Spring 2019

Fatigue Tester

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Capstone Report

FATIGUE TESTER

Nicholas Fazio | Mechanical Projects | 4/20/2019

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Introduction

What is a mechanical engineer? To me, it's someone who is given a problem or a need and through calculations, logical reasoning and problem-solving skills creates a solution. The problem I was tasked with solving in this course was designing something to showcase my knowledge and experience while attending Akron. My solution was to design a tabletop-sized fatigue tester for cantilever beam specimens of various materials. I decided to take it one step further and build my designed tester to test more of my skills and knowledge I've acquired over the course of my career at Akron. In this report, I will cover the steps I took with the research, calculations, and design, as well as the problems I encountered during the building process and their solutions. I will also conclude with my experiences during this project as well as during my career at Akron and how these experiences helped me complete this project.

RESEARCH

To begin the project, I started to research different fatigue testers supplied by companies to see what components they used and how they tested the specimens. I also researched what the size and shape of specimens used on these machines were. I looked at what the specimens were made from and their properties. The first tester I looked at was made by Instron. The model was a general-purpose hydraulic fatigue tester, more specifically model 8872. This model is "ideal for fatigue and static testing of biomedical, advanced materials, and manufactured components. The T-slot base makes it easy to secure orthopedic specimens, automotive components, and manufacturing assemblies" (Instron). The tester can apply about 25 kN of force or about 5620 lbf. These applications

are not something I would be testing or have the capability to build in my current timeframe. It did, however, give me some idea as to what to consider upon doing further research. I needed to consider what force I was looking to apply as well as what sort of application I wanted to test.

This brought me to my next testing apparatus which is made by Zwick/Roell. This testing apparatus is an Electromechanical Servo Testing Actuator. "These versatile electromechanical servo testing actuators are suitable for tensile and compression applications and can be integrated into testing devices with various configurations. They also enable testing in stages of production (for example, assembling/joining, force fitting, and assembly) and are suitable for long-stroke cyclic fatigue strength tests" (Zwick-Roell). This application of cyclic fatigue strength is more of what I was originally looking for in terms of testing applications. This device can test up to speeds of 30m/min which is more then I believed I would be able to produce for my scale and budget. I didn't have the budget to purchase actuators or the hydraulic pumps or pneumatic connections that might be needed to operate it. However, they do operate with a much lower force than the previous tester. These operate from 1 to 5 kN or about 225 lbf to 1125 lbf. This tells me that if I do a form a cyclic loading, I can use much less weight and force. This got me thinking of other ways I could possibly test fatigue with regards to cyclic conditions.

My research then led me to look at LCF and HCF testers and test conditions to gauge whether this was something that could be possible to replicate in my time frame and budget. According to MTS "High-cycle fatigue (HCF), tests are typically conducted

on smooth bar specimens in force control. These tests determine the number of cycles to fracture for each specimen, and the data can be compiled into stress-life (S-N) curves. Nominal stress levels in HCF tests are generally low — significantly below the material's yield strength. As a result, specimen lives may last tens or hundreds of millions of cycles, creating a need to conduct HCF tests at high frequencies to minimize testing time." The fact that millions of cycles would need to be performed in order to see results is something I wouldn't be able to replicate, or attempt based on my budget and time. MTS also states that "with a conventional (50 Hz) system, running a billion-cycle test takes up to seven months. By increasing system capability to 1000 Hz, the same test can be completed in as few as 11 days". Based on this information I determined that being able to demonstrate this type of testing with this kind of apparatus would take too long even if it were possible for me to build. However, the smooth bar specimen concept gave me an idea for a testing apparatus I may be able to finish within my timeline.

I took this research to my project advisor and discussed the possibility of creating a fatigue testing apparatus using a cantilever beam and some sort of cam to strike the specimen repeatedly. The idea came from my previous course work in the program specifically during my time taking the Statics, and Strength of Materials courses. I remembered having to test the moduli of varying materials by hanging different weights off them and recording the plastic deformation and deflection that occurred. I also remembered using an Instron machine to test the tensile strength of different specimens. The smooth bar specimen reminding me of this testing as that was one of the types of specimens used during the experiments. So, I thought I could combine the two by using a

simple rectangular cantilever, striking it on end repeatedly until deformation or even failure occurred. With approval and some guidance from my advisor I then began researching test specimen sizes and materials.

Researching for test specimens led me to determine that a dog done specimen is what's most commonly used in these types of testing. When the specimen is tested, necking or deformation occurs. As the specimen is stretched this necking then becomes permanent deformation and eventually causes the specimen to rupture (ADMET). For my application, I believe that a dog done specimen will work perfectly for what I need. In my calculations, I considered various sizes and thicknesses so that if just a simple rectangular cantilever needs to be used that will have been considered when the components are assembled for the apparatus. This method will allow specimens to be tested safely and accurately. To determine the size of the specimens I went to the ASTM standards located on Instron's website. According to ASTM "There are five allowable specimen types for ASTM D638 which differ in size depending on the thickness of the specimen and the amount of material available. The most commonly used are Type I specimens, which are 3.2 mm thick and are generally created by injection molding. Type I specimens have an overall length of 165 mm and width of 13 mm, with a gauge length of 50 mm. Flat specimens are typically molded, die-cut, or machined into a "dogbone" or "dumbbell" shape, which ensures that the break occurs in the center of the specimen rather than at the clamping areas". Based on this information I determined that I would design the testing apparatus for specimens ranging from a length of 7" to 9" and thickness of ¼" to ½". These standards are designed for polymers and plastics, so I added a little room since

I will be using metals and alloys instead. This concluded my research portion of the project and lead me to the design and building phases.

DESIGN

I started my calculations portion of the project by referring to my *Machine Elements in Mechanical Design* textbook for equations and formulas to help guide me with how to start designing. Using the book, I was able to determine the stress I needed to introduce to each beam based on the material ($\sigma b = \frac{Mc}{I}$) Mc is determined by rearranging the previous equation into $Mc = \sigma b * I$ and using the desired thickness of the material as well as its tensile strength. However, before this equation could be used the moment of inertia for each beam needed to be determined by using the equation $I = \frac{BH^3}{12}$ where I is the moment of inertia, B is the base of the material, and H is the height of the material. Once this was determined the next equation $P = \frac{M}{l} * \frac{t}{2}$ were p is the force, and t is the thickness, was used to determine the weight the cam would need to be to cause the desired deflection based on the thickness of the specimen. Then the equation $\Delta Y = \frac{p*L}{3EI}$ where E is the modulus of elasticity, was used to determine the length the cam would need to be at that weight to cause the needed deflection. These steps and equations were used repeatedly for each different specimen and material considered. These can be seen in Appendix 1 of this report. Using these equations, I determined that using a 1 ½ in cam with a weight of around 1 ½ pounds would be sufficient to cause the stress needed in all material and sizes that were calculated. The next step was to design the cam and specimens using 3d modeling software. These drawings can be seen in

Appendix 2 of this report. The next step was to determine what size motor and rpm would be needed to move this cam to cause the stress needed. I used the horsepower equation $HP = \frac{T*RPM}{63{,}025}$ to determine what horsepower would be needed to spin the cam. T was just the weight of the same multiplied by its length. I used Grainger to compare typically ac and dc motors and see what rpm range they operated in. I determined the around 2250 RPM would be more than enough for my applications and that an ac motor would be better. Based on this I determined that at least a 1/3 HP motor would be required for operation. These calculations can also be found in Appendix 1 of this report. Once the parts were designed that needed to be made and the parts that needed to be bought were chosen, I began building the test apparatus.

BUILD

To start the building phase of this project I needed to determine what I was going to use for the base. I originally planned on using a plate of steel but realized that would be much too heavy for a tabletop application that needed to be generally mobile. My next thought was to use a plate of aluminum as the metal is much lighter than steel. However, I encountered an issue with this base material as well. The sheets available for purchase were very thing. This meant I would need to attach multiple sheets together to fasten the motor and other components to the base. This method would not have only been expensive but time-consuming as well. The other problem with both these solutions was that I would have to drill and tap the holes which is time-consuming. It also wouldn't allow for correction if the holes were slightly off or if modifications needed to be made

further down the line. So, I untimely decided on using wooden boards as they were cheap and much easier to thread and tighten fasteners into.

With the boards measured and cut I began assembling the components onto the base. I decided upon repurposing a bench grinder and using JB weld to attach the cam to one of the shafts on the grinder. I chose a bench vice as a means for holding the test specimens during operation. My thought behind the bench grinder was that the grinding wheel on the opposite side would help balance out the machine as the cam would introduce an imbalance. This was not enough to stop the shaking from the imbalance. The first test run caused part of the motor to snap off the base, so I had to repair it before being able to test it again. To fix this issue I designed counterweights that were the same shape and size of the grind wheel but had them laser cut out of plates of steel. This helped correct the problem but didn't satisfy me during its operation as I thought the apparatus still shook too much. My next thought was to somehow slow down the motor so that the shaking would subside. To do this I purchased a variable router speed control and attached it in series with the motor. This allowed me to slow down the motor and adjust its speed according to different materials. This solution stopped the shaking in the motor, but the base still moved a little due to the vibrations. The solution for this problem was simply putting rubber stops on the base to keep the stand from sliding during operation. Once this was done, I measured the distance I needed my bench vice to be from the cam and attached it to the base. The next problem was figuring out how to count the number of strikes the cam applied to each test specimen. I originally planned on using some sort of mechanical counter. Like a ratchet counter or some sort of tick counter. However, the

problem with this was that the best one I could find was relatively expensive and was only rated for 500 counts per minute. The tester at a minimum would need to go about 1500 rpm so this solution was not feasible. Then I looked into photo eye and laser counters these could handle the number of revolutions I needed. The problem with these is that they were very expensive and require some sort of circuit board and an additional power source. This would add even more costs to the project, so these were not an option currently. My solution was to use a simple tachometer to measure the rpm of the shaft and simply set a timer and multiply the two numbers together at the end to figure out the number of strikes that were applied to the specimen. This is not my ideal solution to the problem but will solve my current needs. Down the line, a photo eye may be added to make the process easier. The apparatus and its components can be seen in Appendix 3 of this report.

CONCLUSION

This project has encompassed all I have learned while attending the University of Akron. I was given a problem and tasked with coming up with a solution to it. The problem is designing something to showcase my knowledge and experience while attending Akron. My solution was to design and build a tabletop-sized fatigue tester to test cantilever beam specimens of various materials. During this process, I was able to not only apply the skills and knowledge I have learned throughout my career but was also able to learn more along the way. The research portion of the project was where I learned the most. Looking into standards, machines, and material properties was informative and enjoyable. The technical report writing course helped me during this process of the

project. The course taught me how to translate complex or in-depth ideas and processes of what I was looking at. This allowed me to accurately and effectively research what I needed to effectively design and complete the project. The design and build portions of the project allowed me to use my problem-solving skills to create a solution to my problem. Designing and locating the components was challenging yet rewarding. Being able to use my skills to design and fabricate components and assemble them was a new experience for me. I've designed many things before this course but never had the chance to build and test them. Building allowed me to diagnose problems I was unaware of or that I didn't consider during the design process. This allowed me to alter and completely redesign components to make it work. The skills I used for this portion were acquired during my time in Mechanical Design one and two. In these courses, you get your first test of designing specific things like gears, shafts, bearings, and beams based on specific design criteria. These skills allowed me to design the test specimens and cams for the project.

Overall this course was the best experience of my college career as it allowed me to independently work on and complete a project while balancing a full-time workload. It gave me an experience of what it is like working as an engineer. I was able to use all my current knowledge and skills to solve a problem by designing a solution. I hope to continue to use the skills and knowledge from this course and all my previous courses as well as acquiring new knowledge and skills as I advance and further my career as an engineer.

APPENDIX 1 CALCS

P.g 173

Endurance Limit

S_u = ultimate tensile strength

Medium Carbon Steel — 48 ksi @ 5×10^6 cycles
Heat-treated alloy steel — 83 ksi @ 5×10^5 cycles

Endurance Strength $(0.50 \times S_u)$

1020 Hot rolled

$E = 30\times10^6$ psi

30×10^3 ksi

$\sigma_b = \dfrac{M_c}{I_c} \Rightarrow M_c = (.5\times 55\text{ ksi})\cdot 0.583 = 16.03$

$M_c = P\times L\left(\dfrac{t}{2}\right) \Rightarrow P = M/L\left(\dfrac{t}{2}\right) \Rightarrow 16.03/7\left(\dfrac{.5}{2}\right) = 0.573$ force

$I_c = \dfrac{BH^3}{12} \Rightarrow \dfrac{7''(1''^3)}{12} = 0.583''$

$\Delta Y = \dfrac{P\cdot L^3}{3EI_c} \Rightarrow \dfrac{0.573\cdot 7^3}{3\cdot 30\times10^3\cdot 0.583} = 0.0037$ deflection

Correct

1117 Hot rolled

$\sigma_b = M_c/I_c \Rightarrow (.5\times 62\text{ ksi})\cdot 0.583 = 18.1$

$M_c = P\times L\left(\dfrac{t}{2}\right) \Rightarrow P = 18.1/7\cdot\left(\dfrac{.5}{2}\right) = .646$

$\Delta Y = \dfrac{.646\cdot 7^3}{3\cdot 30\times10^3\cdot 0.583} = 0.0042$

1340 Annealed

$\sigma_b = (.5\times 102)\cdot 0.583 = 29.7$

$M = P\times L \Rightarrow P = 29.7/7\cdot\left(\dfrac{.5}{2}\right) = 1.06$

$\Delta Y = \dfrac{1.06\cdot 7^3}{3\cdot 30\times10^3\cdot 0.583} = 0.0069$

Size: 1" x 7" x 1/4"

1020 Hot rolled

$$\sigma_b = \frac{Mc}{I} \Rightarrow Mc = (1/4 \cdot 55\,ksi) \cdot 0.583 = 8.016$$

$$Mc = PxL\left(\frac{t}{2}\right) \Rightarrow P = \frac{M}{L}\left(\frac{t}{2}\right) = \frac{8.016}{7}\left(\frac{1/4}{2}\right) = 0.143$$

$$I = \frac{BH^3}{12} \Rightarrow \frac{7''(1'')^3}{12} = 0.583$$

$$\Delta Y = \frac{P \cdot L^3}{3EI} \Rightarrow \frac{0.143 \cdot 7^3}{3 \cdot 30 \times 10^3 \cdot 0.583} = 9.34 \times 10^{-4}\,''$$

(0.000934)

Aluminum 6061

$E = 10 \times 10^6$ psi

10×10^3 ksi

$$\sigma_b = (1/4 \cdot 45\,ksi) \cdot 0.583 = 6.56$$

$$P = \frac{6.56}{7}\left(\frac{.25}{2}\right) = 0.117$$

$$\Delta Y = \frac{0.117 \cdot 7^3}{3 \cdot 10 \times 10^3 \cdot 0.583} = 0.0023$$

$1'' \times 7'' \times \frac{1}{2}''$

Aluminum 6061

$\sigma_b = (1/2 \times 45) \cdot 0.583 = 13.11$

$P = \frac{13.11}{7} \cdot \frac{1/3}{2} = 0.468$

$\Delta Y = \frac{0.468 \cdot 7^3}{3 \cdot 10 \times 10^3 \cdot 0.583} = 0.0092$

Aluminum 6061

Size $\frac{1}{2}'' \times 7'' \times \frac{1}{2}''$

$\sigma_b = (1/2 \times 45) \cdot 0.073 = 1.64$

$I = \frac{BH^3}{12} \Rightarrow \frac{7 \times (.5)^3}{12} = 0.073$

$P = \frac{1.64}{7} \cdot \frac{1/3}{2} = 0.058$

$\Delta Y = \frac{0.058 \cdot 7^3}{3 \cdot 10 \times 10^3 \cdot 0.073} = 0.0091$

$\frac{1}{2} \times 9 \times \frac{1}{2}$

Aluminum 6061

$\sigma_b = (1/2 \times 45) \cdot .093 = 2.09$

$I = \frac{9 \cdot (\frac{1}{2})^3}{12} = 0.093$

$P_L = \frac{2.09}{9} \cdot \frac{1/2}{2} = 0.058$

$\Delta Y = \frac{0.058 \cdot 9^3}{3 \cdot 10 \times 10^3 \cdot .093} = 0.00013$

Steel 1020 Hot rolled

$\sigma_b = (1/2 \times 55) \cdot 093 = 2.56$

$P_L = \frac{2.56}{9} \cdot \frac{1/2}{2} = 0.071$

$\Delta Y = \frac{0.071 \cdot 9^3}{3 \cdot 30 \times 10^3 \cdot 093} = 0.006$

Aluminum 6063

$\sigma_b = (1/2 \times 27) \cdot .093 = 1.26$

$P = \frac{1.26}{9} \times \frac{1/2}{2} = 0.035$

$\Delta Y = \frac{.035 \cdot 9^3}{3 \cdot 10 \times 10^3 \cdot 093} = 0.0091$

$\frac{1}{2} \times 9 \times \frac{1}{2}$

Brass (half-hard)

E= 17 x 10^3 ksi

$\sigma_b = (1/2 \times 58 \text{ ksi}) \cdot .093 = 2.697$

$I = \frac{9 \cdot (\frac{1}{2})^3}{12} = 0.093$

$P = \frac{2.697}{9} \cdot \frac{1/2}{2} = 0.075$

$\Delta Y = \frac{0.075 \cdot 9^3}{3 \times 17 \times 10^3 \cdot 0.093} = 0.0115$

$1/2 \times 9 \times \frac{1}{4}$

$\sigma_b = (.25 \times 58) \cdot 0.093 = 1.35$

$I = \frac{9 \cdot (\frac{1}{2})^3}{12} = 0.093$

$P = \frac{1.35}{9} \cdot \frac{1/4}{2} = 0.0188$

$\Delta Y = \frac{0.0188 \cdot 9^3}{3 \times 17 \times 10^3 \cdot 0.093} = 0.0023$

Brass (half-hard)

$1 \times 7 \times \frac{1}{2}$

$\sigma_b = (\frac{1}{2} \times 58\,ksi) \cdot 0.583 = 16.91$

$I = \frac{7 \times (1)^3}{12} = 0.583$

$P = \frac{16.19}{7} \cdot \frac{1/2}{2} = 0.604$

$\Delta Y = \frac{0.604 \cdot 7^3}{3 \times 17 \times 10^3 \cdot 0.583} = 0.007$

Copper

$E = 30.5 \times 10^3$ ksi

$1 \times 9 \times \frac{1}{2}$

$\sigma_b = (\frac{1}{2} \times 48\,ksi) \cdot 0.75 = 18$

$I = \frac{9 \cdot (1)^3}{12} = 0.75$

$P = \frac{18}{9} \cdot \frac{1/2}{2} = 0.5$

$\Delta Y = \frac{0.5 \cdot 9^3}{3 \times 30.5 \times 10^3 \cdot 0.75} = 0.0053$

$1/2 \times 9 \times 1/2$

Copper

$$\sigma_b = (1/2 \times 58) \cdot 0.093 = 2.697$$

$$I = \frac{9 \cdot 1/2^3}{12} = 0.093$$

$$P = \frac{2.697}{9} \times \frac{1/2}{2} = 0.0749$$

$$\Delta Y = \frac{0.0749 \cdot 9^3}{3 \times 30.5 \times 10^3 \times 0.093} = 0.0064$$

Bronze

$E = 15 \times 10^3$ ksi

$$\sigma_b = (1/2 \cdot 63 \text{ ksi}) \cdot 0.093 = 2.930$$

$$I = \frac{9 \cdot 1/2^3}{12} = 0.093$$

$$P = \frac{2.93}{9} \times \frac{1/2}{2} = 0.366$$

$$\Delta Y = \frac{0.366 \cdot 9^3}{3 \times 15 \times 10^3 \times 0.093} = 0.0637$$

$1 \times 9 \times 1/2$

$$\sigma_b = (1/2 \times 63) \cdot 0.75 = 23.63$$

$$P = \frac{23.63}{9} \cdot \frac{1/2}{2} = 0.656$$

$$\Delta Y = \frac{0.656 \cdot 9^3}{3 \times 15 \times 10^3 \times 0.75} = 0.0142$$

Motor Calculations

$$Hp = \frac{T \times RPM}{63{,}025 \text{ in-lbs}} \quad , \quad T = F \times R \qquad R = \emptyset \text{ cam circle} + \text{cam Length}$$

$$T = 1.06 \text{ lb} \times 1.5 \text{in} = 1.59$$

$$Hp = \frac{1.59 \times 3000}{63{,}025} = 0.075 \text{ Hp}$$

$$Hp = \frac{1.59 \times 1725}{63025} = 0.044 \text{ Hp}$$

$$Hp = \frac{1.59 \times 2250}{63025} = 0.058 \text{ Hp}$$

$$T = 2 \text{ lb} \times 1.5 \text{in} = 3$$

$$Hp = \frac{3 \times 3000}{63{,}025} = 0.143$$

$$Hp = \frac{3 \times 1725}{63{,}025} = 0.082$$

$$Hp = \frac{3 \times 2250}{63{,}025} = 0.107$$

$$T = 1.5\,lb \times 1\,in = 1.5\ in{\cdot}lb$$

$$Hp = \frac{1.5 \times 3000}{63{,}025} = 0.071$$

$$Hp = \frac{1.5 \times 1725}{63{,}025} = 0.041$$

$$Hp = \frac{1.5 \times 2350}{63{,}025} = 0.054$$

$$T = 3\,lb \times 1.5\,in = 4.5\ in{\cdot}lb$$

$$Hp = \frac{4.5 \times 3000}{63{,}025} = 0.214$$

$$Hp = \frac{4.5 \times 1725}{63{,}025} = 0.123$$

$$Hp = \frac{4.5 \times 2350}{63{,}025} = 0.161$$

$$T = 2\,lb \times 2\,in = 4\ in{\cdot}lb$$

$$Hp = \frac{4 \times 3000}{63{,}025} = 0.190$$

$$Hp = \frac{4 \times 1725}{63{,}025} = 0.109$$

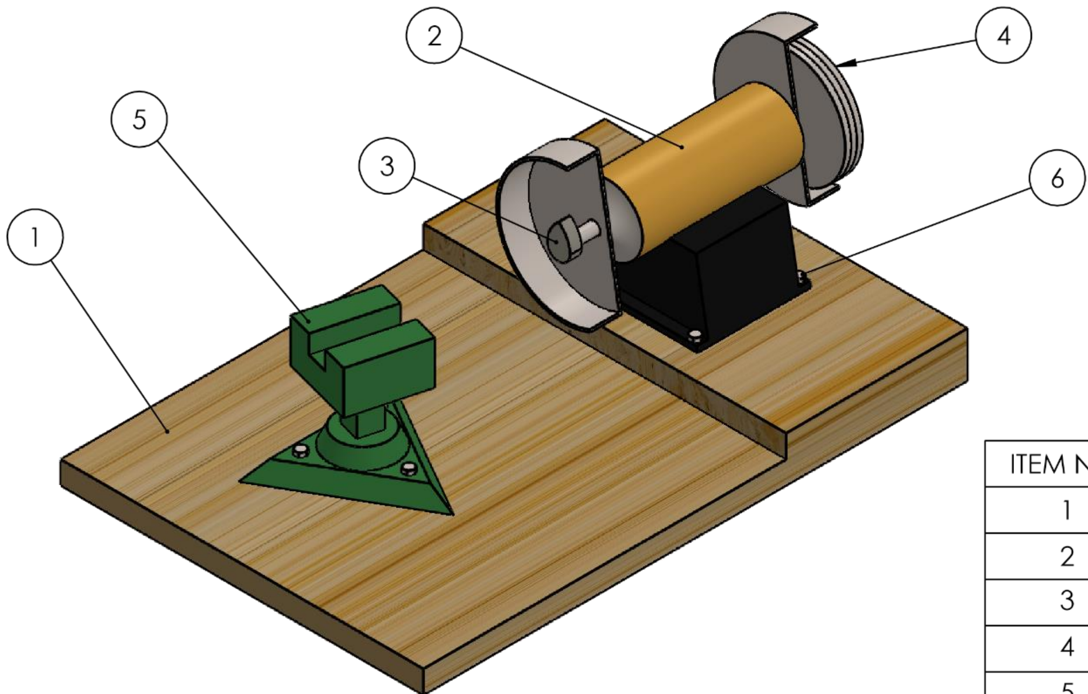
$$Hp = \frac{4 \times 2250}{63{,}025} = 0.143$$

$$T = 3lb \times 2in = 6 \text{ in-lb}$$

$$Hp = \frac{6 \times 3000}{63{,}025} = 0.286$$

$$Hp = \frac{6 \times 1725}{63{,}025} = 0.164$$

$$Hp = \frac{6 \times 2250}{63{,}025} = 0.214$$



ITEM NO.	PART NUMBER	QTY.
1	Base	1
2	Grinder_Motor	1
3	Cam Design 2	1
4	Counter Weight	3
5	Vice_Clamp	1
6	HBOLT 0.2500-28x0.25x1.25-N	7

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NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

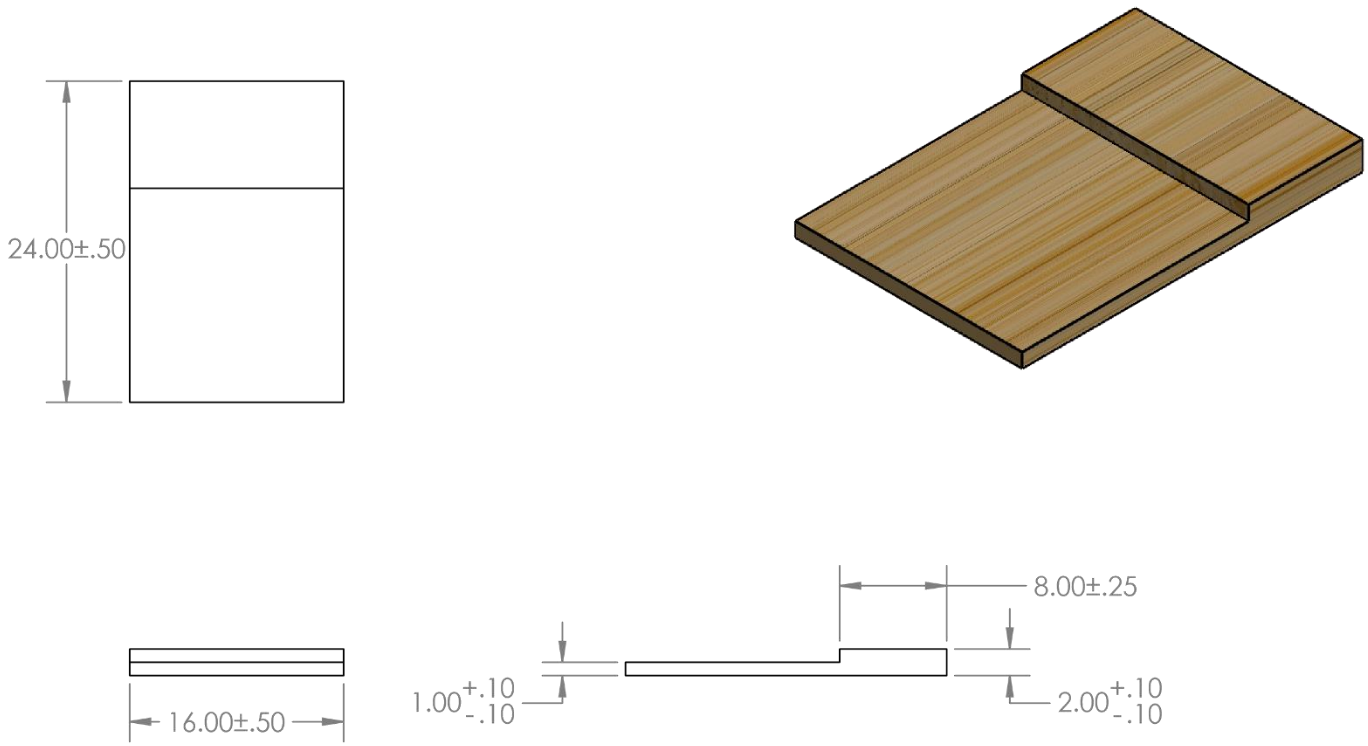
COMMENTS:

TITLE:

Assembly

SIZE **A** | DWG. NO. Fatigue Tester Assembly | REV

SCALE: 1:8 | WEIGHT: | SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

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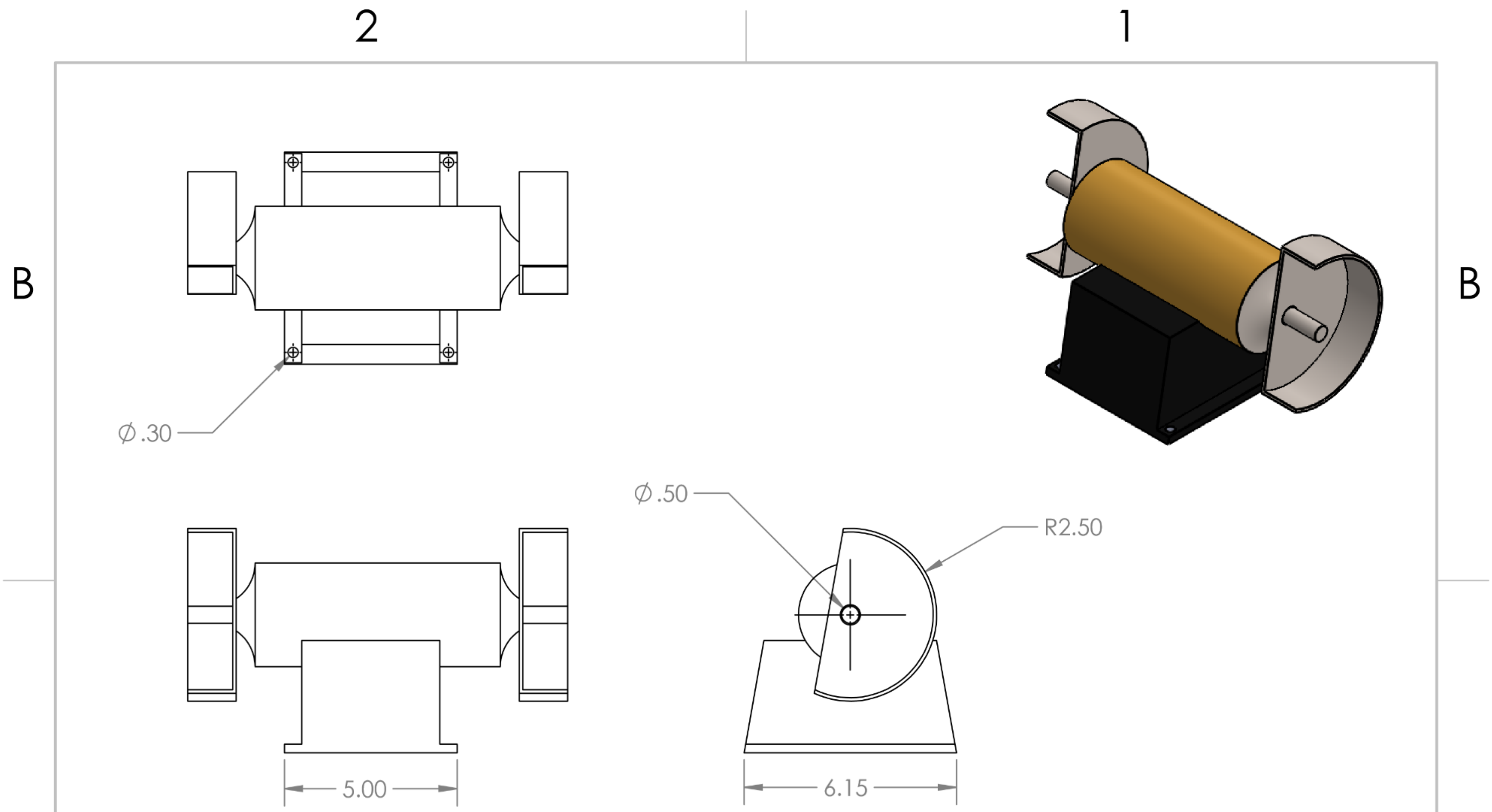

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Multiple

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

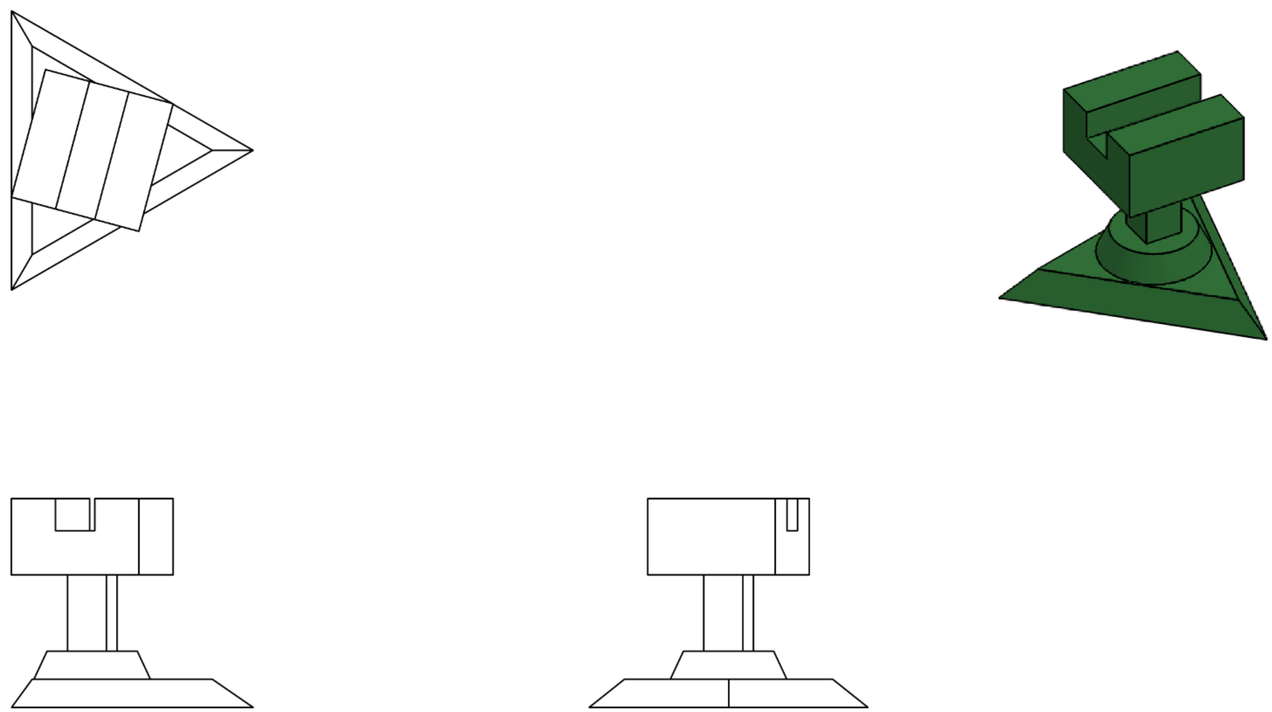
COMMENTS: purchased from Harbor Freight

TITLE:

Fatigue Tester

SIZE A | DWG. NO. Grinder_Motor | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL Various

FINISH

DO NOT SCALE DRAWING

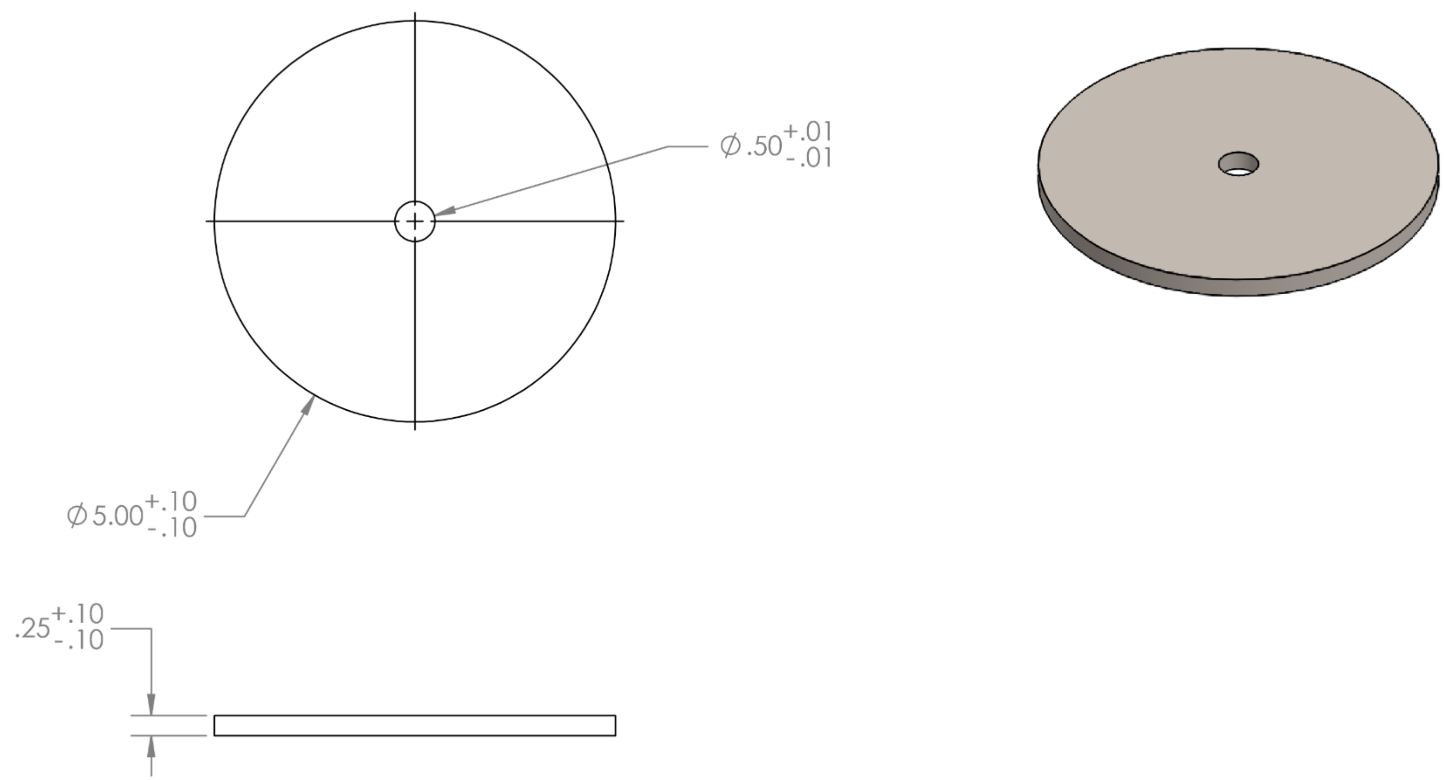
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: purchased at Harbor Freight

TITLE:
Fatigue Tester

SIZE	DWG. NO.	REV
A	Vice_Clamp	

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Steel

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

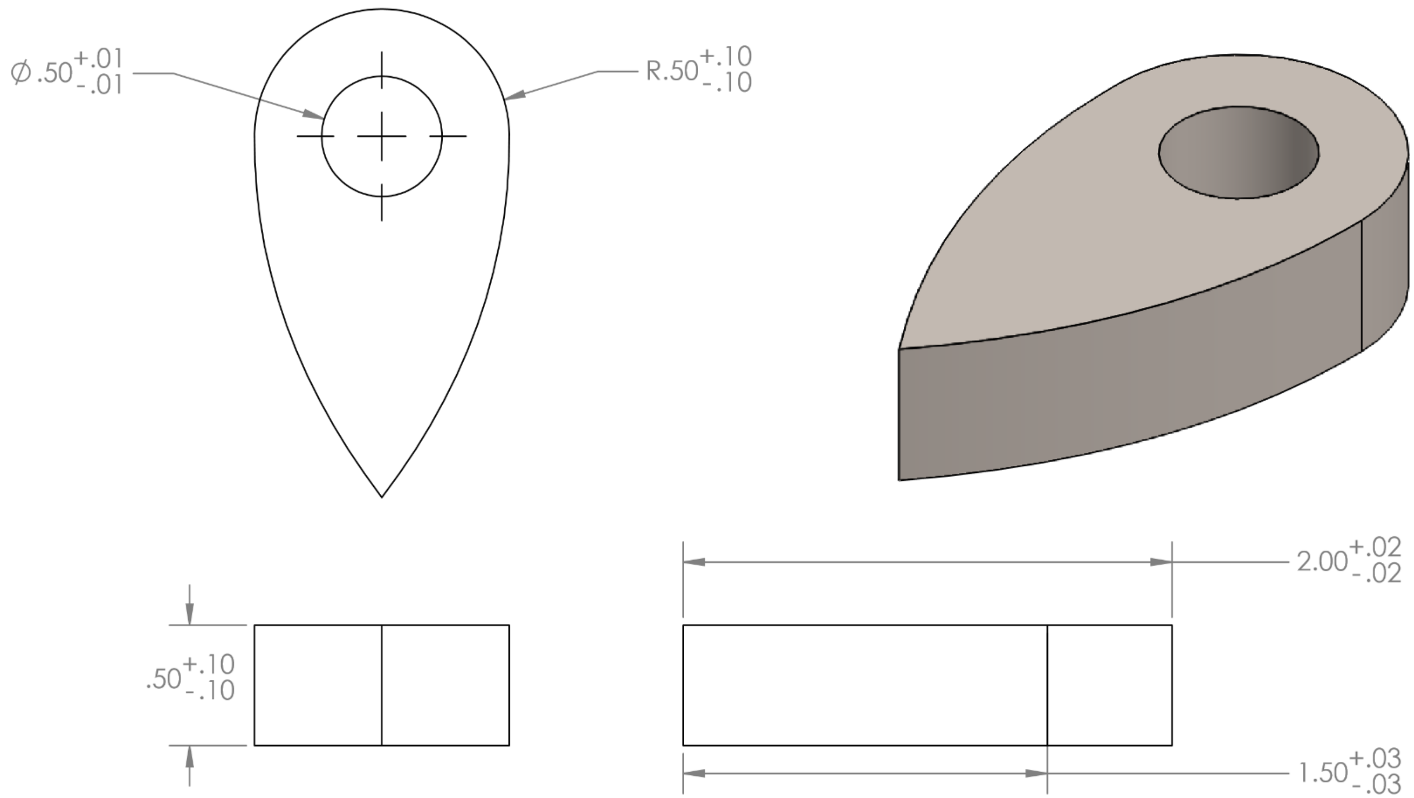
COMMENTS: Laser cut from 1045 cold drawn steel

TITLE:

Fatigue Tester

SIZE: A | DWG. NO.: Counter Weight | REV

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: Fatigue Tester
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL Steel	COMMENTS: Machined from 1020 cold drawn steel			SIZE A DWG. NO. Cam Design 1 REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	

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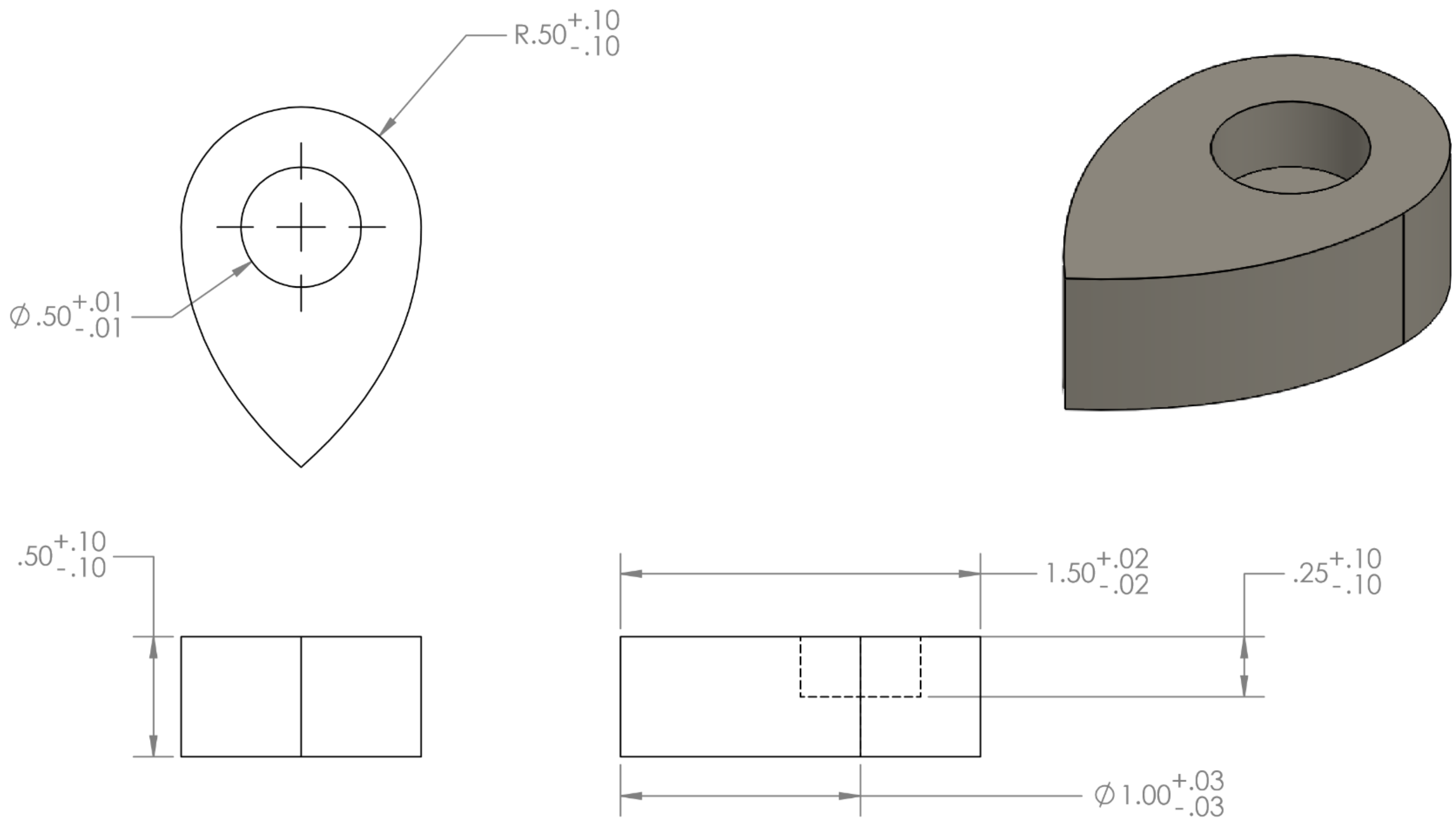


NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Steel

FINISH

DO NOT SCALE DRAWING

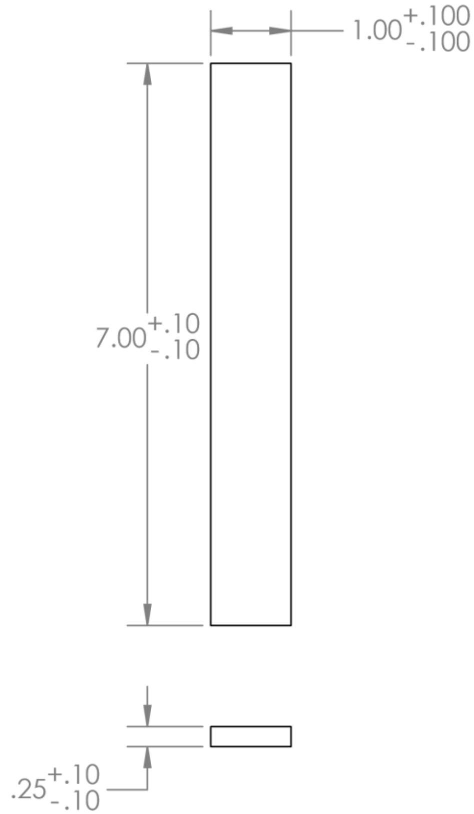
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

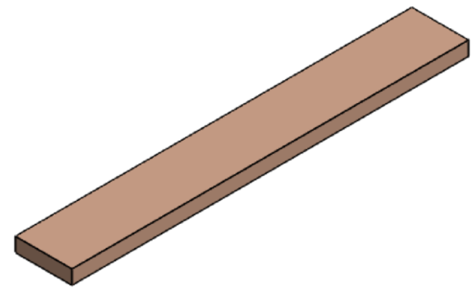
COMMENTS: machined from 1020 cold drawn steel

TITLE:
Fatigue Tester

SIZE **A** DWG. NO. Cam Design 2 REV

SCALE: 2:1 WEIGHT: SHEET 1 OF 1





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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Various

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: can be machined out of Aluminum 6061, 6063 or steel 1020, 1117 hot rolled 1340 annealed or Brass half-hard or Copper or Bronze or any materials with somilar properties and same dimensions

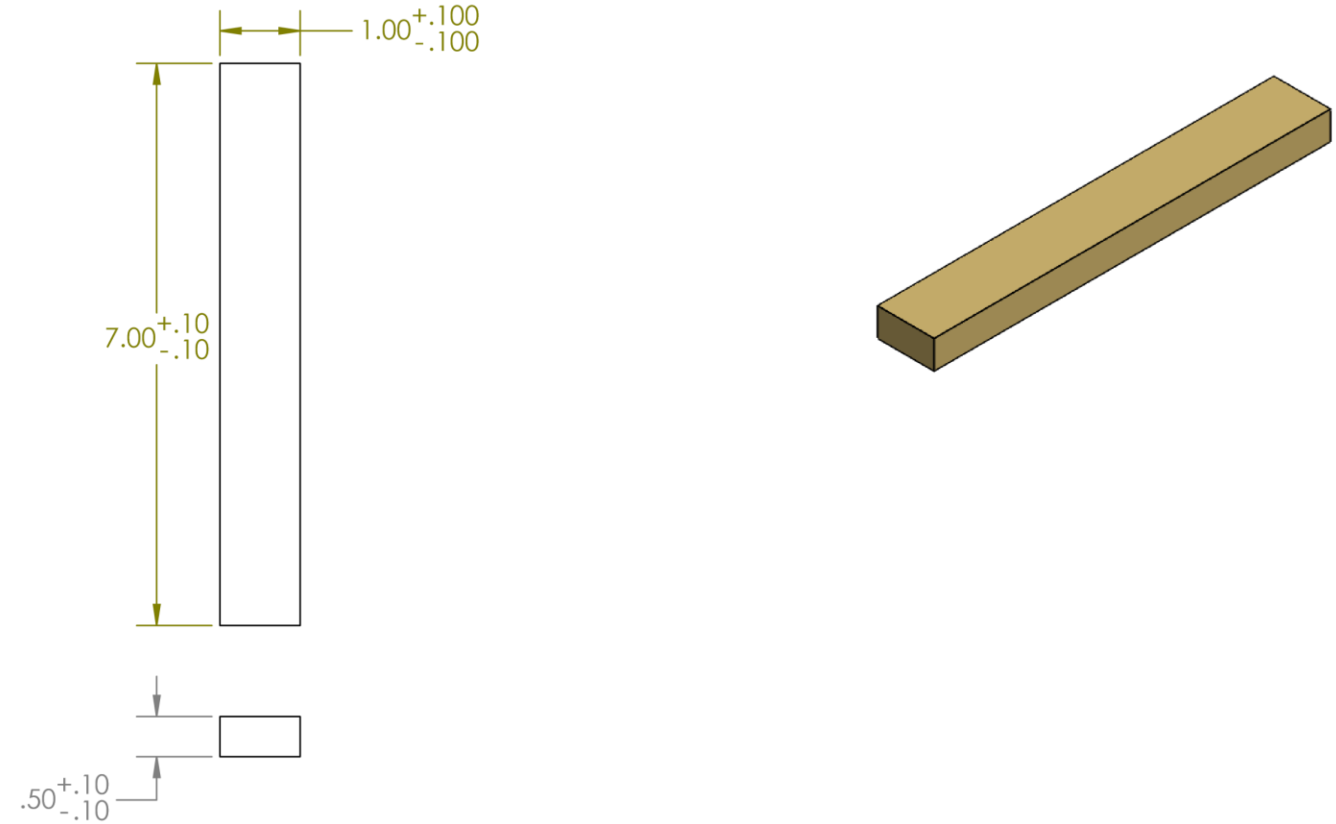
TITLE: **Fatigue Tester**

SIZE	DWG. NO.	REV
A	Test Specimen 1	

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

2 1

B B



A A

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Various

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: can be machined out of Aluminum 6061, 6063 or steel 1020, 1117 hot rolled 1340 annealed or Brass half-hard or Copper or Bronze or any materials with somilar properties and same dimensions

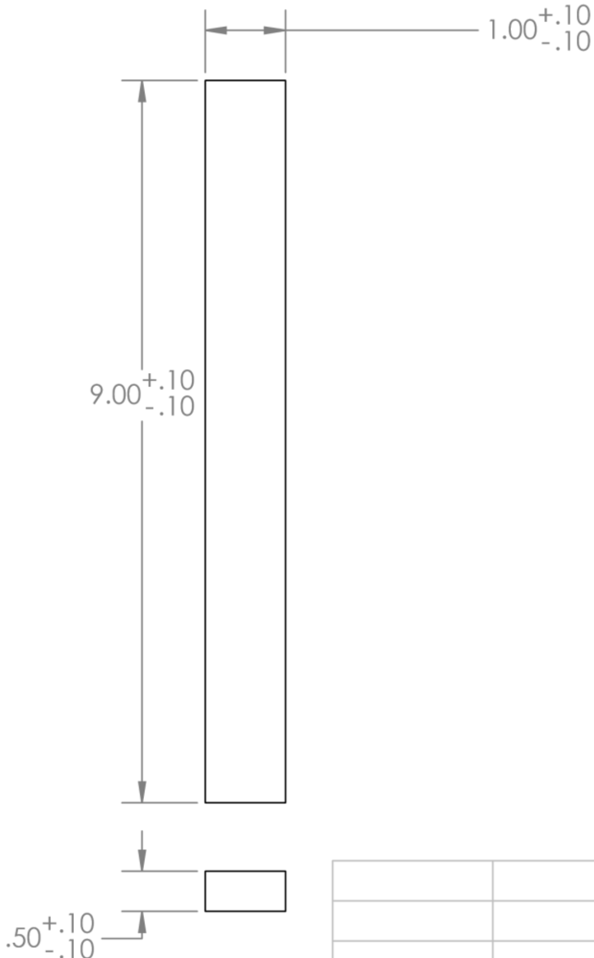
TITLE:

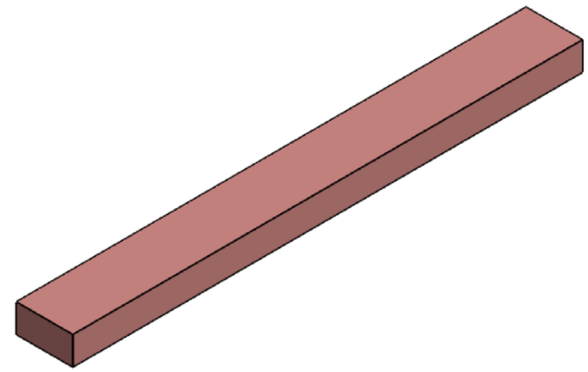
Fatigue Tester

SIZE	DWG. NO.	REV
A	Test Specimen 2	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 1





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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Various

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS: can be machined out of Aluminum 6061, 6063 or steel 1020, 1117 hot rolled 1340 annealed or Brass half-hard or Copper or Bronze or any materials with somilar properties and same dimensions

TITLE:
Fatigue Tester

SIZE A | DWG. NO. Test Specimen 3 | REV

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

APPENDIX 3 PICTURES


CENTRAL MACHINERY
5" BENCH GRINDER
ITEM 94186
120 V~,60 Hz, 1/2" Arbor, 3,450 RPM
WARNING
To prevent serious injury:


CENTRAL MACHINERY
5" BENCH GRINDER
ITEM 94186
120 V~,60 Hz, 1/2" Arbor, 3,450 RPM
WARNING
To prevent serious injury:
VAR OFF FULL
INPUT V. 120V
MAX A. 15 A

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