A Preliminary Examination of an Articulating Ankle Prosthesis

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Overview

- The LEGS project
- Restrictions
- Modeling the ankle
- Proposed Solutions
  - Torsion Bar
  - Torsion Spring
- Further research and experimentation

Current LeTourneau Design

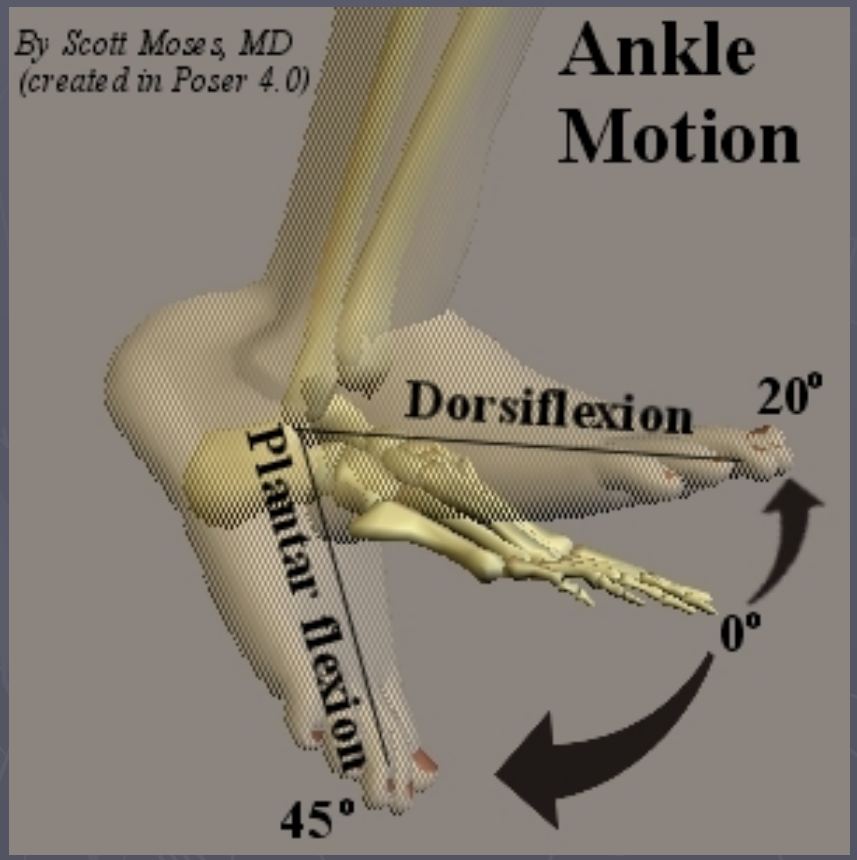
- Knee is mimicked by a 4-bar linkage.
- All of the materials are easily accessible; they are machinable, and affordable. (prosthesis mainly consisting of aluminum).
- The shin and foot are both rigid, and fixed at a 90 degree angle.
- By adding an articulating ankle the gait of patients would more closely mimic the normal gait patterns.

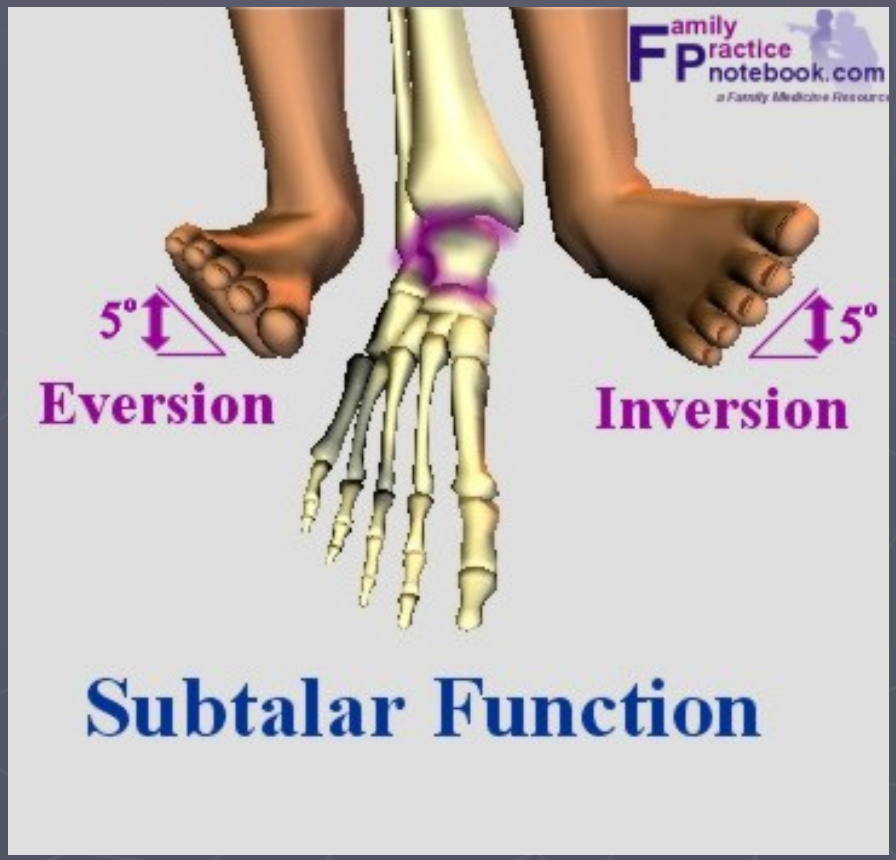
Restrictions

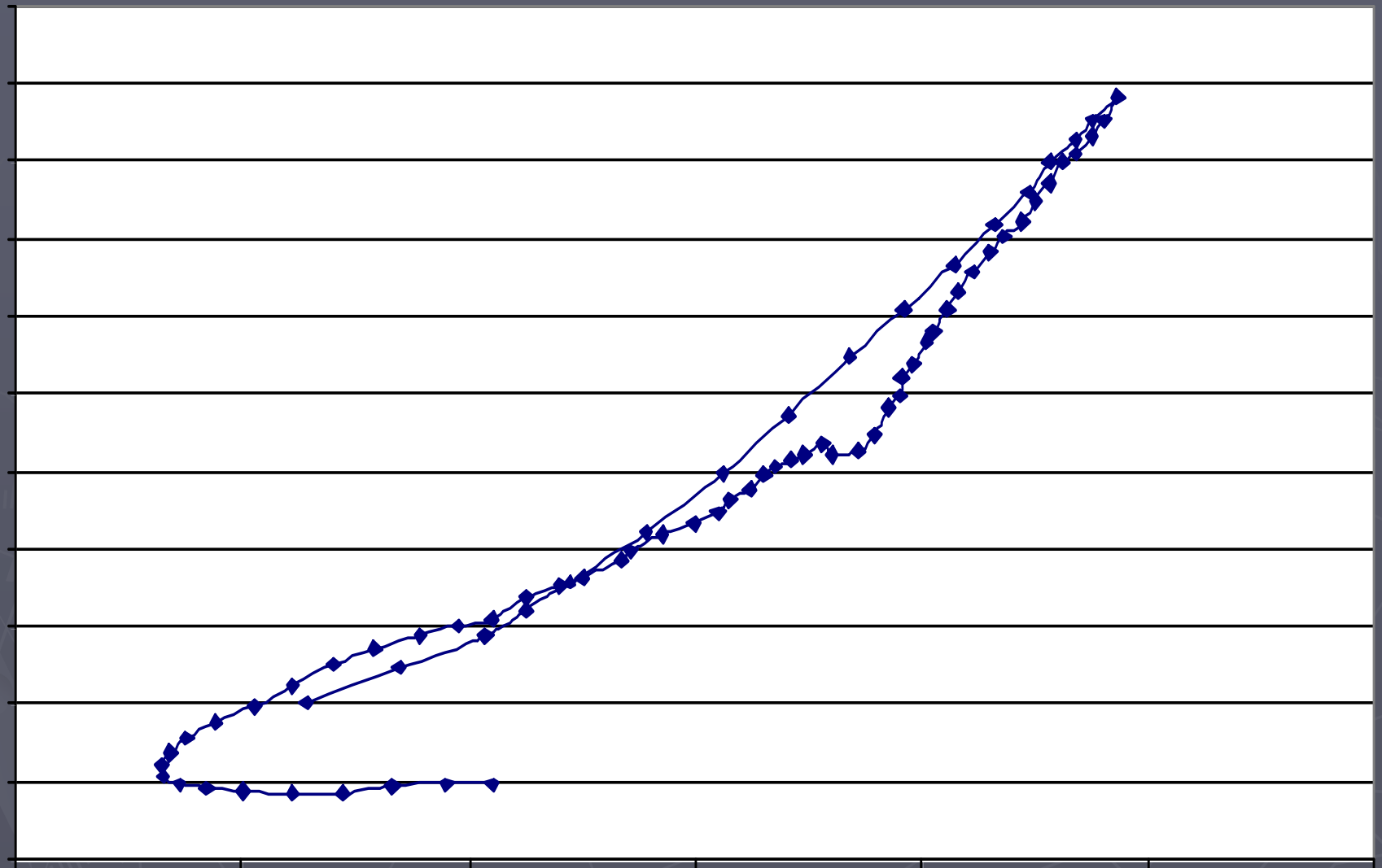
- The highest demand for lower limb prostheses are in areas that walking is essential to daily life.
- These places are generally within poor countries that are without means and technology.
- The proposed ankle must follow material and manufacturability constraints, while still promoting proper gait.
  - Material cost and availability.
  - Durability and maintainability.

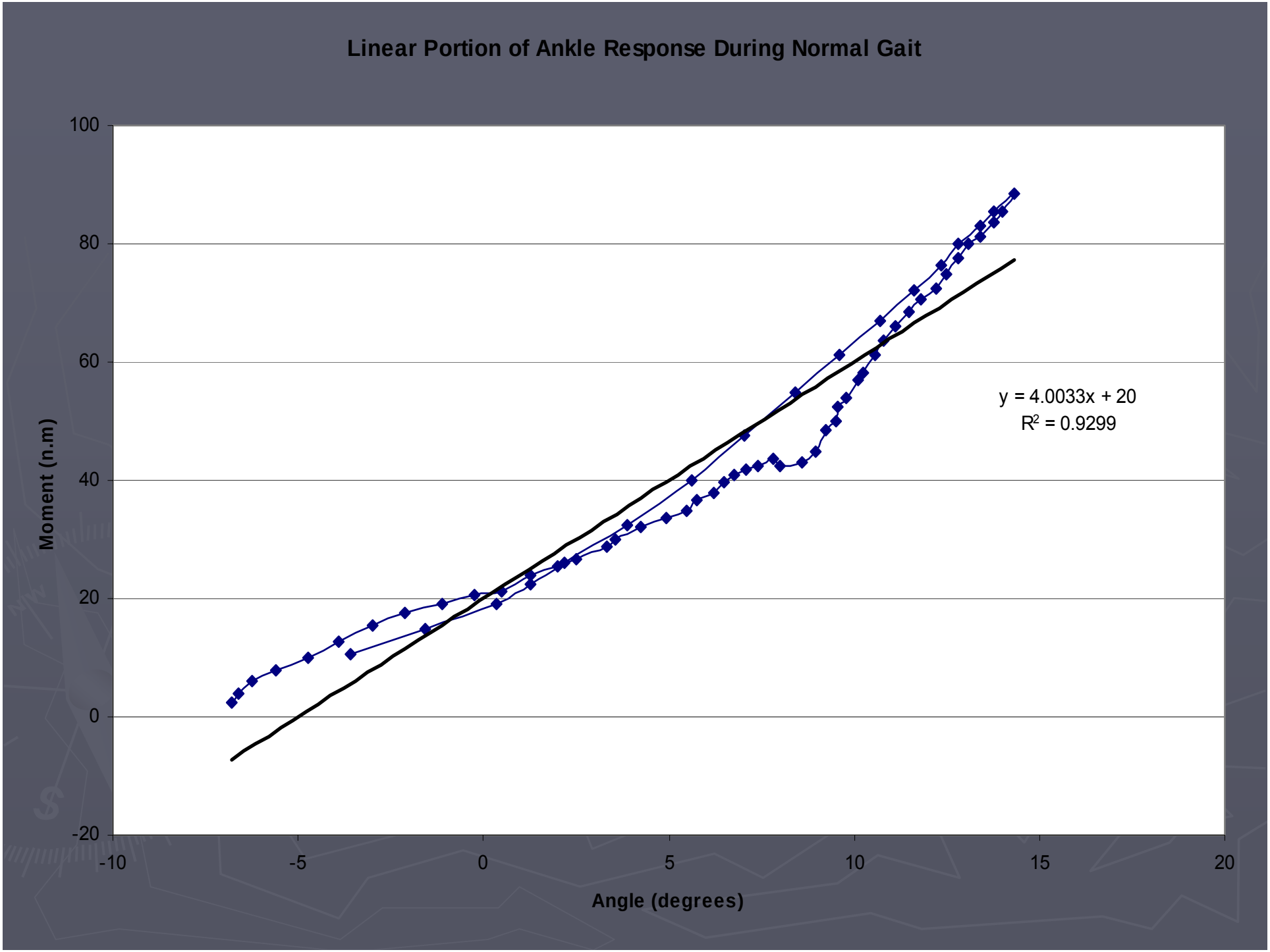
Modeling the Ankle

Simplification of Ankle Motion





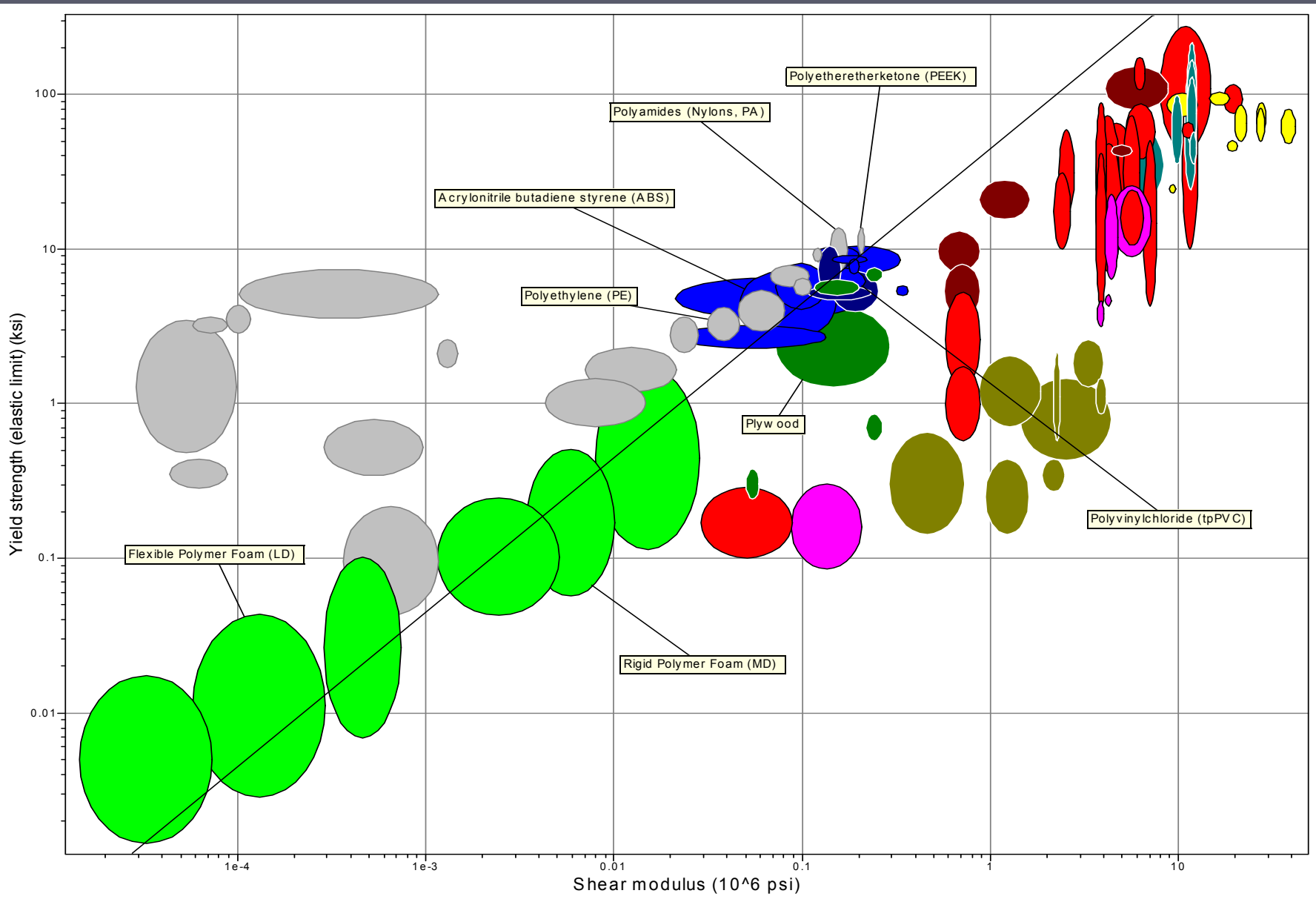



Linear Portion of Ankle Response During Normal Gait
100
80
60
40
20
0
-20
Moment (n.m)
-10
-5
0
5
10
15
20
Angle (degrees)
y = 4.0033x + 20
R2 = 0.9299

A Torsion Bar or Spring Ankle?

- A torsion bar uses the properties of the material to react against torsion and provide spring action.
  - Torsion Bar Specifications
    - Total length < 3.5 inches
    - Diameter < 0.5 inches
    - S.F. = 1.5
    - Ratio of G/Sy = 25.5 (pa/pa) to model the linear characteristics of the ankle response.

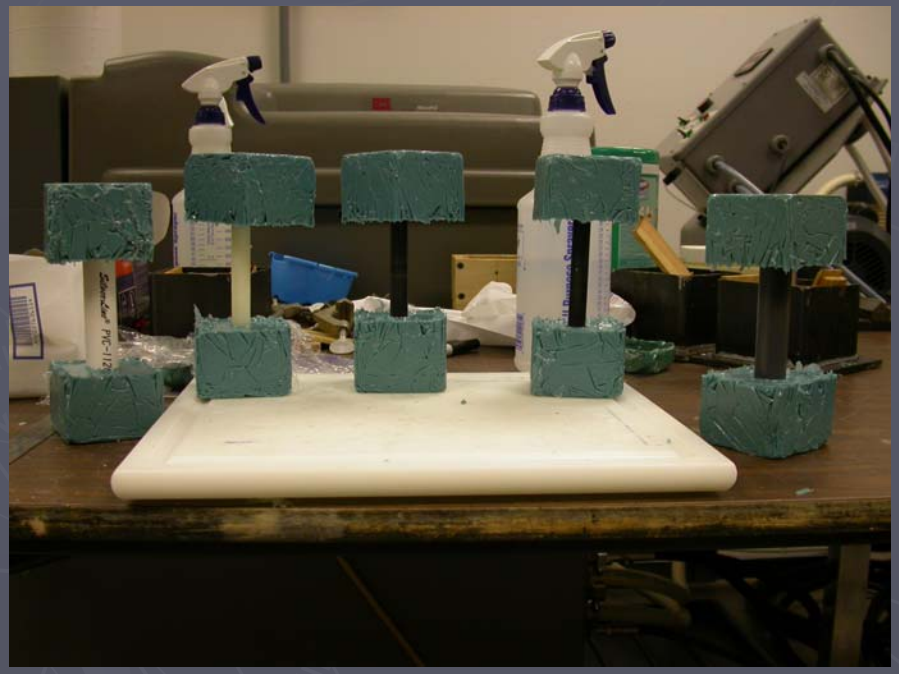
Materials Selection



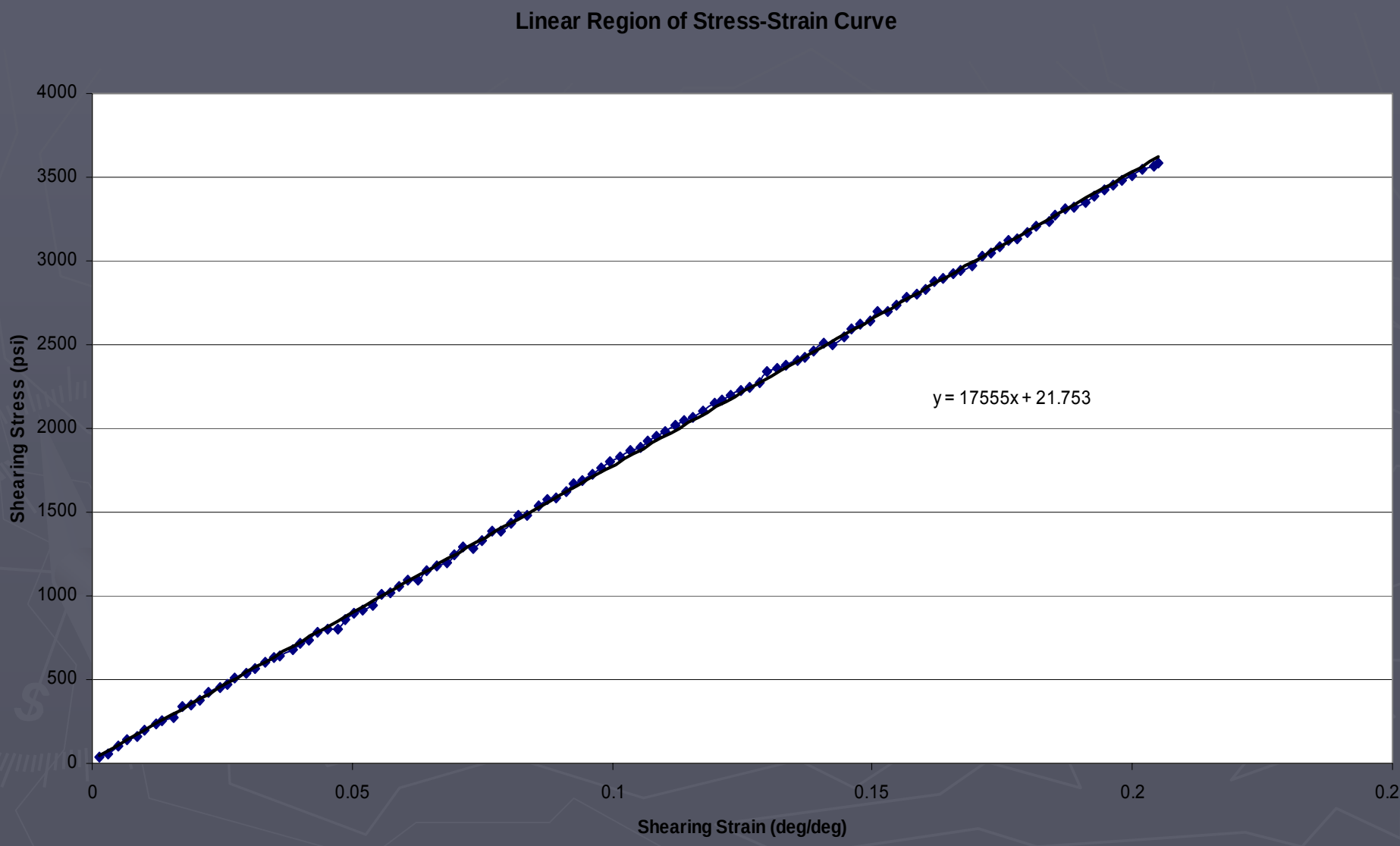
Testing of the Torsion Bar Specimens

Potting, Torsion Tests, and Fatigue

Potting, Torsion Tests, and Fatigue



Results: Finding Ratio of G/Sy

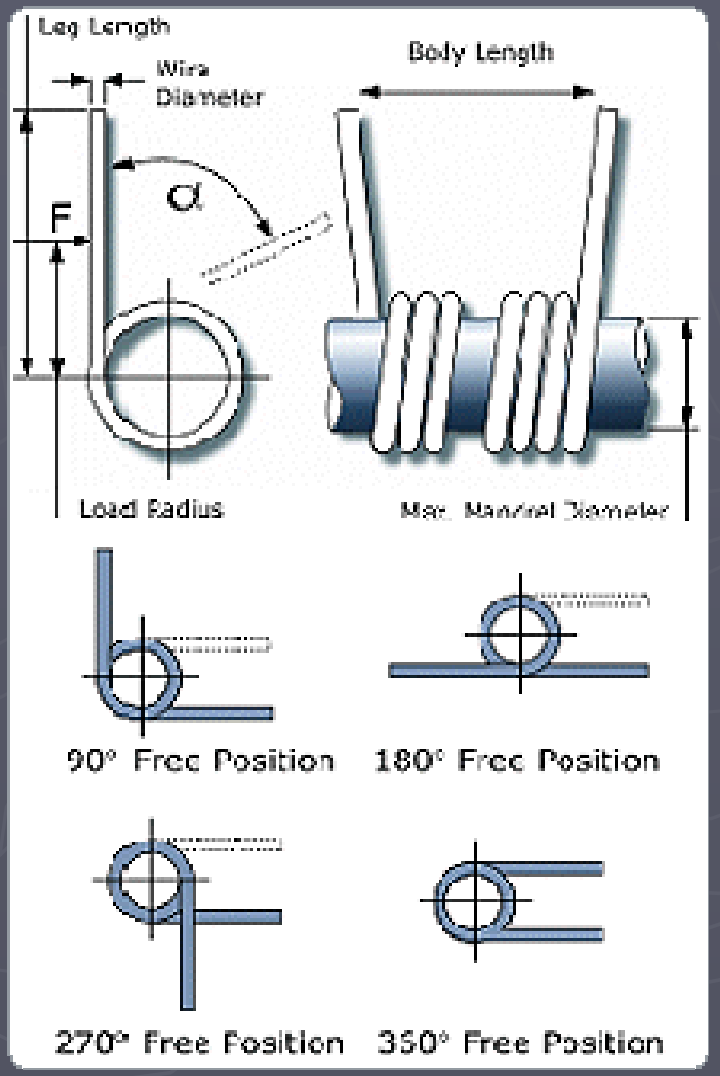


Fatigue Testing

- ABS Fatigue Test
  - Initial test at 0.5 Hz to simulate actual speed of gait. (300 cycles)
  - Secondary test for long-term fatigue analysis: 2 Hz; 20,201 cycles. The fatigue caused a shear failure along the potting interface.
- PVC Fatigue Test
  - 2 Hz; 2 cycles per second
  - 12,100 cycles, representing 12,100 steps taken on that leg.
  - The stabilizing screw wore away at the dynacast, so the PVC torsion bar was not being fatigued at the correct specifications.

Torsion Spring Option

- Large deflection relative to the reactions of a normal walking gait
- Not readily available:
  - After talking to various companies, a custom spring was the only option.



Equation Attempt

- Conditions:
  - Used the moment and deflection needed to duplicate a normal walking gait
  - Calculated the $\frac{M}{\theta}$ for weights ranging from 30 to 120 kg
- Solving for wire diameter
  - Resulted in extremely small diameters
- Conclusion:
  - Determined that it was infeasible to continue with a torsion spring

Compression Spring Option

- Produced small deflections relative to the spring-size that is needed to withstand the weight of a person
- More accessible:
  - More options of compression springs
  - Already in mass production

Finding the Right Spring

- Substitution Method
  - Attempted to take the properties of a compression spring and implement them into the torsion spring equations
  - Continued to produce extremely small diameters
- “Trial and Error” Method
  - Began examining possible compression springs

Examination Criteria

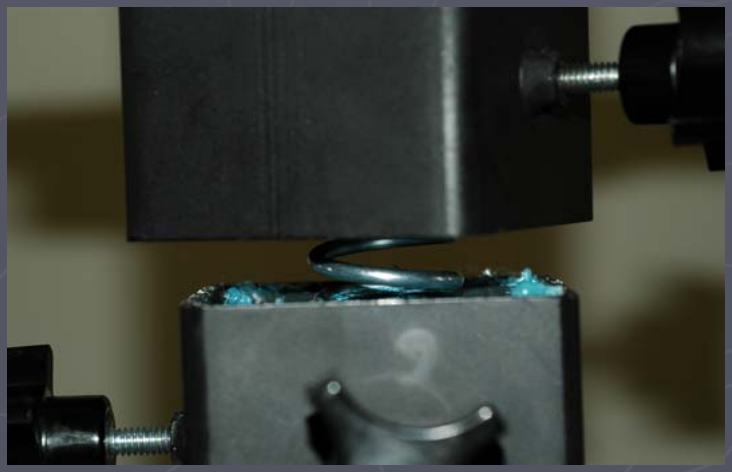
- Wire size
  - Found that the more coils, the more deflection
- Load range
  - The force necessary to compress solid
- Overall Length
- Spring Design
  - wanted closed and ground ends
- Wanted steel material, tempered?

Obstacles

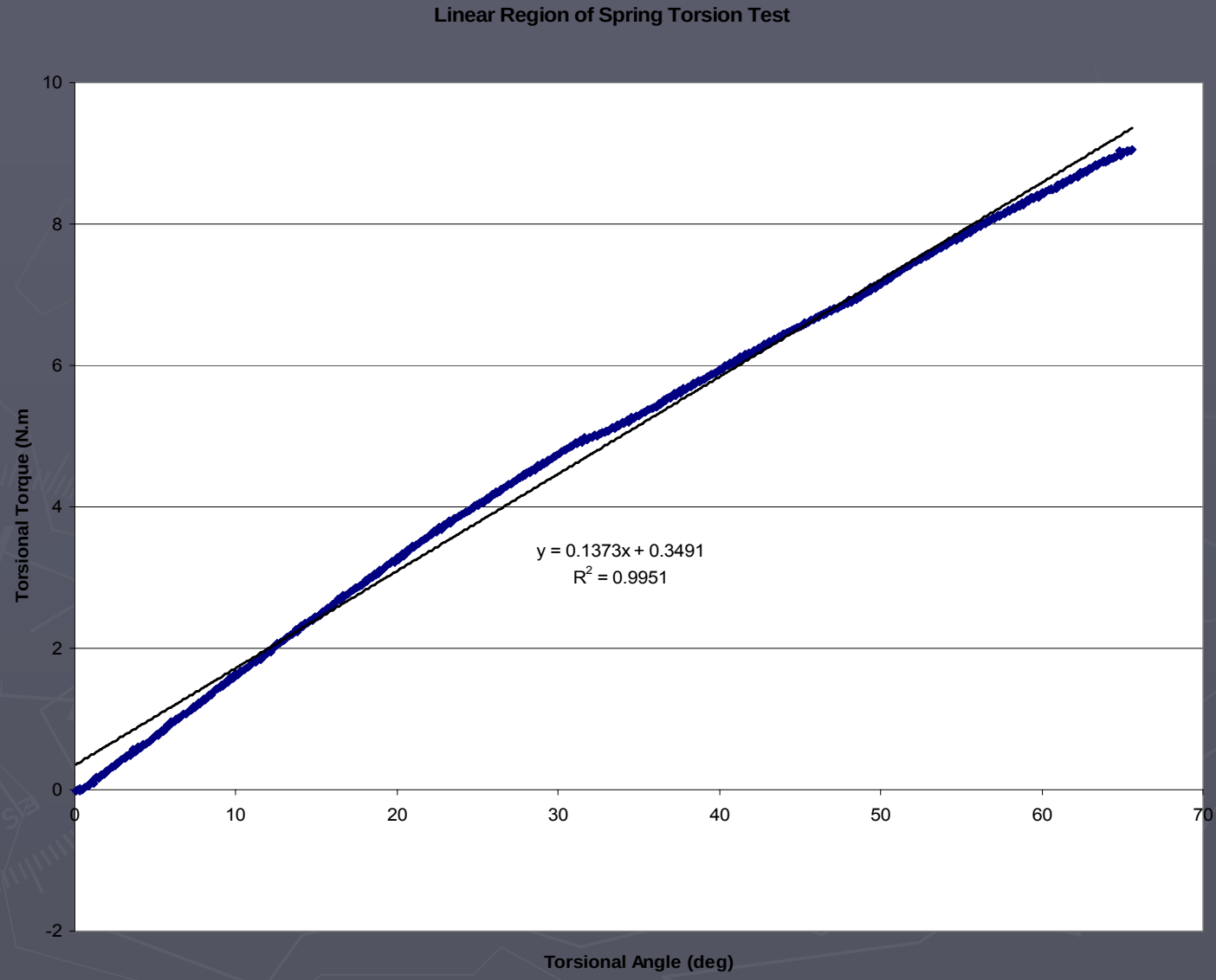
- Will the compression spring serve well in torsion?
- Is welding a possibility?
  - Exposure to heat can diminish or destroy the properties of the spring

Testing of the Spring

- Tested the spring in the MTS machine
- Deflected the spring at a rate of 1°/s till it reached 146.96°
- At 15° the torsional torque was 21.7 in-lbs



Torsion testing



Design

- “Dual-Shaft”
  - A stabilizing shaft placed in the center, while another shaft encloses the spring.
  - Allows for the spring to be completely enclosed to protect it from environmental factors
  - Easy manufacturability

Future Testing

- Weld Strength testing
  - “Shaft-spring” would be tested under an applied torsional force
- Fatigue testing
  - Load the individual compression spring under torsion
- Materials testing
  - Improvement of potting materials to be tested
  - Is there a better solution besides a torsion bar or torsion spring?

QUESTIONS?