FINAL DESIGN REVIEW:

Incremental Motion Knee Joint

Larry Jones
Rajiva Rampersad
Giselle Rojas
Donna Wright

FAMU-FSU College of Engineering

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Agenda

- Problem Statement/Specifications
- Concept Comparison/Selection
- Analysis & Calculations
- Design Details
- Machining Process
- Fabricated Prototype/Simulation
- Cost Analysis
- Problems Encountered/Solutions
- Conclusion

Problem Statement

- Fillauer Inc., a leading manufacture of prosthetics and orthotics in the world, would like an **incremental motion orthotic knee joint designed and fabricated.**

FUNCTION:

- To help patients with contractures, who have trouble straightening their leg
- To assist in standing from a seated position
- A knee joint that has incremental locking points but extends freely

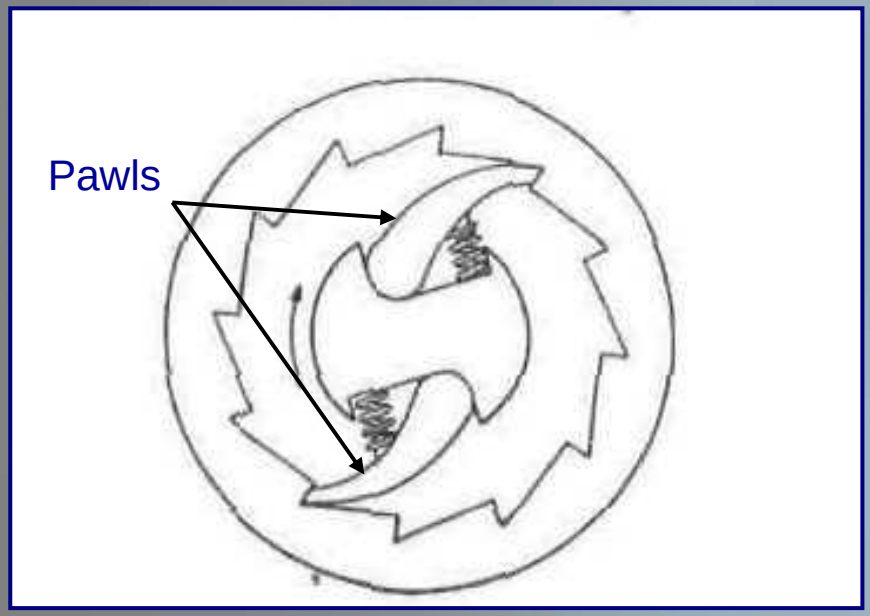
Product Specifications

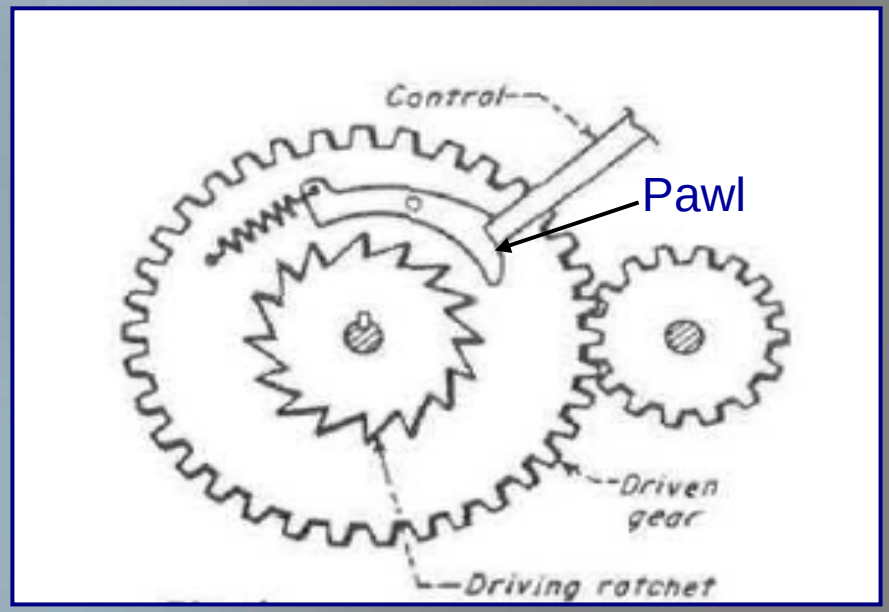
- Should allow free motion joint settings.
- Needs to accept all KingPin bars.
- Needs to withstand a moment of 80 Nm on test machine for 1 million cycles.
- Needs to withstand a moment of 12 Nm medial laterally for 1 million cycles.
- Manufacturing price target $40 for just the joint. (Medicare)
- Range of motion from straight (Zero degrees) to minus 110 degrees; would like 130deg.
- Maximum increments 15 degrees; would like 10 degree increments
- May have an infinite number of locking positions.
- Conform to ISO standards: ISO/TC 168/WG 3

Decision Matrix

	Manufacturability	Cost	Range of Motion	Ease of Use	KingPin Interface	Total
Internal Ratchet w/ spring loaded pawls	5	5	5	3	3	**21**
Pawl & Ratchet Clutch	4	4	5	5	4	**22**
Roller Clutch	3	2	5	4	3	**17**
Planetary Transmission Clutch	3	3	5	2	2	**15**

Preliminary Mechanism Concepts



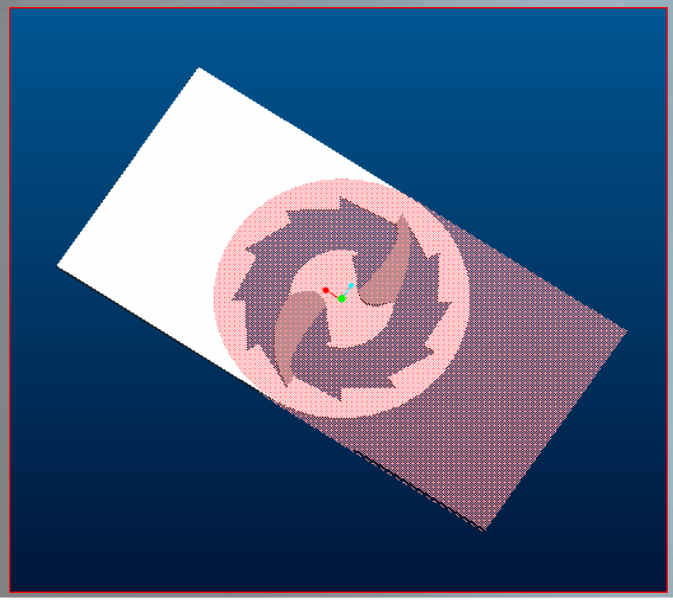


Mechanism #1:
2 pawls
2 springs
actuator
internal ratchet

Mechanism #2:
1 pawl
1 spring
lever
external ratchet

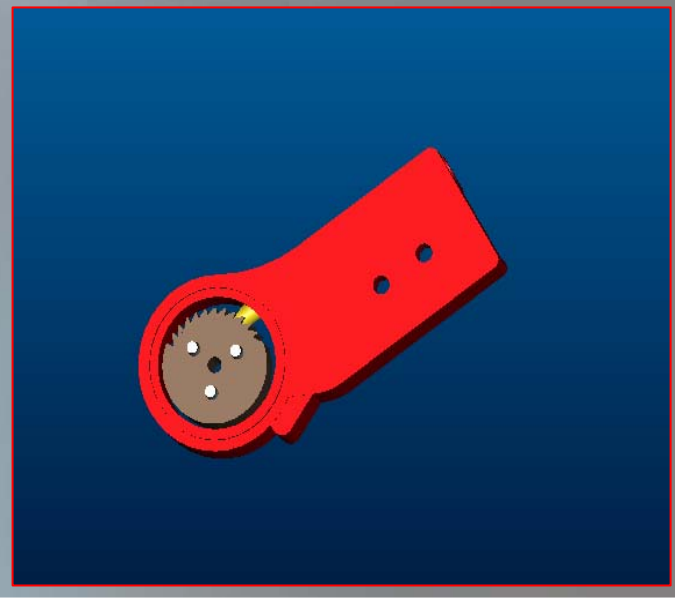
Preliminary Design Concepts

Design #1: Internal Ratchet with Spring Loaded Pawls



PRO's	CON's
Simple mechanism	Double Parts
Machinability	Difficult actuation concept
	KingPin Bars Interface

Design #2: Pawl and Ratchet Clutch

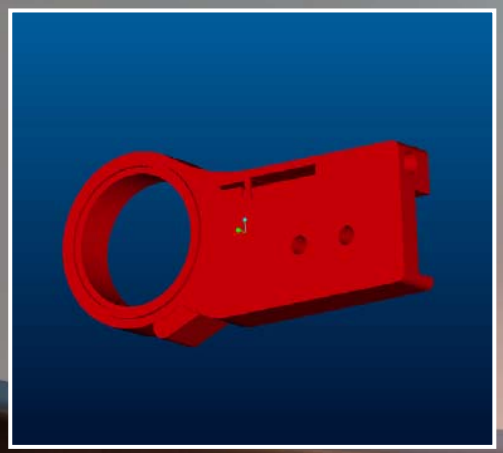


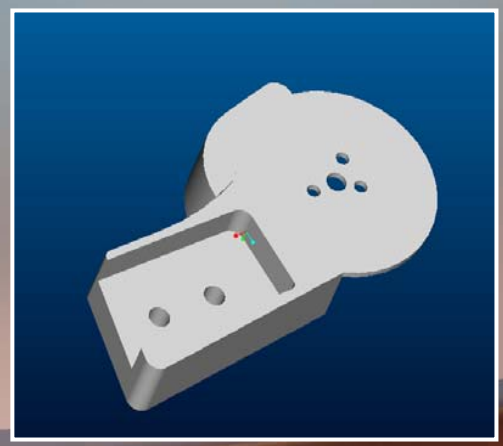
PRO's	CON's
Utilize similar housing of KingPin	Machining
External ratchet	
Ease of Use	

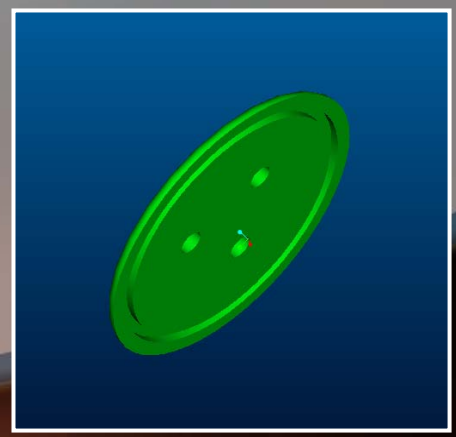
Design Components

Mechanism

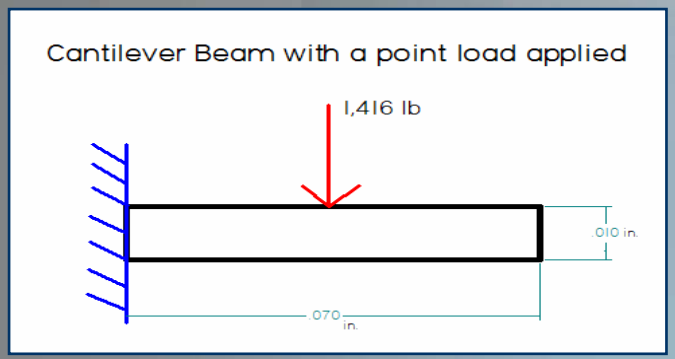
Housing







"Cantilever Beam" Assumption

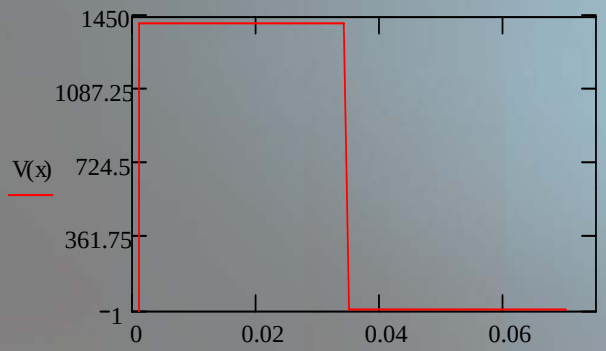


$$\sigma \max = \frac{M \cdot c}{I}$$ **Max Bending Stress**

$$\sigma \max = 6.09 \times 10^4 \frac{lb}{in^2}$$

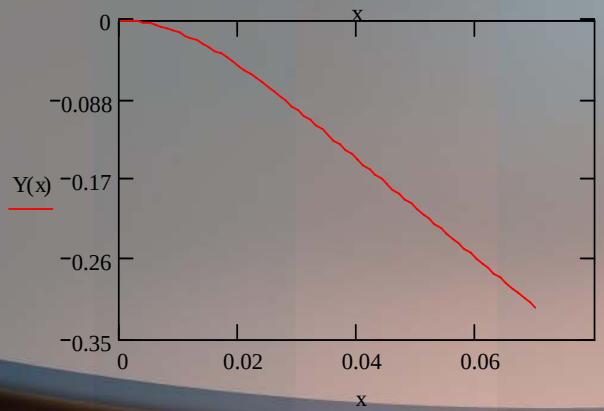
***ultimate tensile strength = 160000 psi**

****yield strength =150000 psi**



Shear Stress

V= 1416 lb/in^2



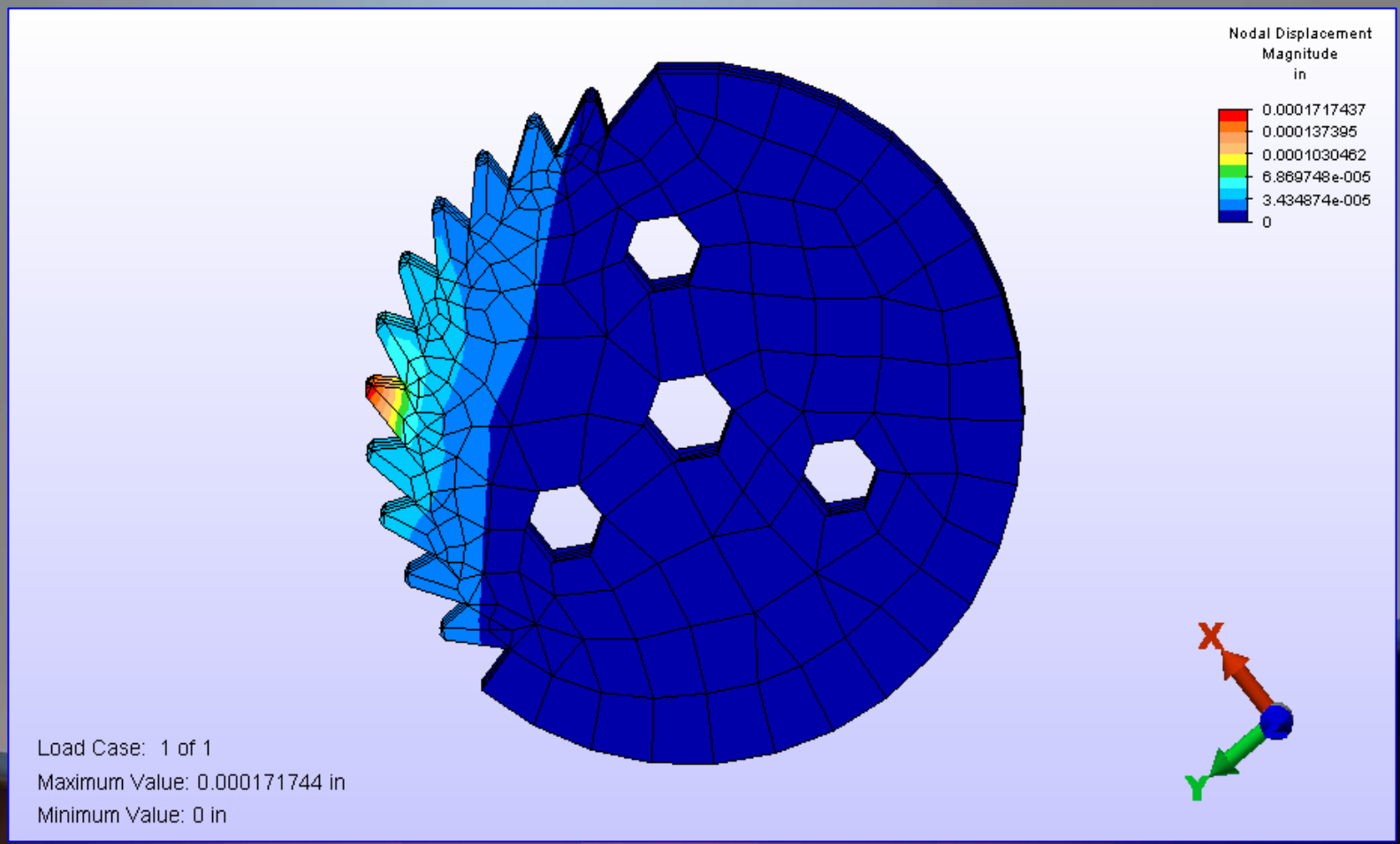
Deflection

Y= 3.15* 10^-5 inches

Finite Element Analysis: ALGOR

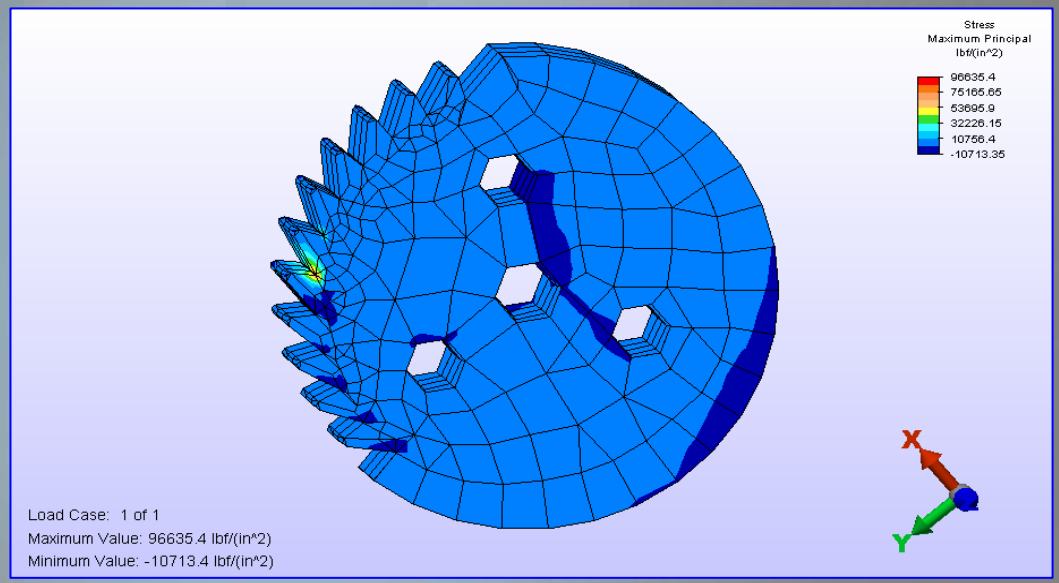
- **Capable of analyzing stresses on complex geometries**
- **Assumed a non-uniform rectangular cross-section**
- **Analyzed with a distributed load**

Nodal Displacement= 3.4348e-5 in.

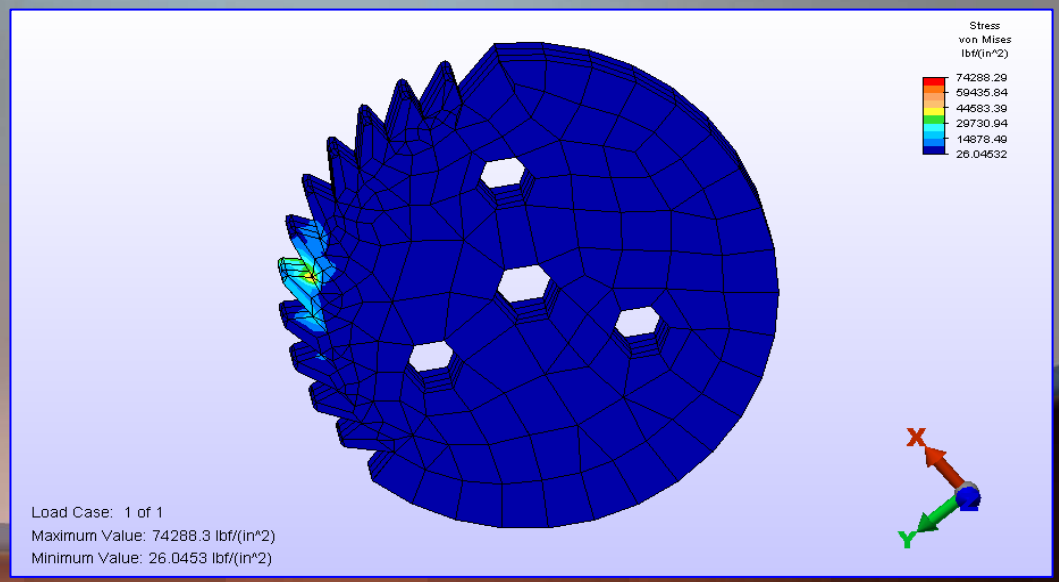


Finite Element Analysis: ALGOR

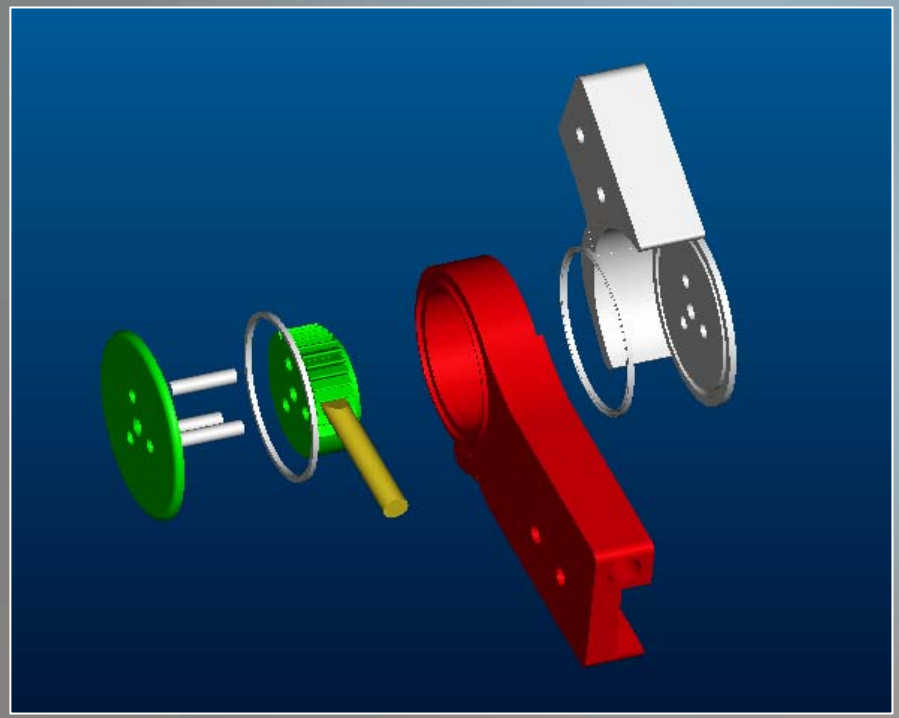
Maximum Principal Stress= 96,635.4 lb/in²



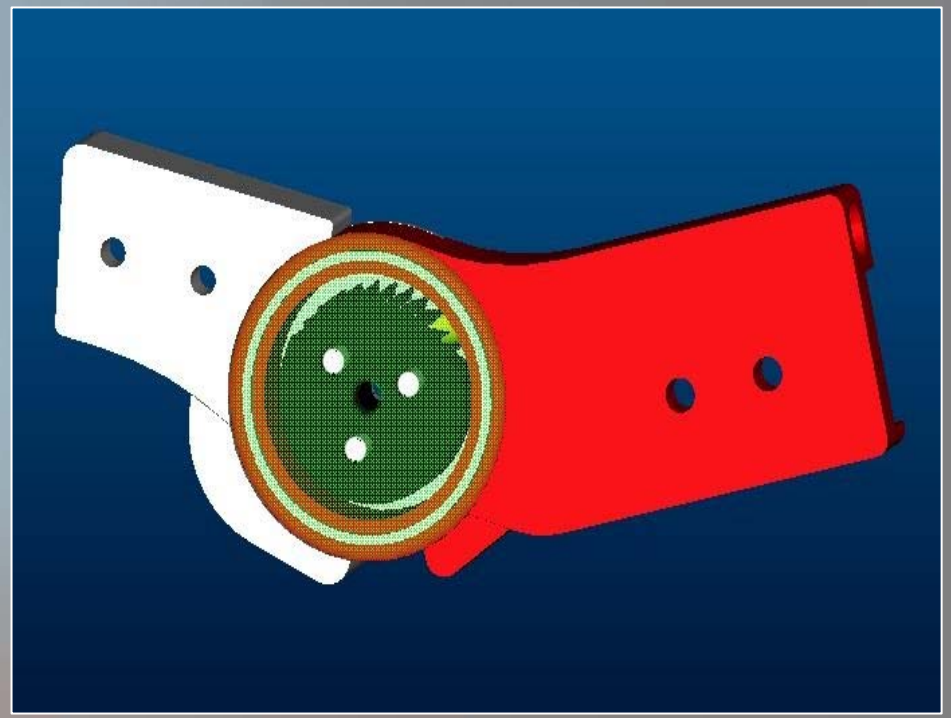
Von Mises Stress= 74,288.3 lb/in²



Design Concept Assembly



Exploded View



Assembled View

Machining Process

- Electrical Discharge Machining
  - Ratchet Gear
  - Pawl
- complex shapes and geometries
- affordable when low counts and/or high accuracy is desired.

- Lathe
  - Pins
  - Gear Ratchet Backing

Prototype Components

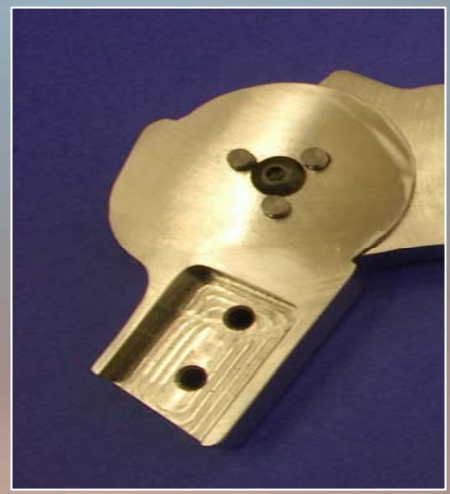
Gear Hub

Actuation System

Pawl

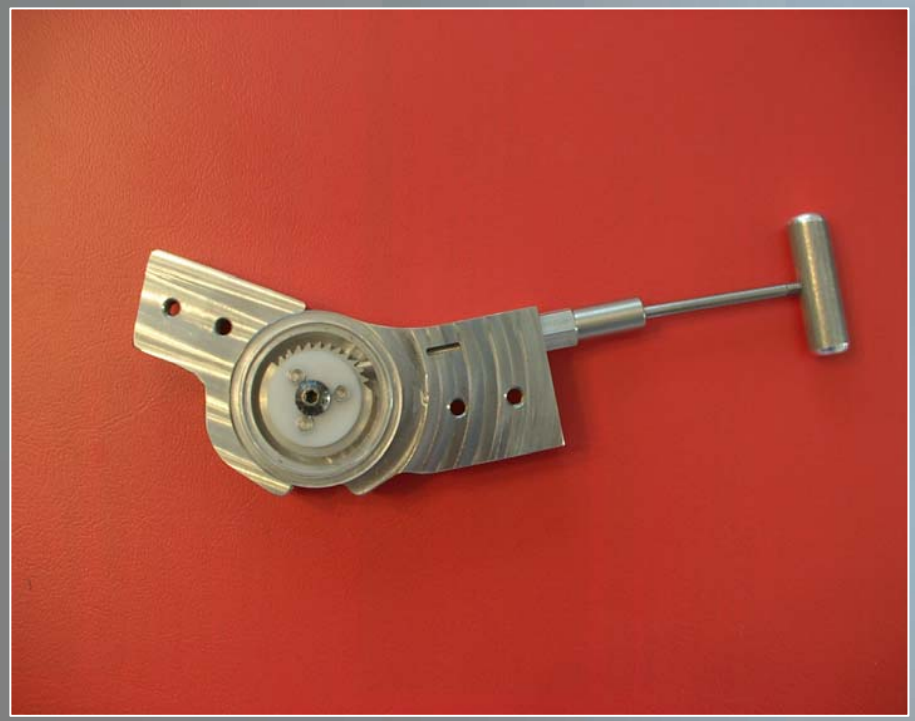
Middle Housing

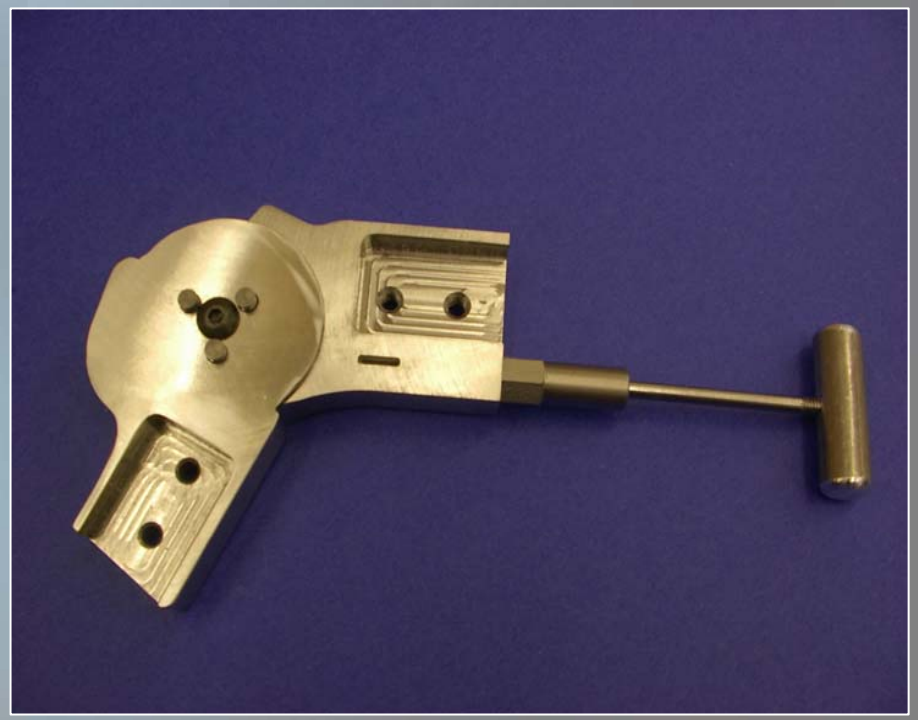
Outer Housing



Backing

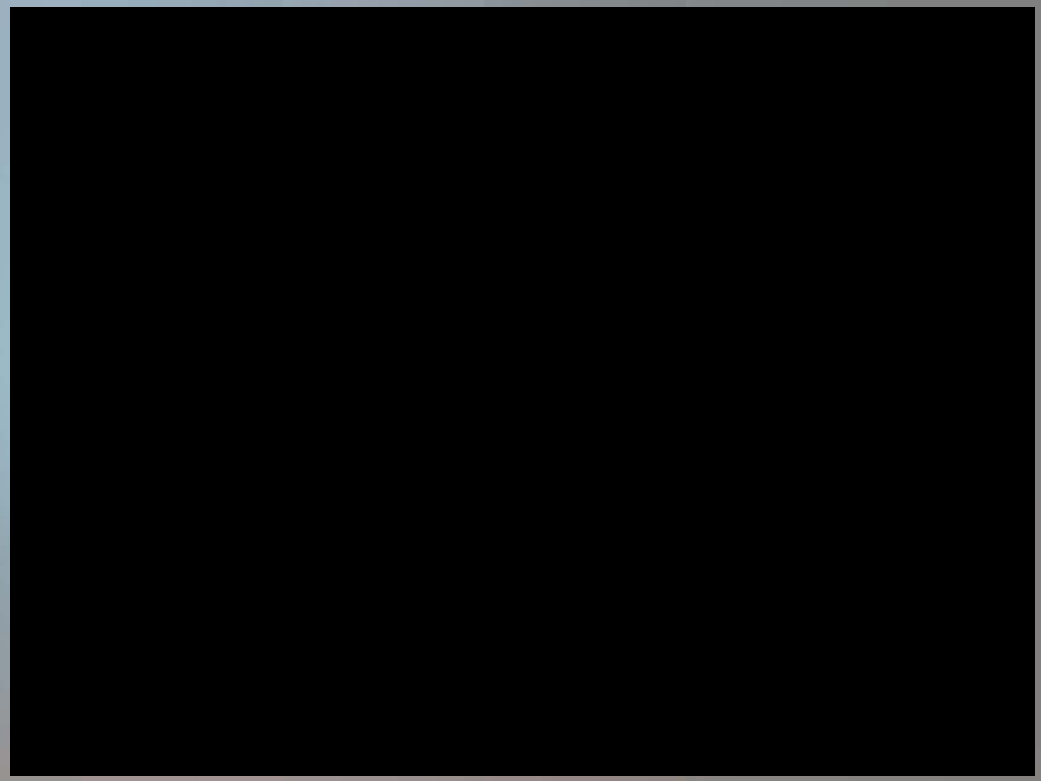
Prototype Assembly





Weight: 0.75 lbs
Thickness: 0.5 inches
Length: 4.25 inches
(does not include actuation device)

Simulation



Cost Analysis

Material Description (Bulk)	Total Price	No. of Parts per Bulk Order	Knee Joint Part
Type 17-4 PH Hardened Stainless Steel Rod 1-1/8” Diameter, 1” Length (Same as 87205K14)	$20.89	3	**Ratchet Gear** 1” Diameter 0.32” Length
Type 416 Stainless Steel Rod 1-1/2” Diameter, 1” Length (Same as 89095K32)	$31.19	16	**Ratchet Gear Backing** 1-1/2” Diameter 0.0625” Length
Type 416 Steel Precision Ground Rod ¼” Diameter, 4’ Length (Same as 88955K25)	$14.19	3	**Pawl** 0.25” Diameter 1.24” Length
Virgin Electrical Grade Rod of Teflon PTFE 1-3/8” Diameter, 3‘ Length	$20.33	20+	**Bearing** 1.34” Diameter
Type 416 Ss Dowel Pin 1/8” Diameter, ½” Length, MIL Spec 16555-627, Packs of 50	$10.46	16	**Pins** 1/8” Diameter ½” Length

Total Cost for Materials = $97.06

Approx. Cost per joint = $32.35

Testing Process

** 1 Million Cycles for 24 hours

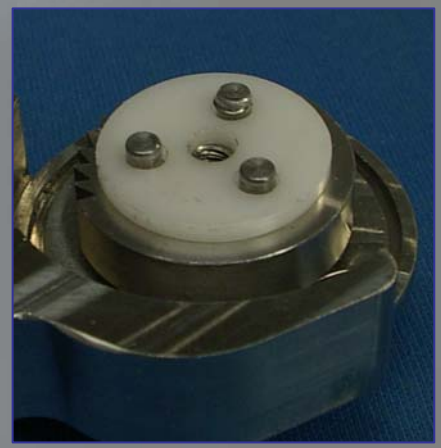
** Testing Gear Tooth Strength in 1 Position

Problems Encountered & Proposed Solutions

Spacing within housing

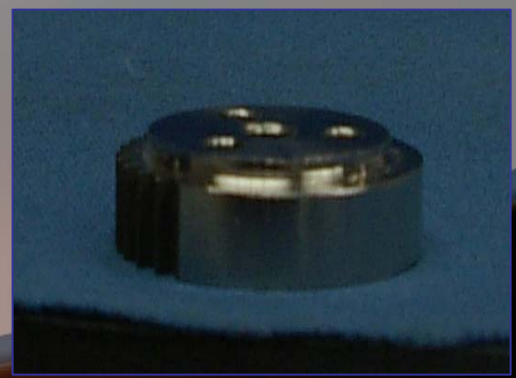
Short-Term

Insert plastic spacers



Long-Term

Increase protrusion thickness



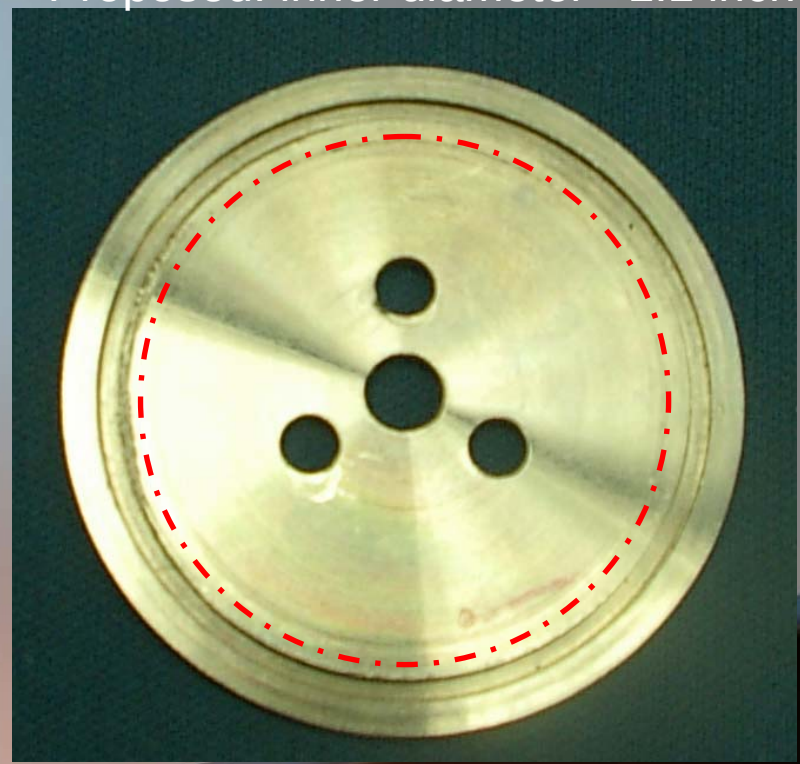
Problems Encountered & Proposed Solutions

Placement of bearings

Change dimensions (depth & diameter) of bearings and grooves

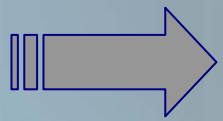
Current: inner diameter =1.25 inches

Proposed: inner diameter =1.1 inches



Problems Encountered & Proposed Solutions

Mechanism does not lock properly



Redesign gear tooth angle steepness

Stiffer Spring

Conclusion

- Machined 2 prototypes
- Prototype met range of motion specifications
- Met specified dimensions (thickness/weight)
- Gear teeth were designed at 11.25° increments
- Met the target budget
- Foundation for marketable product

Acknowledgements

Fillauer Inc., Sponsor

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FAMU/FSU COE Machine Shop

Brian Moore, T.A.

QUESTIONS & COMMENTS

THANK YOU FOR YOUR TIME
AND ATTENTION!