Team 2 – Biaxial Tensile Tester

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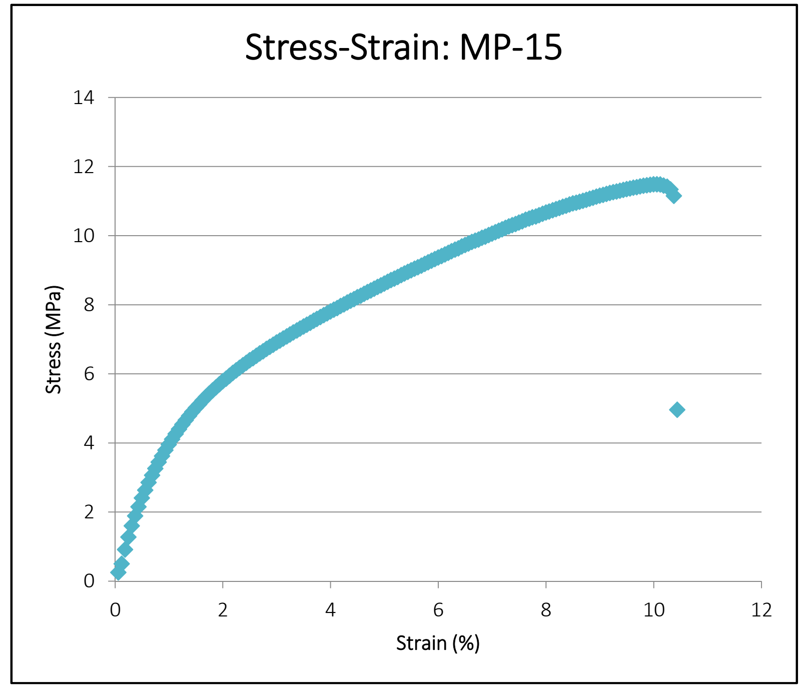
Sponsor: Cummins, Inc. (Terry Shaw)
Graduate Consultant: Parker Harwood
Faculty Advisor: Dr. Williams Oates

Questions to be Addressed

- Why is a compression test difficult for gasket material?
- What exactly does a biaxial test provide?
- Is pulling along more axes always better?

Elastomers

- Have ability to achieve large deformations and elastically spring back into original shape.
- The moduli of elasticity is quite small AND varies with strain since stress-strain curve is no longer linear
- As a tensile load is applied the crosslinked molecular chains will uncoil in the stress direction[2].



Stress-Strain Curve of MP-15 gasket material. Data provided by Parker Harwood.

Gasket Material

- ➢Rubber
- ➢Paper
- ➢N-8092
- ➢TS-9003
- ➢MP-15

Material Testing

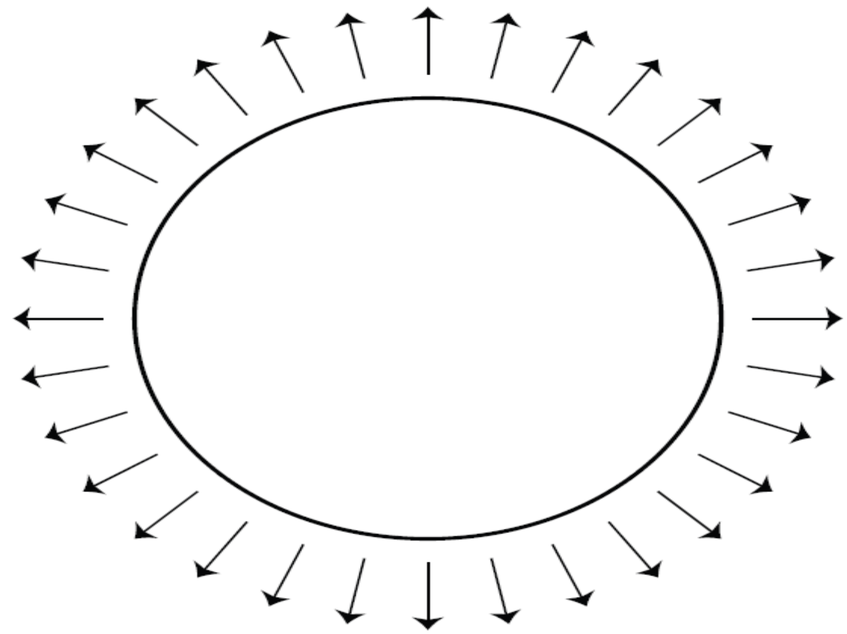
- In order to model materials, accurate predictions of properties are needed
- Uniaxial tension
- *Easy to obtain with standard tensile test*
- Pure shear
- *Done with planar tension test*
- Uniaxial Compression
- *Inaccurate due to the friction between the load plates and the specimen*
- *Causes a mixed state of compression, shear, and tensile strain*[1]

Why Biaxial Tension?

- A biaxial tensile strain is equivalent to a uniaxial compressive strain[1].
- Mohr's Circle
  - *Becomes a point circle*
  - *No shear forces are present*[2]
- Poisson's Ratio nearly 0.5
  - *Means a process of constant volume*
- $\gamma = -\frac{\epsilon_z}{\epsilon_x}$

Equal Biaxial Tension

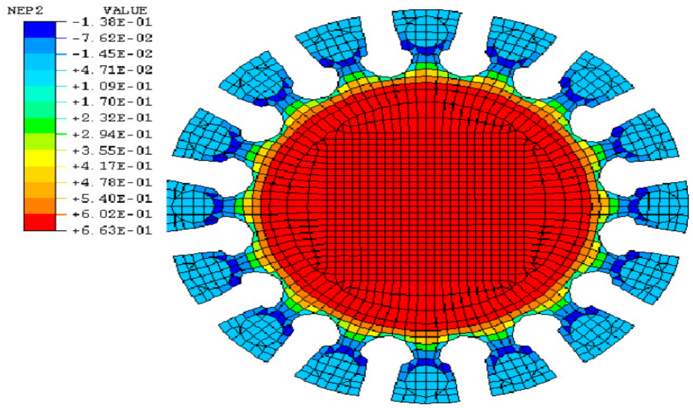
- For incompressible materials this creates a state of strain equivalent to pure compression.
- Free of the frictional effects



Ideal Equal biaxial stress state[1]

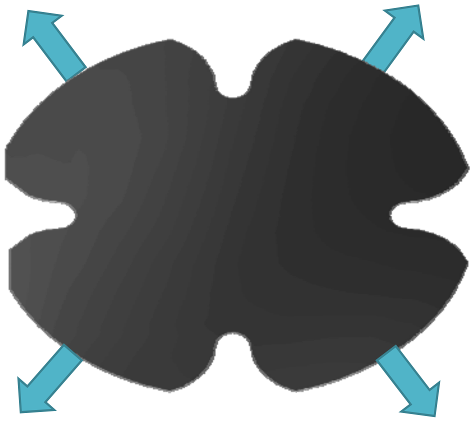
Specimen Geometry

- ➢While researching found relatable specimen geometry
- ➢Assumptions:
  - ➢ *Modeled with natural rubber's material properties*
  - ➢ *Assumed a symmetric load applied radially*
  - ➢ *Neglected the effects of the clamping from the grips during testing*
  - ➢ *Need a uniform strain distribution throughout sample*

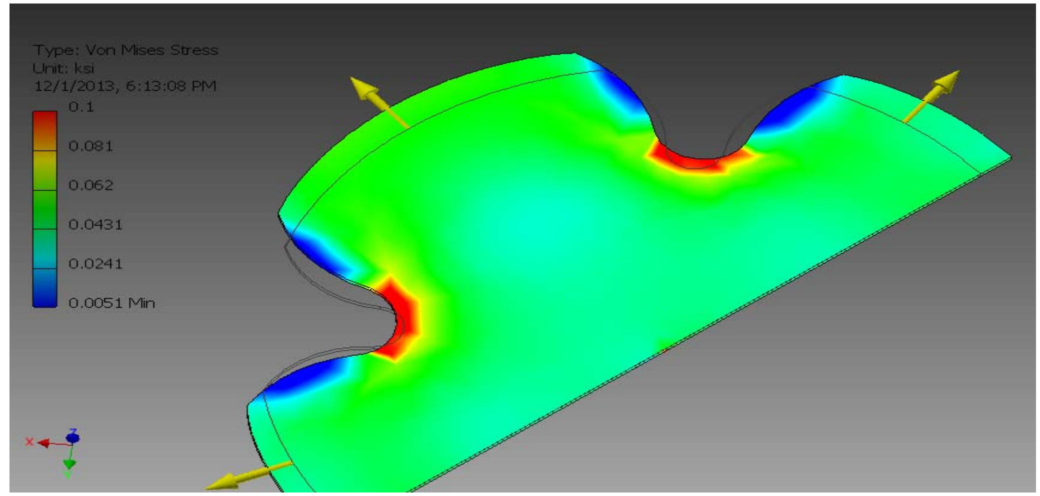


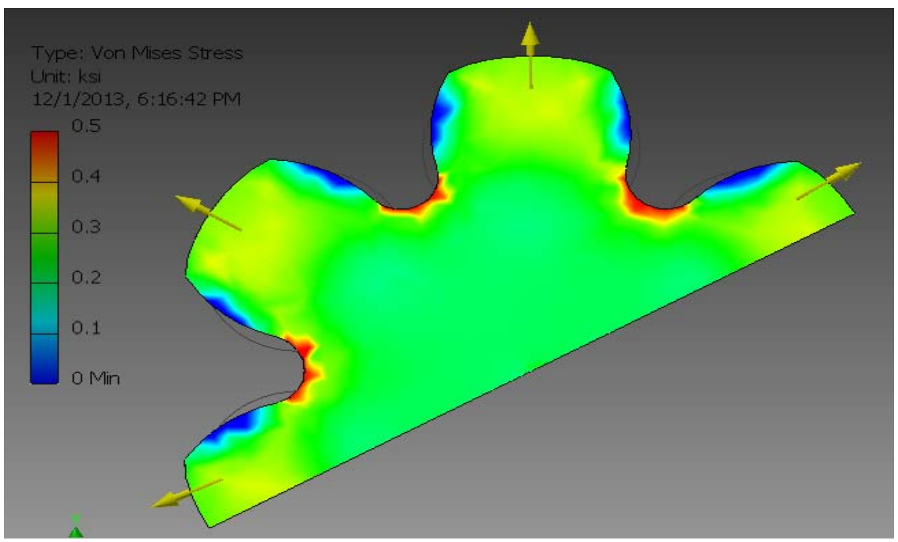
(Top) FEA analysis of tensile specimen at Axel Physical Testing Services [3]

Specimen Geometry Cont.

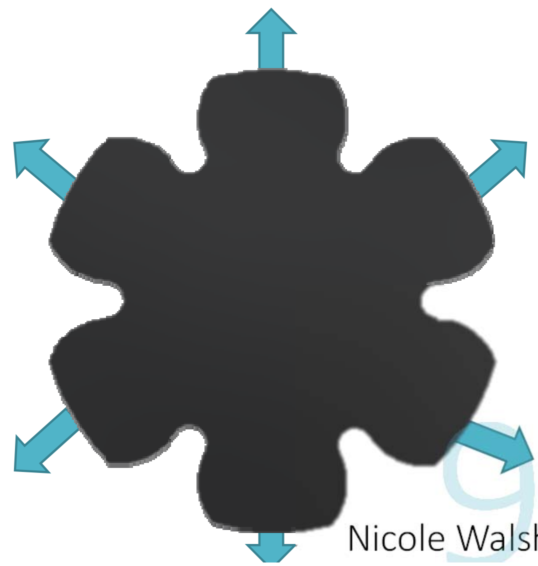


2 Axes

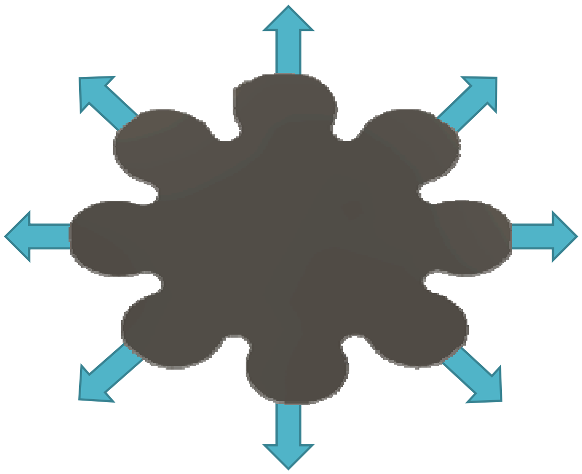


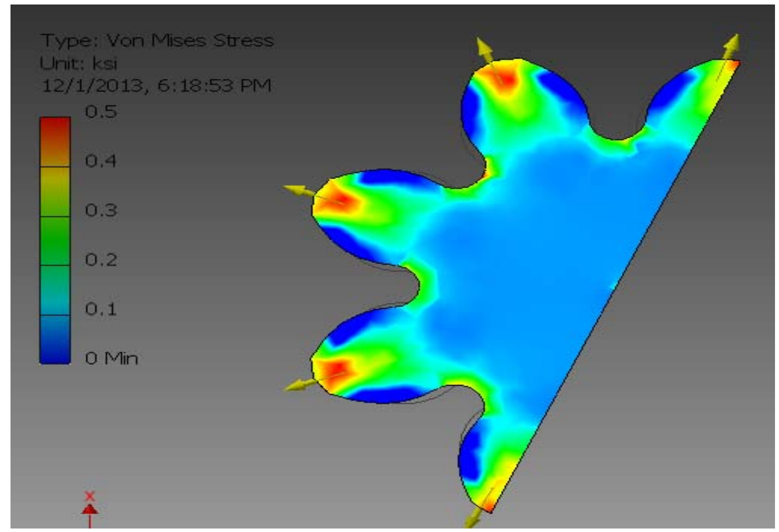


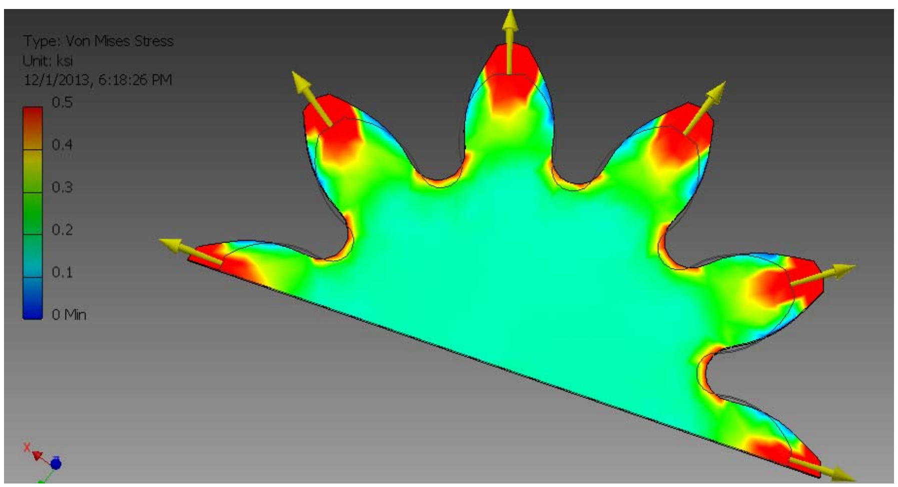
3 Axes

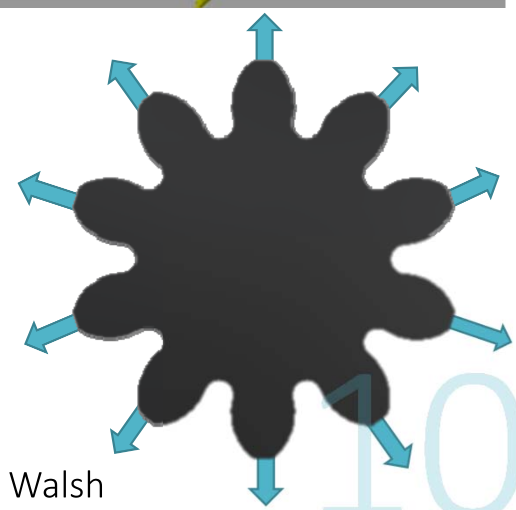


Specimen Geometry Cont.









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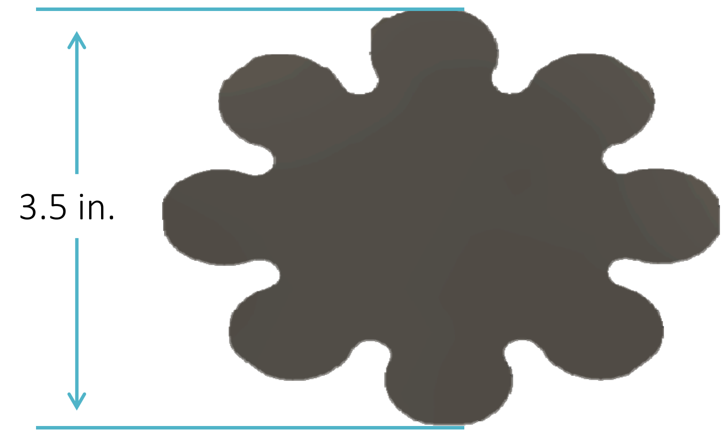
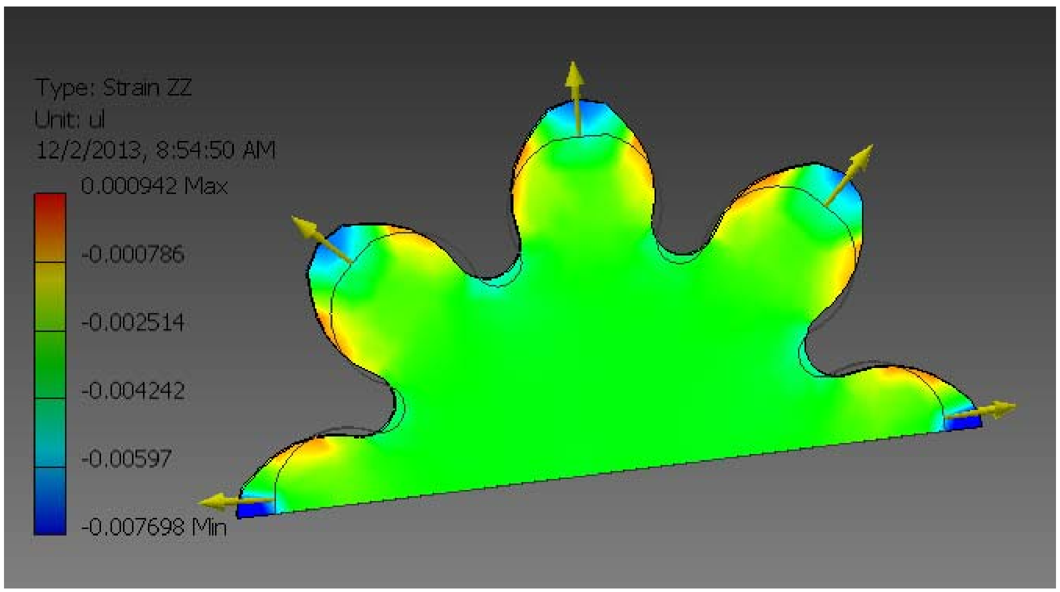
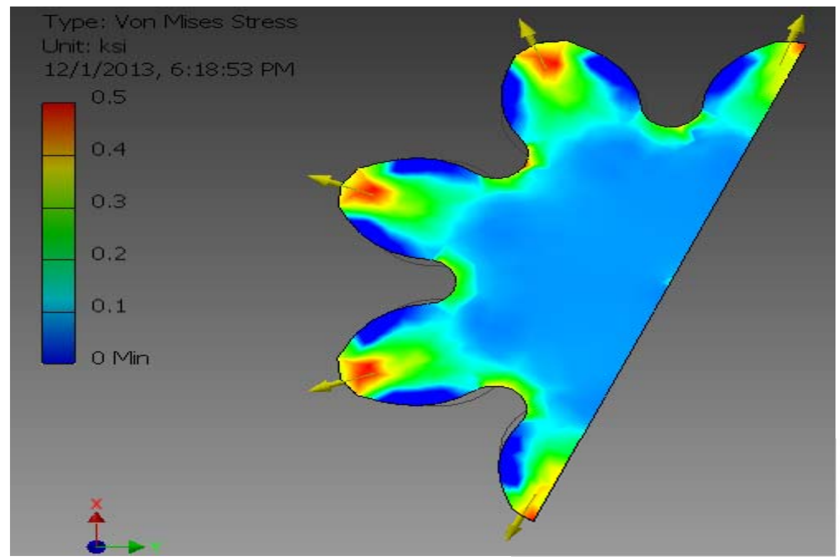
Final Specimen Geometry





The strain profile in the ZZ plane after load is applied



The resulting Von Mises Stresses as force was applied radially

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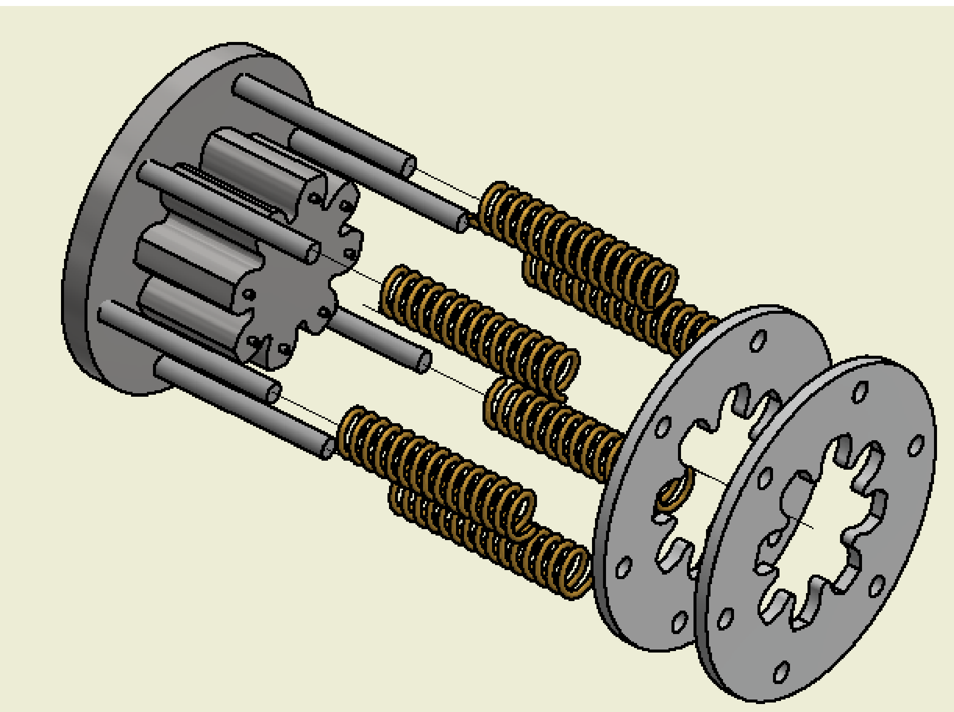
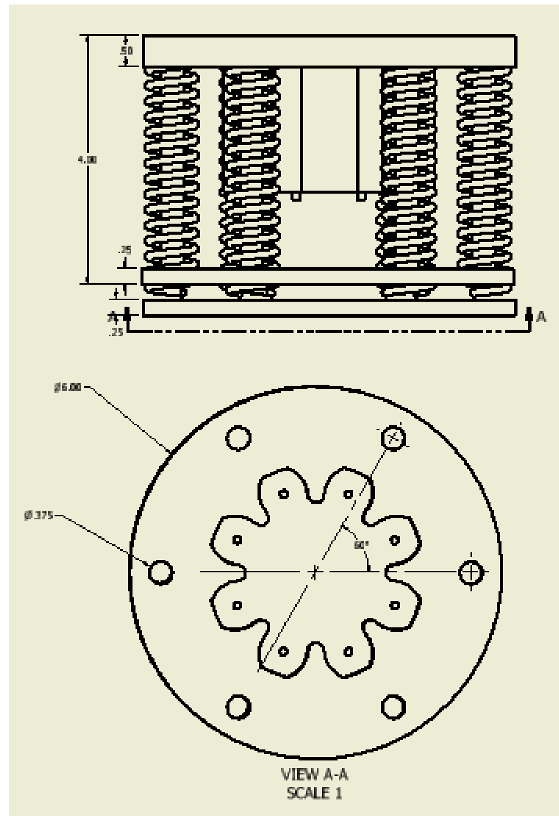
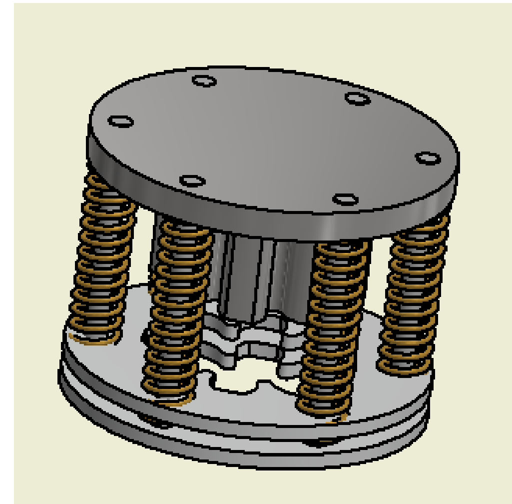
Specimen Production

- A punch must be constructed so each specimen is identical for testing







Budgetary Concerns

Stand Alone Systems

- Load Cells $100+ ea.
- *Minimum $800*
- Hydraulic Actuators $110ea.
- *Minimum $880 + $600 pump*
- Electric Actuators $150ea.
- *Minimum $1200*

Both over budget already.

MTS Integrated Systems

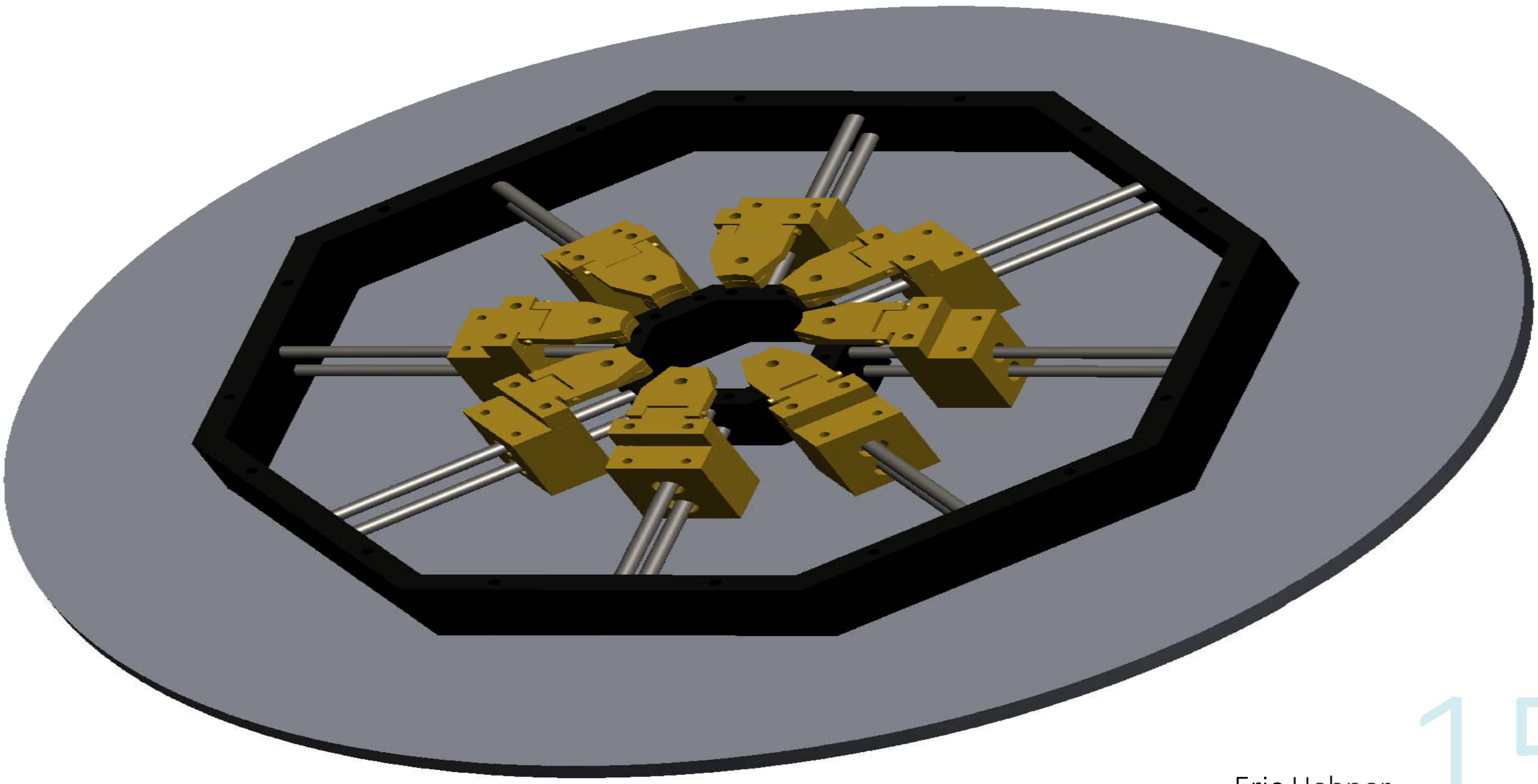
- Load Cell already present.
- *$0*
- Actuator already present
- *$0*

Budget Breakdown

Item	Source	Price	Shipping
Alimex Cast Al Plate (0.75"x46"x43")	Midwest Steel and Aluminum	$471.85	347.99
6061 T6 Al Plate (0.75"x30"x36")	Midwest Steel and Aluminum	$239.84	
6061 Al Square Bar (2"x2"x36")	Midwest Steel and Aluminum	$55.70	
2 Hardened Steel Rods (12mmx2000mm)	Thomson Linear Motion	$134.78	---
16 Linear Bearings (12mm)	eBay	$20.22	---
steel bolt, nut, washers (1/4"x3 1/2")	Amazon	$29.64	---
Stainless Steel Pulley	McMasterCarr	$56.72	---
Galvanized Steel Eyebolt	McMasterCarr	$36.32	---
Steel Ball Bearings	McMasterCarr	$113.44	---
End-Fitting for Wire	McMasterCarr	$261.66	---
Aluminum Stop Compression Sleeve	McMasterCarr	$7.97	---
	Total:	**1428.14**	**347.99**

Eric Hebner

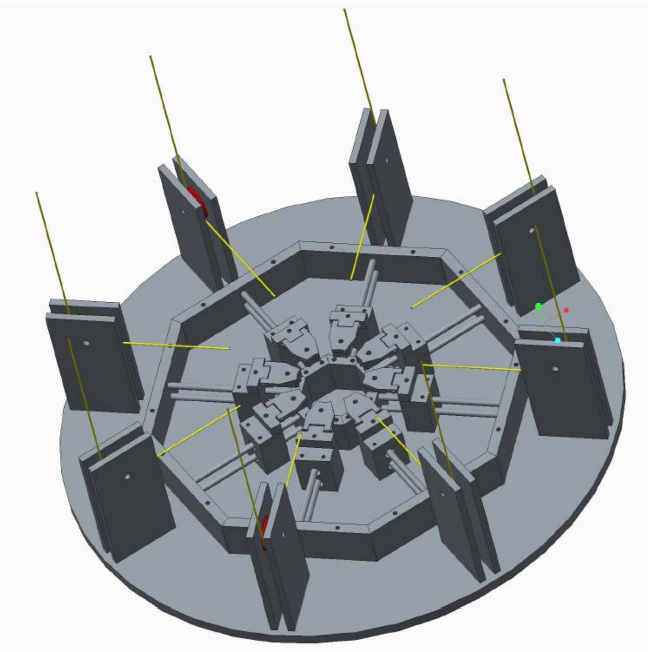
Universal Base Plate Design



SCALE 1:2

Eric Hebner

Model of Baseplate with Pulleys



- ➢Has 8 pulleys for ends of each axis
- ➢Utilizes steel cable to attach to gripping mechanism and pull specimen
- ➢Pulleys are support by two plates on either side with a shaft passing through and attaching to plates by ball bearings to allow rotation

Analysis of the Cable

- Assumed maximum force applied overall is 4000 lbf, which would make it 81.633 lbf on each strand in the cable, and the diameter of the cable is 0.125 in
- Yield stress of 316 stainless steel cable is 515 MPa, it will be plenty strong to support loads required

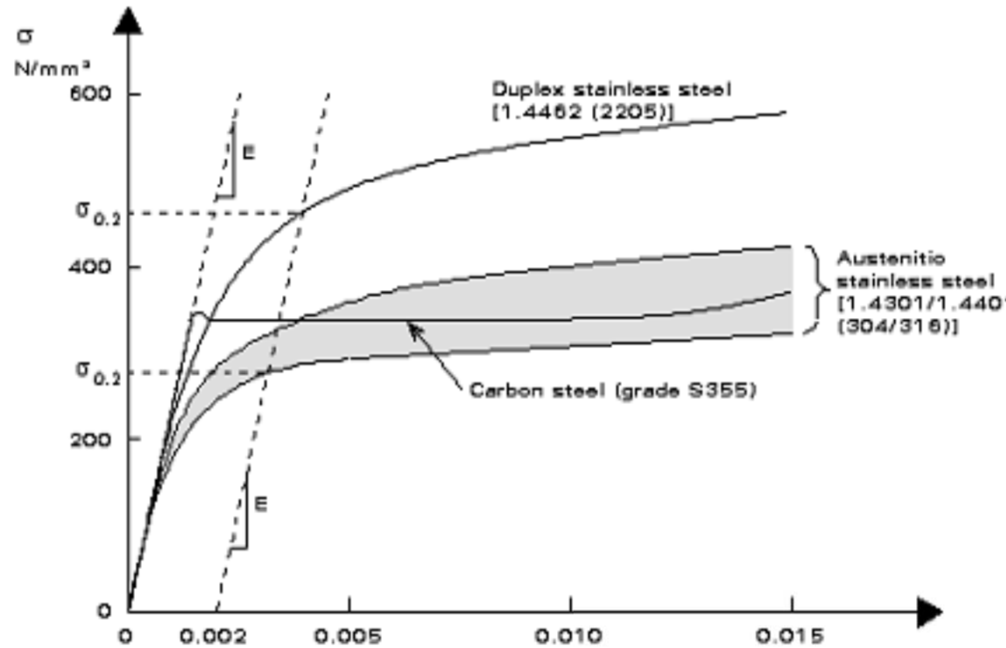
Desired Value	Equation	Result
Cross-Sectional Area	$A_c = \frac{\pi * d^2}{4}$	0.012 in^2
Force in Each Strand	$F_{strand} = \frac{F}{49\ strands}$	81.633 lbf
Maximum Stress	$\sigma_{max} = \frac{F}{A_c}$	45.864 MPa

Ben Hainsey

Analysis of Pulley

➢ Pulley chosen for initial analysis is made of steel with a work load limit of 685 lbf

Desired Value	Equation	Result
Force in each pulley	$F_{pulley} = \frac{F_{max}}{8 \text{ pulleys}}$	400 lbf
Safety Factor	$n = \frac{F_{allowed}}{F_{pulley}}$	1.37



Ben Hainsey

Plans for the Rest of This Semester and Next

- Talk to PE at the Magnet Lab to alter drawings to a more reasonable task for machining
- Get all materials machined and ready for assembly
- Assembly of prototype
- Testing materials and comparing to nominal data
- Calibrating machine and making any alterations necessary
- Developing instruction manual for use with detailed procedures and warnings

References

1. http://www.axelproducts.com/downloads/CompressionOrBiax.pdf
2. Callister, W.D. (2007). *Material Science and Engineering, An Introduction;* 7th ED. York, PA: John Wiley & Sons, Inc.
3. Day, J. and Miller, K. (July 2000), Equibiaxial Stretching of Elastomeric Sheets, An Analytical Verification of Experimental Technique. *Equibiaxial Stretching, Rev 2. 1-8.*