TEAM 2 – BIAXIAL TENSILE TESTER

GROUP MEMBERS:

BEN HAINSEY

NICOLE WALSH

ERIC HEBNER

SPONSOR:

TERRY SHAW (CUMMINS INC.)

GRADUATE CONSULTANT:

PARKER HARWOOD

FACULTY ADVISOR:

DR. WILLIAM OATES

Questions to be addressed

- What exactly does a biaxial test provide?
- Is pulling along more axes always better?
- Why is a compression test difficult for our gasket material?
- What are some different techniques of testing materials on more than one axis?

POLYMERS

- Three different types of stress-strain behaviors:
  - Curve A: Brittle
  - Curve B: Plastic
  - Curve C: Elastomer
- Strain rate and temperature greatly influences mechanical behavior[1]

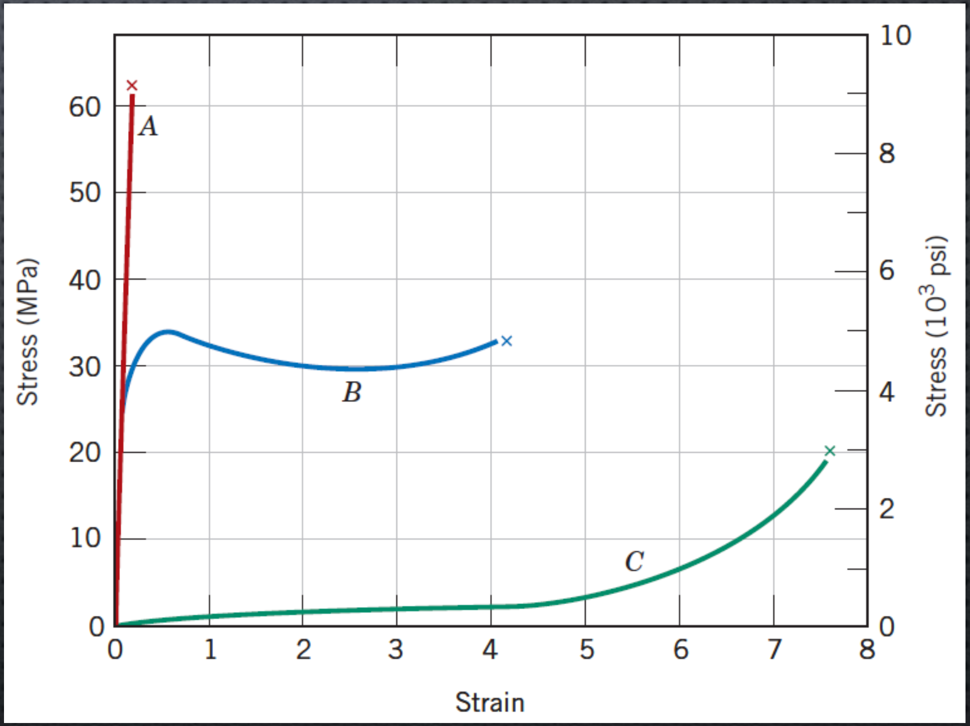


Figure 1: Stress-strain behavior of polymers. [1]

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

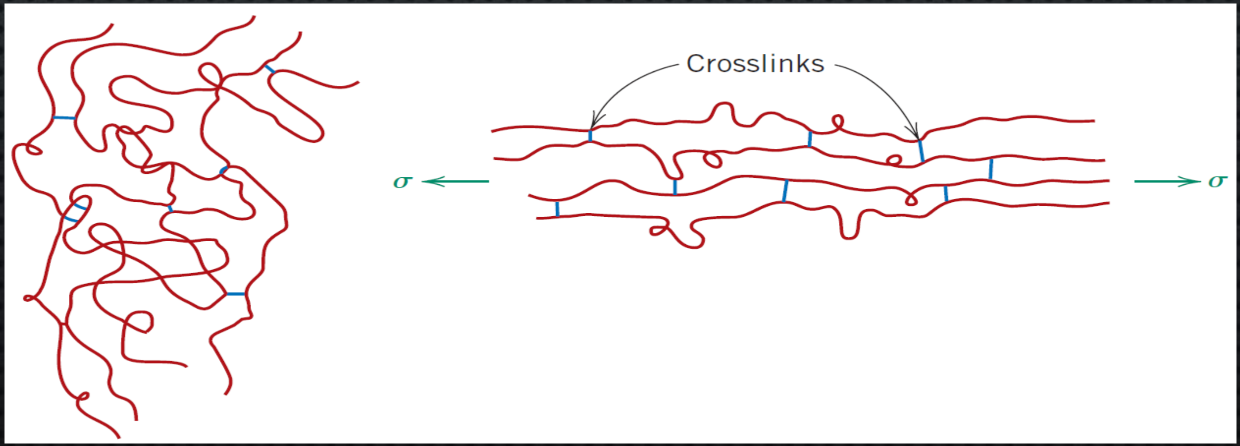


Figure 2: Schematic of Crosslinked Polymer chain molecules. [1]

ELASTOMERS (CONT.)

- VULCANIZATION
  - THE CHEMICAL REACTION WHICH PRODUCES CROSSLINKING IN ELASTOMERS.
  - MODULUS OF ELASTICITY, TENSILE STRENGTH, AND RESISTANCE TO DEGRADATION ALL ENHANCED BY VULCANIZATION
- UNVULCANIZED RUBBER
  - FEW CROSSLINKS
  - SOFT, TACKY, POOR RESISTANCE TO ABRASION

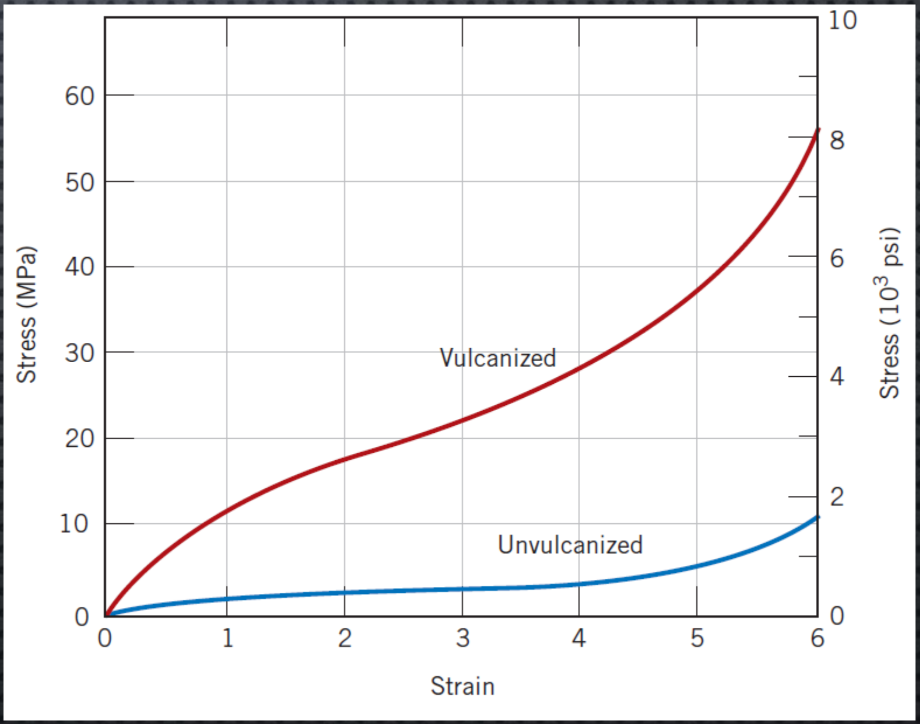


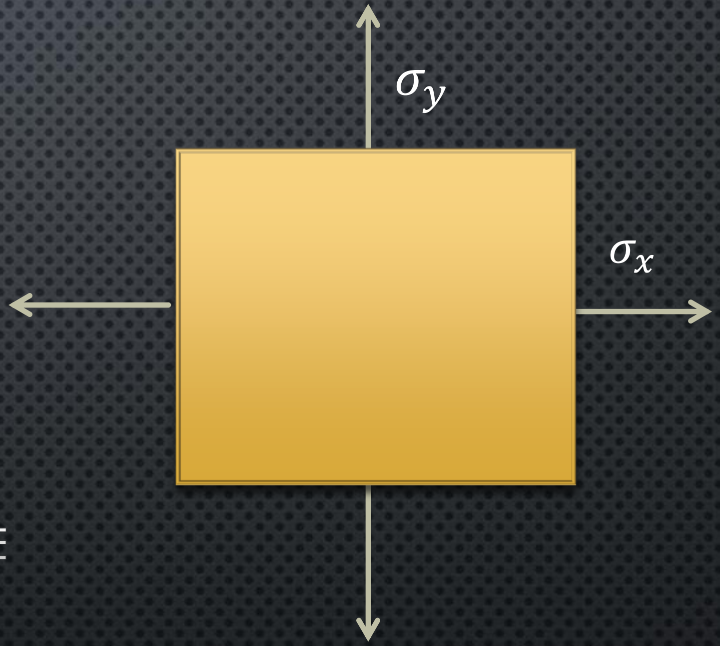
Figure 3: Stress-strain curve that depicts what the process vulcanization does to elastomers. [1]

Material Testing

- In order to model materials properly accurate predictions of properties are needed
  - Uniaxial tension
    - Easy to obtain with 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[2]

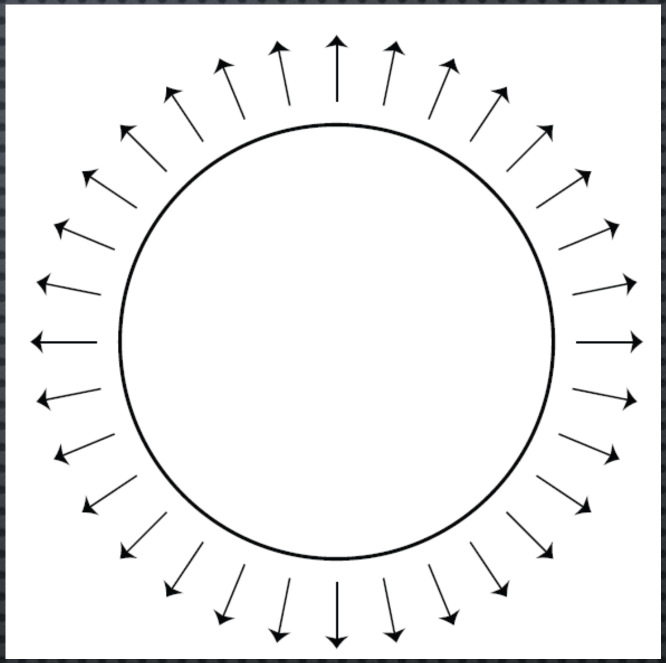
Why Biaxial Tension?

- A biaxial tensile strain is equivalent to a uniaxial compressive strain.
- Mohr's Circle
  - Becomes a point circle
  - No shear forces are present
- 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



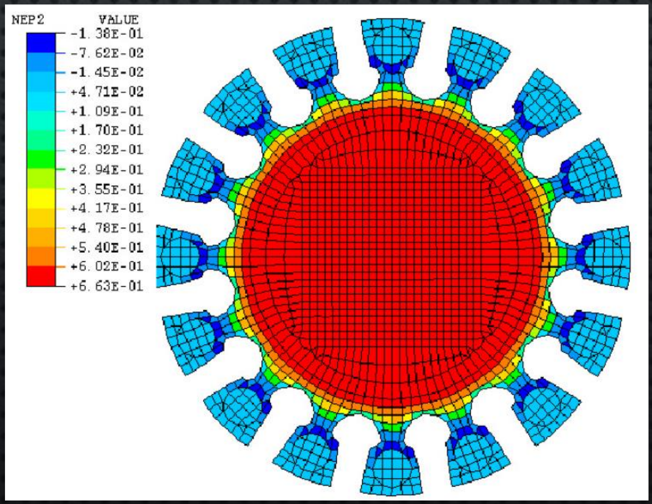
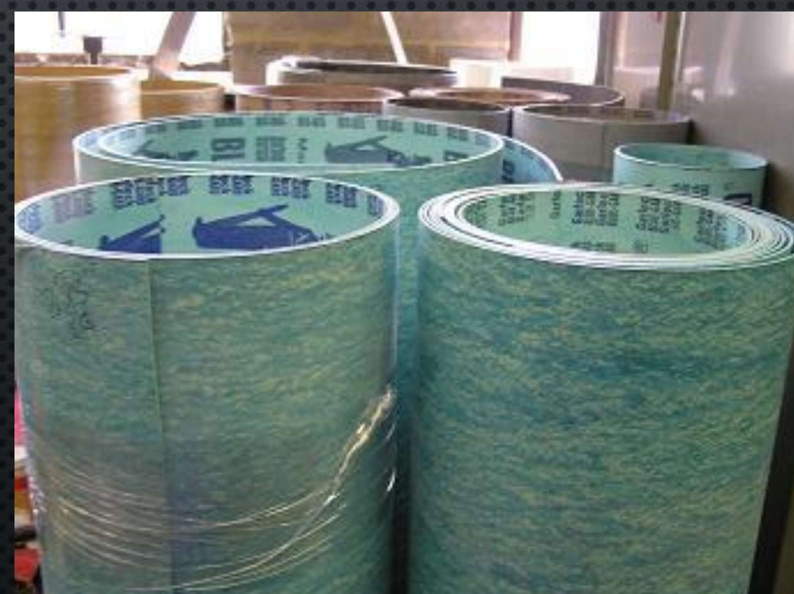


Figure 4: (Top) Equal biaxial stress state. (Bottom) FEA analysis of equal tensile strain [2]

Gasket Material

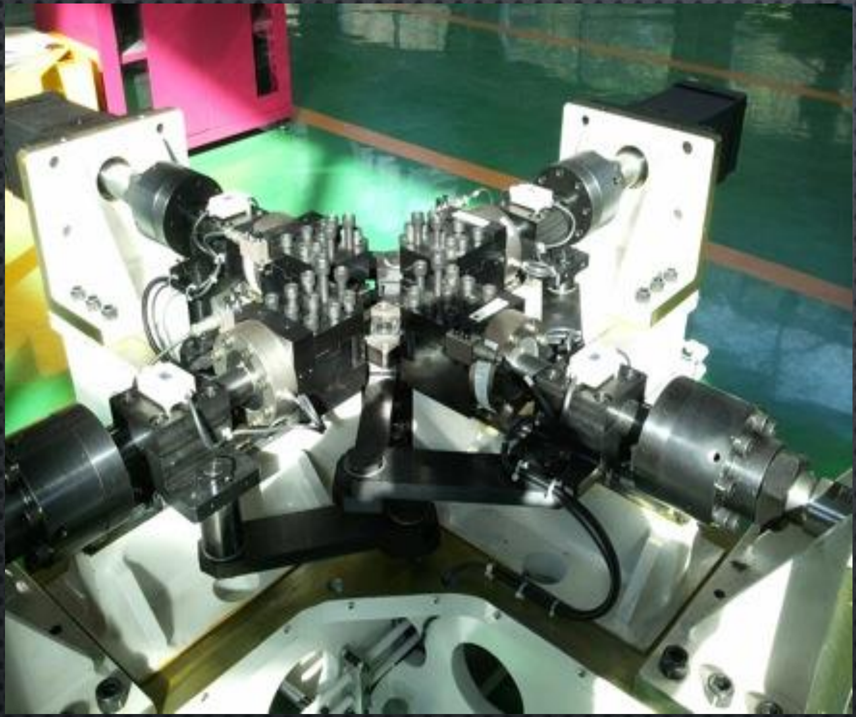
- Rubber
- Paper
- N-8092
- TS-9003
- MP-15



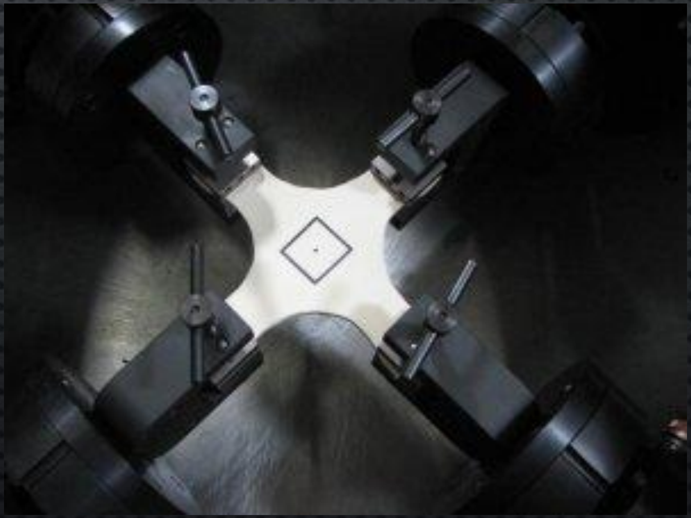
Existing Biaxial Machines

- Several Existing Commercially Available Machines
- Typical drawbacks include size, application, but the most important is price
- How ours is supposed to be different

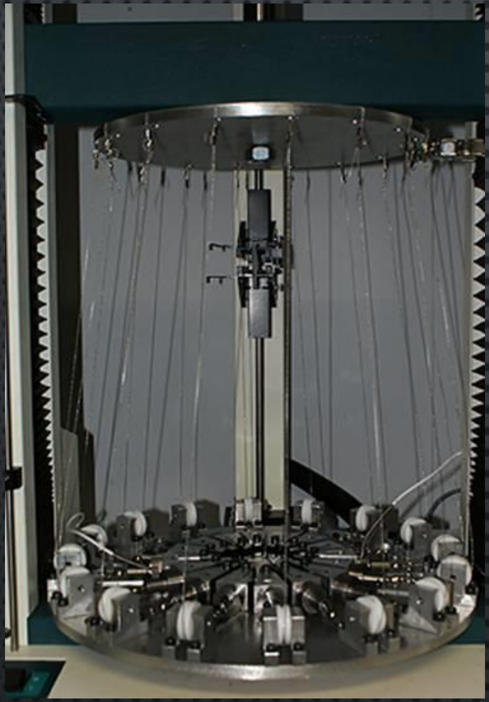
EXISTING BIAXIAL MACHINES(CONT.)



- Pulls along two axes
- Complexity
- Why this is undesirable for our material



EXISTING BIAXIAL MACHINES (CONT.)



- Size is important!
- Pulls Along 8 Axes (16 Pulleys)
- Better, but not good enough

- Similar to previous design
- Problem with loading
- Again, size is important

Ways of Applying and Measuring Force

- Two Options When Applying Force
  1. Self-Powered System
  2. Have System Driven By MTS Machine

Ways of Applying and Measuring Force (Cont.)

1. If Self-Driven
   - Must Use System to Measure Applied Force
     - Spring System
     - Load Cell
2. If Powered By MTS Machine
   - Load Cell Built In
   - Only Needs to be Calibrated

Grips

- Requirements
  - Deform the sample as little as possible
    - More likely to tear at grips
  - Hold through full range of stretch
  - Maintain planar orientation
    - No bending or shear
  - Be as small as possible
    - Maximizes number of grips
    - Makes smaller samples possible
  - Strong enough to endure forces without fatiguing

Grips (cont.)

- Current Design Parameters
  - Maintaining planar orientation
    - Cable and grip in same horizontal plane
    - Attach to base to prevent twisting
  - Fatigue prevention
    - Design to endure force greater than force at which cable would snap

Grips (cont.)

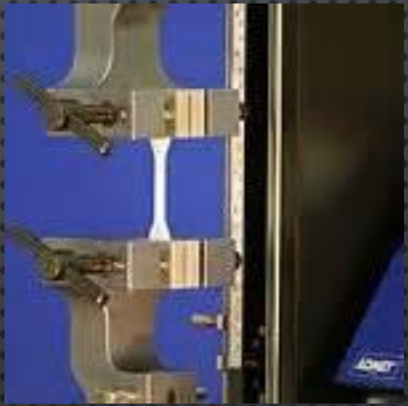
- Attachment Possibilities
  - Surface of Pads
    - Tacky Surface
    - Horizontal Ridges
    - Spikes
  - Tensioning Methods
    - Spring
    - Bolts or Screws
  - Non-Contact with Surface
    - Adhere material to the sample
    - Have grips push against material

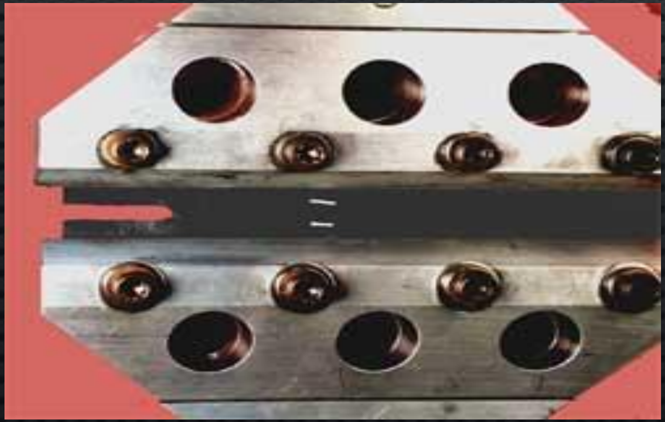
Finite Element Analysis (FEA) Models

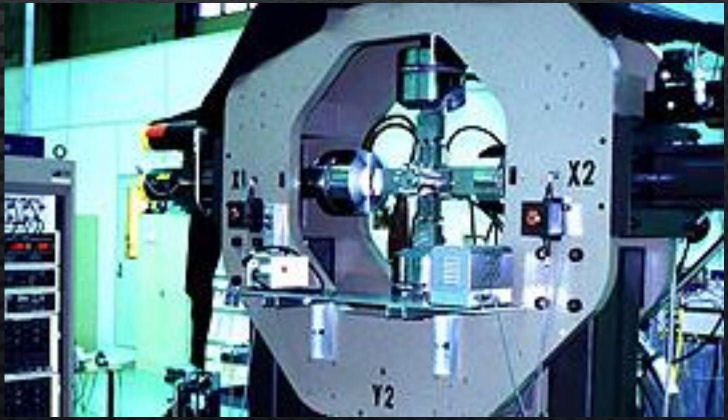
- Neo-Hookean
- Mooney-Rivlin
- Ogden
- Yeoh
- Many Others
- Stress-Strain Curves
- Best Model Depends on Material Properties

FEA (Cont.)

- Required Test Data
  - Simple Tensile
  - Planar Tension
  - Biaxial Planar Tension

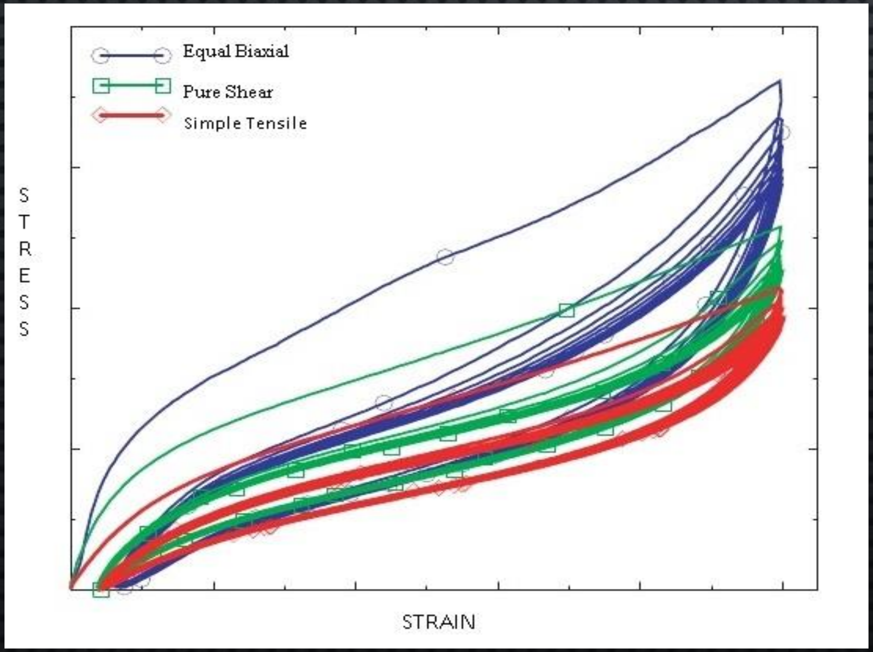


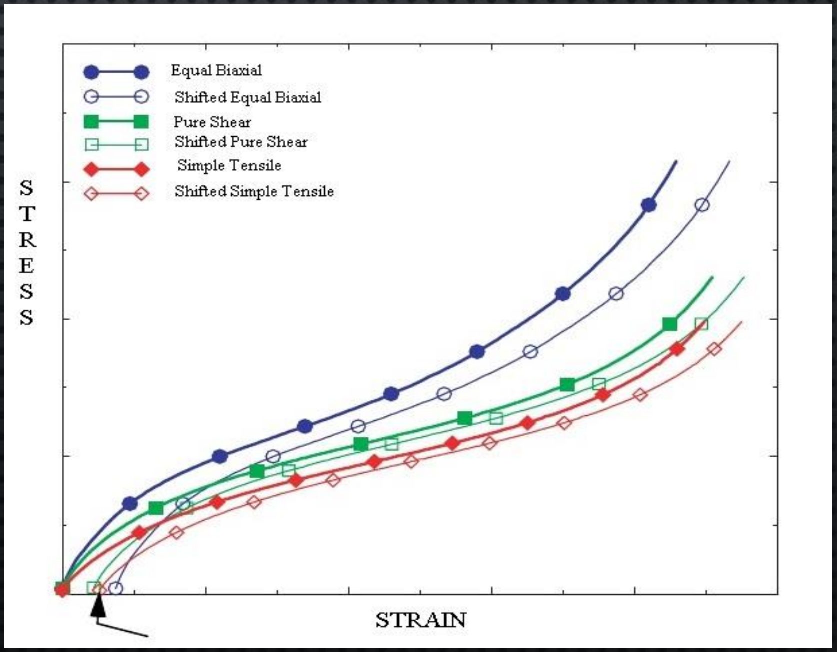




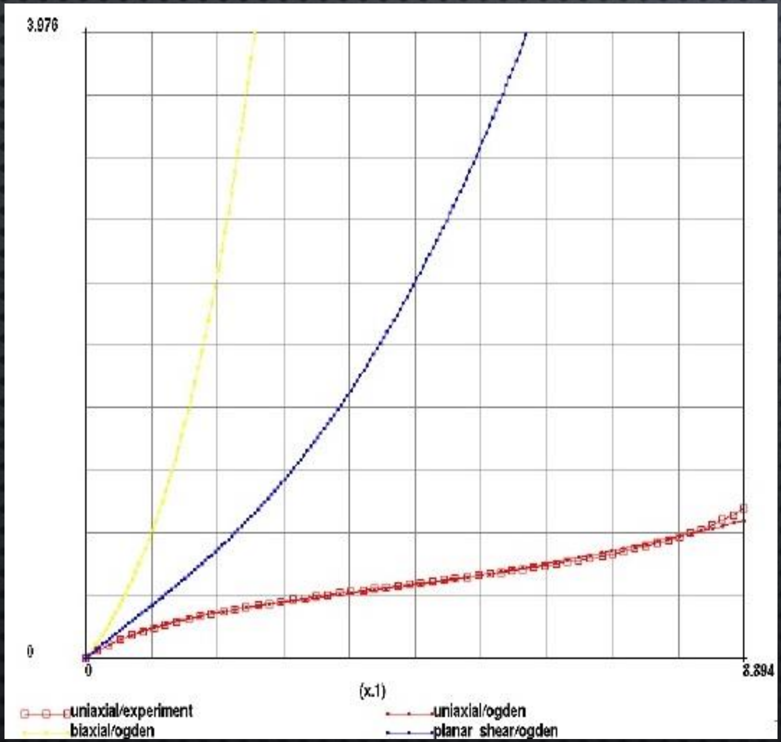
FEA (CONT.) GETTING USEFUL DATA AND SELECTING A MODEL

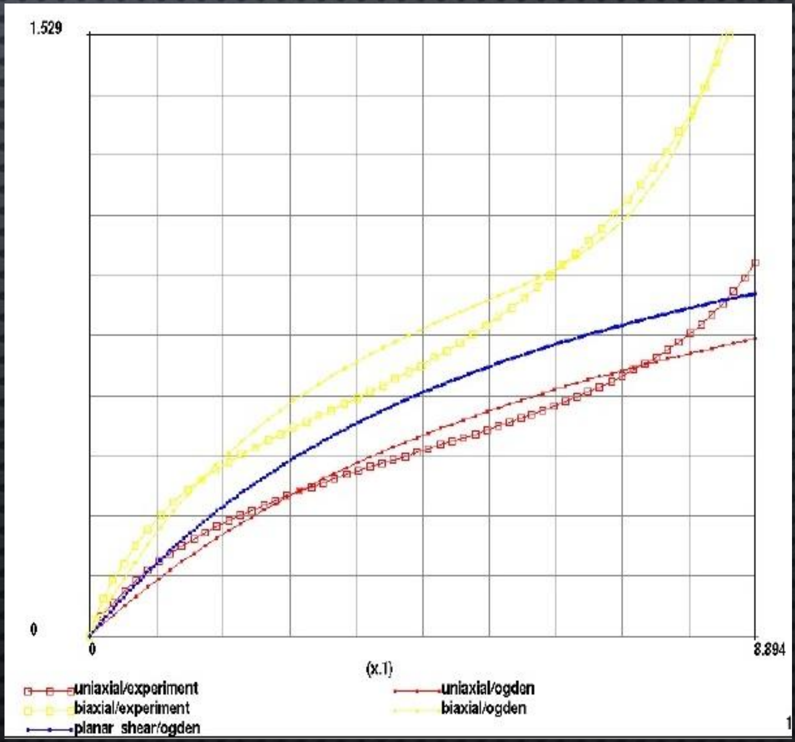
- Perform all three tests at same rate of strain
- Eliminate excess data points
- Run several models and select one that best predicts behavior



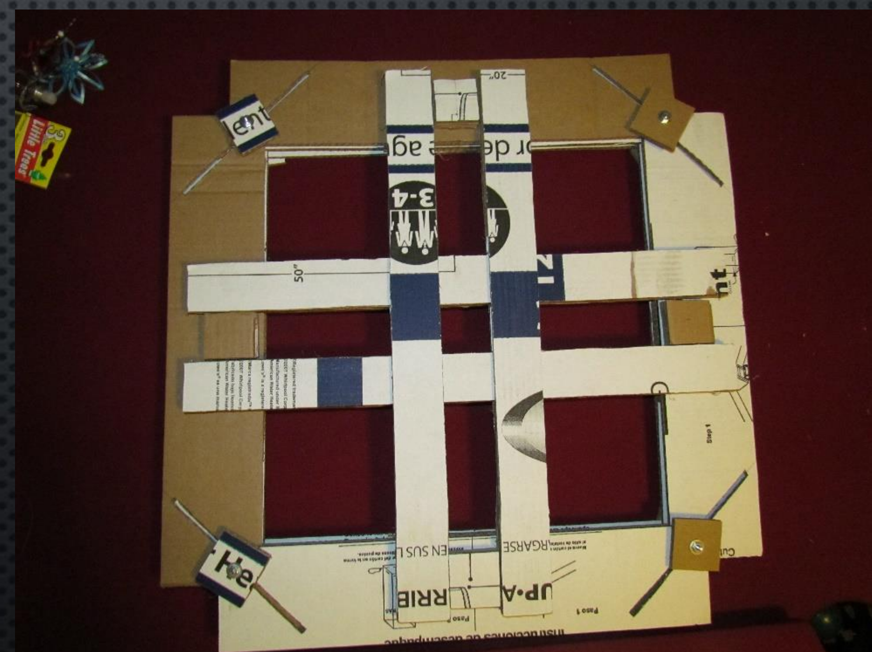


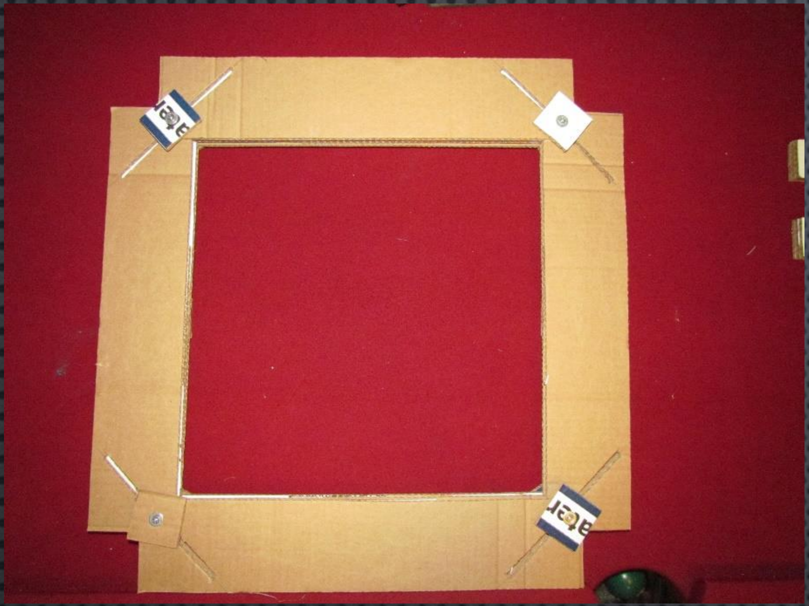
FEA (CONT.) FINAL RESULTS

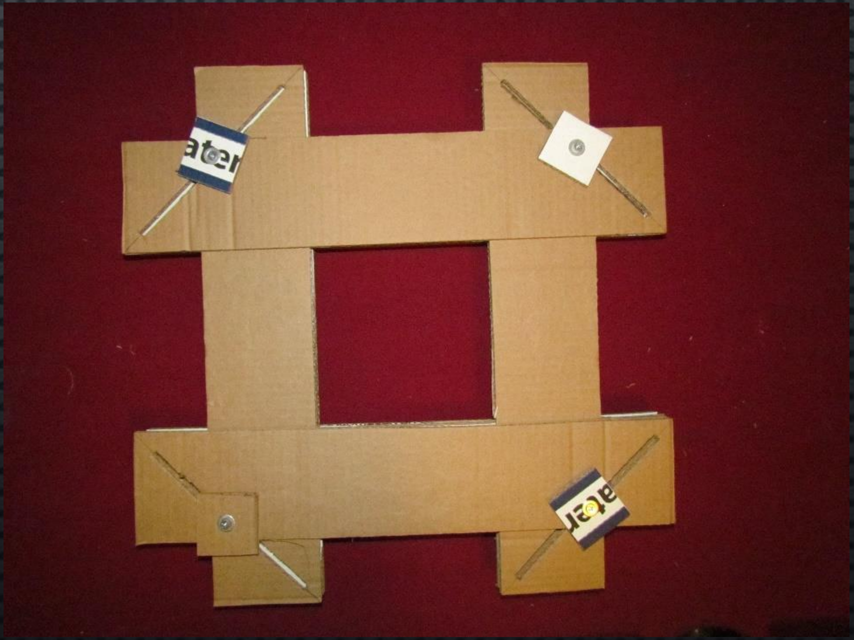




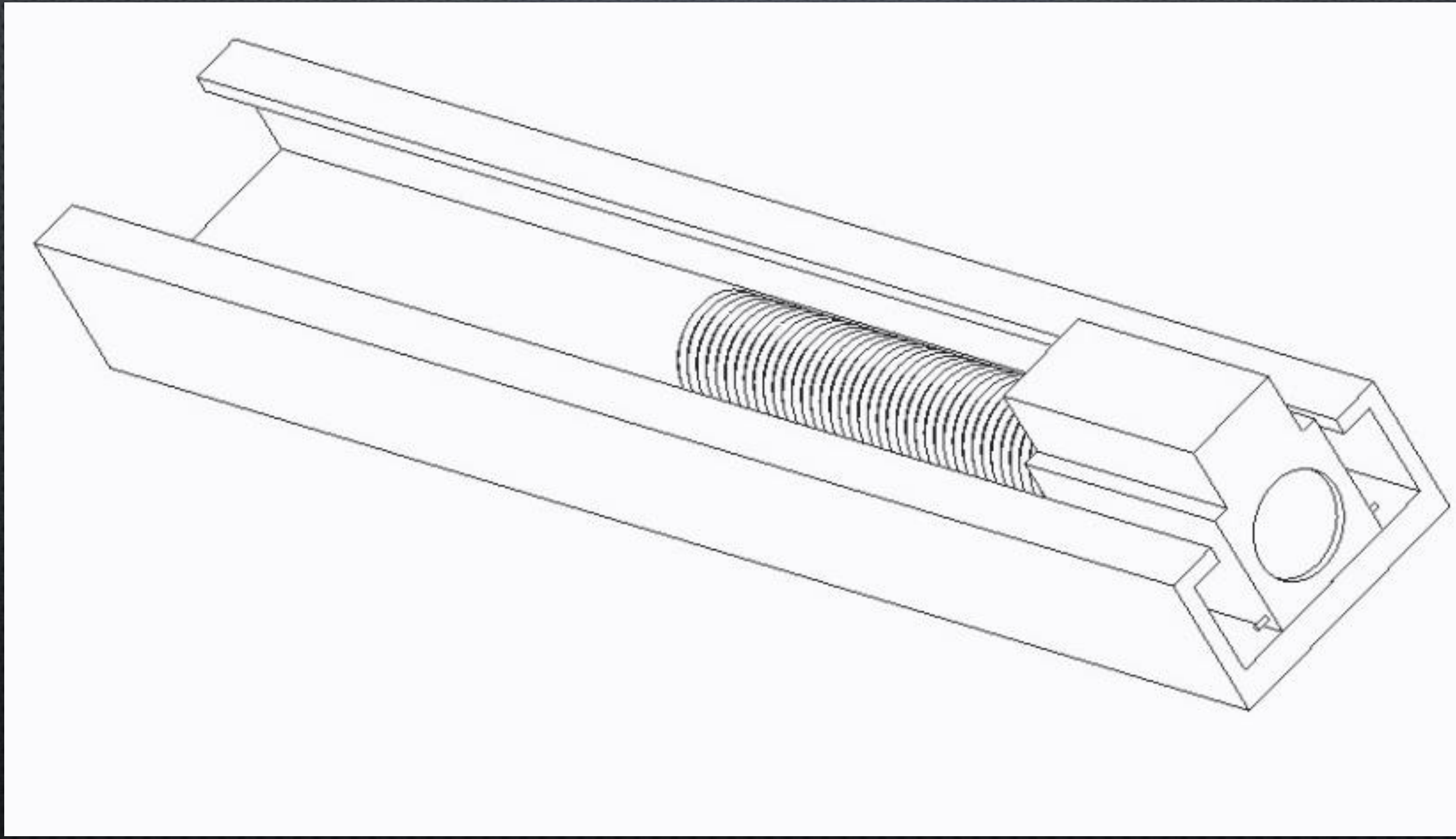
VERY PREMATURE PROTOTYPE (FOR FUN)







CHANNEL FOR GRIPS TO SLIDE



Conclusion

- We still have a lot of work to do in design due to extensive background research
- Design will include multiple axes
- Different data acquisition techniques will be considered in design of our system

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.*
4. ALI, A., HOSSEINI, M. AND SAHARI, B.B. (APRIL 2010), A REVIEW AND COMPARISON ON SOME RUBBERY ELASTICITY MODELS.
5. MSC.SOFTWARE CORPORATION (2003), EXPERIMENTAL ELASTOMER ANALYSIS, PART NUMBER: MA*2003*Z*Z*ZSM-MA103-MT1