Shear Stress Sensor Design

EML 4552C-Senior Design- Spring 2013

DESIGN OF MANUFACTURING, RELIABILITY, & COST

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Manufacturing Process Selection

There are only four necessary manufacturing components needed for the creation of the testing apparatus; a water jet, mill, CNC mill, and a lathe. The first necessary manufacturing component is a computer controlled water jet. The water jet cuts through thick metal with the extreme speed and precision but only in one dimension and all cuts are “through” cuts. It’s best used when a component needs to be made from a larger piece of material or the component needs to be manufactured to high tolerances. The baseplate is the most important component of the entire assembly. An out of place mounting point for the motor block, bearing tower, measurement circle, light holder arm, or sensor holder arm will result in the baseplate being useless because all of these components are dependent on each other for accuracy. A water jet cuts the overall shape of the baseplate which would take more time on a mill and makes all of the mounting holes based on the CAD model which is the most accurate form of the design; resulting in a process that mitigates the chance of human error. All of the components manufactured were initially cut in one dimension using a water jet.

A mill with digital position readout was used to make the components that required machining in more than one dimension. These components were first given their initial shape in the water jet but require machining on more than once face or cuts that aren’t “through” cuts. The mill also allows accurate threading of non-cylindrical components. The mounting hole can be made and then the tap applied without any x or y axis movement of the component or tool. The mill can also make large extrudes by moving the table that the component is on and varying the height of the cutting tool.

A CNC mill was used for the bottom shear block piece which required very precise machining. A CNC mill could replace the job of the mill but due to the simplicity of the parts that require a mill and the limited quantities needed; a mill is less time consuming than a CNC mill. These pieces are very thin and need to be a specific thickness so they don’t cause the shear block to be taller or shorted, which will cause an unequal pressure on the liquid crystals once linear motion is applied to the shear block. The “U’ shape of one of the shear blocks required the precision of the CNC mill because the depth of the “U” shape was only 0.04”

The load to shear rod and the adapter for the new load cell both are cylindrical which means that they need to be made on a lathe. A lathe allows for the sculpting of cylindrical work and the addition of threads to the work can be made in the absolute center of the work due to the nature of a lathes construction. The load to shear rod and the adapter for the new load cell both require this level of precision because an uneven rod or adapter will result in the uniaxial linear motion needed being in more than just one axis.

Selection Process of Material Type

Selection of material for the apparatus was straight forward. The apparatus needed to support its own weight and be able to handle 10N or less in the lateral direction. Any standard metal could handle the stress of the system but aluminum was chosen because it is cheap, easily machinable, and some stock aluminum was already available from previous projects.

Decision on Where to Make Parts

The FSU-FAMU College of Engineering machine shop was selected as the location to make the parts for the testing apparatus. The FSU-FAMU College of Engineering machine shop has a water jet, mill, CNC mill, and lathe as well as two machinists. The machines and the time of the machinists is provided free of charge to the students. Lag time was minimized because the machining of all components was done in the fall semester when the machine shop isn't overly busy.

Bill of Materials and Product Specifications

Bill of Manufactured Materials	
Part	**Quantity**
Baseplate	1
Motor Block	1
Arm Pin	2
Arm	1
Measurement Circle	2
Bearing Tower	1
8020-1515 Structural Aluminum	3
Load to Shear Rod	1
Load Cell Adapter Rod	1
Shear Block Top	1
Shear Block Middle	1
Shear Block Bottom	3

Table 1- Bill of Manufactured Materials

Apparatus Specification	
Weight	6.2lbs
L x W x H	15.0 in x 4.5 in x 11.2 in
Measurement Angles	90°-20°
Maximum Specimen Size (L x W)	3 in x 1 in

Table 2- Design Specs

Manufacturing Optimization

Two of the parts made can be optimized and the rest of the parts made don't need to be altered and are compatible with the manufacturing process. The two parts that need to be optimized are the motor block (Figure 5) and the middle shear block (Figure 16). Each of these components have mounting holes that are redundant and aren't structurally needed. The middle shear block has been altered to remove the middle mounting hole (Figure 1) and the motor block has been altered to remove the two middle mounting holes (Figure 2).

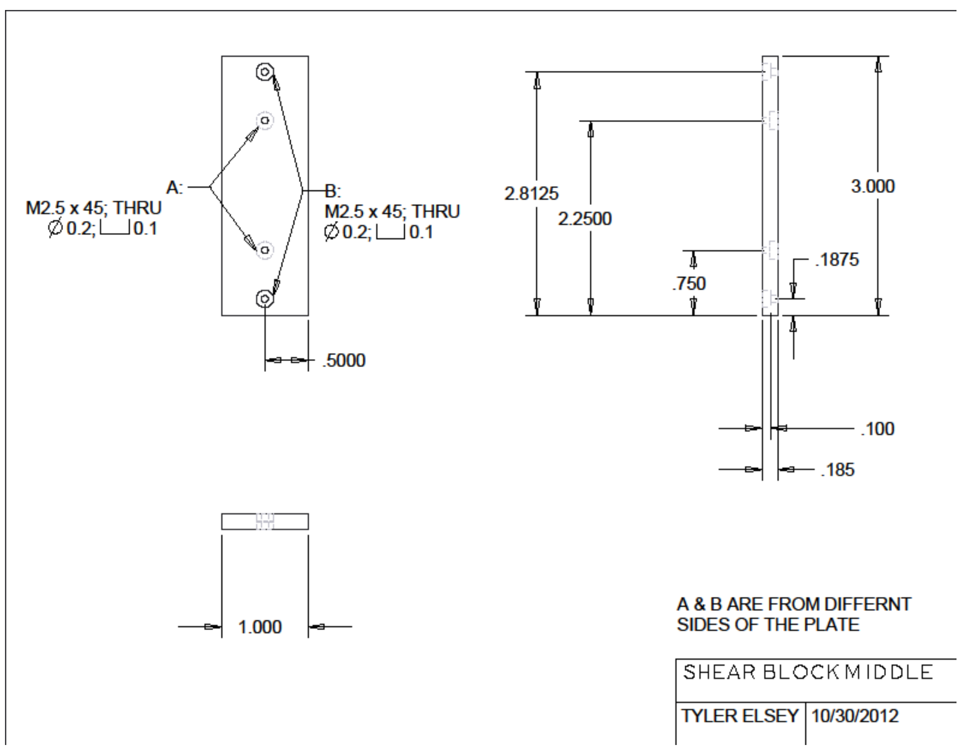

Figure 1- Altered for Manufacturing: Shear Block Middle

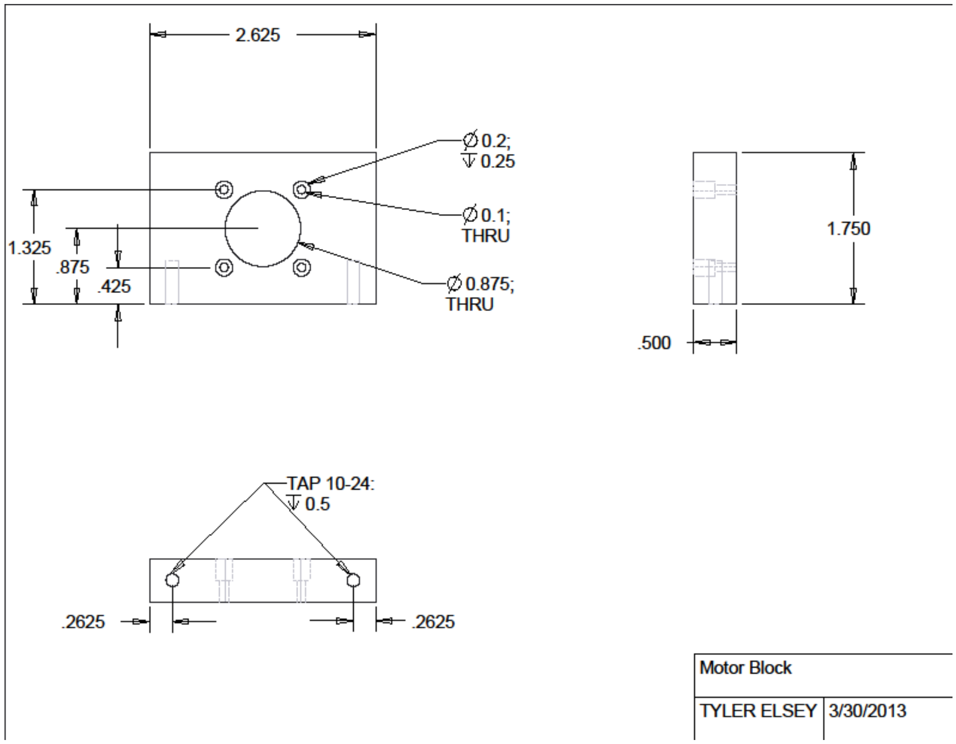

Figure 2- Altered for Manufacturing: Motor Block

In the manufacturing process much of the same steps will need to be followed as the design for the prototype is currently. The reasoning behind this is because the prototype will still be used for research, but the quantity demanded for prototypes will be a small quantity. If a sensor is to be created, the process of manufacturing would be applicable, but at this current stage the process can't be determined until after research has been thoroughly processed. For the current prototype, small changes can be implemented; such as the elongation of the baseplate, so there will not be such small area for all the assembled parts. The other change in the prototype would be the legs that are currently being used, because the choice for legs will be on what materials are the most cost effective and machinable.

Assembly drawings and instructions

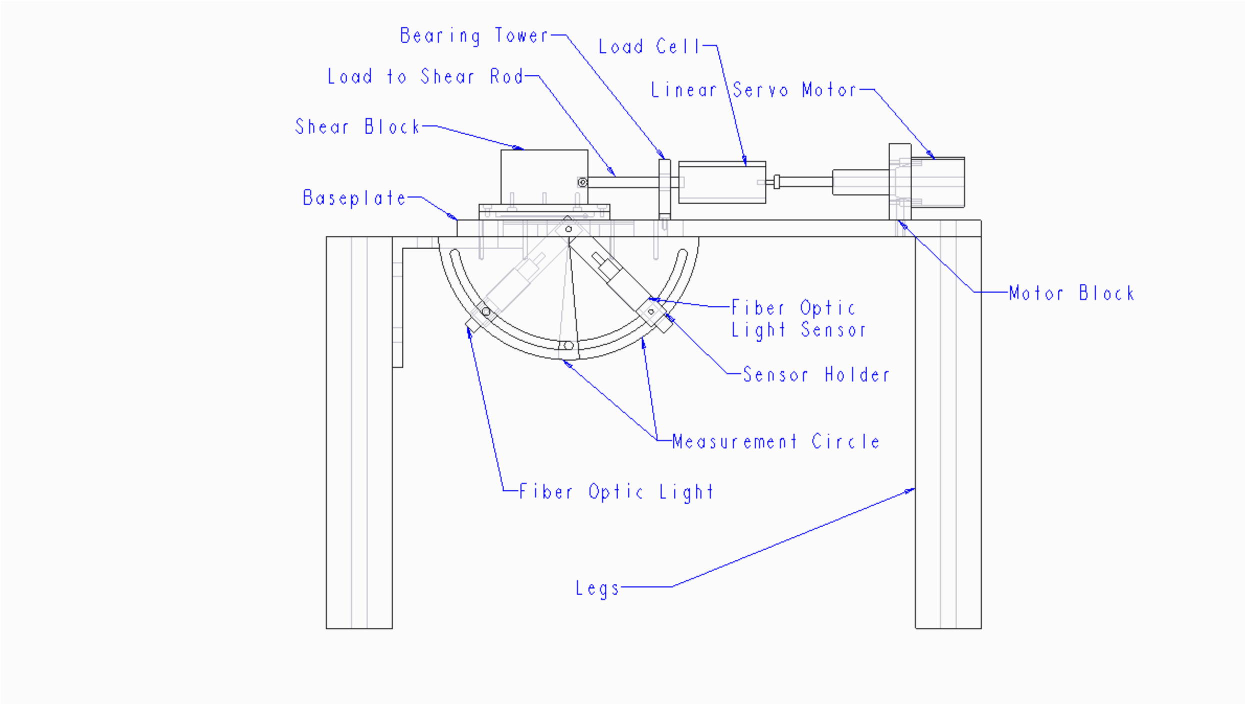

Figure 3-Testing Apparatus Assembly

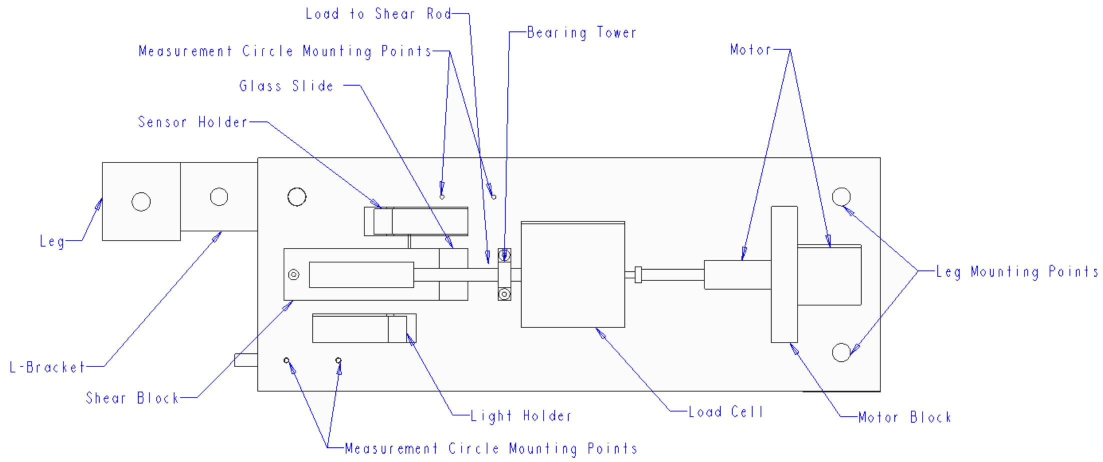

Figure 4-Testing Apparatus Assembly

Use Figure 3 and Figure 4 in concert with the following instructions for assembly of the apparatus.

1. Attach the motor side legs to the baseplate using ¼-20 fasteners.
2. Attach the L-bracket to the shear block side of the baseplate with a ¼-20 fastener and nut. Then attach the leg to the L-bracket using a ¼-20 fastener and t-nut.

3. Place the light holder arm in the extrude of the baseplate in line with the lateral hole in the extrude. Inset the arm pin into the aforementioned lateral hole and through the arm. Repeat for the sensor holder arm.
4. Attach the motor block to the baseplate with the counter bores facing the interior of the baseplate with 10-24 fasteners.
5. Attach the bearing tower and measurement circles to the baseplate with M2.5 fasteners.
6. Attach the shear block top to the middle shear block with M2.5 fasteners
7. Insert the heat pad in the bottom shear block cutout.
8. Attach the bottom shear block to the middle shear block with M2.5 fasteners.
9. Attach the motor to the motor block with the arm facing the interior of the baseplate.
10. Attach the load cell adapter to the load cell.
11. Attach the load to shear rod to the load cell with the load to shear rod passing through the bearing tower.
12. Attach the load cell adapter to the motor block with the load cell already attached.
13. Slide the shear block onto load to shear rod and secure it with the set screw.
14. Place the spectrometer and light fiber optic cables into their respective arms and secure them with set screws.
15. Secure the light and sensor arms in their desired location with M5 fasteners that first pass through the measurement circle before entering the arms

Challenges encountered or anticipated in the manufacturing

Anticipated challenges in manufacturing will be the tolerances for the locations of the holes for the motor block, bearing tower, and locations of the sensor/light source arms. Other than the aforementioned parts, the tolerances are large as to cut down the cost of machining and time. Encountered problems in the manufacturing process of the current prototype are the unclear details of the engineering drawings. In some cases, parts were assumed during machining to be symmetrical, but they were not and there were assumptions that all holes were screws, which was not the case either.

Design of Reliability

To ensure reliability in the apparatus special attention will be needed for a few crucial parts. The main piece of equipment that has to be maintained properly during experiments is the load cell; because of the how sensitive the load cell is proper handling must be followed. Maximum load for the current load cell is 10 Newtons, and exceeding that value can severely damage if not brake the component. For this reason the relay has been installed, so that if the load cell starts to become overloaded there is an automatic shutoff for the load cell in place. Another component that will need to be monitored during experimentation is the shear block just to assure that the shear block is always in the correct location on the liquid crystals/glass slide. Also the spectrometer and fiber optic cable for the light source need to be noted in the experiments to make sure that the intensities are being properly recorded. The liquid crystals need to be analyzed during the creation process as to ascertain the proper characteristics wanted for experiments. The design of the measurement circles needs to be analyzed because simply making quarter circles for the degree notation is not the correct procedure because the measurement circle must correspond to a rotational axis about the liquid crystal location. Factors of safety due to forces and failure due to forces in the equipment will not be necessary due to the small loads being applied in experimentation. For long term survivability, the only need would be to replace the Teflon bearing or linear actuator, but the linear actuator should have a long life cycle except for when user error is involved in operation. The Teflon bearing does not have high stress factors on the component, but wear over a long period of time could have an effect to where replacement may be necessary.

Design for Economics

Due to the simplistic approach of the testing apparatus, design changes will not be necessary in the respect of economics. The cost of materials will be the main economic decision making to change the apparatus. Since aluminum is currently being used for the prototype, the decision to change the material to steel could be a possibility. Using steel as the new material will be cheaper but harder to machine, so the cost of machining will more than likely outweigh the gain of cheaper material. Also due to purchasing large quantities of materials the unit cost per prototype will decrease, so being cost effective materially will be attained by ordering in larger quantities. In the manufacturing aspect of economics, having a fully automated system will not be necessary due to the small quantities of prototypes necessary, the automation will not pay for itself over time in comparison to manufacturing in a machine shop. As previously detailed, having a machine shop create machinable parts will suffice because of the low complexity in the design and low quantities being demanded.

Appendix

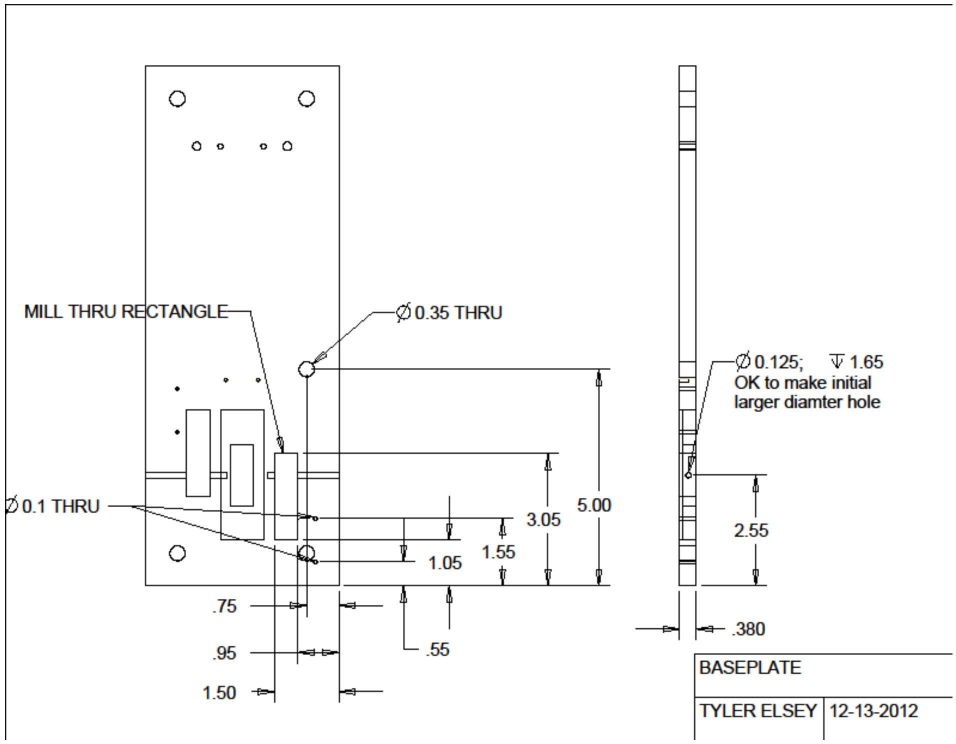

Figure 5- Baseplate

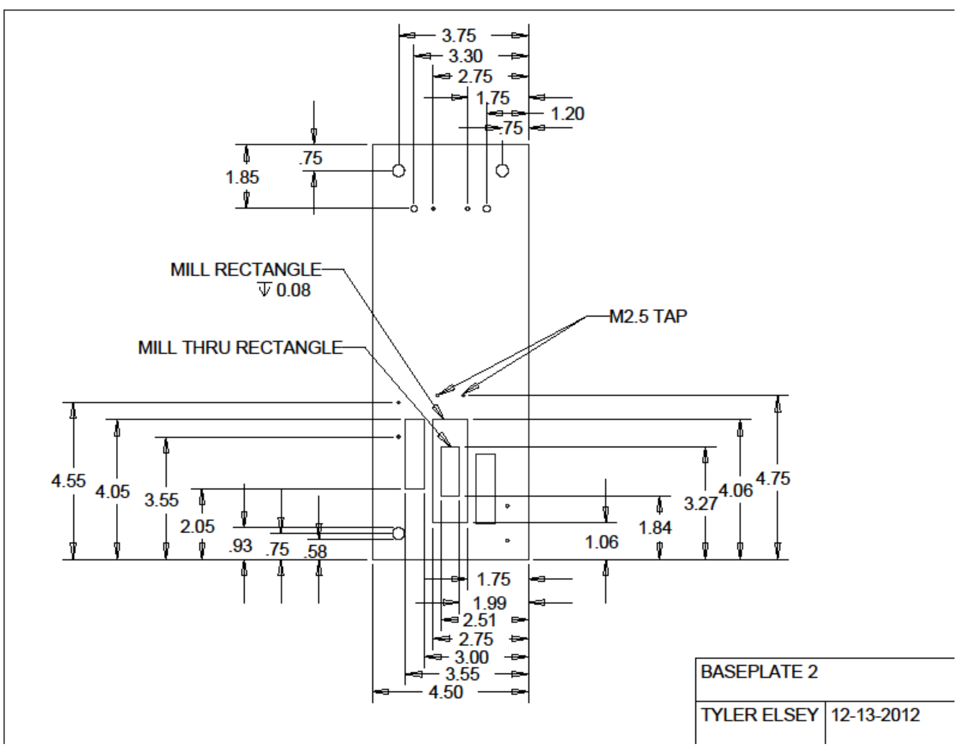

Figure 6- Additional Baseplate Drawing

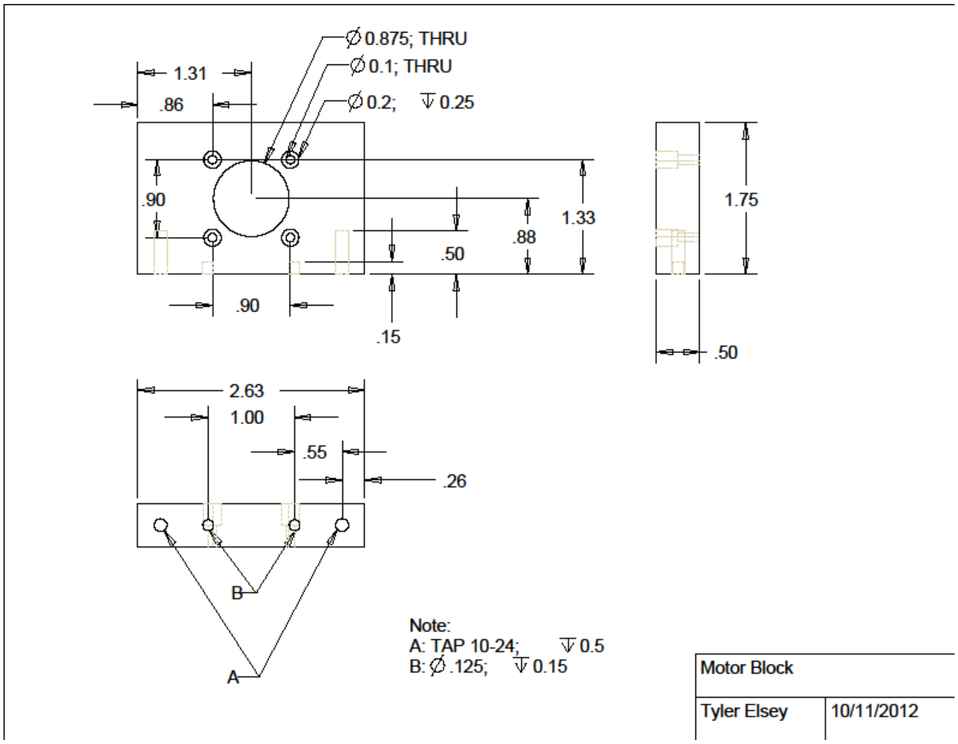

Figure 7- Motor Block

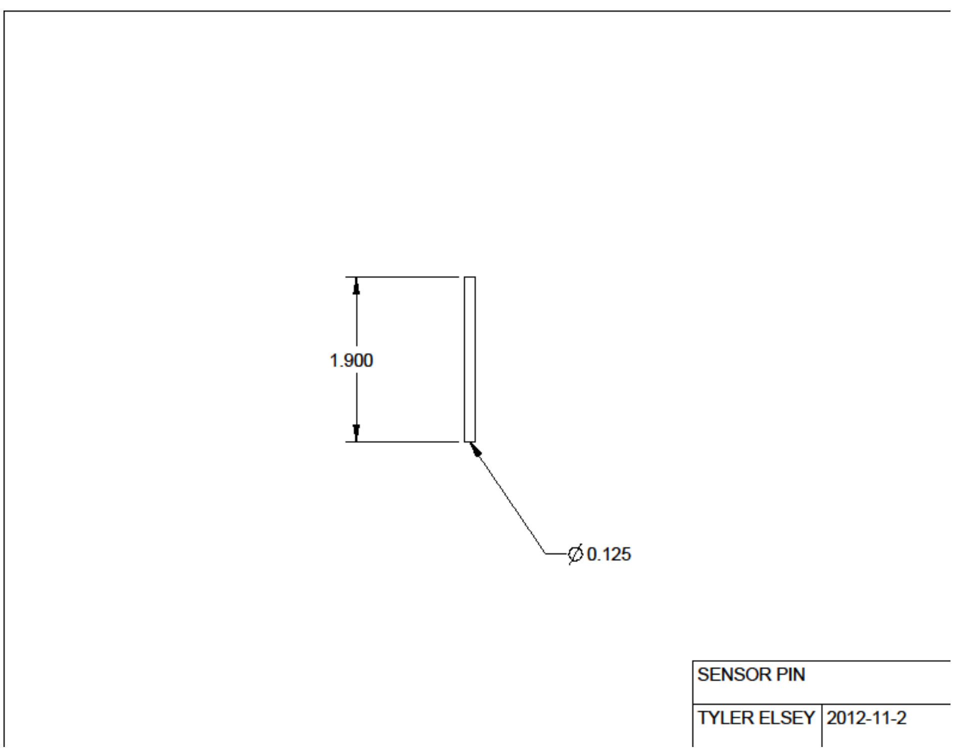

Figure 8- Arm Pin

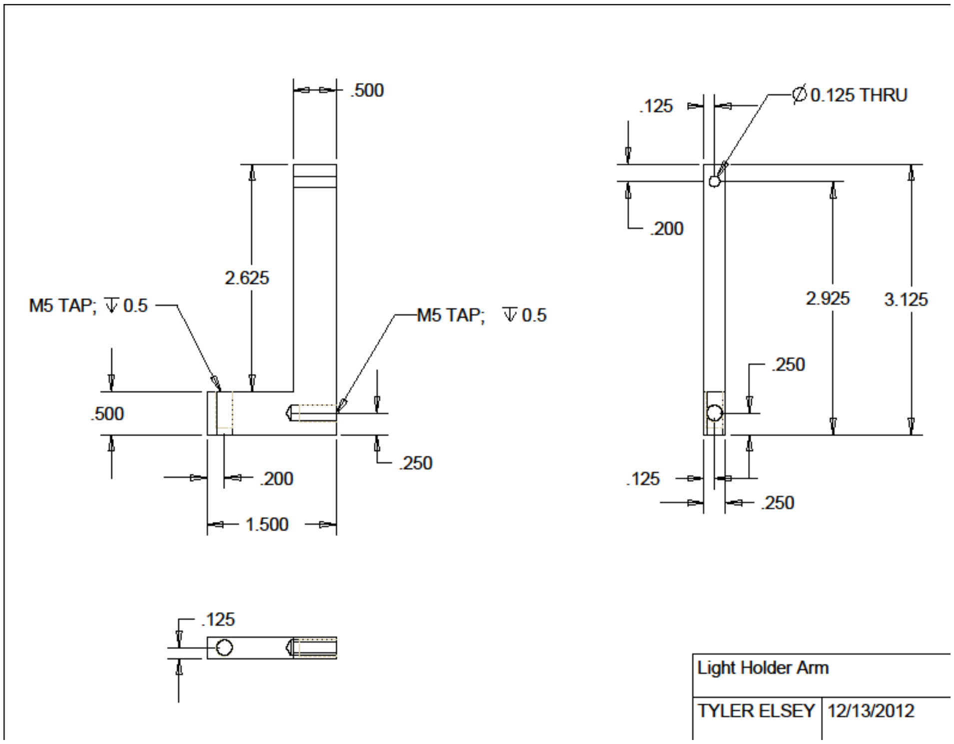

Figure 9- Light & Sensor Holder Arm

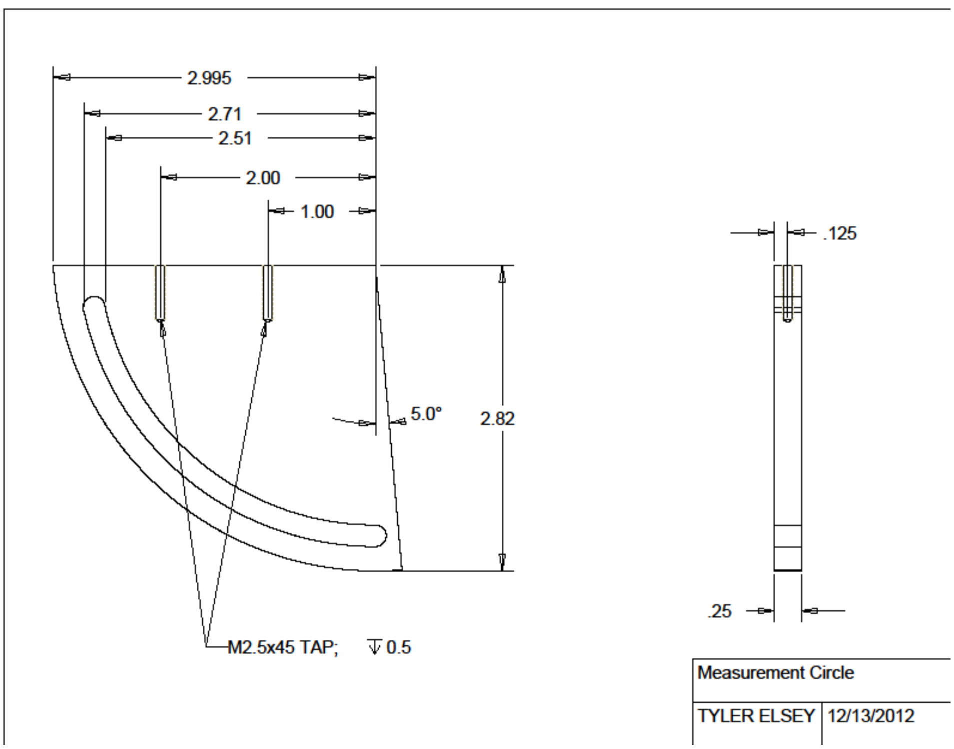

Figure 10- Measurement Circle

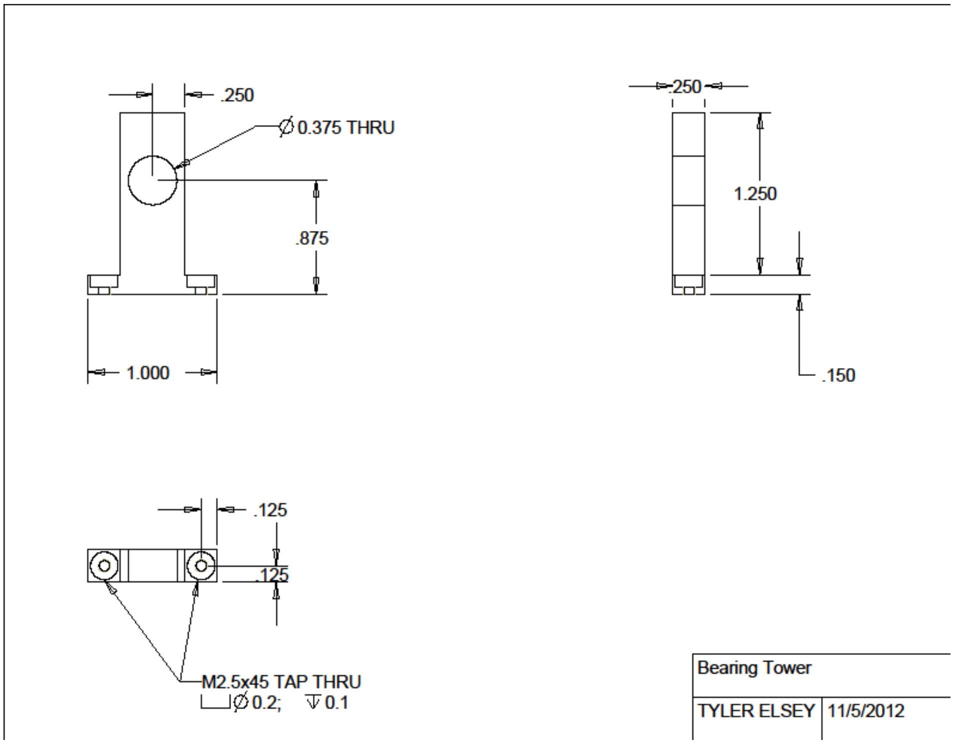

Figure 11- Bearing Tower

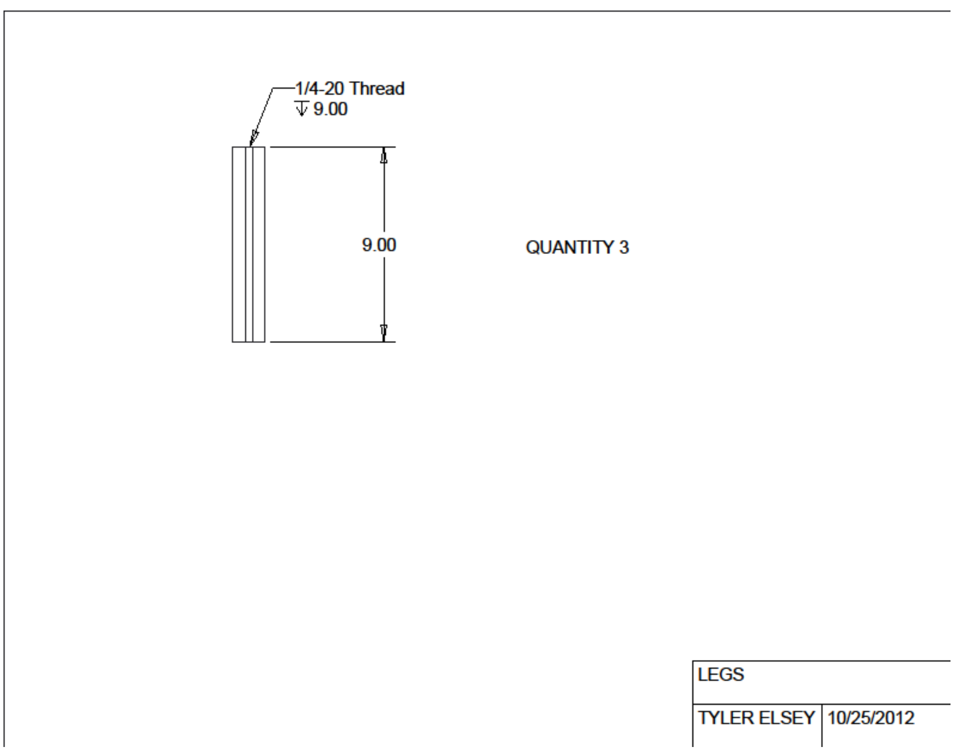

Figure 12- Leg

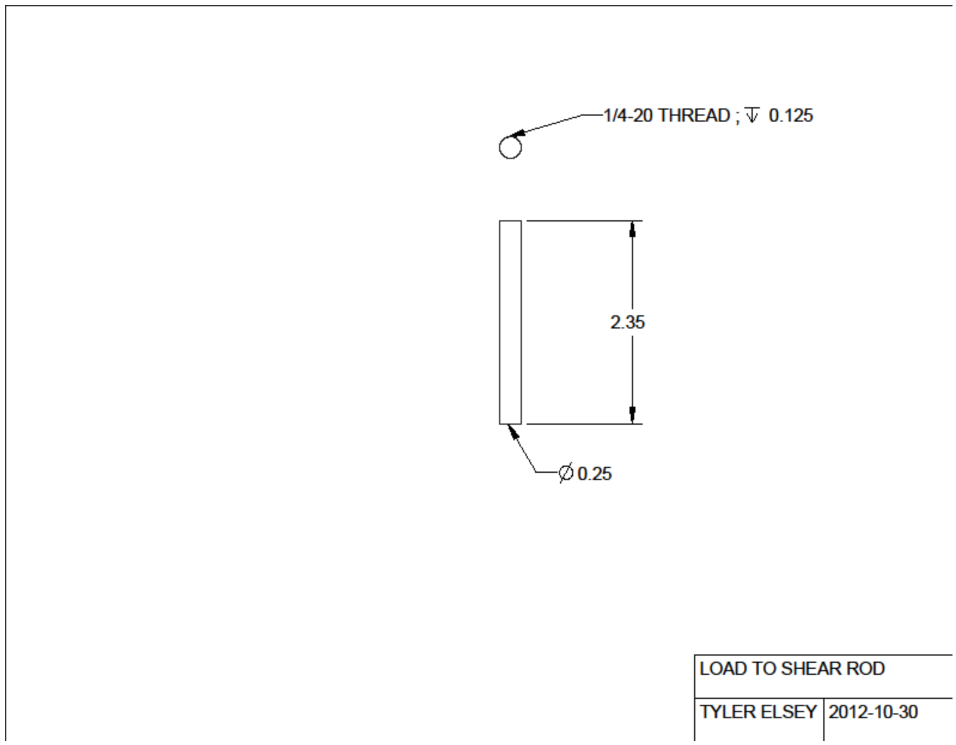

Figure 13- Load To Shear Rod

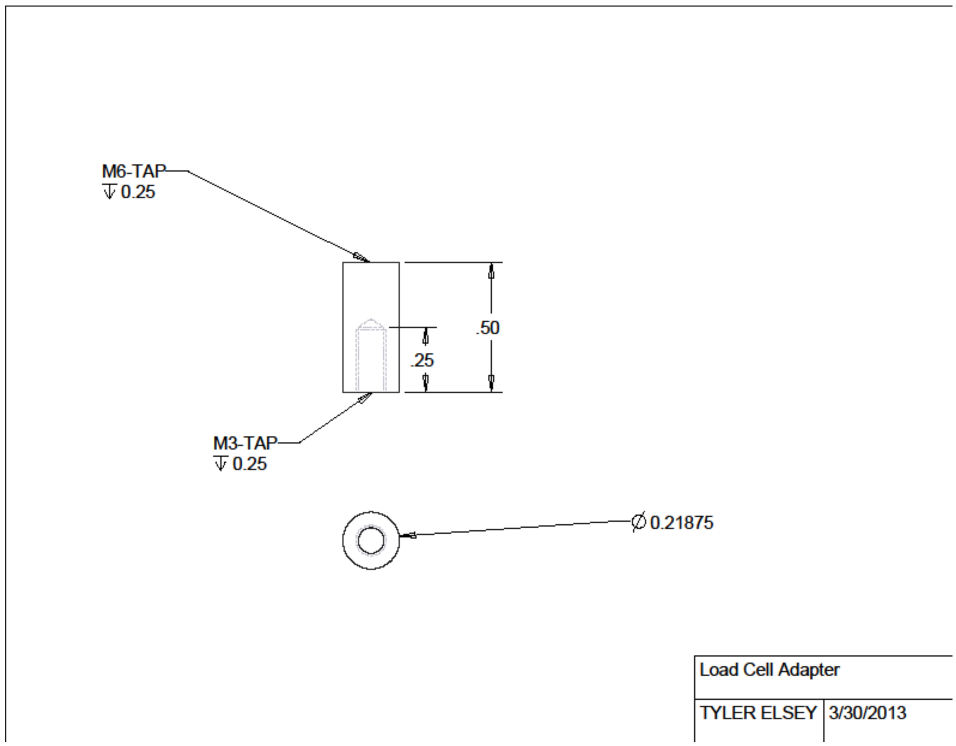

Figure 14- Load Cell Adaptor

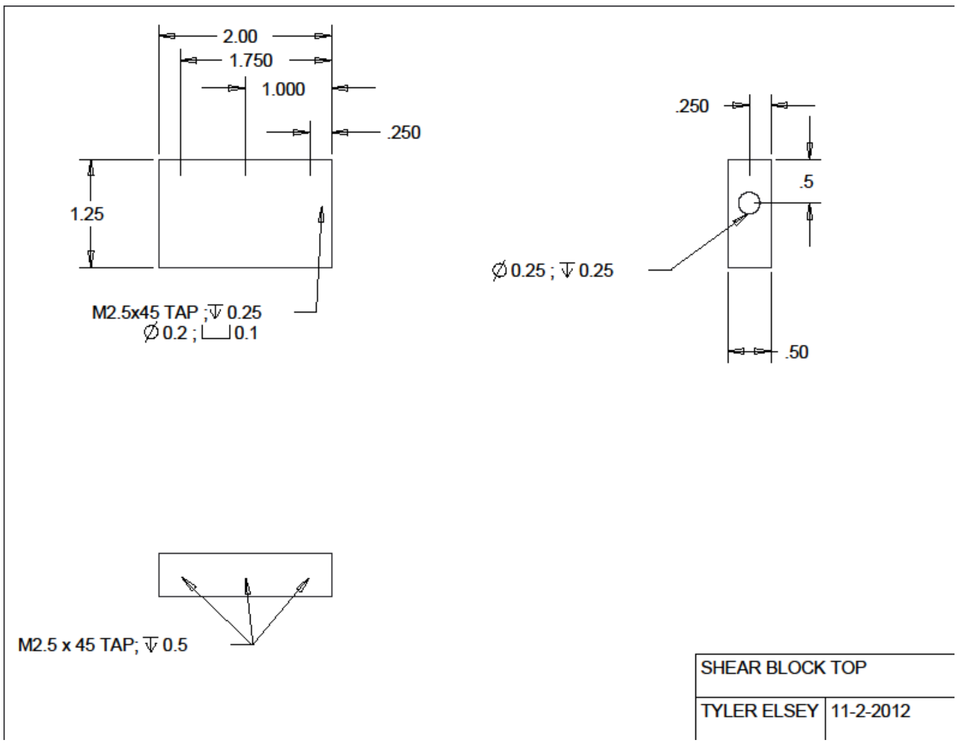

Figure 15- Shear Block Top

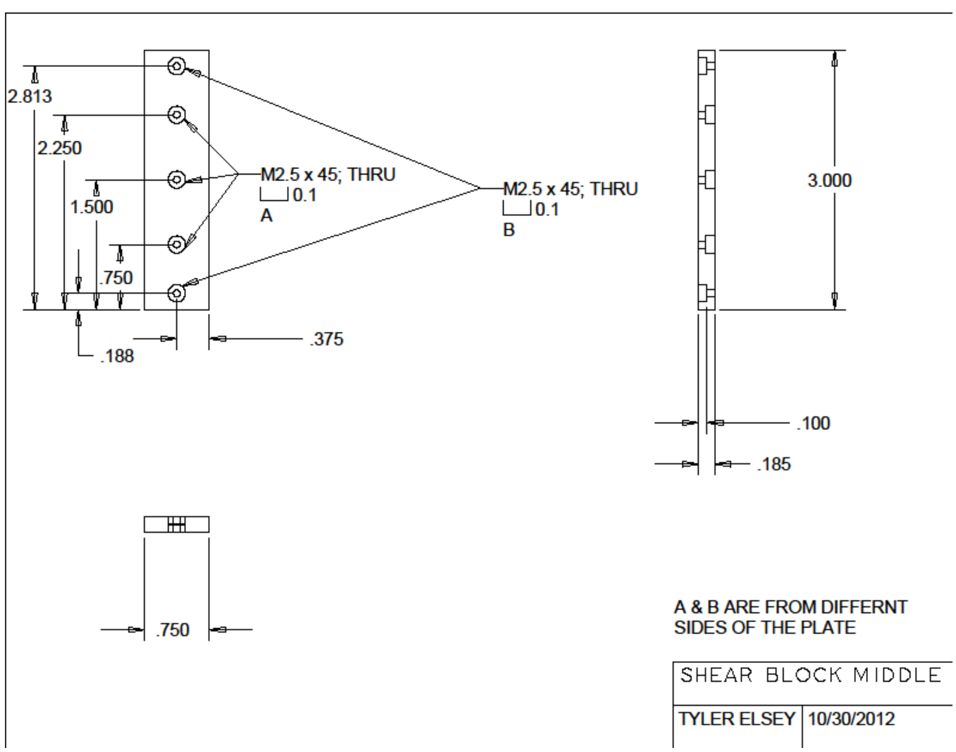

Figure 16- Shear Block Middle

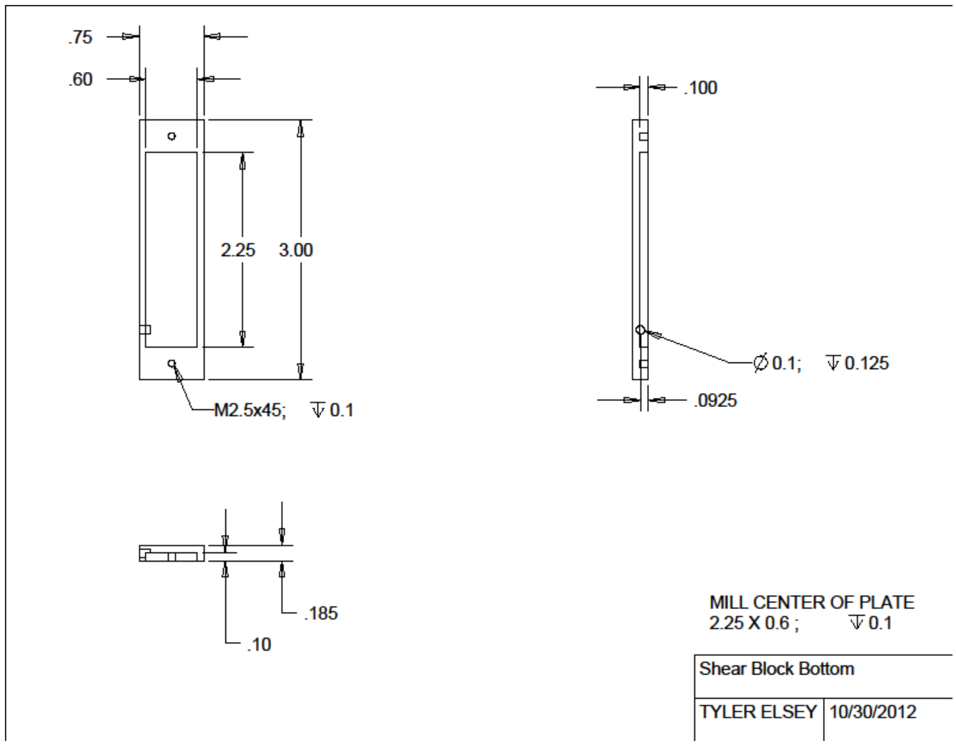

Figure 17- Flat Bottom Shear Block

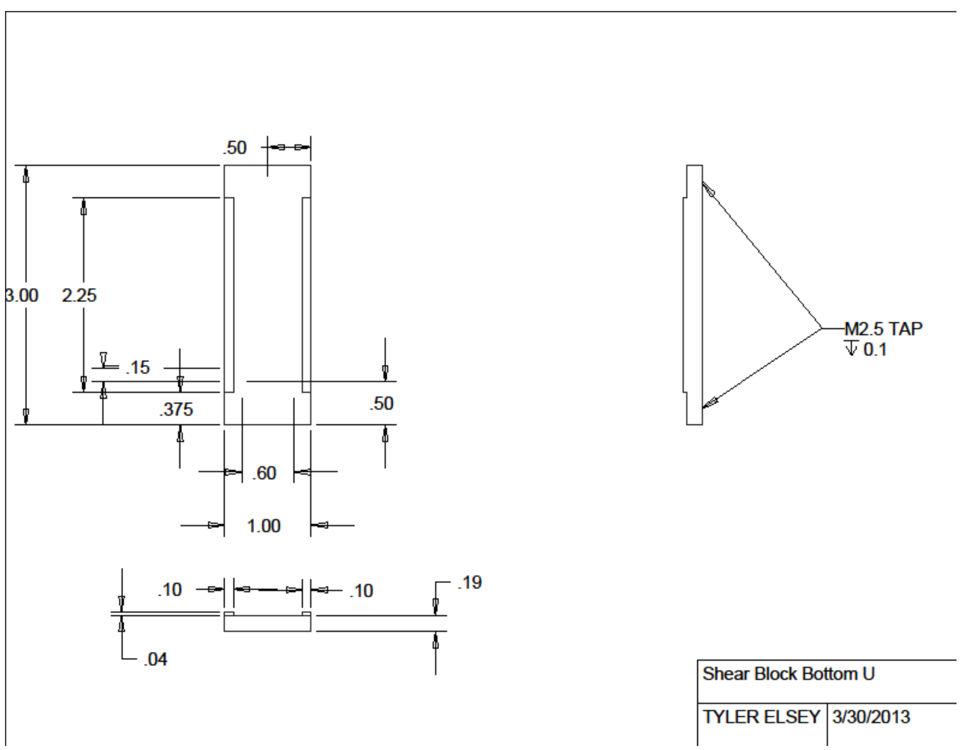

Figure 18- U Shaped Shear Block Bottom

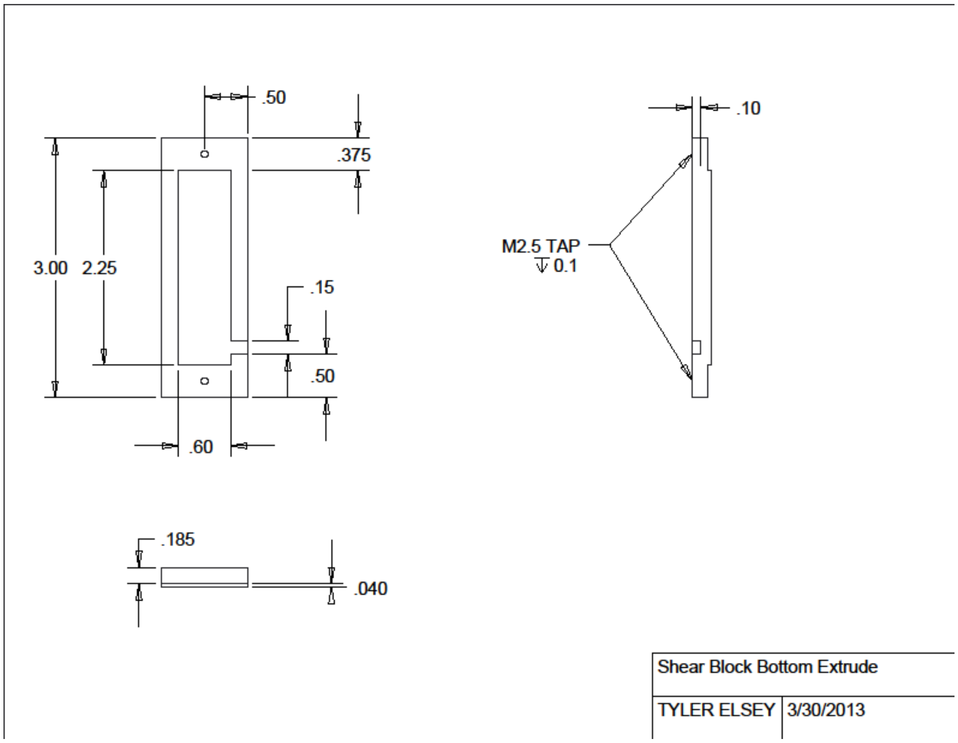

Figure 19- Extrude Shear Block Bottom