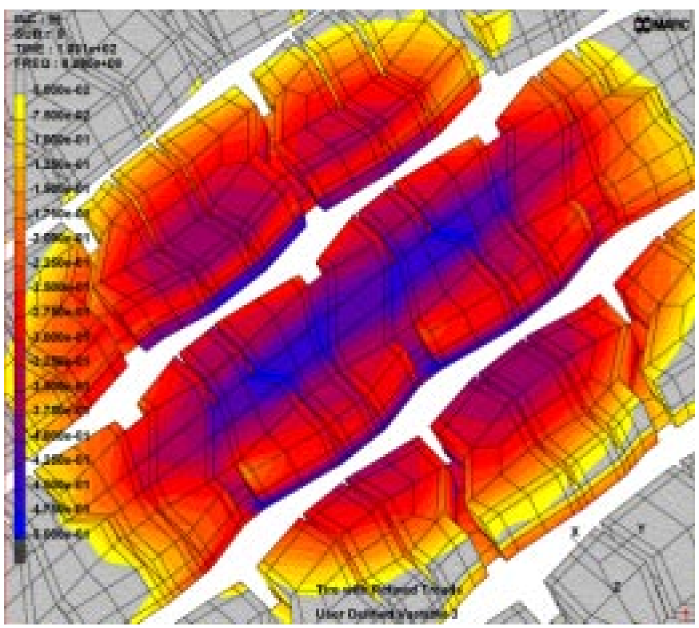
Shared: 64 400-MHz CPUs; 1 GBytes RAM/CPU

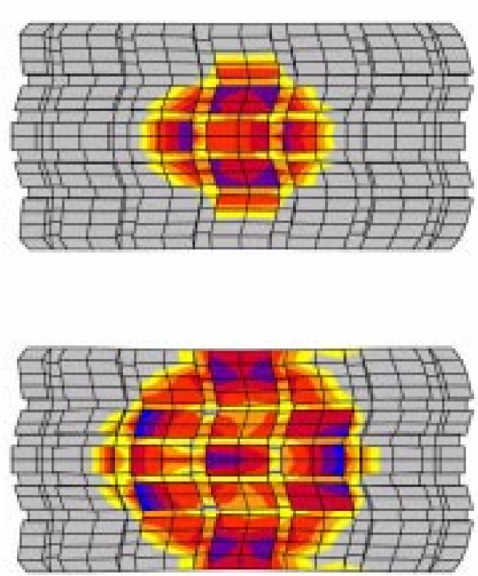
$$S_{64} = 58.3$$

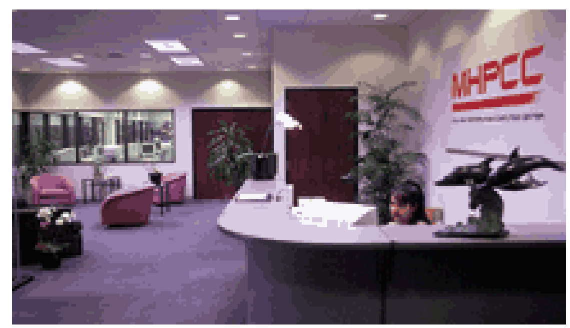


Distributed: 64 Hosts; 1 GBytes RAM/Host









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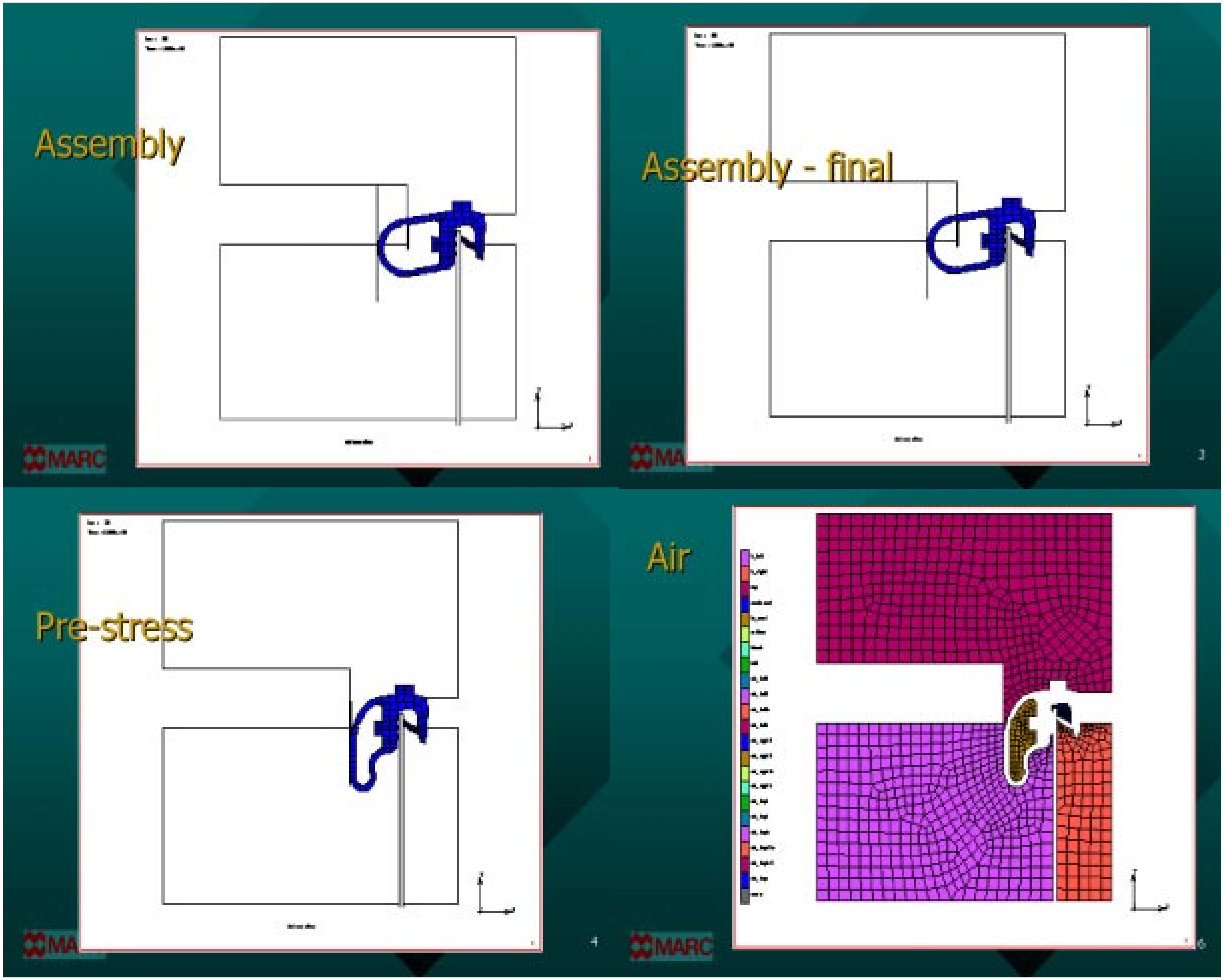
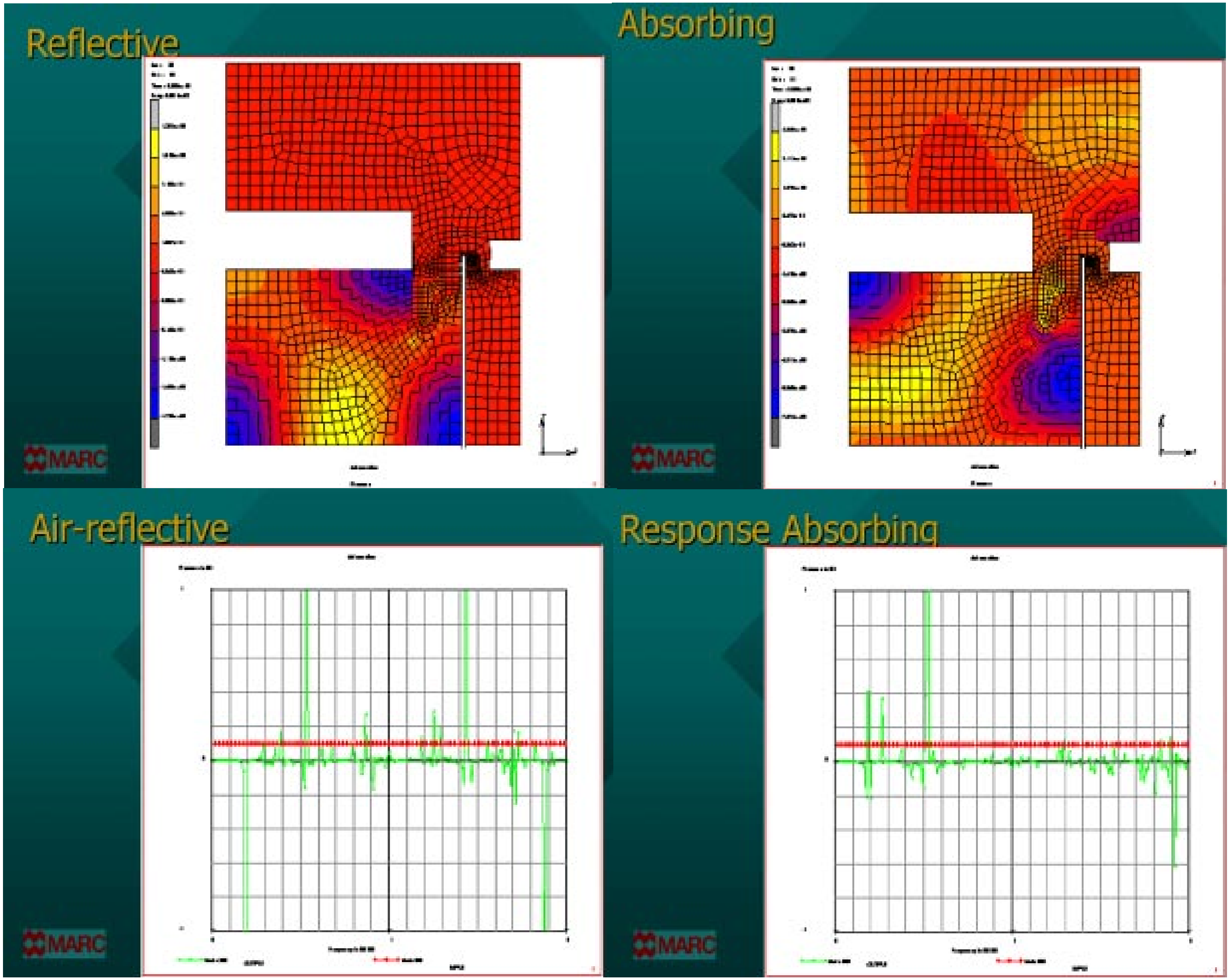
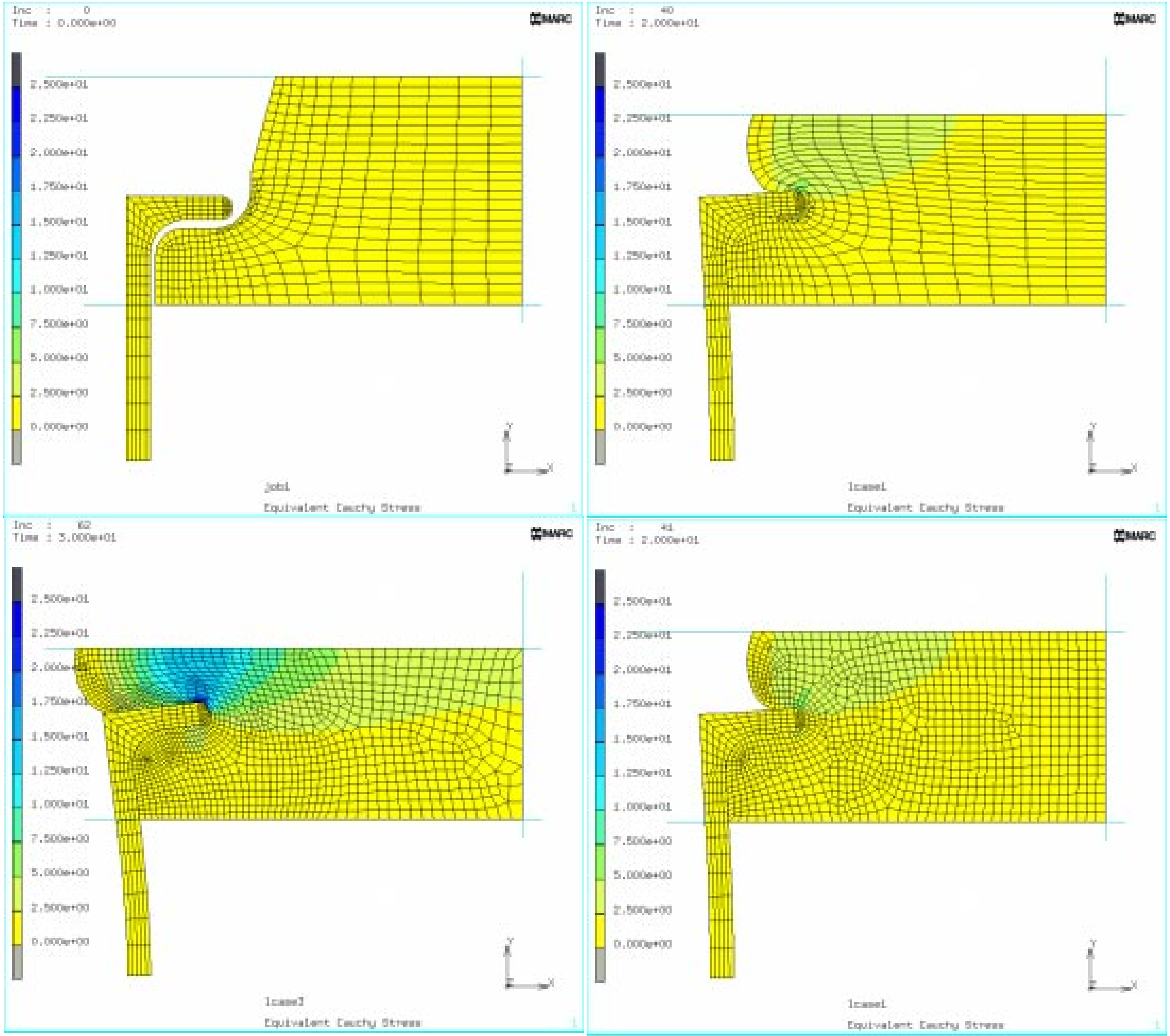
Coupled Acoustic-Structural Modal



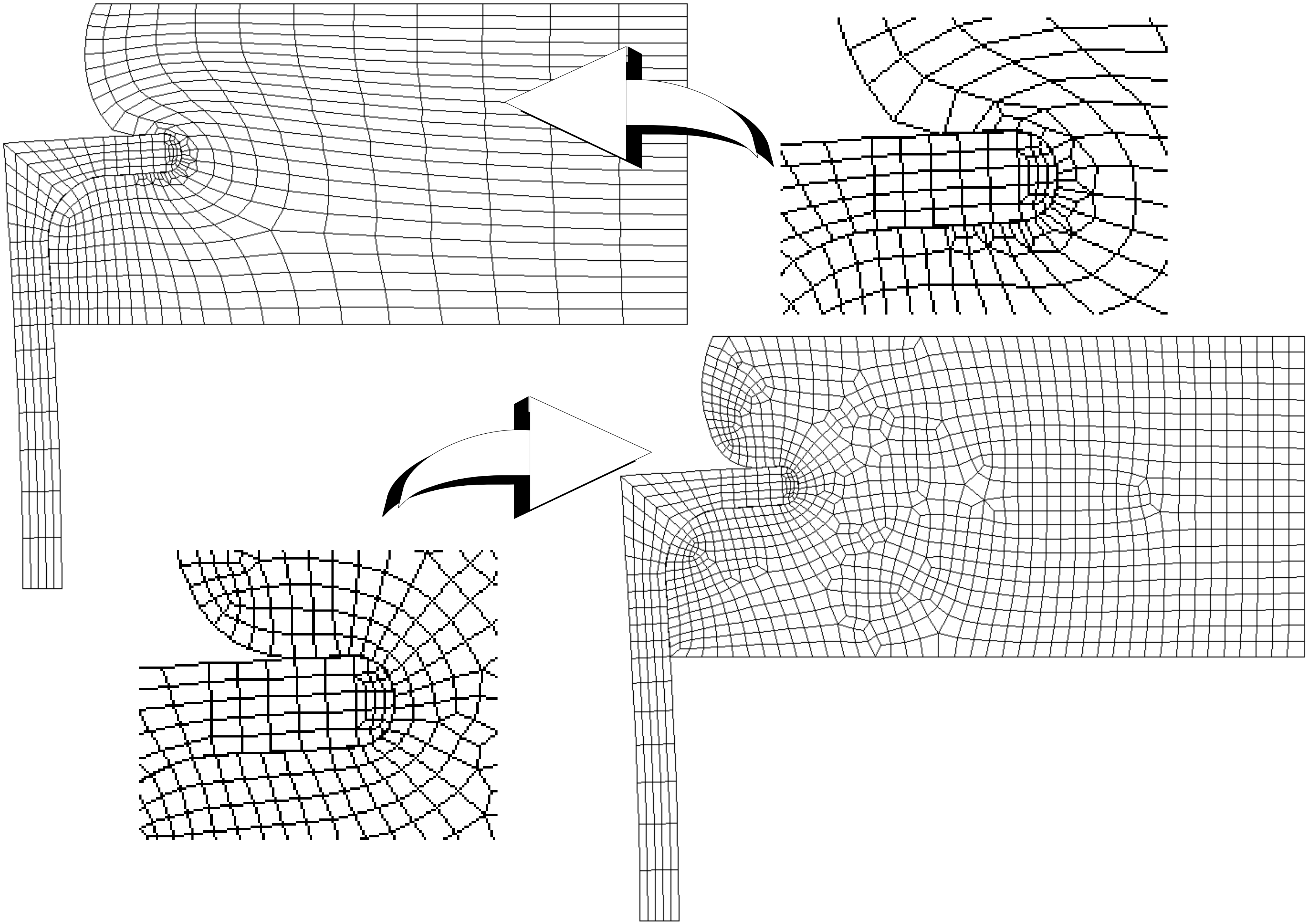
Coupled Acoustic-Structural Modal



Automatic Rubber Remeshing

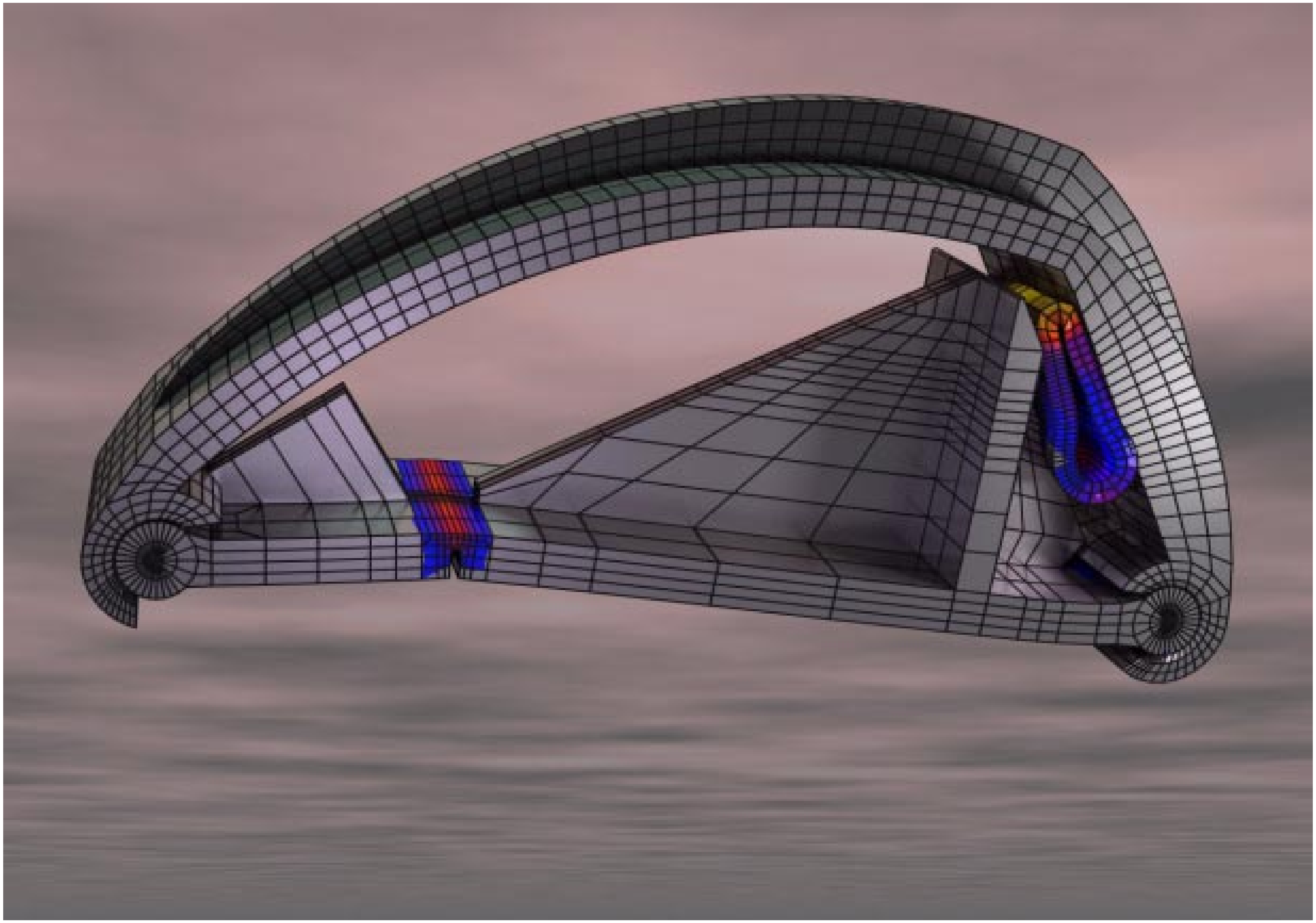


Automatic Rubber Remeshing



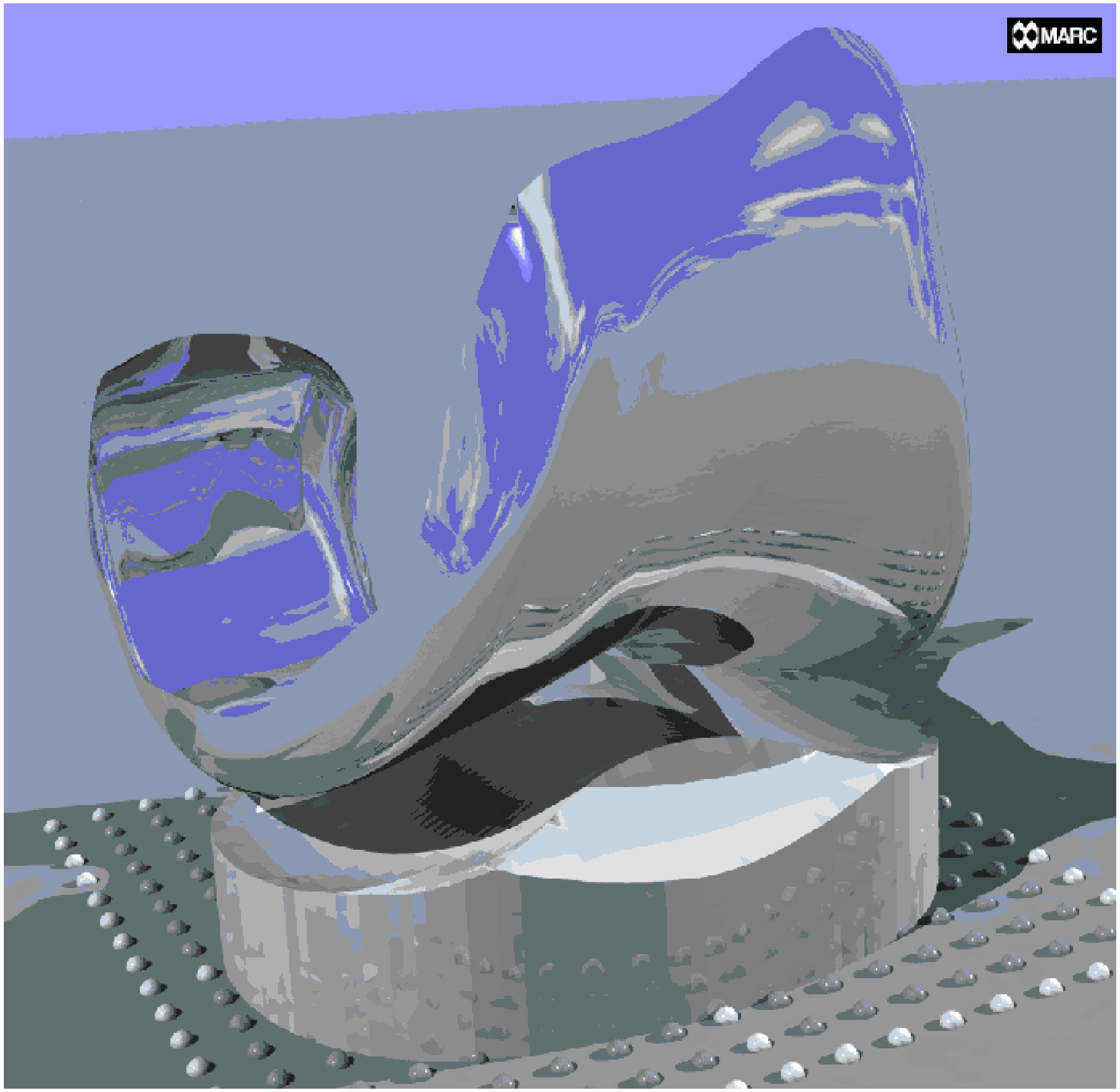
Intravenous Medical Tube Clamp

See www.marc.com/Theater/movies/ivclamp.htm

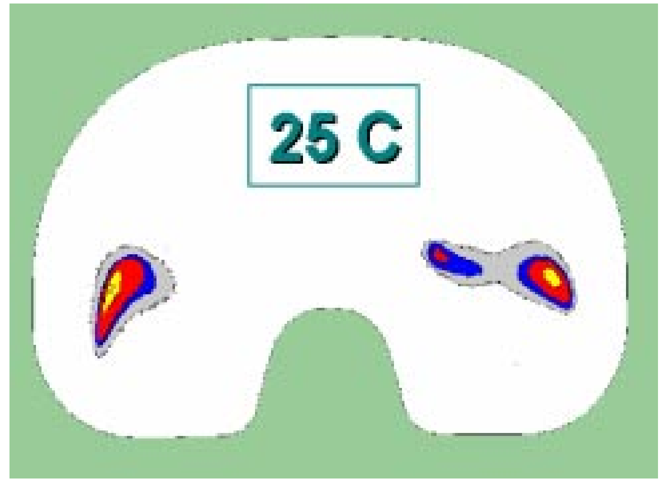


Knee Implant

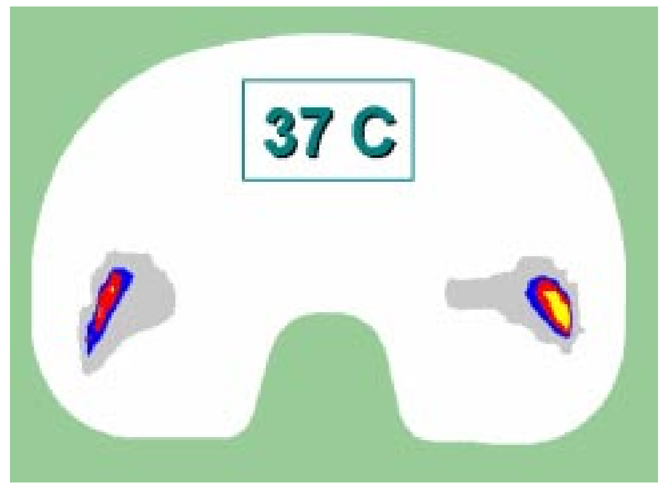
Orthopedic Research Laboratory, Cleveland, Ohio



Experimental: Fuji Film



Predictions: MARC FEA



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Experimental Elastomer Analysis Training Class

"The experience of obtaining the experimental data in one room then walking to the next room and using it in FEA was invaluable", Greg Rea, Standard Products;

"Excellent. My understanding of experimental testing and data reduction, elastomer material modeling, and material model confirmation using FEA increased tremendously. This workshop should be required for anyone involved with the FEA of elastomers", Ken Ogilvie, BTR;

"The EEA workshop provides valuable guidance as to what one can expect and cannot expect elastomer FEA models to predict, and when correctly approached, how powerful FEA of elastomers is in a field traditionally viewed as art", Larry Castleman, Busak & Shamban.

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