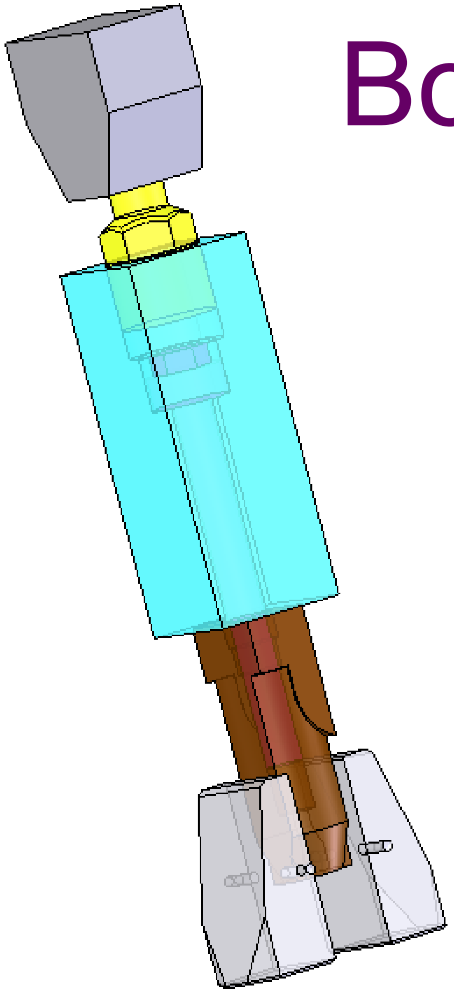
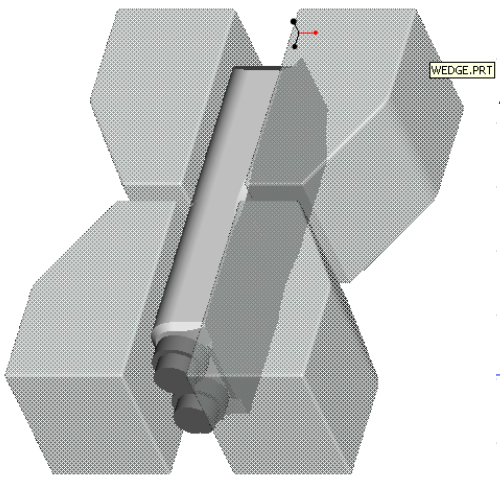
Group 1

Bolted Joint Rig Test Development





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Ana Erb

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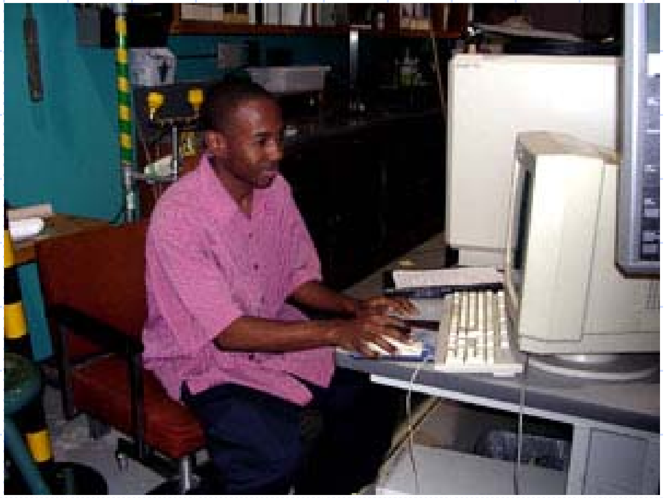
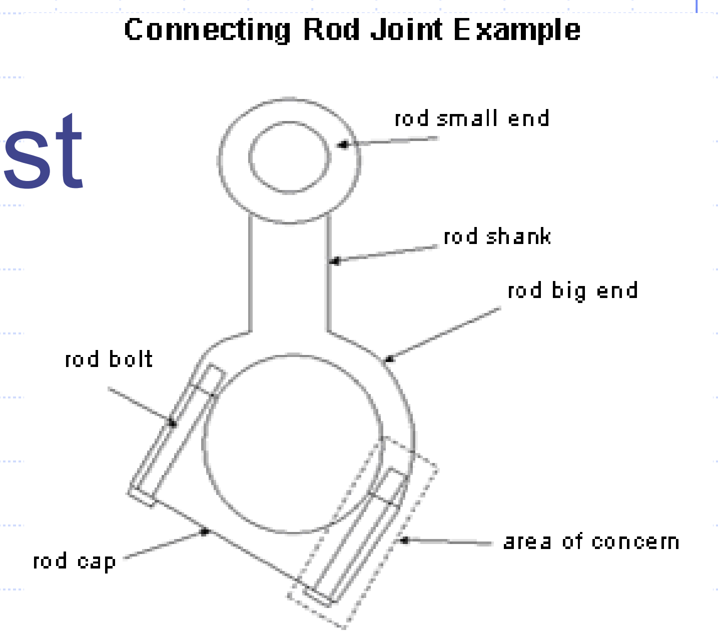
Outline

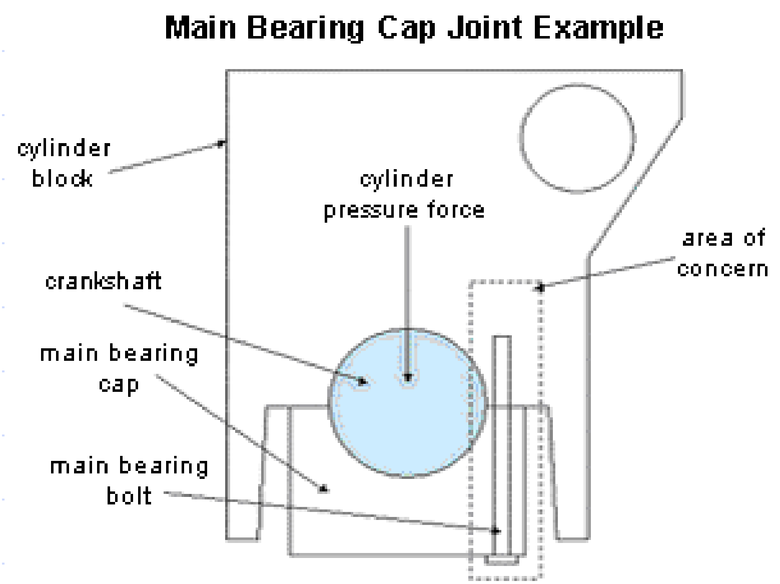
- Project Purpose
- Bolt / Metal Fatigue Overview
- Material Testing System (MTS)
- Design needs and specifications
- Design generations and selection
- Parts and cost analysis
- Testing
- Results
- Recommendations
- Conclusion



Bolted Joint Rig Test Development

The purpose of the project is to design a test fixture that can be used to evaluate design improvements to fatigue life of threaded joints. While most of the bolt load is carried in the first few threads, this is not necessarily where failure occurs.



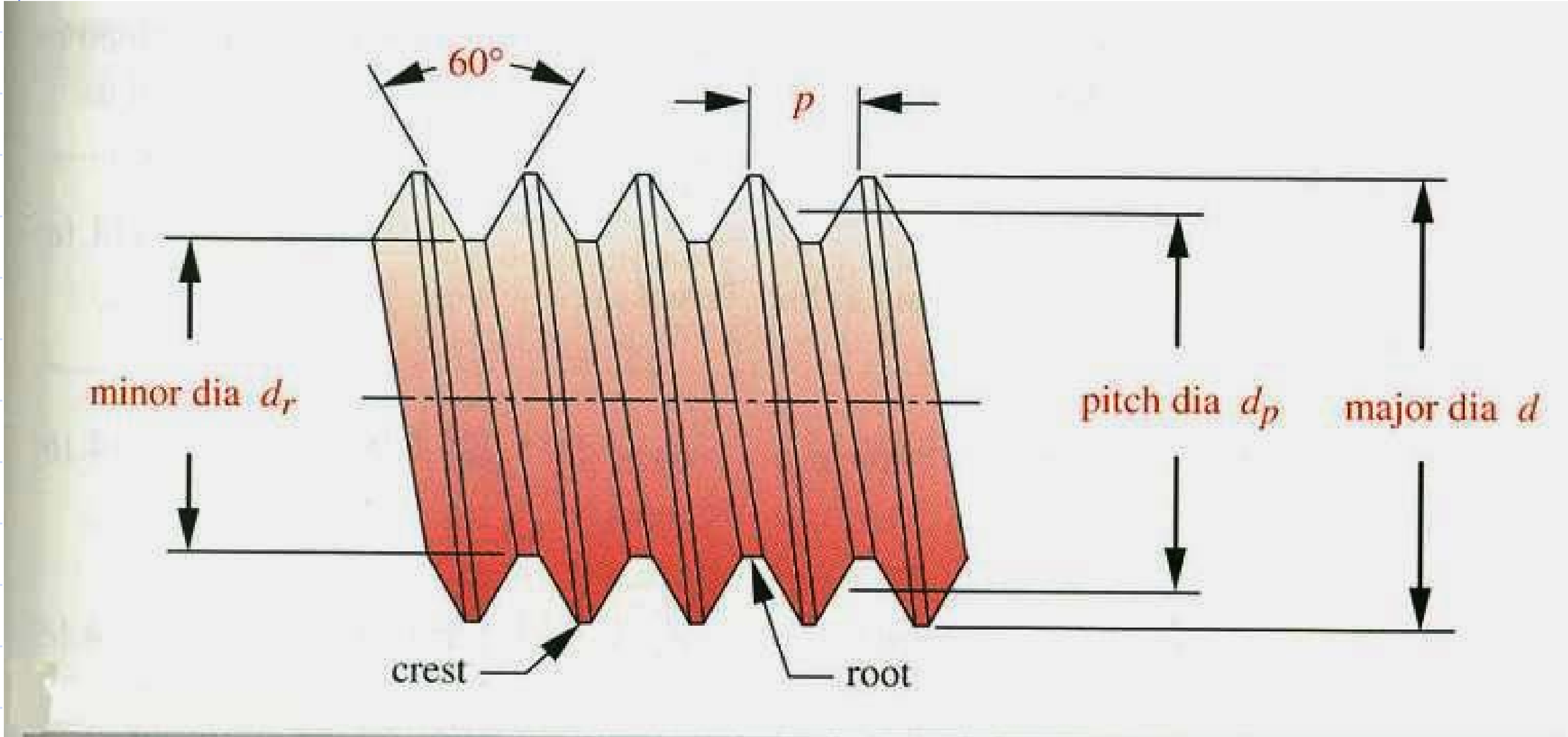


Project Objective

- Cummins needs
  - A test fixture than can evaluate threaded joints
    - Connecting rod
    - Main bearing cap
  - Fatigue failure on threaded joints

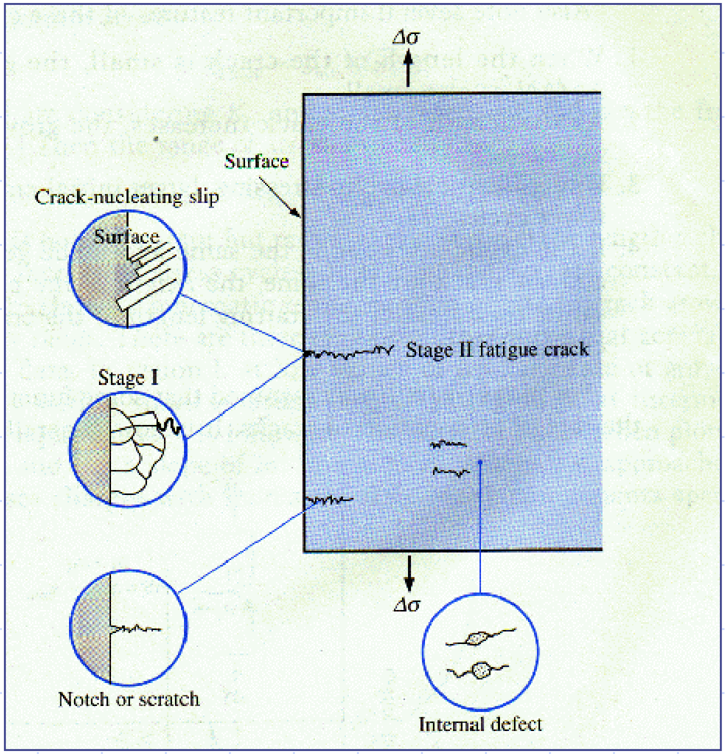
- Industrial needs
  - To know when the threaded joints will fail

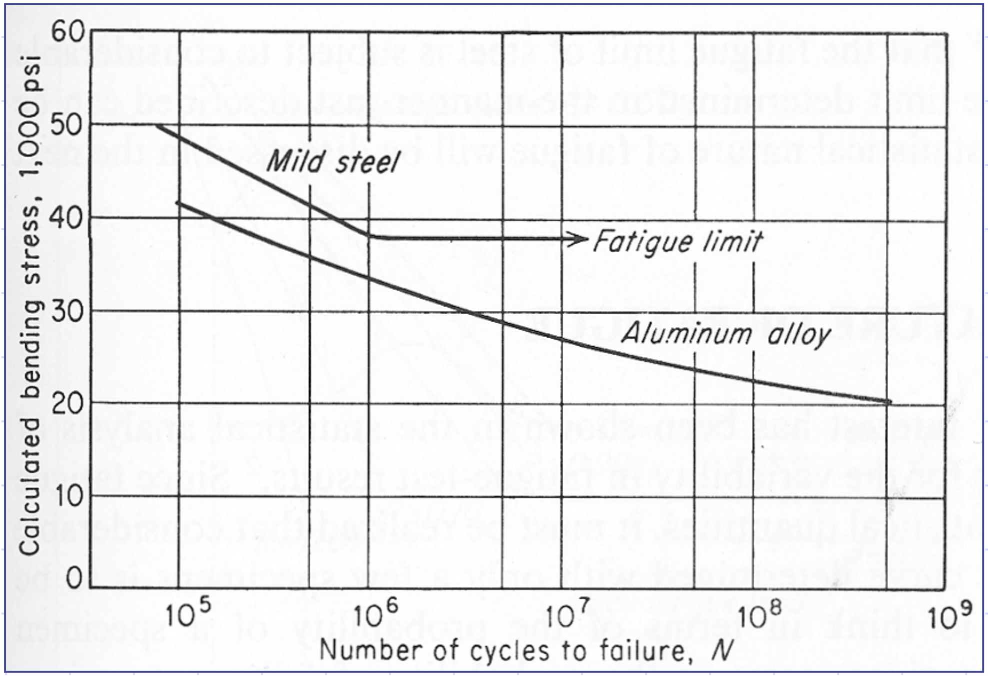
Threaded Bolt



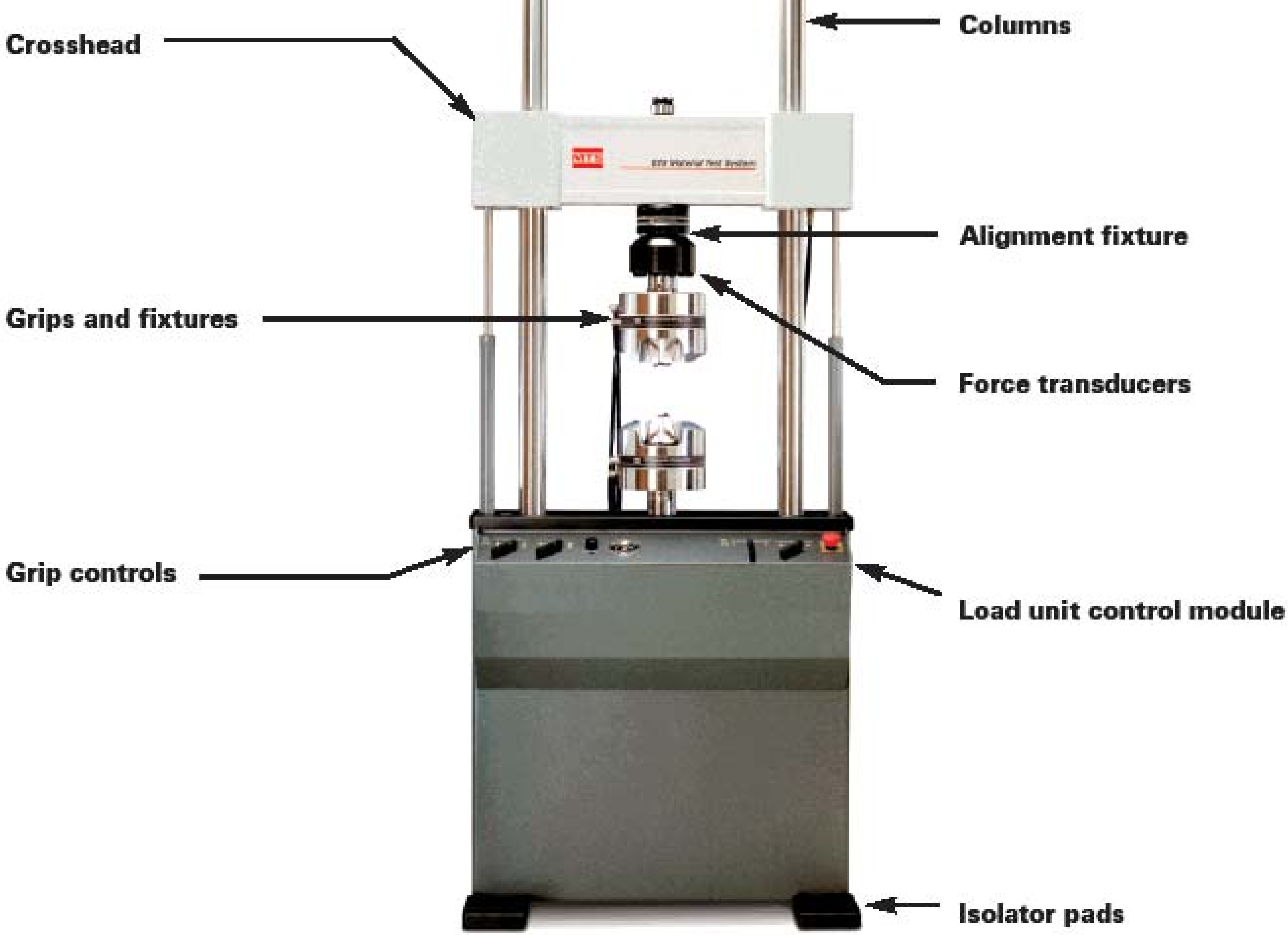
Unified National and ISO Standard Thread Form

Metal Fatigue Overview





MTS and its components:



Test Equipment

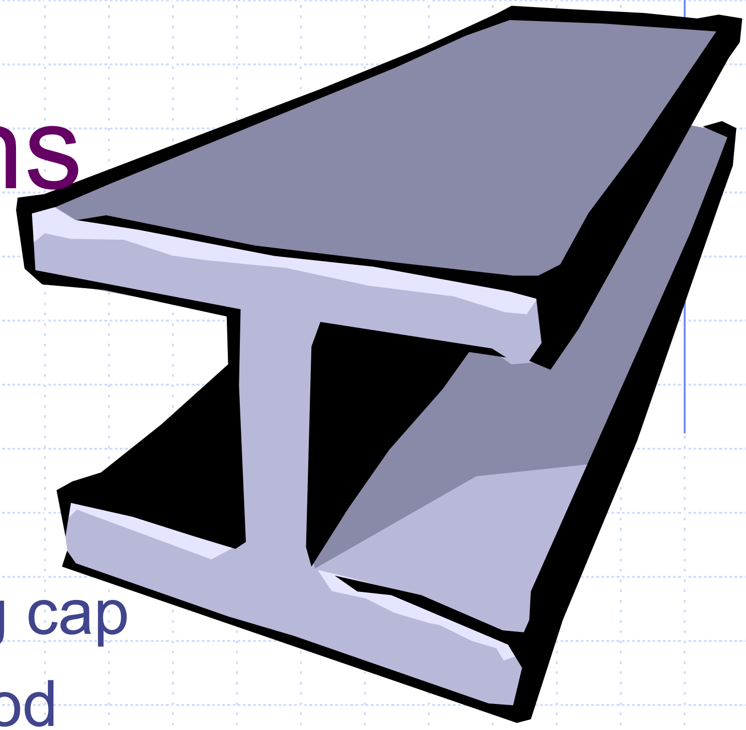
- MTS Machine
  - What it is
  - Alignment fixture
  - Grips
  - Wedges

Samples Sent by Cummins

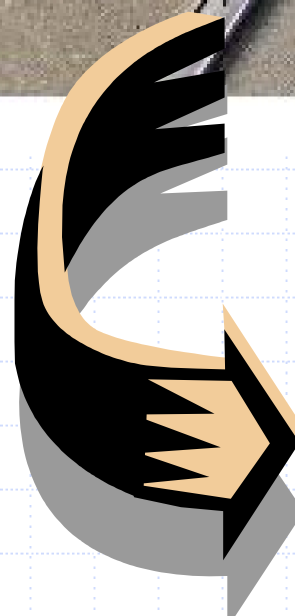
Design Needs

Demands	Requirement	Importance
Demand	Two different set ups, one that will test the main bearing cap and another that will test the connecting rod joints.	10
Demand	Test fixtures should reproduce the failure mode of real components	10
Demand	Design will interface with a fatigue test rig, (e.g. MTS Servohydraulic machine)	10
Demand	Pre-load on the main bearing Cap be 45,000 lbs	10
Demand	Pre-load on the connecting rod be 16,000 lbs	10
Demand	Bolt boss diameter, thread pitch, thread type, counterbore depth, number of engaged threads, bolt preload, and alternating load should be studied	10
Demand	Estimated cost of Hardware (samples will be provided)	8

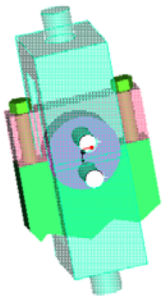
Design Specifications



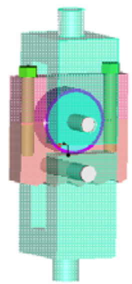
- Specifications
  - Pre-load requirements
    - 45,000 lb for main bearing cap
    - 16,000 lb for connecting rod
  - Testing for 500,000 cycles
  - Dimensions
    - Seen in engineering drawing(s) of our final selection



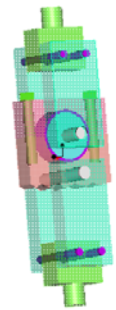
Design Generation & Selection



Concept A

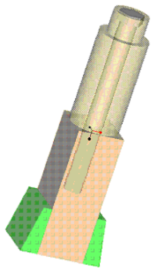


Concept B

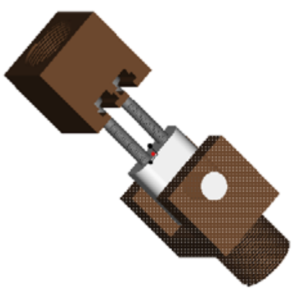


Concept C

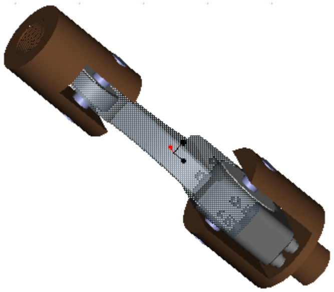
Concept D



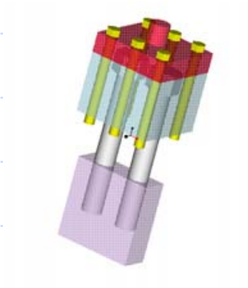
Concept E



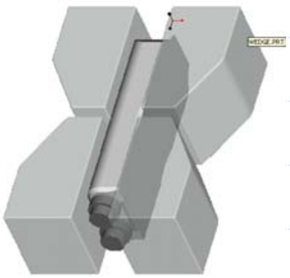
Concept F



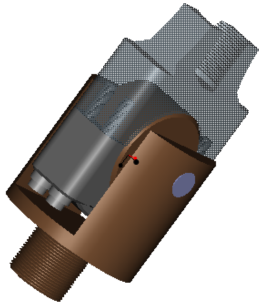
Concept G



Concept H

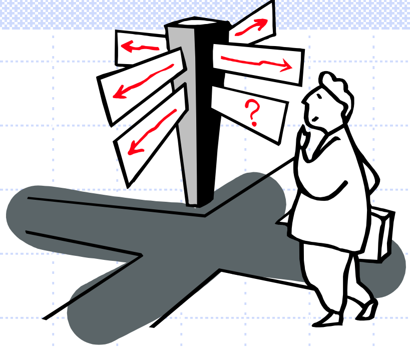


Concept I



Concept J

Design Selection

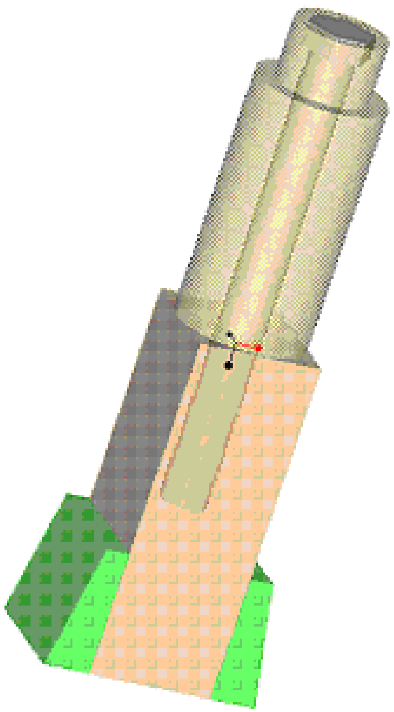


	Cost	Man	Rel	Perf	Cus.S	Total
A	0.8	0.75	1.05	1.4	2.1	6.1
B	0.8	0.75	4.05	1.4	2.1	6.1
C	1	0.9	1.05	1.4	2.1	6.45
D	0.8	0.7	1.05	1.3	2	5.85
E	1.6	1.35	0.75	1.4	2.1	7.2
F	0.8	0.45	1.2	1.6	2.1	6.15
G	1	0.6	0.6	0.6	0.6	3.4
H	1	1.2	0.75	1.4	2.1	6.45
I	1.2	1.05	0.75	1.4	2.1	6.5
J	1.6	1.35	0.75	1.4	2.1	7.2

Each concept is ranked from 1-10. (1 being the worst, and 10 being the best) The ranking is then multiplied by the weighted values below and then added up to show the final total. The concept with the highest total will show what the final design concept should be.

Selection for main bearing cap

- Based on design matrix, the final design

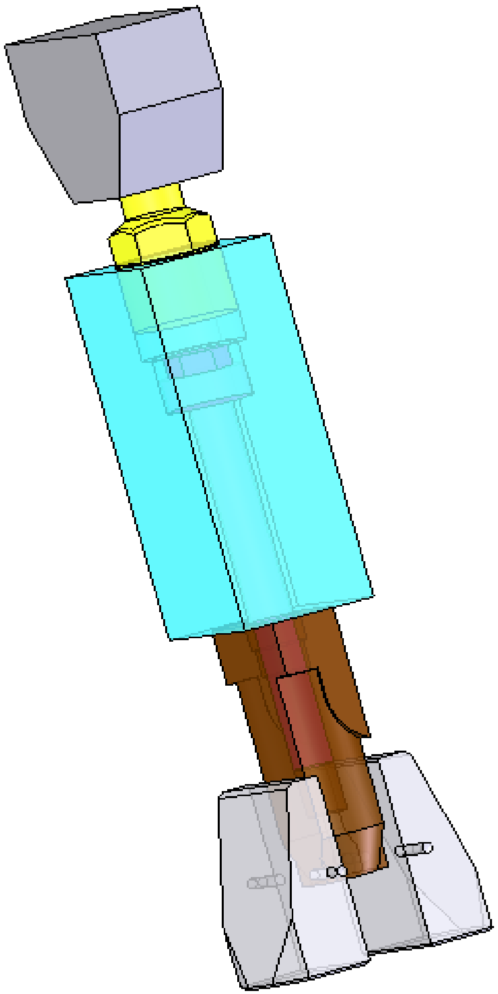


Chosen for ease of manufacturability and simplicity.

Fixture is small enough to fit within wedges inside of the MTS machine.

Top will be screwed into the top portion of the MTS machine

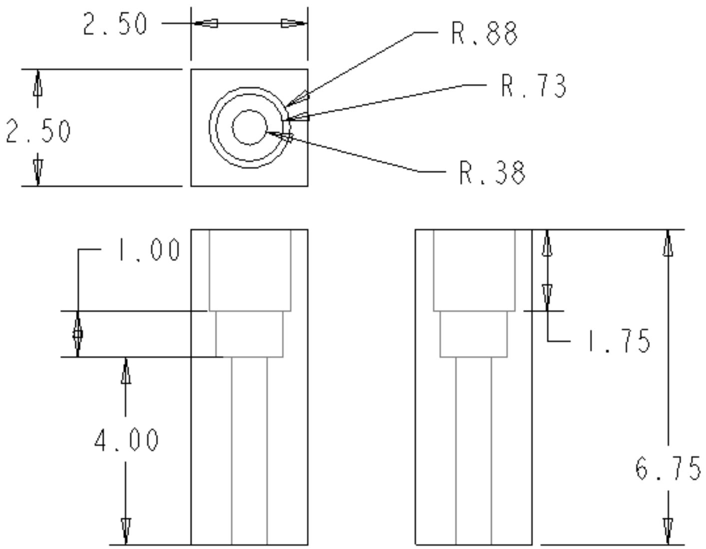
Modifications done to bearing cap selection:



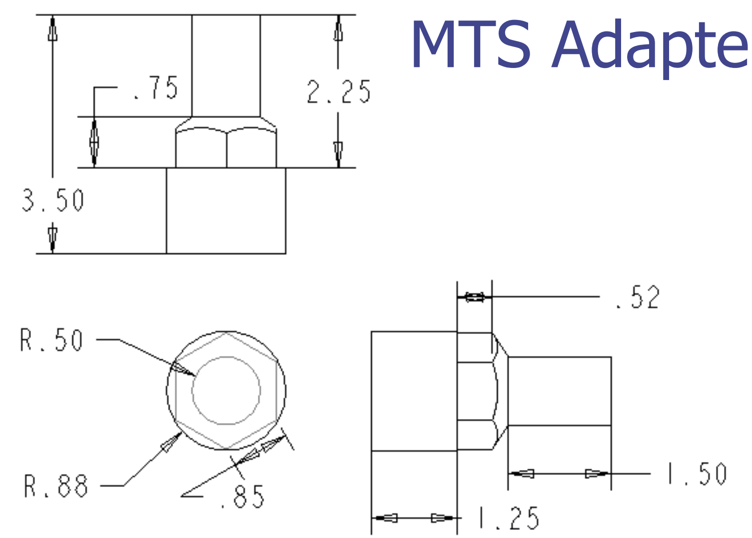
- Bolt head of previous design was too large to fit into MTS machine
- Adapter (yellow) was made to fit fixture (light blue) within MTS machine.
- Engine block cut out specimen is in brown, wedges are in gray, and bolt being tested can be seen through the transparent fixture.

Engineering Drawing / Dimensions of Final Selection

(Main Bearing Cap)



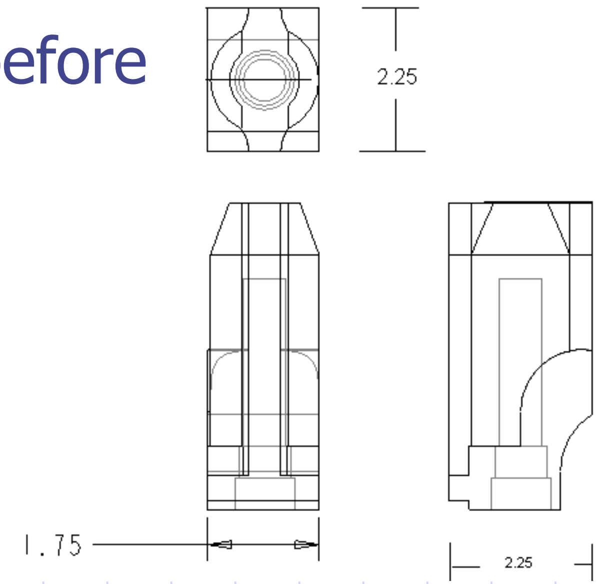
Test Fixture

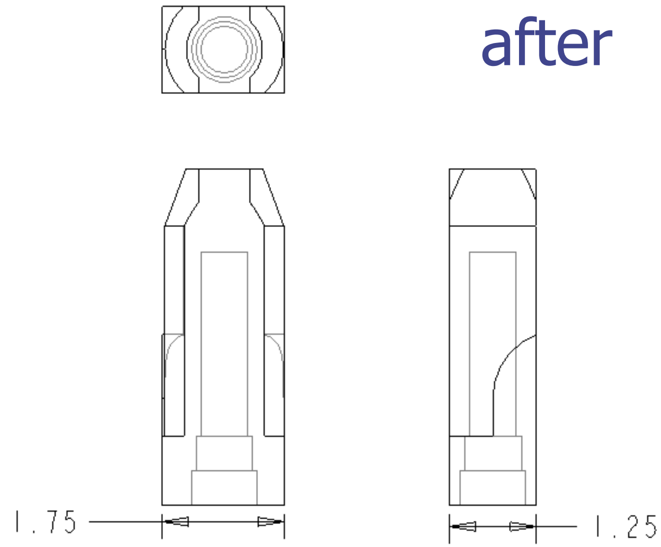


MTS Adapter

Main Bearing Cap

before

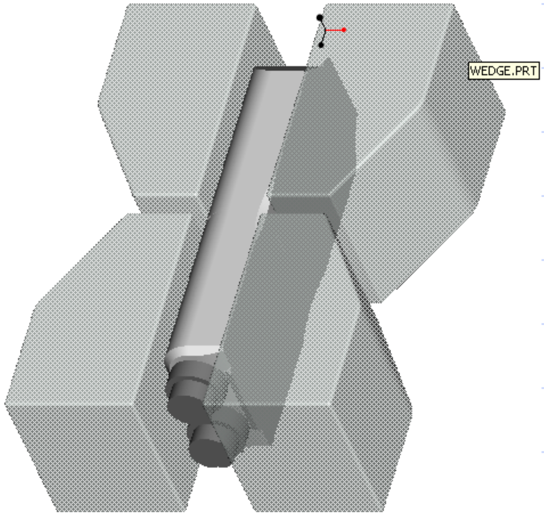




after

Selection for connecting rod

- Based on design matrix, the final design concept is:

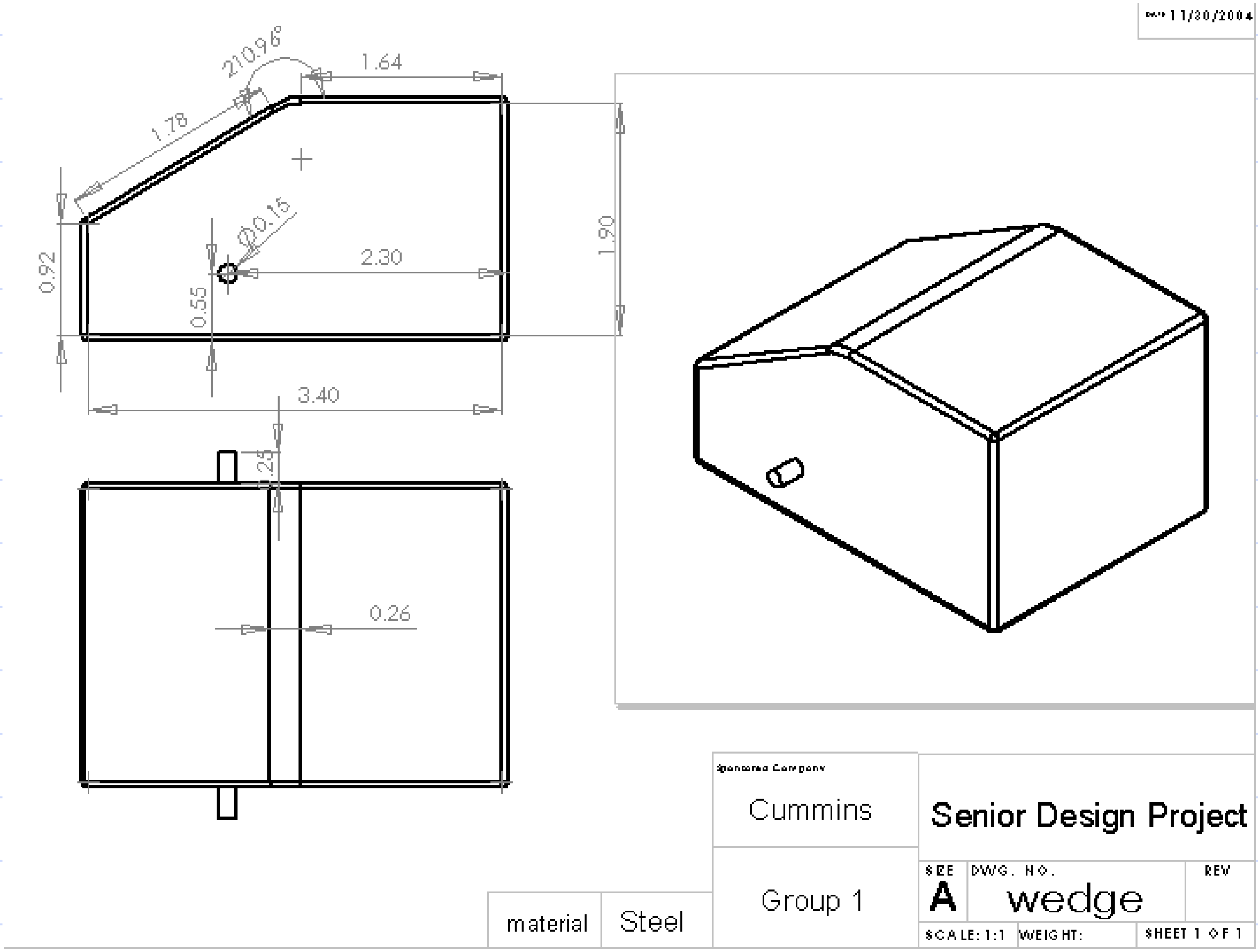


Chosen for ease of manufacturability as well.

Multiple test samples from individual part.

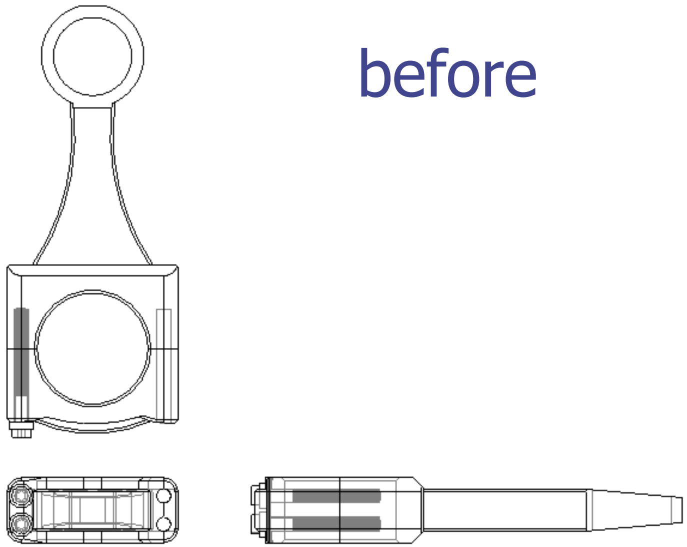
Uses two vice grips for top and bottom connections.

Engineering Drawing / Dimensions of Final Selection (Connecting Rod)

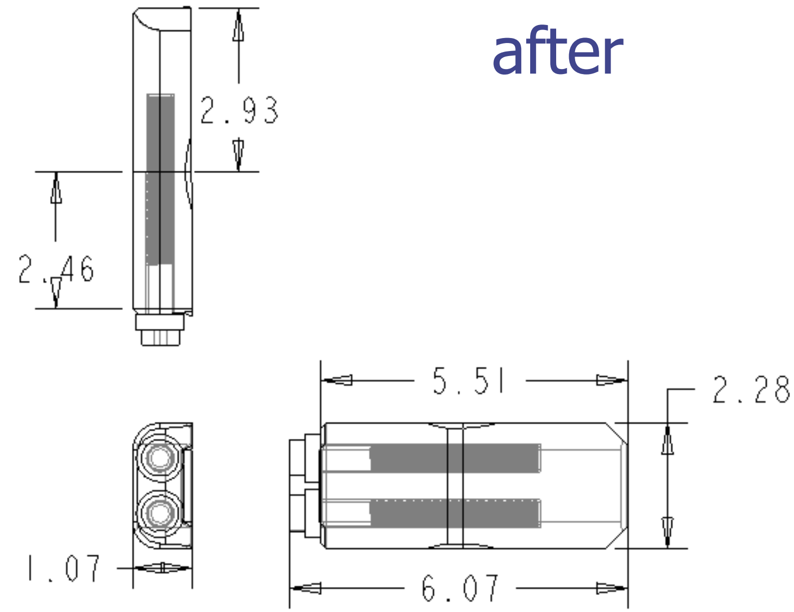


Connecting Rod

before



after



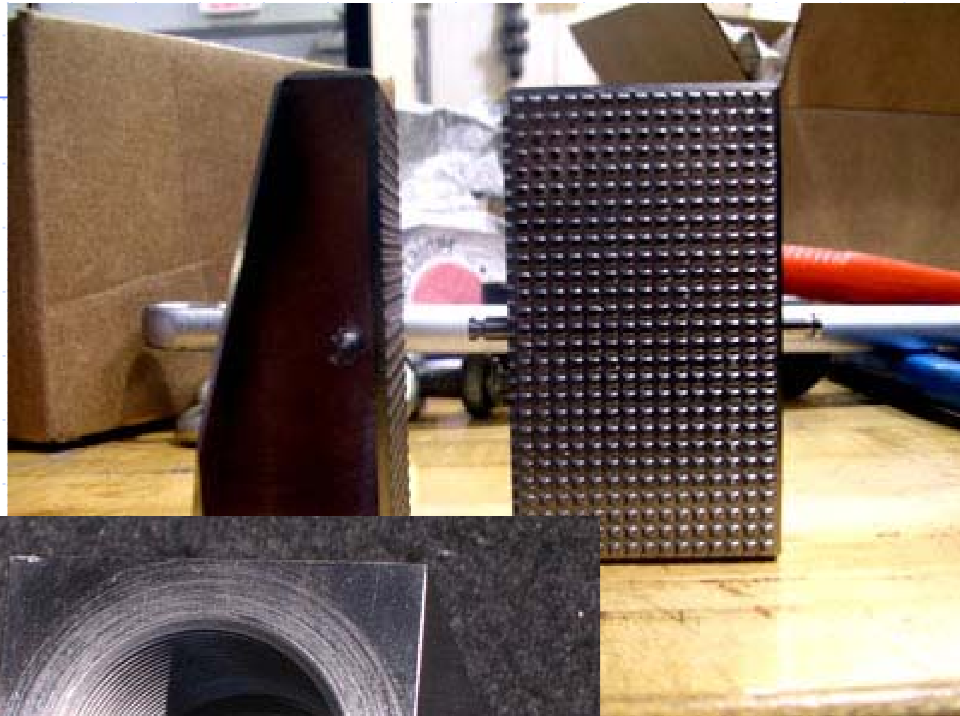
Trip to Bonifay

- Went to Bonifay, Jan 28, 2005
  - Holmes Machine Shop
- Met with Tim Steverson
  - Talked about parts and machining.
  - Minor changes were made
    - Part finishes – save money
    - Material – 4140 HT steel

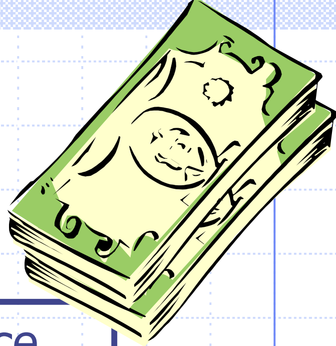
Material and finish changes:

- Wedges
  - 4140 Steel chosen
    - 311 HB (enough for our testing)
    - Available by Holmes Machine Shop
    - Saved time and money
- Finish on Wedges
  - Finish was suggested by Bob Walsh (NHMFL)
    - Not feasible with our time & money constraints
  - Altered by Holmes Machine Shop
    - Adequate finish for our testing

Final Parts



Costs

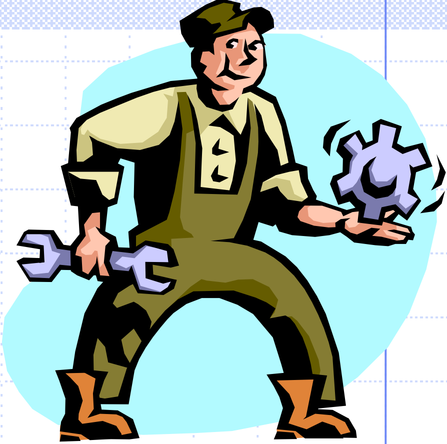


Qty	Description	Unit price	Total price
4	Wedges w/ pins 4140 HT	$250.00	$1,000.00
1	Modify connecting rod	$200.00	$200.00
1	Cylinder for fixture	$125.00	$125.00
1	Square housing for fixture	$300.00	$300.00

Total cost $1625.00

The Engine block samples were machined in the machine shop here at the Engineering School at no cost.

Getting ready for testing



applying torque to bolts:

$$T = k \cdot d \cdot F$$

where T is the torque, k is the torque coefficient, d is the bolt diameter, and F is the preload value

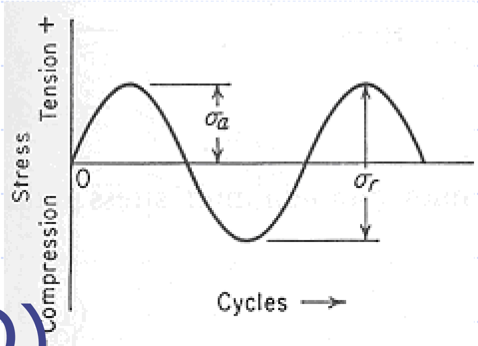
	Connecting Rod	Main Bearing Cap
Pre-Load, F (lbs)	16,000	45,000
Bolt diameter, D (mm)	12	20
Torque coefficient, k	0.21	0.21
Calculated Torque (ft-lbs)	130	620 → 330

Torque

The connecting rods were torqued at the NHMFL, while we had to go to Florida Rock to torque the main bearing cap bolts.

- Testing
  - Four test
- Results
  - Connecting Rod
  - Main Bearing Cap
- Recommendations
  - Test setup
- Conclusion

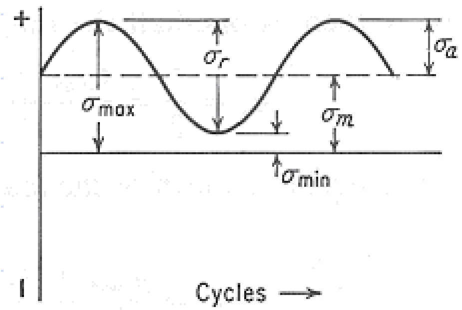
Testing



Connecting Rod Test #1 (REBD)

- Torque applied per bolt 65 lb-ft
- Tension & Compression @ 3 Hz
- Applied load 8,000 lbs
- Amplitude of 16,000 lbs
- Specimen slipped 3 times
- 1.3 million cycles total
- Specimen did not break

Testing

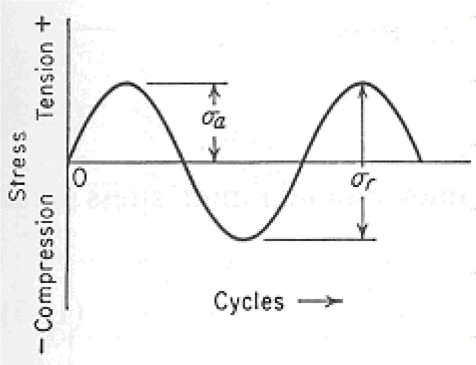


- Connecting Rod Test #2 (JB)
  - Torque applied per bolt 130 lb-ft
  - Tested only in tension @ 3 Hz
  - Initial load 16,000 lbs
  - Final load 24,000 lbs
  - Specimen slipped twice
  - 1 million cycles total
  - Wedge failed.

Testing

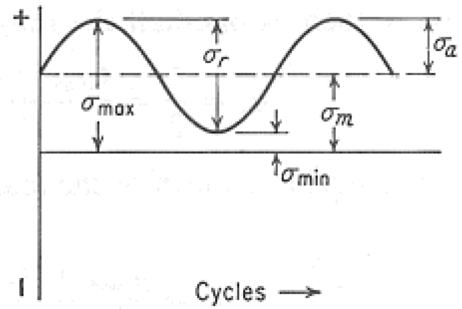
◆Main Bearing Cap Test #3

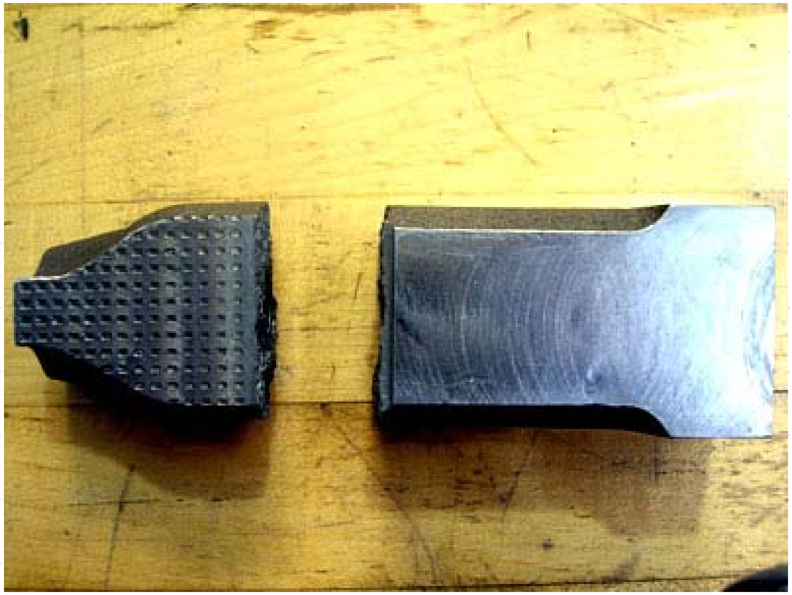
- Engine block was modified
- Torque applied 300 lb-ft
- Tension & Compression @ 2 Hz
- Amplitude of 45,000 lbs
- 1 thousand cycles total
- Specimen failed unexpectedly



Testing

- Main Bearing Cap Test #4
  - Engine block modified
  - Torque applied 330 lb-ft
  - Tension only, @ 2 Hz
  - Amplitude of 22,500 lbs
  - 10 thousand cycles total
  - Specimen failed





Results

- **Connecting Rod**
  - JB tested up to 1.3 million cycles
    - Specimen did not fail
  - REBD tested up to 980,389 cycles
    - Wedge failed

- **Main Bearing Cap**
  - First set up failed at 1,000 cycles
  - Second set up failed at 10,000 cycles

Recommendations

- Make wedges out of harder materials
  - High Carbon Steels
  - Tool Steel
- Decrease the wedges thickness
  - Allows for a larger sample

Conclusions

- Our objectives were;
  - Design a fixture
  - Test & Evaluate threaded joints
- Design process
  - Manufactured test fixture
  - Performed 4 test
    - 2 test on the connecting rod
    - 2 test on the main bearing cap
  - Threads didn't fail

Acknowledgements

- Cummins
  - Bob Tickel
  - Dave Parsons
- Dr. Luongo
- Dr. Kalu
- NHMFL
  - Bob Walsh
  - Chika Okoro
- Holmes Machine Shop
- Keith Larson
- Florida Rock

References

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- Callister, William D. Jr. Material Science and Engineering: An Introduction. New York: John Wiley & Sons Inc, 2003.
- Kalu, Peter. Fatigue of Metals. PowerPoint Presentation, Fall 2003.
- Norton, Robert L. Machine Design: An Integrated Approach. Upper Saddle River, NJ: Prentice Hall, 2000.
- http://www.sv.vt.edu/classes/MSE2094_NoteBook/97ClassProj/anal/kelly/fatigue.html

Questions?