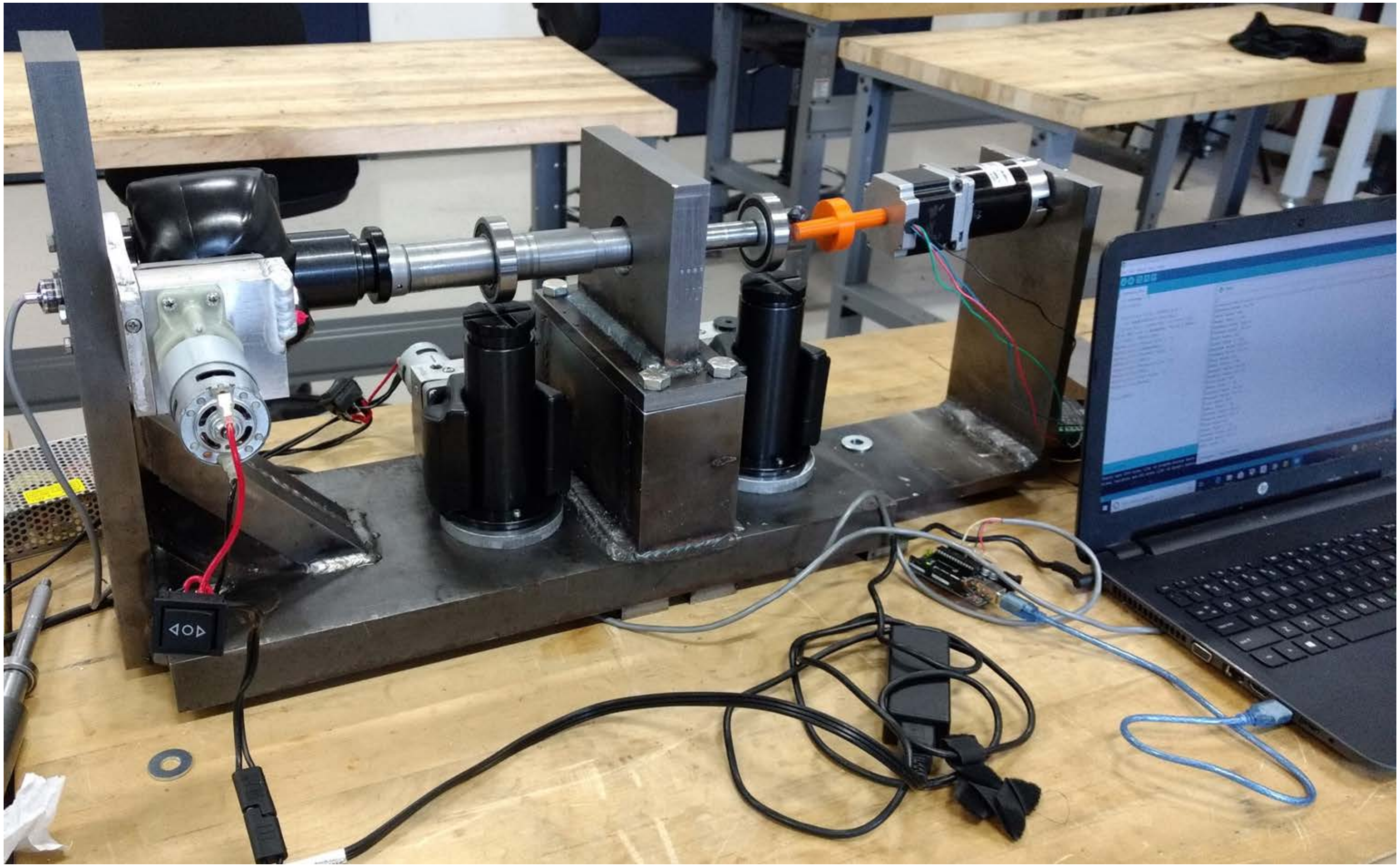
NAU Honeywell Bearing Project

Date: 4/25/2019

Subject of this Review



Problem

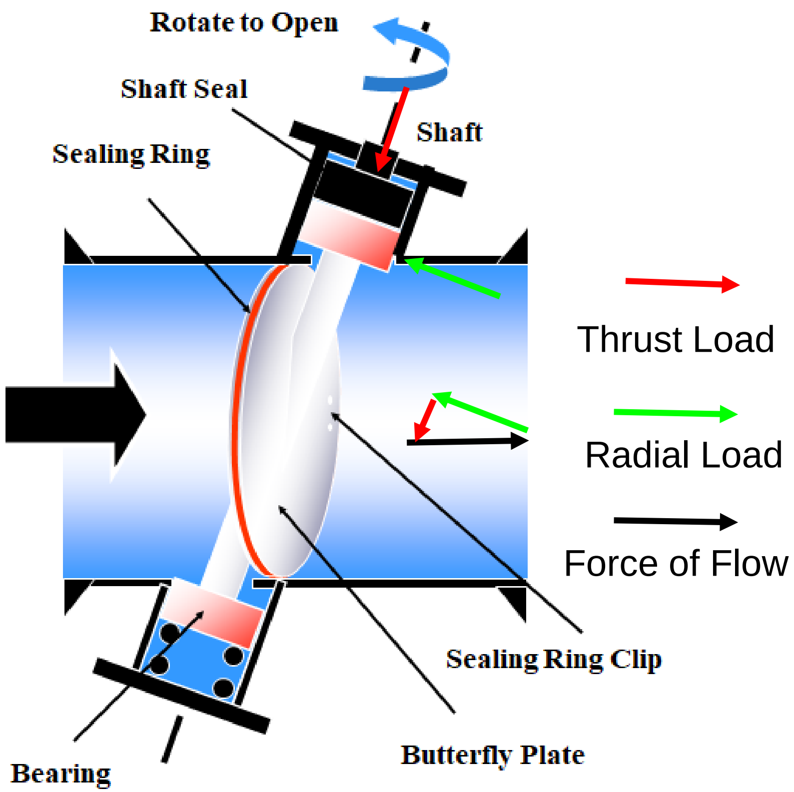


Figure 1: Butterfly Valve

Problem Statement: Honeywell requires a test fixture that will quantify the friction within bearings of various size in real time by simulating the conditions they are subjected to within butterfly valves. This system must be simple to use.

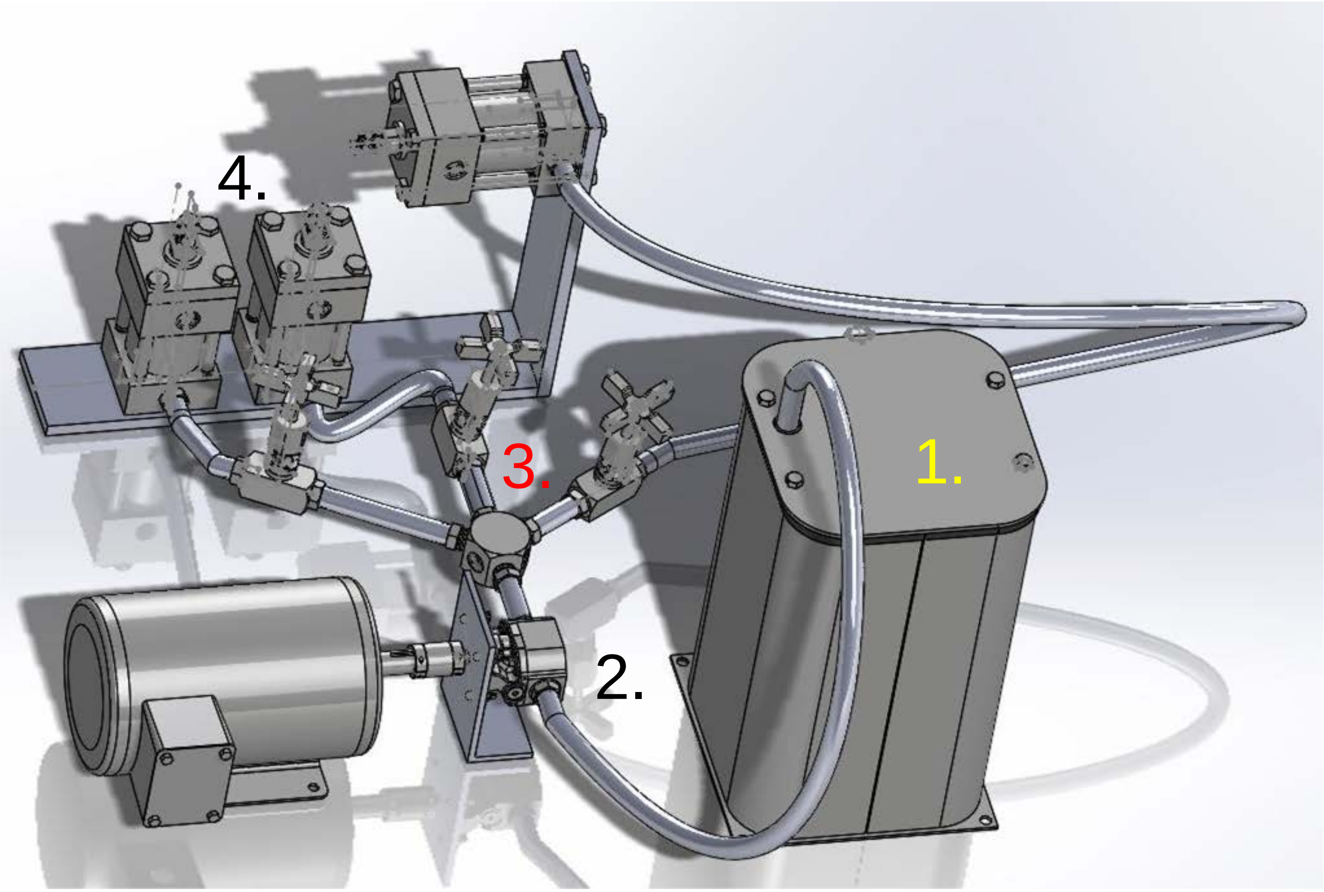
Design Requirements

- Impart a maximum radial load of 8,000 lbf
- Impart a maximum thrust load of 4,000 lbf
- Capable of testing bearings of the following sizes: R14, R12, R8, and 38
- Only powered by a standard wall socket
- Costs $1,500 or less
- Shaft rotates 90º at 10º/s or less
- Torque needed to rotate the shaft must be quantified
- Two people must be capable of moving the fixture
- Must plot friction vs. applied loads in real time
- Occupy a volume of 9 ft^3 or less

Slide Responsibility: Project

Design Configuration

Design Solution: First Iteration



Force Application

- Fully hydraulic system
- Highest quality solution
  - May have offered best controllability and accuracy of results
- Shaft spun via hydraulic rotary actuator
- Rejected in favor of less costly solution

Slide Responsibility: Project

Design requirements, TRL, requirements flowdown

Design Solution: First Iteration

Honeywell

Pneumatic Systems Engineering

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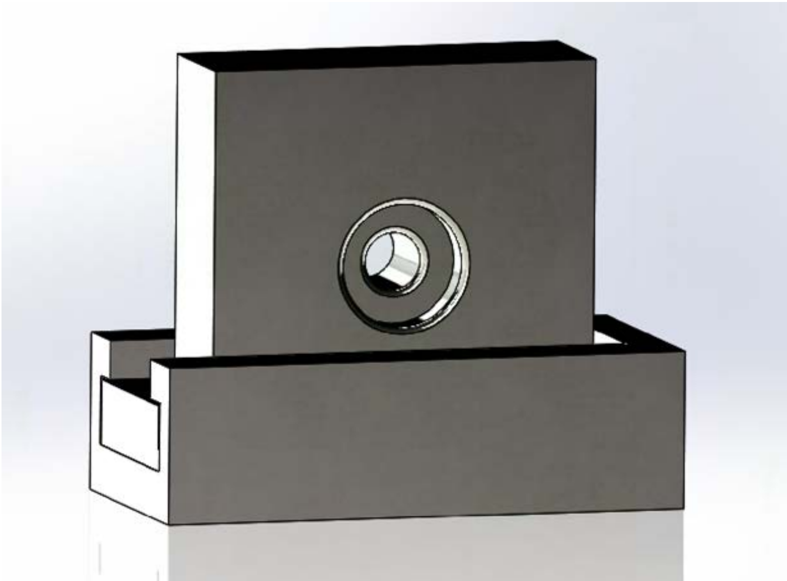

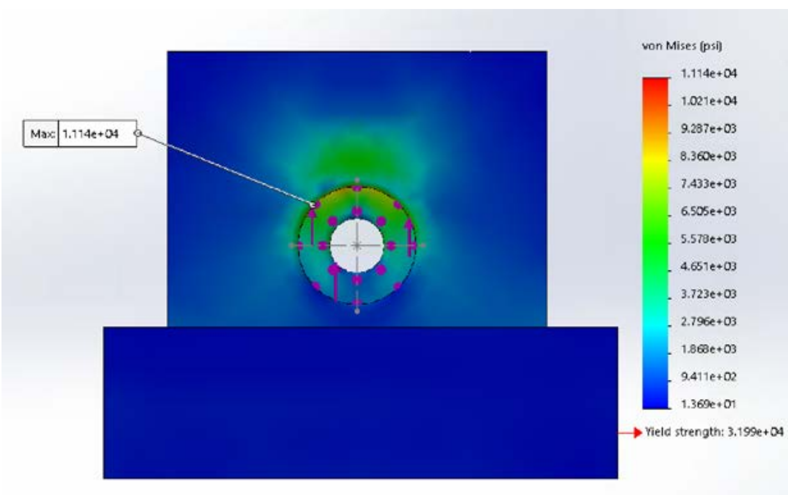

Frame Design

- Housing contains appropriately sized bearing
- Housings are changed by sliding in and out of the frame
- Design shown did not yield under simulation
- Rejected due to the high cost of steel stock required and lack of machinability

Force Measurement

- Load Cells
- Strain Gages
- Pressure Transducer
- Arduino

Slide Responsibility: Stress

Stress analysis summary, mini-report number

Design Solution: Final Iteration

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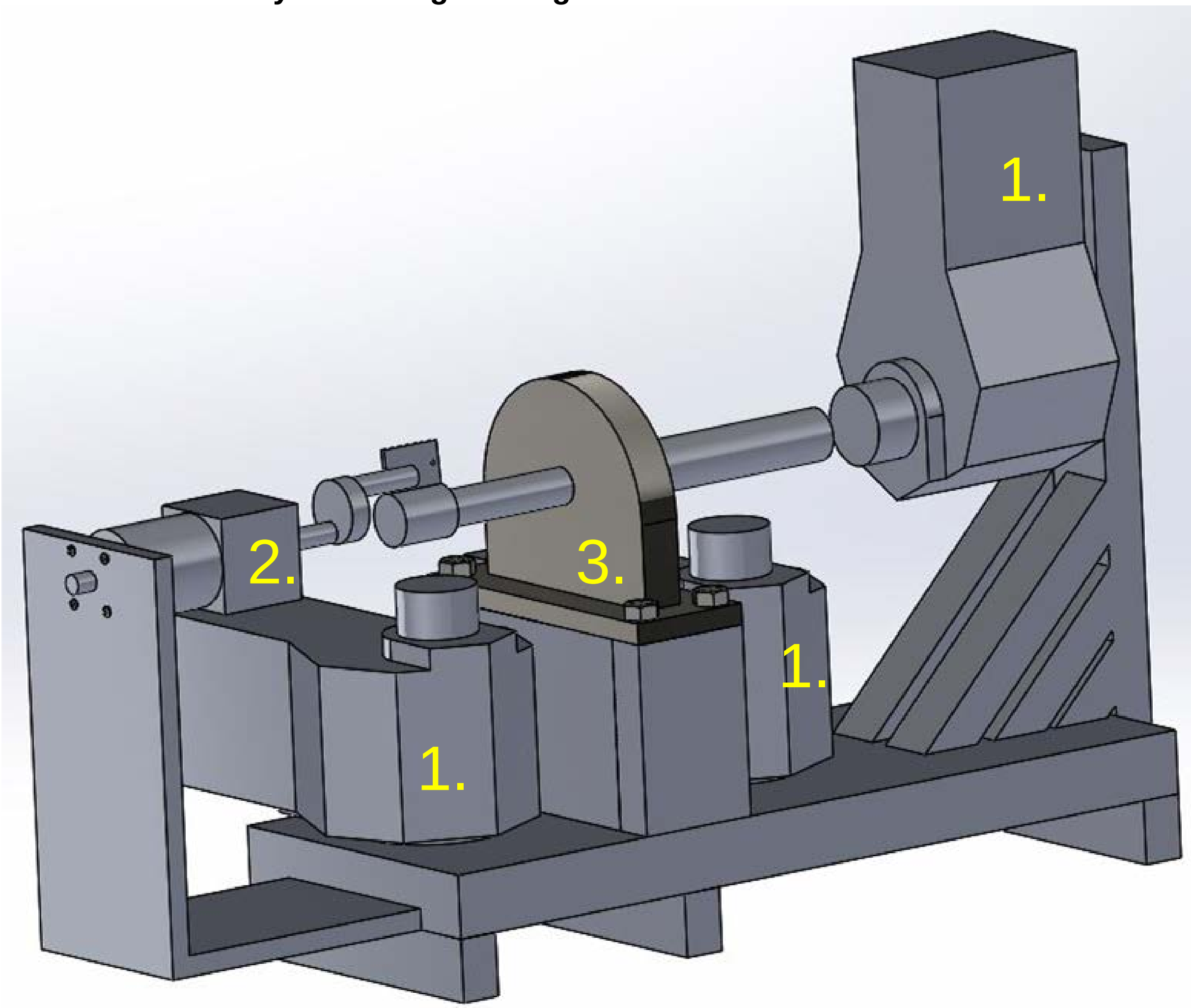


Force Application

- Hydraulic car jacks used (1)
- Shaft is spun via a stepper motor and crank (2)

Bearing Housing

- Bolted in and out of stand (3)

Shaft Design

- 4 for each bearing size
- All mount R14 load bearings

Force Measurement

- Jacks tapped, pressure transducers mounted
- Torque found with an equation

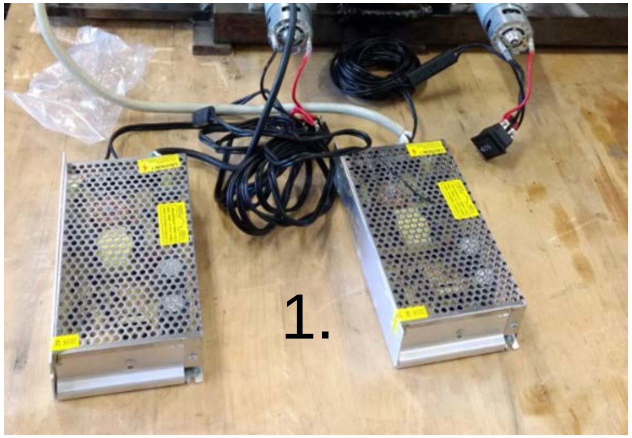
Design Solution: Assembly and User Considerations (HUE)

- Limit rotational speed
- Hydraulic fluid is incompressible
  - Will not explode if jacks are over-pressurized
- Bearing is deep within a steel housing
  - If the bearing fails, fragments will be contained
- Simple instructions will be provided with the design

Slide Responsibility: Design

Layout views or DR and doc number reference

- The electronics that will be used for this project will all be powered by a traditional 110V-120V wall outlet
  - 120V AC to 12V DC power converters (1) will be needed to run the motor and jacks as both use DC power



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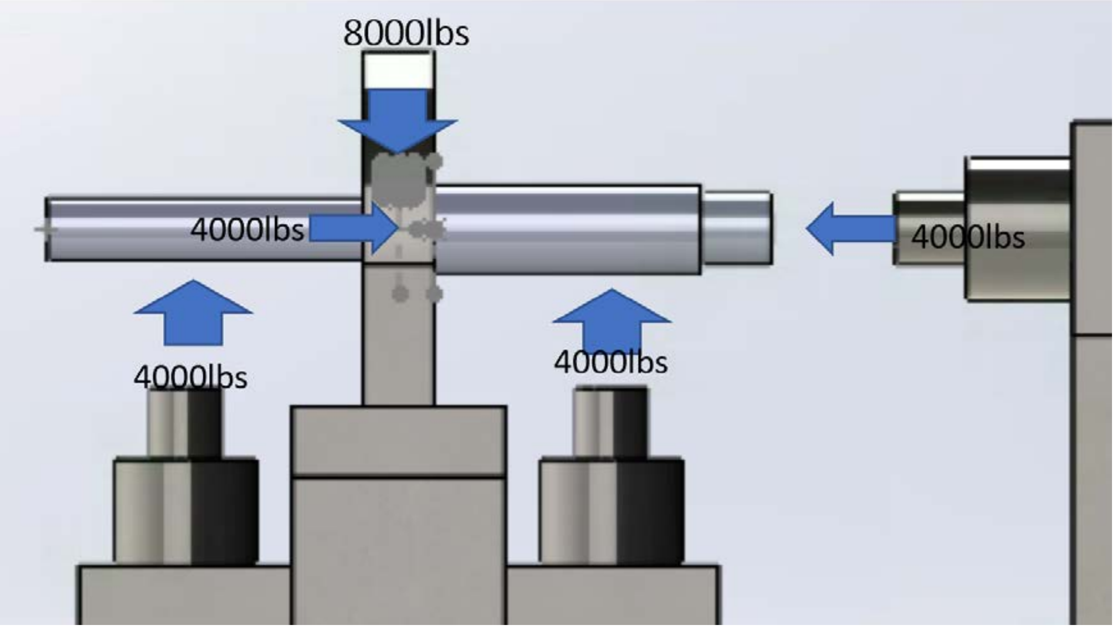
Slide Responsibility: Project

Analyses

Stress Analysis

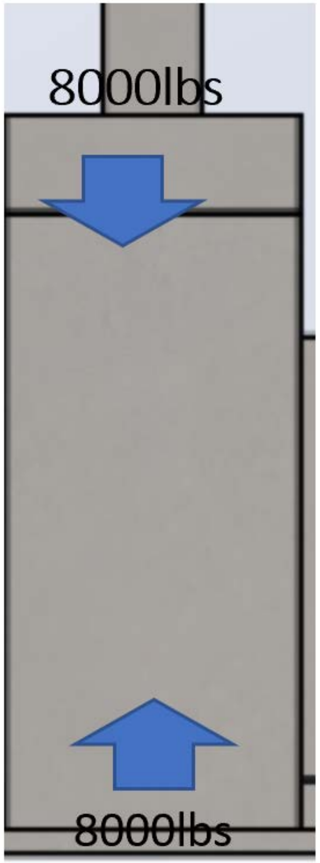
- Max Radial load of 8000 lbs
- Max Axial load of 4000 lbs
- Interchangeable
- Solidworks

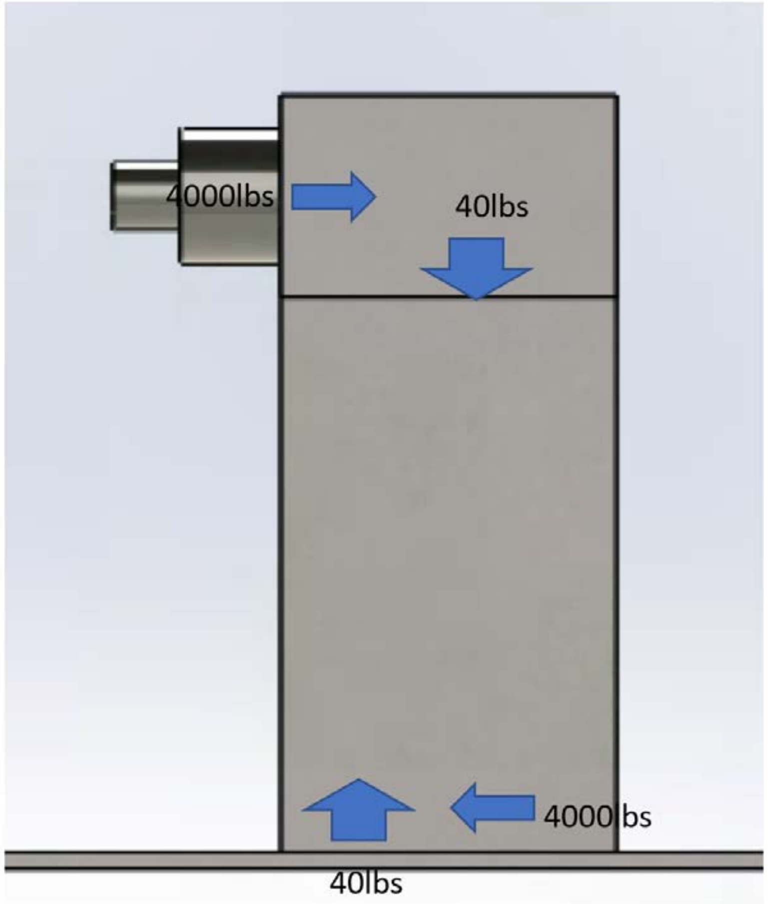


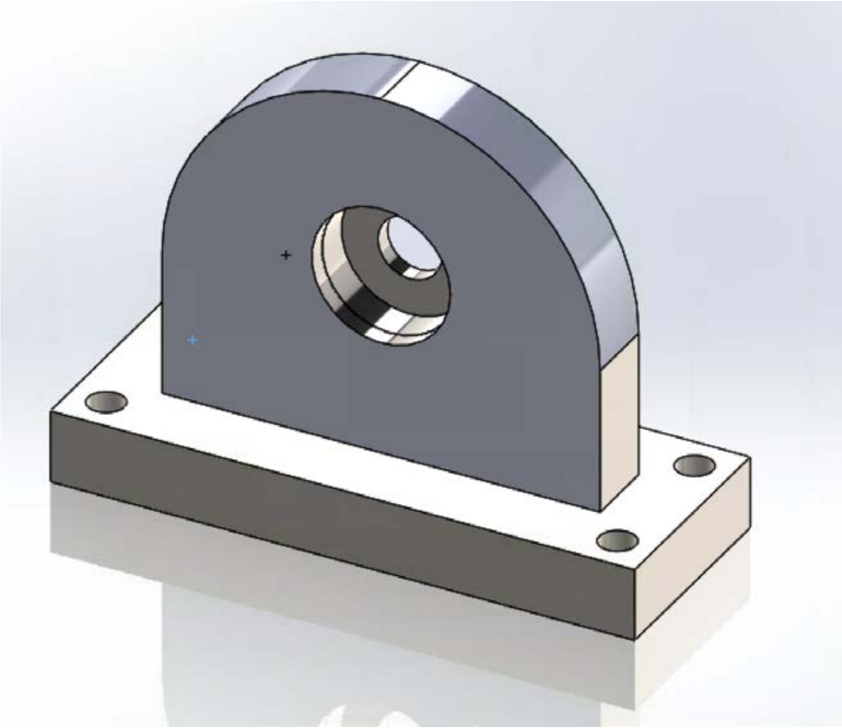
Slide Responsibility: Stress

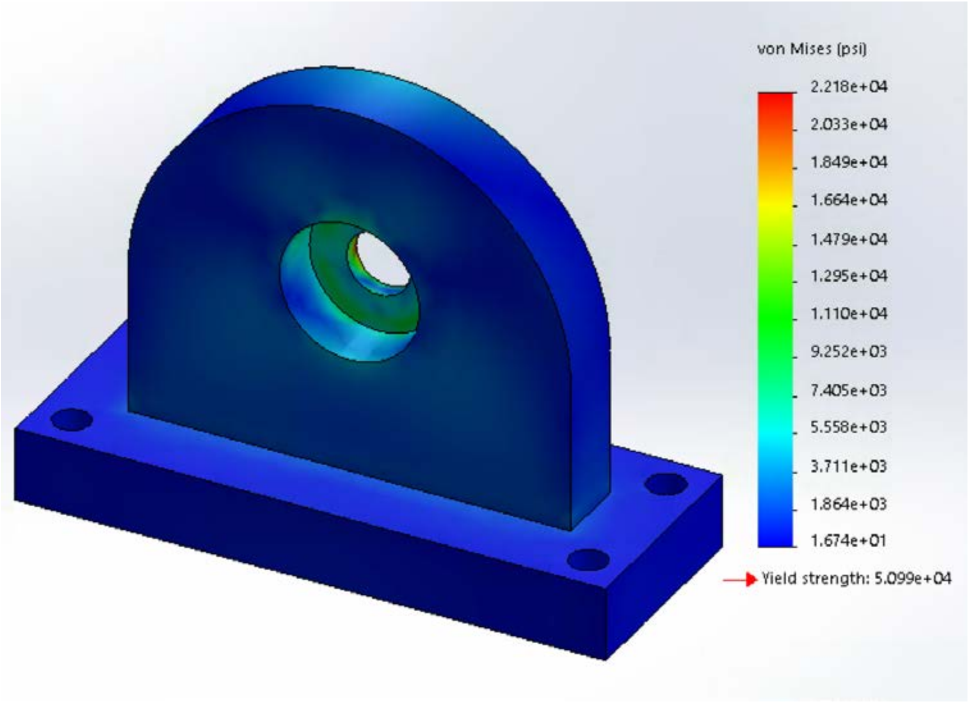
Stress analysis summary, mini-report number

Force Diagram



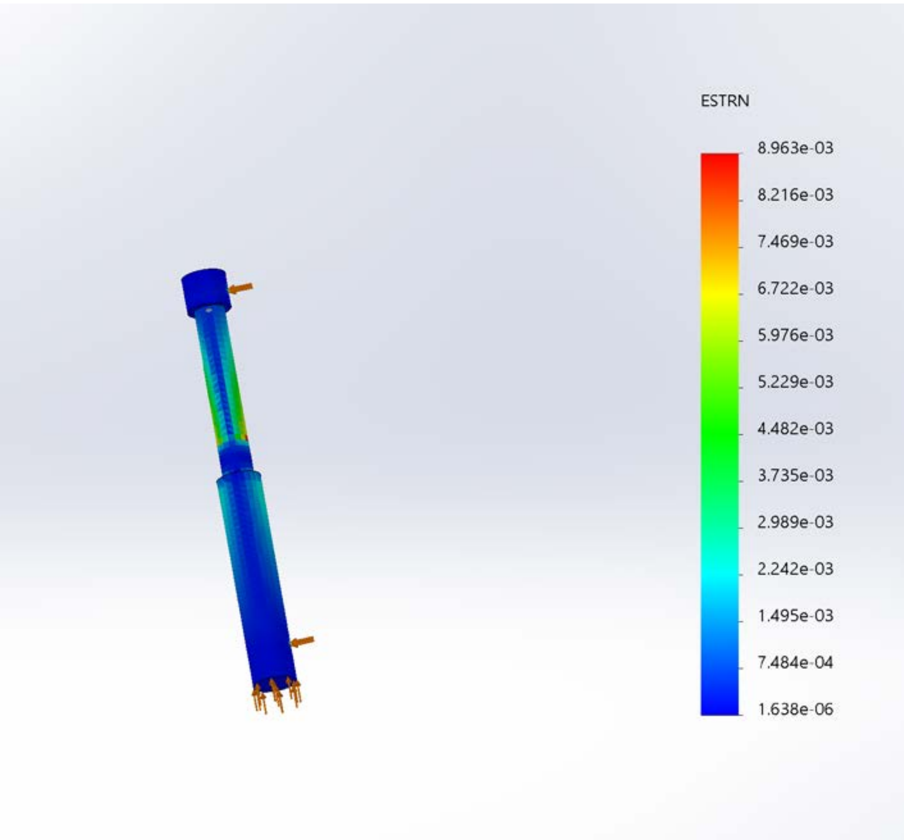


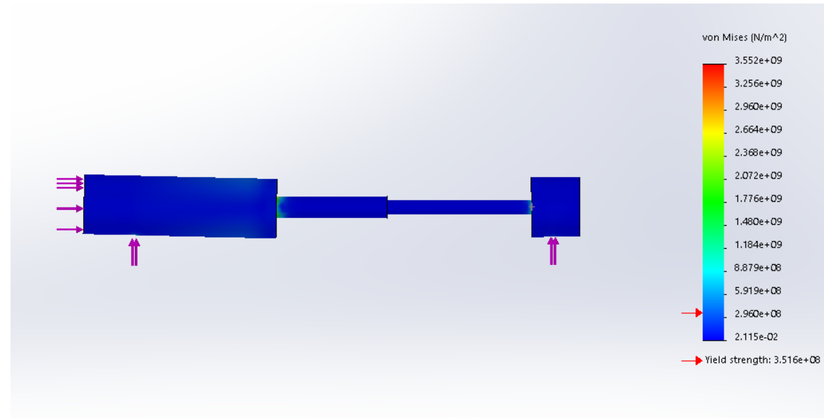




Slide Responsibility: Stress

Stress analysis summary, mini-report number



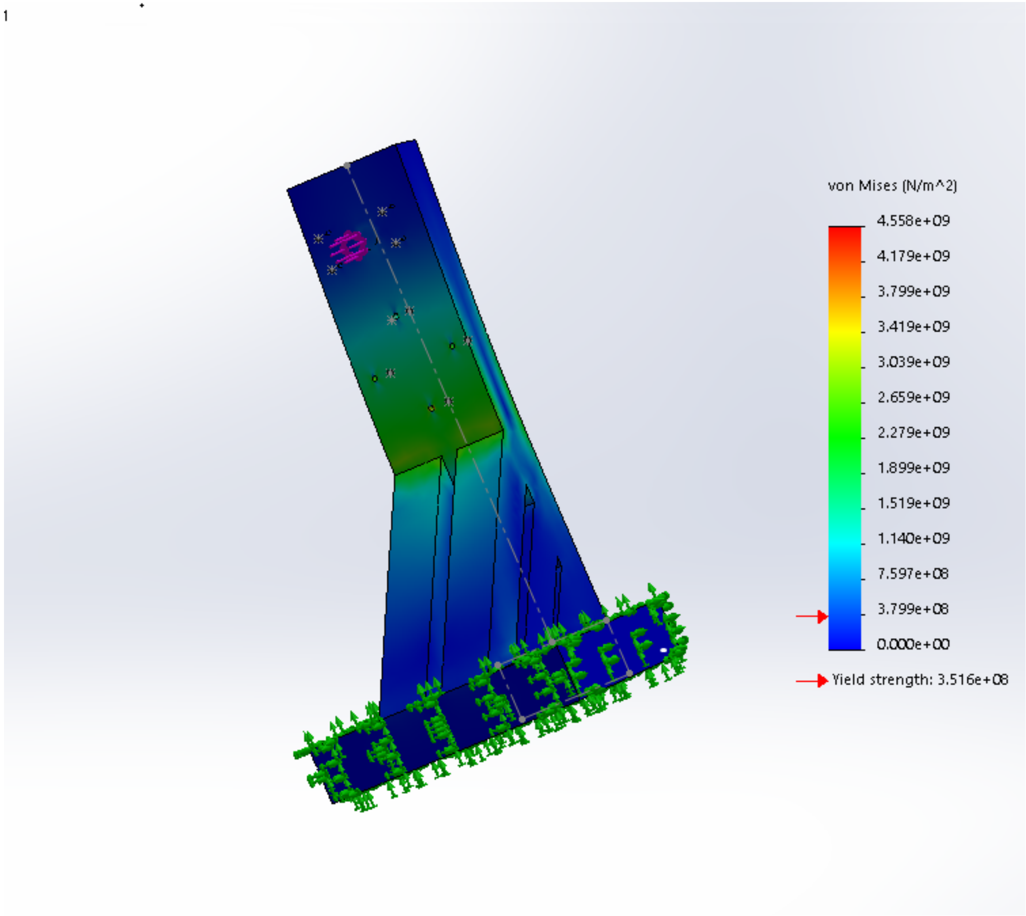


Assumptions:

- Locked an inch of the shaft in place
- force applied 3.5 inches away from bearing holder
- The two pieces were treat as one solid part

Slide Responsibility: Stress

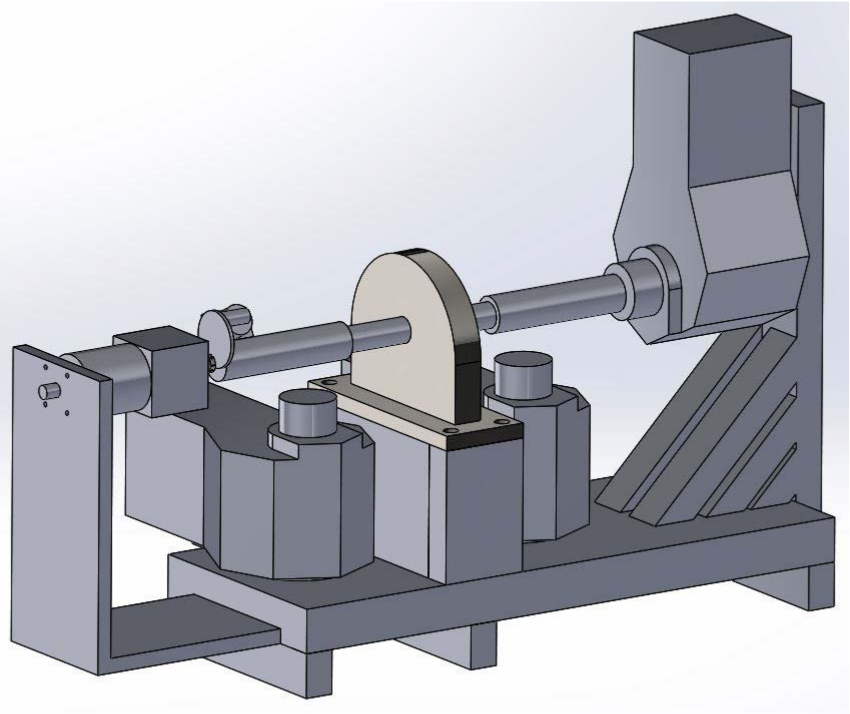
Stress analysis summary, mini-report number



Assumptions:

- Locked the bottom of the frame
- Ignore the weight of the jack

- The team was unable to run a whole frame analysis in Solidworks
- The team ran each individual component
- Assembly FEA proved too difficult in Solidworks

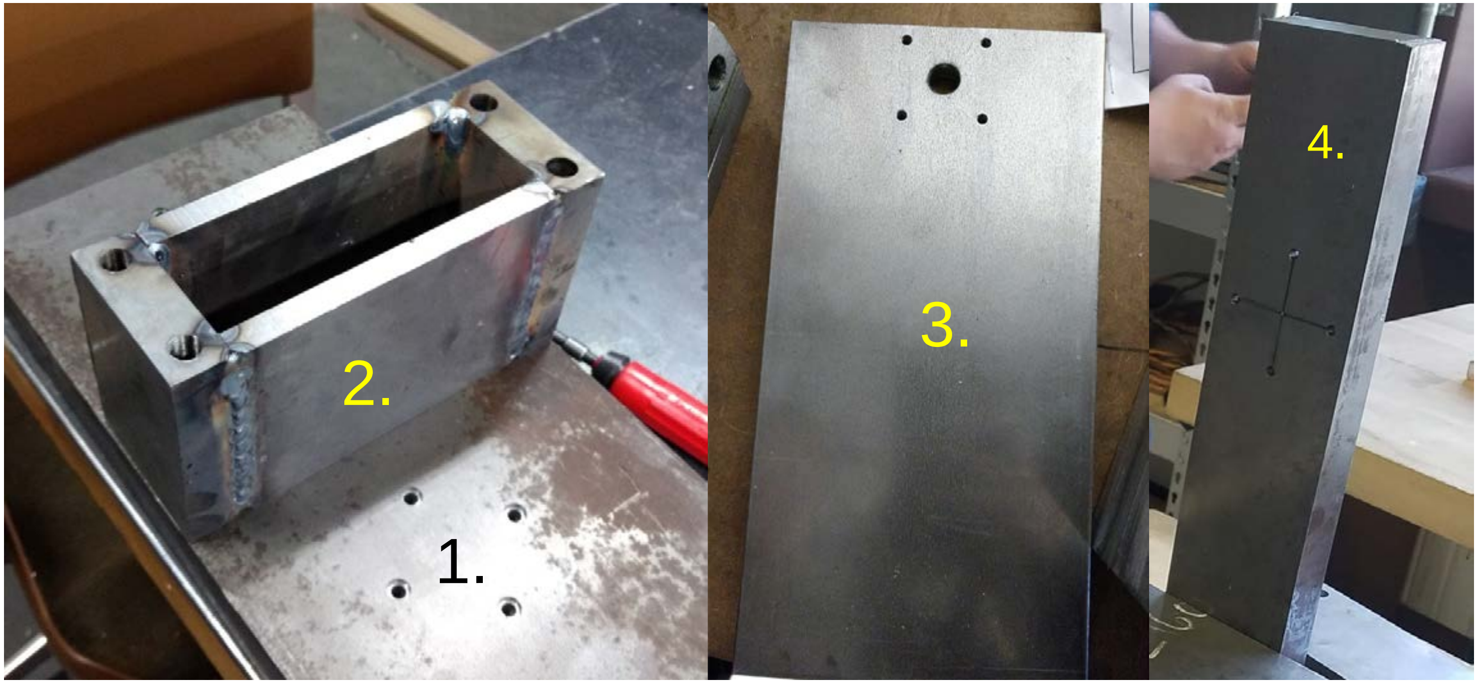


Materials

- 1018 Hot Rolled Steel for frame and shaft
  - All load bearing parts ran under simulation with no problem

- Crank made from PLA plastic as it is 3D printed

Slide Responsibility: Material Sciences



- Holes were drilled out on the base plate (1) and thrust frame (4) before welding
  - These provide a mounting point for the jack
- Holes were also drilled out on the motor mount (3) and bearing riser (2) before they were welded to the frame

Manufacturing/Testing

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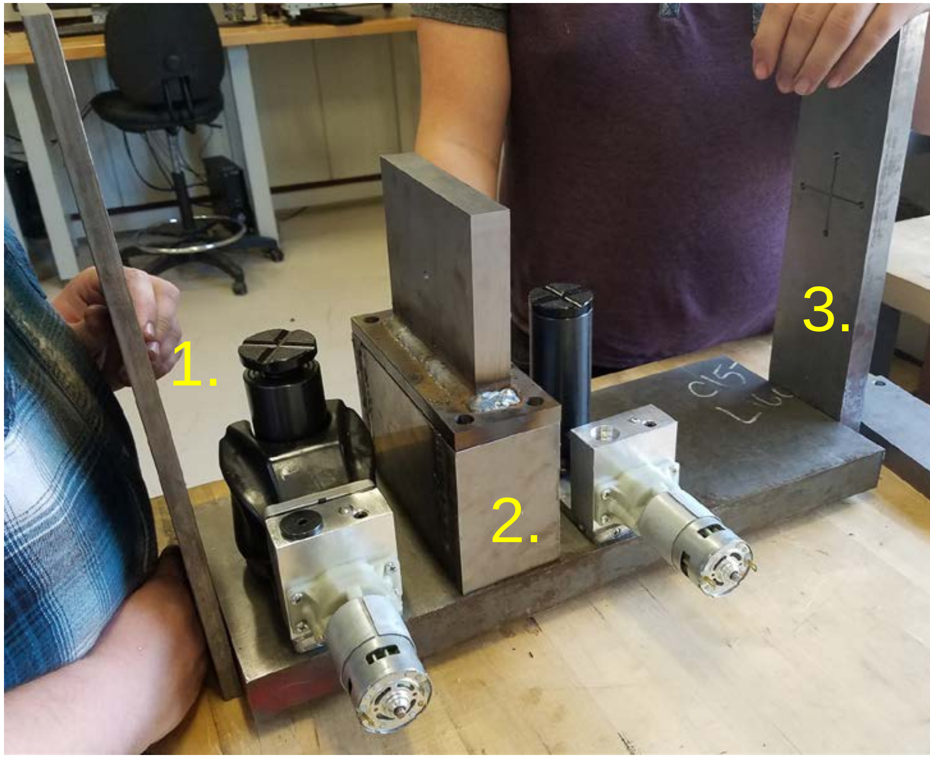
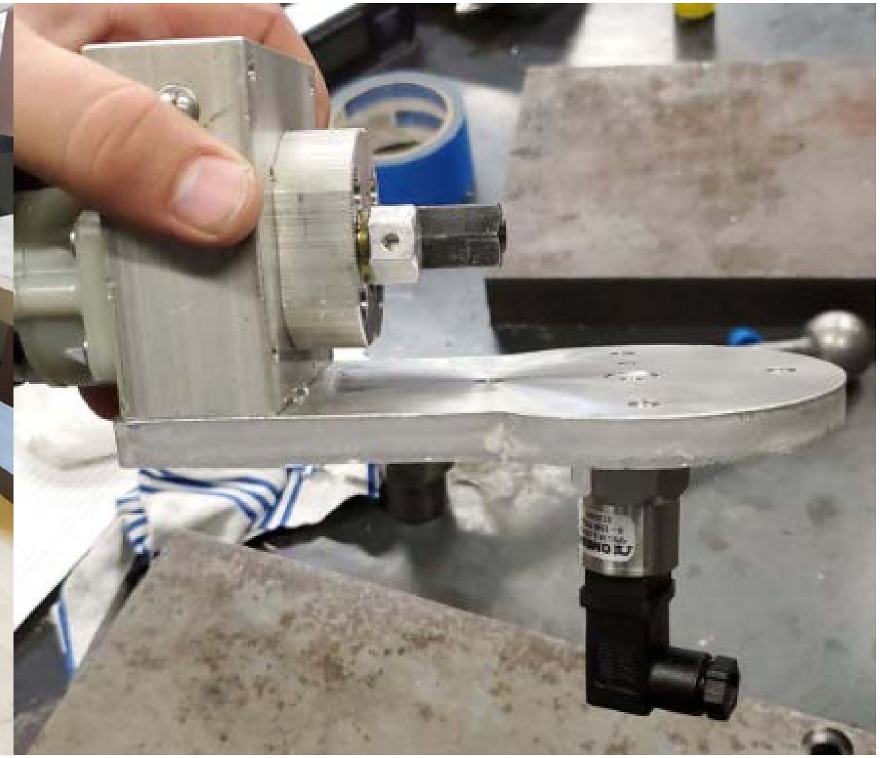
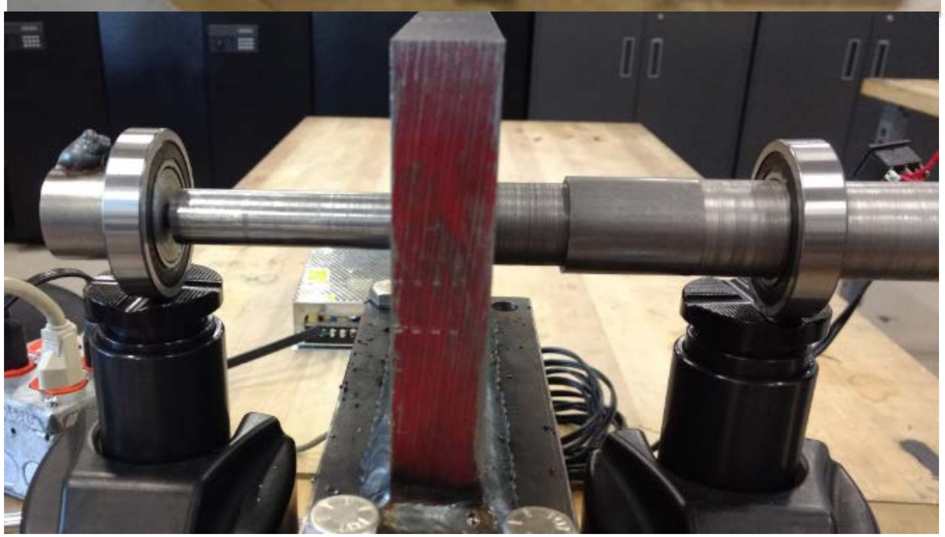




- The motor mount (1), bearing riser (2), and thrust frame (3) are all welded to the base plate
- Not shown, a the truss system is welded to the thrust frame

- The jacks were disassembled, and tapped to place a pressure transducer

Manufacturing/Testing



- The base of the bearing housings consists of 1/2 in plates with holes drilled into them
- A mill was used to make the bearing housings
- The housings were welded to the plates
- All shafts were turned down
- Need the R14 and 38 bearings to finish all work
- An R14 load bearing is placed at each point the jacks make contact with the shaft
    - Each handle a load greater than 4,000 lbf

Manufacturing/Testing

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Results of the Force Test

- The R-12 shaft deformed
  - Fix: Use alloyed steel
- The jacks were able to impart the correct loads
- Some changes were made to the design since the shaft analysis was ran
- It is uncertain if pressure gauge readings were accurate
- The shaft could not rotate due to deformation
  - Motor could rotate shaft before deformation

Weight Analysis

- The test fixture is yet to be weighed(cannot find a scale big enough)
  - The apparatus requires two people to lift
- The goal is to keep the apparatus under 300lbs

Slide Responsibility: Design

Weight analysis, customer requirement, mitigation plans

Manufacturing/Testing: Force Measurement

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```
Radial 2 Pressure value: 84.00
Radial 2 Force value: 180
Thrust Sensor Value : 1017
Thrust Pressure value: 170.00
Thrust Force value: 364
Total Radial Force 321
Radial 1 Sensor Value : 101
Radial 1 Pressure value: 66.00
Radial 1 Force value: 141
Radial 2 Sensor Value : 104
Radial 2 Pressure value: 84.00
Radial 2 Force value: 180
Thrust Sensor Value : 1017
Thrust Pressure value: 170.00
Thrust Force value: 364
Total Radial Force 321
Radial 1 Sensor Value : 101
Radial 1 Pressure value: 66.00
Radial 1 Force value: 141
Radial 2 Sensor Value : 104
Radial 2 Pressure value: 84.00
Radial 2 Force value: 180
Thrust Sensor Value : 1016
Thrust Pressure value: 160.00
Thrust Force value: 342
Total Radial Force 321
```

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Stress analysis summary, mini-report number

Reliability Summary

- As given to us the torque range of 100 lb-in to be within 1% accuracy
- Torque is measure by the voltage required by the motor
- Accuracy of all forces is uncertain because readings from the transducers are uncertain

Slide Responsibility: RM&S

Reliability analysis, requirement. prediction and basis

Programmatics

Knowledge, Skills, and Experience Gained

- Design for Manufacturing
- Tolerancing
- Experience with Arduino systems
- Static and material analysis
- Force transfer analysis
- Machine design of shafts
- Solidworks FEA
- How to work under a tight budget
- Troubleshooting problems after manufacturing

Lessons Learned

- Team communication
- Tolerancing
- Do not wait to code Arduino until last minute
- Weld first drill second
- Weld a support to all vertical surfaces
- More realistic assumption for stress analysis

Appendix