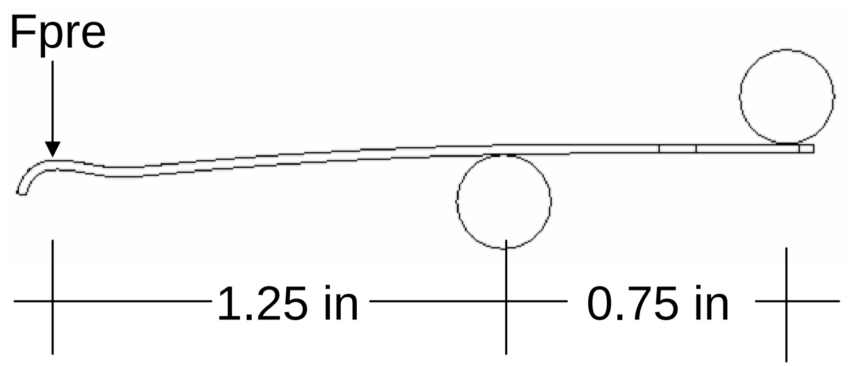
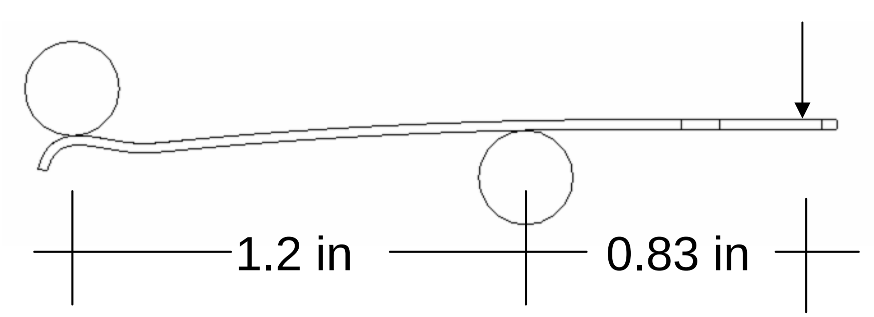
Spring Analysis 9/20/08

Hello DesertFox
I’m trying to model a spring that is used in one of our products. I visualized the free body diagram as a simply supported beam. I wanted to verify my experimental results with ANSYS and analytical results. Depending on what method gave me the best results as compared to the experimental results, I would then use that method for analyzing the spring in the product. My test setup used two dowel pins that supported the spring at preload and then when the handle is pressed. A Chatillion force gauge and dial indicator were used to measure the resulting force and deflection.

PRELOAD EXPERIMENTAL



TRIGGER EXPERIMENTAL



Material:AISI 1095 Steel, oil quenched from 800°C (1475°F), tempered at 480°C (900°F) (Approximate Blue Tempered)
Spring Dimensions:
2.125”Lx0.34”Dx0.025”H

Spring in product:
The force required to deflect the spring to it’s preloaded deflection of 0.625” is 3.5 lbf.
The force required to deflect the spring to it’s handle deflection of 0.700” is 15 lbf.

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PRELOAD	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force
	2	4	5.5	6	6.2			
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.20	0.30	0.40	0.43			
	Actual Defl	Actual Defl	Actual Def	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
PRELOAD	0.09	0.18	0.28	0.38	0.40			

TRIGGER	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force
	4.25	6.5	8.25	10	11	11.75	12.25	12.25
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
Similar To	Actual Defl	Actual Defl	Actual Def	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
Trigger	0.08	0.12	0.17	0.21	0.25	0.30	0.35	0.40

The data above shows the required force to deflection for preloading setup and the trigger setup.

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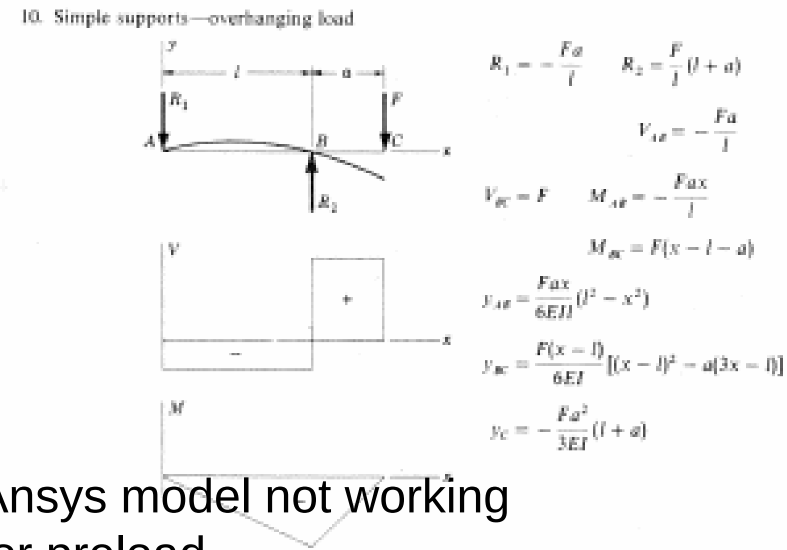
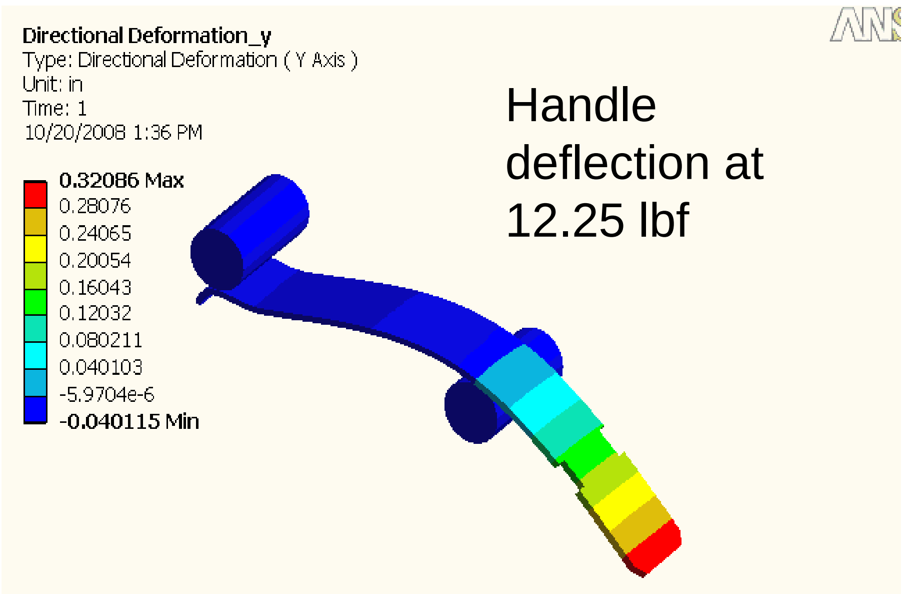
Comparing Simply supported beam to experimental results:

EXPERIMENTAL RESULTS VS ANALYTICAL:

PRELOAD	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force
	2	4	5.5	6	6.2			
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.20	0.30	0.40	0.43			
	Actual Defl	Actual Defl	Actual Def	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
PRELOAD	0.09	0.18	0.28	0.38	0.40			
Simply	Calc Defl Orig:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:
Supported	-0.228	-0.456	-0.627	-0.684	-0.707			
	ANSYS TRIG I	ANSYS Defl	ANSYS De	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl
	at Exp Force	at Exp Force	at Exp Forc	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force
	x	x	x	x	x	x	x	x
TRIGGER	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force
	4.25	6.5	8.25	10	11	11.75	12.25	12.25
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
	Actual Defl	Actual Defl	Actual Def	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
Trigger	0.08	0.12	0.17	0.21	0.25	0.30	0.35	0.40
Simply	CALC Trigger	Trigger Defl:	Trigger De	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:
Supported	-0.103	-0.157	-0.200	-0.242	-0.266	-0.284	-0.296	-0.296
	ANSYS TRIG I	ANSYS Defl	ANSYS De	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl
	at Exp Force	at Exp Force	at Exp Forc	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force
	0.110	0.168	0.212	0.257	0.281	0.299	0.311	0.311
stress	89106	138910	172590	208600	228380	241830	252830	252830



Ansys model not working for preload



Handle deflection at 12.25 lbf

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Comparing Castigiliano's Method to experimental results:

EXPERIMENTAL RESULTS VS ANALYTICAL:								
PRELOAD	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force
	2	4	5.5	6	6.2			
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.20	0.30	0.40	0.43			
	Actual Defl	Actual Def	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
PRELOAD	0.09	0.18	0.28	0.38	0.40			
Castigiliano's	Calc Defl Orig:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:
Method	0.156	0.312	0.429	0.469	0.484			
	ANSYS TRIG D	ANSYS De	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl
	at Exp Force	at Exp Forc	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force
	x	x	x	x	x	x	x	x
TRIGGER	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Forc
	4.25	6.5	8.25	10	11	11.75	12.25	12.25
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
	Actual Defl	Actual Def	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
Trigger	0.08	0.12	0.17	0.21	0.25	0.30	0.35	0.40
Castigiliano's	CALC Trigger	Trigger De	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:
Method	0.032	0.050	0.063	0.076	0.084	0.090	0.093	0.093
	ANSYS TRIG D	ANSYS De	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl
	at Exp Force	at Exp Forc	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force
	0.110	0.168	0.212	0.257	0.281	0.299	0.311	0.311
stress	89106	138910	172590	208600	228380	241830	252830	252830

where $$U = \int_0^x \tfrac{1}{2} x \frac{M^2}{E*I} dx = \frac{F^2}{2xExI} \int_0^x x^2 dx = \frac{F^2}{2xExI} \Big|_0^x \frac{x^3}{3}$$

$$\delta_A = \frac{\delta U}{F_A} = \frac{F \bullet (x^3)}{E \bullet I \bullet 3}$$

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Comparing Strain Energy Method to experimental results:

EXPERIMENTAL RESULTS VS ANALYTICAL:								
PRELOAD	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force
	2	4	5.5	6	6.2			
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.20	0.30	0.40	0.43			
	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
PRELOAD	0.09	0.18	0.28	0.38	0.40			
Castigiliano's	Calc Defl Orig:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:	Calc Defl:
Method	0.156	0.312	0.429	0.469	0.484			
	ANSYS TRIG De	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS	
	at Exp Force	at Exp Forc	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp F	
	X	X	X	X	X	X	X	
TRIGGER	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force	Exp Force
	4.25	6.5	8.25	10	11	11.75	12.25	12.25
	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl	Dial Defl
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl	Actual Defl
Trigger	0.08	0.12	0.17	0.21	0.25	0.30	0.35	0.40
Castigiliano's	CALC Trigger	Trigger De	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:	Trigger Defl:
Method	0.032	0.050	0.063	0.076	0.084	0.090	0.093	0.093
	ANSYS TRIG De	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl	ANSYS Defl
	at Exp Force	at Exp Forc	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force	at Exp Force
	0.110	0.168	0.212	0.257	0.281	0.299	0.311	0.311
stress	89106	138910	172590	208600	228380	241830	252830	252830

$$\frac{1}{2} \times F \times y = \sum U$$

$$\text{where} \quad U = \int_0^x \frac{1}{2} x \frac{M^2}{E*I} dx = \frac{F^2}{2\,xExI} \int_0^x x^2 dx = \frac{F^2}{2\,xExI} \Big|_0^x \frac{x^3}{3}$$

$$\frac{1}{2} \times F \times y = \frac{F^2}{2\,xExI} \Big|_0^x \frac{x^3}{3} \Rightarrow \quad y = \frac{F}{ExI} \Big|_0^x \frac{x^3}{3}$$

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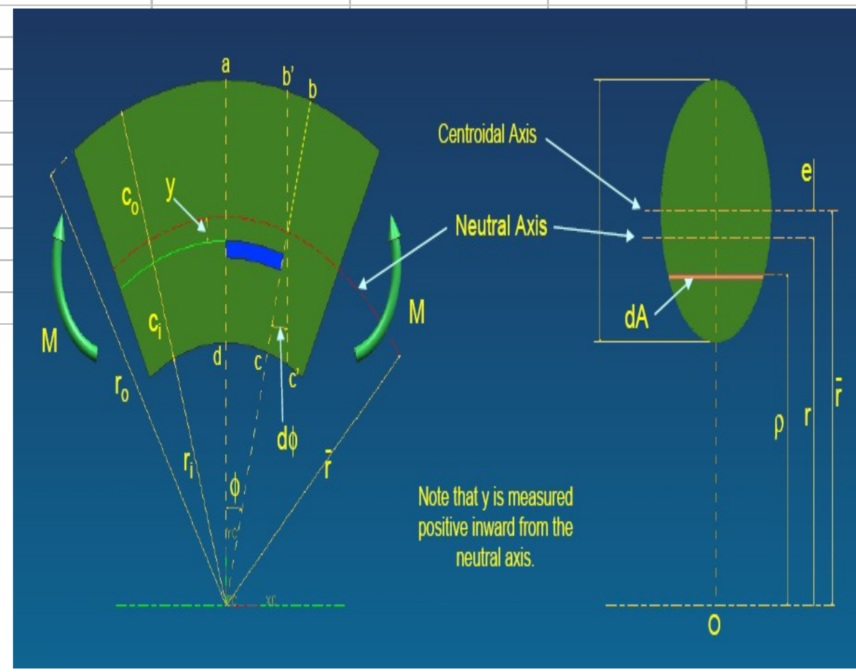
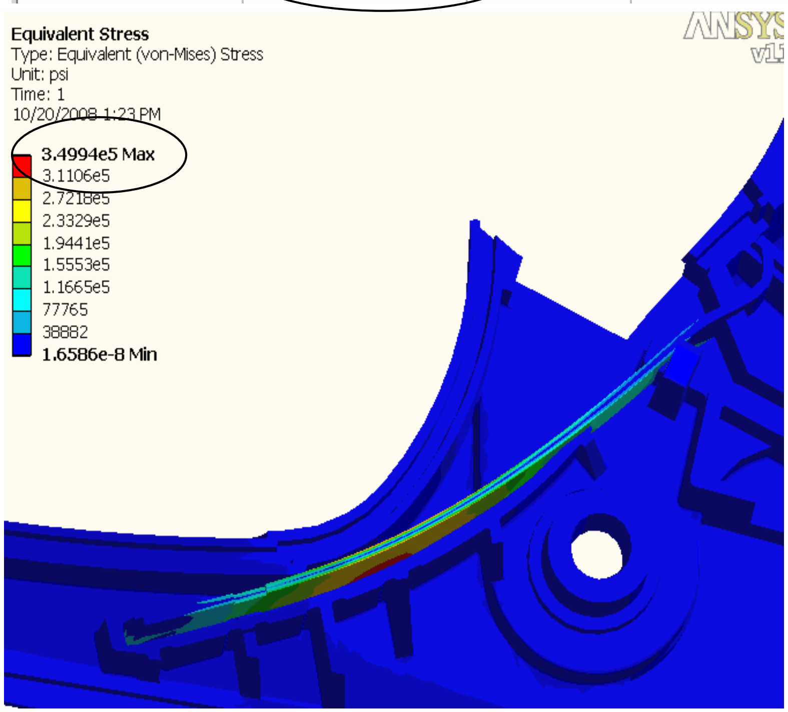
Comparing Curved Beam Stress at largest Moment to ANSYS results:

AISI 1095 Steel, oil quenched from 800°C (1475°F), tempered at 480°C (900°F) (Approximate Blue Tempered)							
Force	Spring length	Modulus of Elasticity	Moment Arm length	base	height	moment of interia	Cross-sectional Area
(lbf)	(in)	(lbf/in^2)	(in)	(in)	(in)	(in^4)	
						1/12*B*H^3	
F	**l**	**E**	**a**	**base**	**height**	**Imom**	
12	2.125	29700000	1.0625	0.34	0.025	0.00000044	0.0085
r̄	0.9770						
ro	0.9895						
ri	0.9645						
r=h/(ln(ro/ri)	0.9769						
e	0.000053312						
co	0.0126						
ci	0.0124						
Ma	12.7500						
Mb	12.7500						
σi=Ma*ci/(Aeri)	**363094.5011**						





My ANSYS model show that the equivalent stress for the actual part matches closely to the Curved Beam Stress analysis, but required force to do this was

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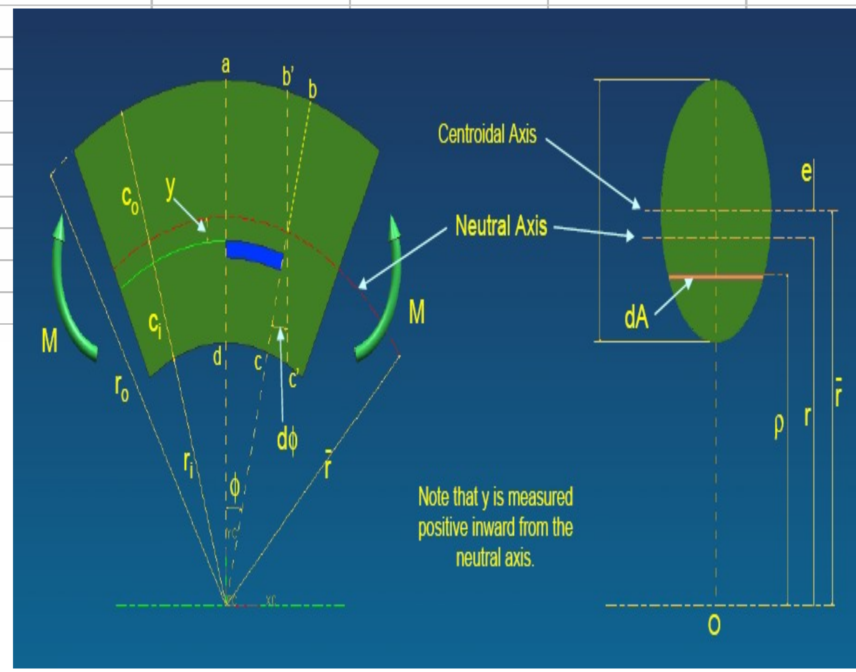
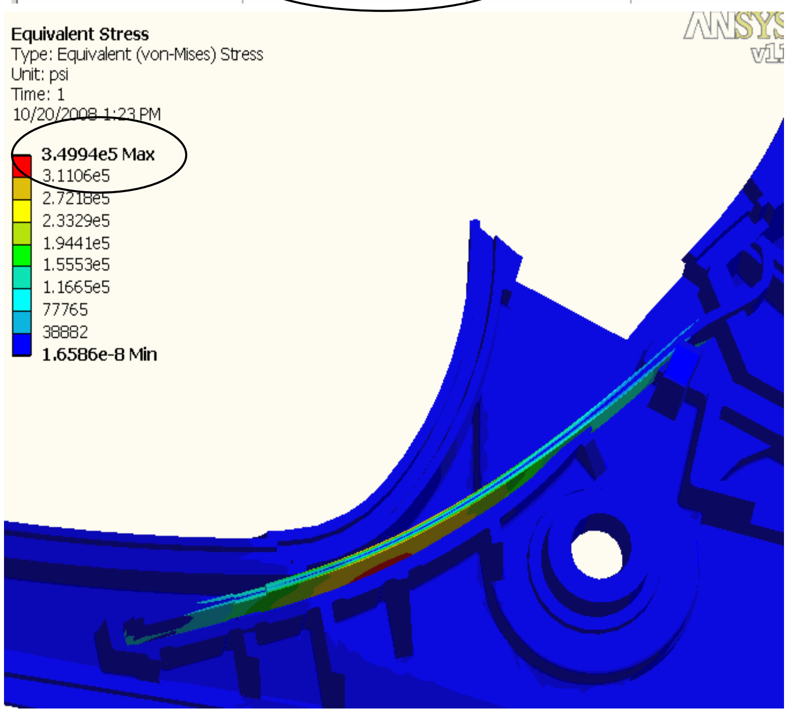
AISI 1095 Steel, oil quenched from 800°C (1475°F), tempered at 480°C (900°F) (Approximate Blue Tempered)							
Force	Spring length	Modulus of Elasticity	Moment Arm length	base	height	moment of interia	Cross-sectional Area
(lbf)	(in)	(lbf/in^2)	(in)	(in)	(in)	(in^4)	
						1/12*B*H^3	
F	**l**	**E**	**a**	**base**	**height**	**Imom**	
12	2.125	29700000	1.0625	0.34	0.025	0.00000044	0.0085
r̃	0.9770						
ro	0.9895						
ri	0.9645						
r=h/(ln(ro/ri)	0.9769						
e	0.000053312						
co	0.0126						
ci	0.0124						
Ma	12.7500						
Mb	12.7500						
σi=Ma*ci/(Aeri)	**363094.5011**						





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