Material Testing Fixture

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Report 4

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1. Problem Statement

1.1 Introduction

Our project is to design a new testing fixture for a Magnetic Shape Memory Alloy (MSMA). The current testing fixtures are causing fatigue failure in the specimens which is undesirable. The new testing fixtures which we design will be installed on an Instron 8874 hydraulic bi-axial testing rig. These testing fixtures will operate in the presence of a magnetic field due to the nature of specimens. Because the specimens are extremely rare and expensive, axial alignment is one of the most critical components of this project. The project is to create a new fixture that is able to perform both tensile and compressive tests on the MSMA specimens.

1.2 Background Research

Dr. Ciocanel has been involved in conducting research, along with the Chemistry department, in the field of Smart Materials. Specifically, Dr. Ciocanel has been looking into ways of storing electrical energy in carbon-fiber-based materials. If materials were embedded with electrical storage capacity, it could help industries to reduce weights and costs of manufacturing.

Another area in which Dr. Ciocanel has been involved with is the use of Magnetic Shape Memory Allow. By conducting complex loading scenarios, Dr. Ciocanel can study the effects and properties of this material for future industry use. A key feature of the material is that it experiences up to 6 percent elongation when introduced to a magnetic field. The growth of the material also induces changes in magnetization, and voltage can be harnessed if a coil is placed around the specimen.

1.3 Needs Identification

During our meeting with Dr. Ciocanel, he explained to us how the current testing fixtures caused unwanted eccentric loading of the specimens. This unwanted loading in the material is caused by misalignment of current testing rig. This misalignment causes fatigue cracks to form in the specimens, ultimately leading to catastrophic failure. These specimens are highly expensive and extremely rare, as they are only produced in two places around the world. The cost of each specimen is roughly $1,000, and it can take up to one year to grow the specimen. This fixture is also slightly larger than the specimen, which allows the specimen to move when the magnetic field is introduced. Dr. Ciocanel expressed the need for a new testing that will not cause the specimen to prematurely break. Dr. Ciocanel also expressed an interest in a testing fixture that would be able to perform compression and tension tests. The current fixture design only allows for compression testing.

1.4 Project Goal and Scope of Project

The goal of our project is to create a new testing fixture that is capable of performing tension and compression tests on magnetic shape memory alloy. This goal includes being able to repeatedly test specimens without causing them to fatigue and break prematurely. We are limiting the scope of our project to the small scale testing performed by the Instron 8874 hydraulic bi-axial testing rig.

1.5 Objectives

In our project there are four main objectives. First, the connection between the pushrods and base need to be axial aligned. If this connection is not aligned, the eccentric loading will cause the specimen to break. Second, the new fixture must be able to perform both compression and tension tests. Third, it is imperative that the new fixture not damage the specimen. The cost and rarity of the material make this objective of great importance. Finally, the new design should be as inexpensive as possible without sacrificing any of our objectives. On the next page, in **Table 1: Objectives** our objectives and basis for measurement are shown.

Table 1: Objectives

Objective	Basis for Measurement	Units
Axial Alignment	**Distance from perfect axial alignment**	**μm**
Tension/Compression Tests	**Repeated Testing**	**# of Tests**
Does not damage material	**Cost of new specimen / Time for replacement**	**$$ / Months**
Inexpensive	**Cost to machine and purchase material**	**$$**

1.6 Constraints

For this project, we have defined seven constraints that the new design must meet. These constraints are listed below, along with a short description.

1) **Specimen size:** The specimen size is (3 x 3 x 20) mm.
2) **Exposed length:** There must be at least 6mm of exposed specimen for the camera to monitor.
3) **Fixture must not damage specimen:** The fixture cannot bite into the material causing damage.
4) **Fixture must be non- magnetic:** The magnetic field of the fixture must not interfere with the applied magnetic field.
5) **The distance between magnets:** The space between the magnets when the specimen is located can be no more than 10mm.
6) **Magnetic field:** The applied magnetic field varies from (0.5 ~ 1.0) Tesla (T).
7) **Axial Alignment:** It is crucial that the specimen be axially loaded.

1.7 Criteria Tree

After discussing our client's needs we created a criteria tree that helps to visualize the different aspects of our project. This tree is shown in **Figure 1: Criteria Tree.**

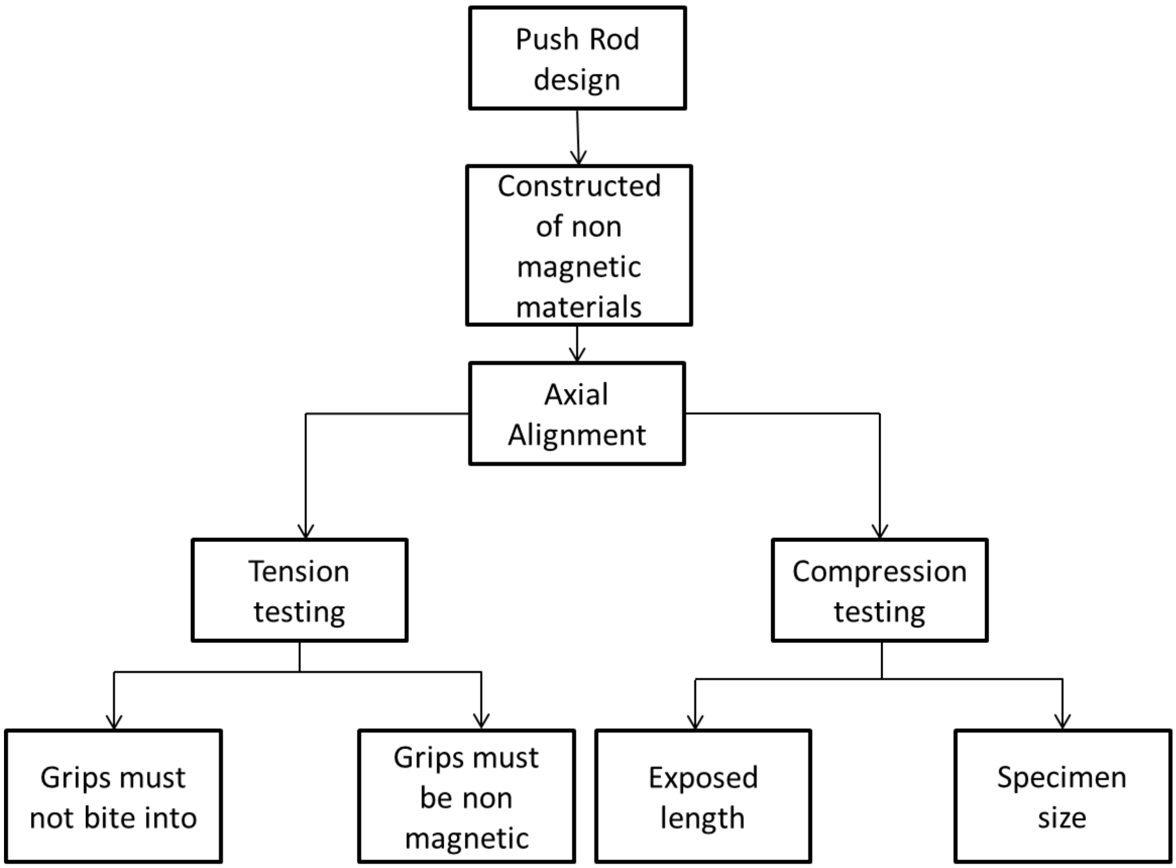

Figure 1: Criteria Tree

As we can see from this figure, every component of this design is related to the axial alignment of the pushrod. Because this is the case, axial alignment is the most critical part of our project.

1.8 Quality Function Deployment

After talking with our client, we were able to create a Quality Function Deployment. This diagram, shown in **Figure 2: Quality Function Deployment** shows the relationship between our customer's requirements and our engineering requirements.

		Engineering Requirements						
		Strain	Tension	Compression	Exposed Length	Grip Size	Magnetic Field	Cost
Customer Requirements	Does not break	X	X	X				
	Tension Test		X					
	Axial Loading		X	X		X		
	Inexpensive				X			X
	Fits in Testing Device				X	X		
	Magnetic Field				X		X	
	See Specimen				X	X		
	Units	mm/mm	N	N	mm	mm^2	T	$$
		1.2	18	60	6	100	1	TBD
		Engineering Targets						

Figure 2: Quality Function Deployment

In order to help our team fully understand what this meant, we created a House of Quality. Shown in **Figure 3: House of Quality**, our engineering requirements are related to one another in a positive or negative manner.

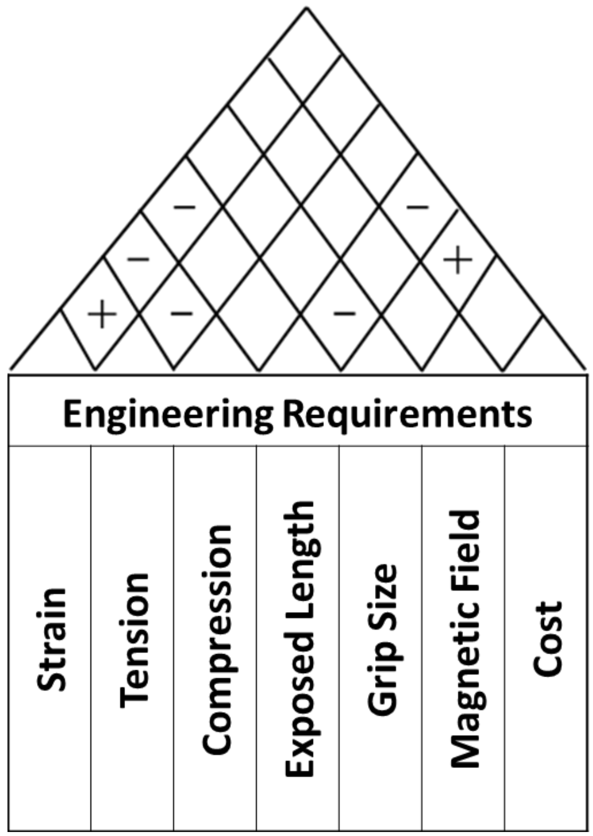

Figure 3: House of Quality

2. Concept Generation

2.1 Clamp Tip

This design consists of a redesigned pushrod, four independent clamping components, screw adjustable tension clamp, and a rubber insert. The unique feature of the clamp tip is the screw guided clamping components which are controlled by the tension clamp. This design is user friendly and allows for easy one screw adjustment while also maintaining axial alignment. In the center of the four clamping components is a rubber insert or rubber coating to ensure that the specimen remains undamaged while conducting tension testing. Below in **Figure 4: Clamp Tip**, a model of this design is shown.

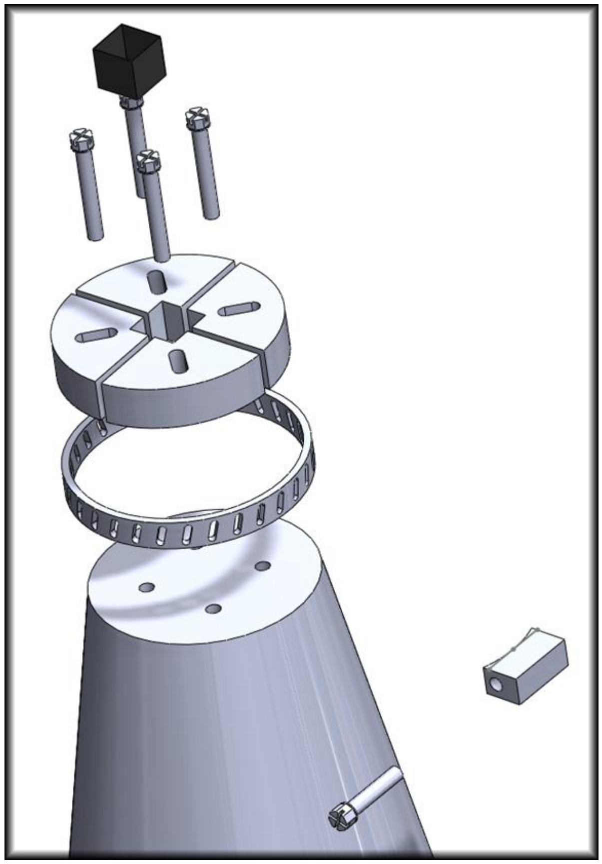

Figure 4: Clamp Tip

2.2 Screw Tip Design

The goal of the screw tip design is to ensure the axial alignment of the specimen by using four set screws to control the alignment of the specimen. This design also allows for the specimen to be tested in tension. In order to make the design not damage the specimen, a rubber insert is placed between the screw ends and the specimen. This design however will require a lot of adjustment each time a specimen is tested. Below in **Figure 5: Screw Tip**, a model of this design is shown.

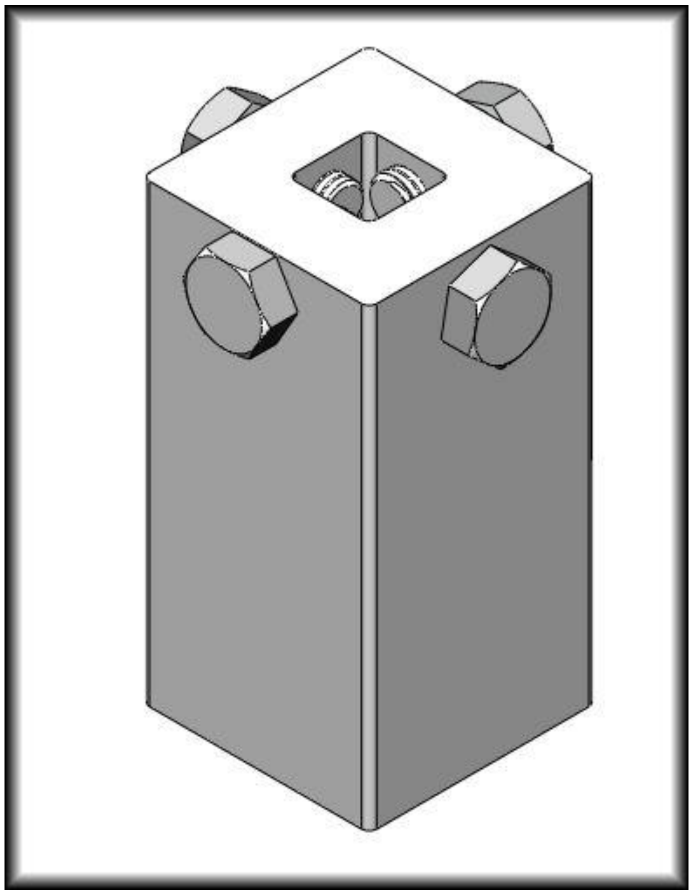

Figure 5: Screw Tip

2.3 Adjustable Base

In this design there are 4 adjustment screws that press on the force analyzer to align the tip that hold the specimen. The problem with this design is that while it corrects the alignment of the specimen, it transfers the misalignment to the force analyzer. This simply shifts the location of the problem rather than fixing the design. Below in **Figure 6: Adjustable Base**, a model of this design is shown.

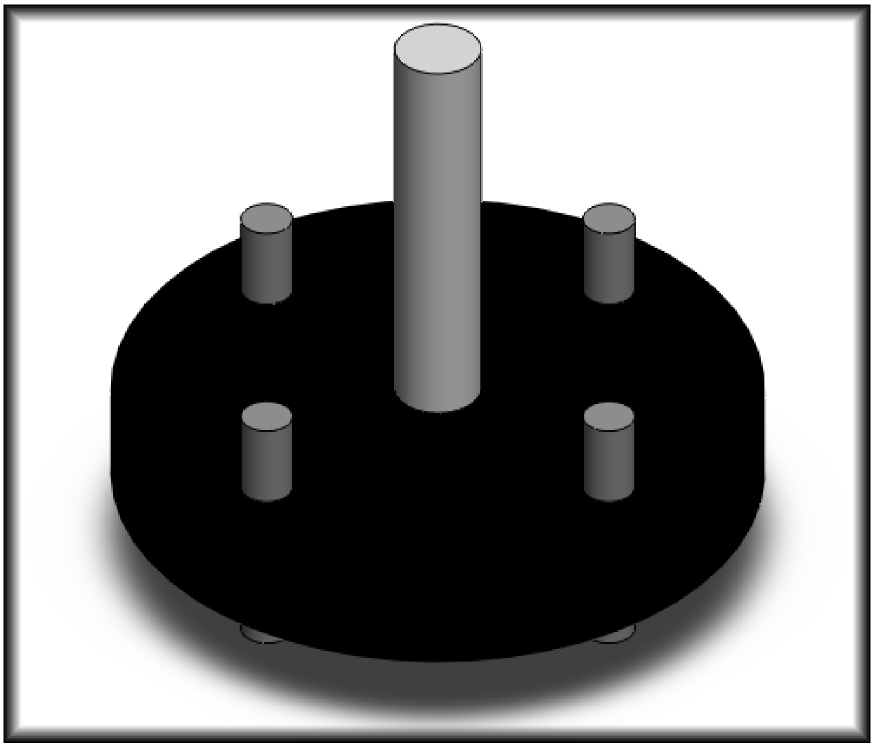

Figure 6: Adjustable Base

2.4 Base Sleeve

This design is comprised of four main components. They are the pushrod, sleeve, force analyzer and securing screw. First the pushrod is inserted into the sleeve. Then the sleeve and pushrod are inserted into the force analyzer. Next, a screw will be used to secure sleeve and the pushrod. This design has three main characteristics. First, in order to keep the connection between the pushrod and base perfectly aligned, the sleeve will be made as large as possible. This large base will ensure that the pushrod is stable. Second, in order to ensure axial alignment, the tolerance between pushrod and sleeve will about 50μm.

Finally, because there is only one screw, this design requires very little adjustment. Below in **Figure 7: Base Sleeve**, a model of the base sleeve is shown.

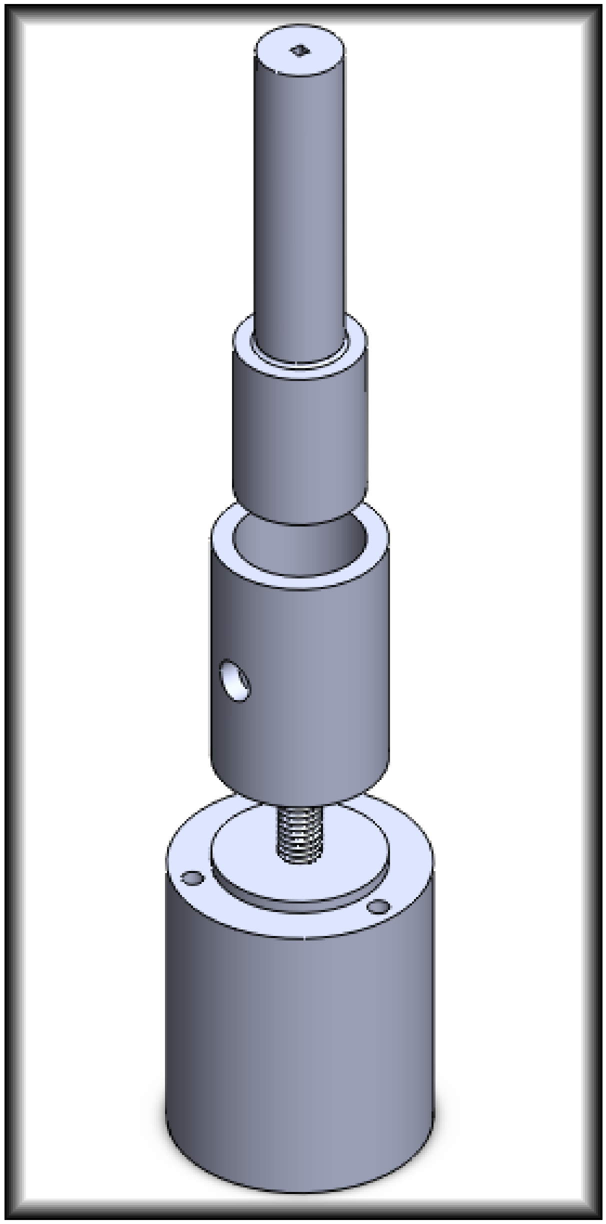

Figure 7: Base Sleeve

2.5 Collar Base

This design is comprised of four main parts. They are the pushrod, collar, force analyzer, and four screws. Using the existing screw holes on the force analyzer, the screw holes are extended and tapped out. Then using the tapped out screw holes, the collar will be secured to the force analyzer. This will ensure the axial alignment of the pushrod. Then the pushrod will be inserted in the center hole of collar, and a set screw will be used to secure the pushrod to the collar. This design will ensure that the pushrods are axially aligned and there is no extra horizontal force applied to the force analyzer or specimen. This collar will ensure that the bottom of the pushrod and the force analyzer sensor are perfectly aligned. This sensor is used to collect data for the compression force. Finally, the tolerance between the center hole of the collar and the pushrod will also be machined to about 50μm to provide the perfect axial alignment. Below in **Figure 8: Collar Base**, a model of the collar base is shown.

Figure 8: Collar Base

2.6 Updated Design

The updated pushrod design is based off the former design known as the screw tip. For this design we eliminated the four independent clamping components and elected to use a single screw to secure the specimen during testing. This new design significantly reduced the tip size which ensures that the tip does not interfere with the 10 mm distance between the magnets. This was one of the problems with the previous designs. The new design is also easy to adjust, utilizing one screw to secure the specimen within the tip of the pushrod. Below in **Figure 9: Updated Design,** a model of the new design is shown.

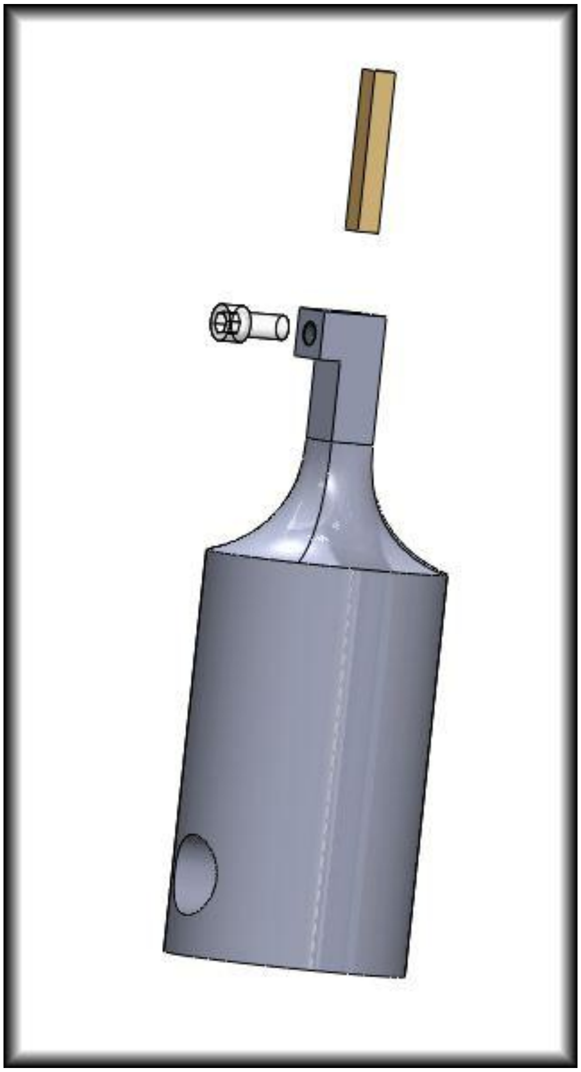

Figure 9: Updated Design

3. Concept Selection

In this section we will discuss the decision making process and the methods used in selected an initial design. The first aspect of the concept selection process was to weigh our goals and objectives. In order to do this we created a table to help us choose between our designs. Below in **Table 2: Analytical Hierarchy** is a table that rates the importance of our objectives to a scale from 1 to 9.

Table 2: Analytical Hierarchy

Judgment of Importance	Numerical Rating
Extremely Important	9
	8
Very Important	7
	6
Strongly Important	5
	4
Moderately Important	3
	2
Equally Important	1

As seen in the table above, this rating is on a scale of 1 to 9 in order of equally important to extremely important. Using this criteria we can then make a judgment of how importance of each objective. To do this we created a matrix and assigned values to each of our objectives. Below in **Table 3: Weighted Objectives**, the values and the corresponding objectives are shown.

Table 3: Weighted Objectives

Axial Alignment	9
Tension & Compression	5
Damage To Specimen	9
Inexpensive	4

As can be seen from this table, “Axial Alignment”, and “Damage To Specimen” are critical. The axial alignment is crucial because the eccentric loading of the test specimen is causing crack propagation. This ultimately leads to the catastrophic failure of the test specimen. Because of the rarity of the specimens it is crucial that the specimens not be damaged. For this reason, “Damage To Specimen” is rated as extremely important.

Although not a primary objective of this project, we would also like to design the new fixture to be able to perform tension tests which are currently not supported. For this reason the objective “Tension & Compression” was given a rating of 5, which corresponds to “Strongly Important.”

Finally, we would like to make the new fixture as inexpensively as possible without compromising any of our objectives. Thus, the objective “Inexpensive” was given a rating of 4, which corresponds to slightly more than “Moderately Important.”

To proceed with the selection process another scale was created that relates how closely our designs match our objectives. Below in **Table 4: Objective Matching Scale**, this scale is shown. The values range from 1, meaning the design does not meet objective, to 5, meaning that the design meets the objective extremely well.

Table 4: Objective Matching Scale

Meets Objective	Numerical Rating
Extremely Well	5
Very Well	4
Well	3
Not Well	2
Not At All	1

Next, all of these criteria are substituted into a large decision matrix. Below in **Table 5: Decision Matrix**, each of the designs is matched to our objectives and then weighted. The weighted total is calculated and shown at the bottom of the matrix.

Table 5: Decision Matrix

	Tip		Base			
Objectives	**Clamp Tip**	**Set Screw Tip**	**Adjustable Base**	**Base Sleeve**	**Collar Base**	**Objective Weight**
Axial Alignment	5	2	1	4	5	9
Tension & Compression	4	4	3	3	4	5
Damage To Specimen	4	4	N/A	N/A	N/A	9
Inexpensive	2	4	4	3	2	4
Total	15	14	8	10	11	
Weighted Total	109	90	40	63	73	

According to the decision matrix and our ranking scales, we decided that for our initial design, we will proceed with the Clamp Tip and Collar Base.

4. Engineering Analysis

4.1 Material Analysis

In our project, all parts of the fixture must be composed of non-magnetic materials since the fixture will be used in a magnetic field environment. After researching, we found several non-magnetic materials. They are:

1. Copper
2. Silver
3. Lead
4. Magnesium
5. Platinum
6. Aluminum Alloy

After comparing each material, we decided to focus on the aluminum alloy because it is inexpensive and readily available. Another reason we chose aluminum was because many of the other materials did meet our requirements. Copper has a low yield strength which is not what we are looking for in a pushrod. Silver and platinum are too expensive to use. Lead is a toxic material that would not be user friendly or easy to handle. Finally, magnesium is very chemically active, making it unsuitable for this project.

For aluminum alloy, there are many different alloys from which we can choose. They range from 1000 series to 7000 series. Each of these alloys has different properties and is used for different applications.

- 1000 series is basic aluminum without any other addition.
- 2000 series is the aluminum alloyed with copper which is formerly used in aerospace applications.
- 3000 series is the aluminum alloyed with manganese. It is a good rust-proof material which is commonly used for construction.
- 4000 series is the aluminum alloyed with silicon which is a wear resistant material.
- 5000 series is the aluminum alloyed with magnesium which is widely used in ship building because that material can prevent the oxidation.

- 6000 series is the aluminum alloyed with magnesium and silicon which has a good machine property and inexpensive.
- 7000 series is the aluminum alloyed with zinc which is used for aerospace application now.

In this project we have chosen to use aluminum 6061-T6 as the material for pushrod, sleeve, and pin. There are three main reasons why we choose aluminum 6061-T6. First, it is a precipitation hardening aluminum alloy with high yield strength which will be suitable for compression and tension. Second, it has a good mechanical property, and is easy to machine. Finally, because this alloy is one of the most common alloys on the market, it is inexpensive and easy to obtain.

For the screw, which is used for securing the specimen to the pushrod, we decide to look at a few different materials. These materials are nylon type 66, brass, and aluminum. Each of these materials has different characteristics that make them suitable for our project. After comparing the different materials we decided to use nylon type 66 for the screw. The reason we chose nylon is that it is one of the most commonly used polymers which means that it is inexpensive and easy to acquire. The most important reason why we chose this material is because the yield strength of nylon 66 is less than the aluminum which will be used for the pushrods. This will ensure that the screws will not ruin the pushrod or specimen.

4.2 Compression Analysis

After looking at the different materials for this project, we continue our analysis. A compression analysis was performed in order to analyze the compressive forces on the small area in which the specimen sits. In order to calculate the forces the pushrod will see in a compression test, the area must be calculated. To do this, the length and width, both 3 mm, are multiplied to obtain an area of 9 mm^2, using the following equation:

$$Area = L \times W = 3mm \times 3mm = 9mm^2 \quad \textbf{(1)}$$

Next, in order to keep the units consistent in calculations, the area in mm^2 was converted to square meters, with the following equation:

$$Area = 9mm^2 \times \frac{1m^2}{(1000mm)^2} = 9 \times 10^{-6}\ m^2 \tag{2}$$

After converting the area into the proper units, we then took a varying force of 10 N to 100 N, and divided each force by the area to obtain a compression stress for each force. The following equation is an example calculation:

$$Stress = \sigma = \frac{F}{A} = \frac{60N}{9 \times 10^{-6}\ m^2} = 6.667 \times 10^6\ N/m^2 \tag{3}$$

Below, in **Table 6: Compression Stresses**, the forces ranging from 10N to 100N, with their corresponding stresses are shown.

Table 6: Compression Stresses

Force [N]	Stress [N/m^2]
10	1.111E+06
20	2.222E+06
30	3.333E+06
40	4.444E+06
50	5.556E+06
60	6.667E+06
70	7.778E+06
80	8.889E+06
90	1.000E+07
100	1.111E+07

A compressive force of 60 N is highlighted in the above table. The reason attention is drawn to the 60 N force is that this is the maximum compressive force that the specimen will see. By compressing it at 60 N, our client can generate accurate test data, yet still allowing for multiple tests to be performed.

4.3 Bearing Analysis

This analysis focuses connection between the pushrod and the base sleeve of the testing rig. During testing this pin will experience a bearing stress caused by the base component and pushrod being compressed into each other. For this analysis we focused primarily on the compression testing because the forces seen in tension are insignificant when compared to those in compression. The bearing stress was calculated using equation **(3)**. This analysis was performed for varying wall thicknesses and pin diameters and the resulting stresses are shown in **Table 7: Bearing Stresses**

Table 7: Bearing Stresses

	Pin 10mm	Pin 15mm	Pin 20mm	Pin 25mm
Outer Diameter (mm)	Stress (MPa)	Stress (MPa)	Stress (MPa)	Stress (MPa)
31.0	16.00	10.67	8.00	6.40
32.0	8.00	5.33	4.00	3.20
33.0	5.33	3.56	2.67	2.13
34.0	4.00	2.67	2.00	1.60
35.0	3.20	2.13	1.60	1.28
36.0	2.67	1.78	1.33	1.07
37.0	2.29	1.52	1.14	0.91
38.0	2.00	1.33	1.00	0.80
39.0	1.78	1.19	0.89	0.71
40.0	1.60	1.07	0.80	0.64

As we can see in **Table 7: Bearing Stresses**, as the wall thickness and pin diameter increase the stresses experienced by the sleeve are reduced.

4.4 Screw Analysis

In this project one of the goals in creating a new testing fixture is to create a rig that is capable of performing tension tests. In order to accomplish this it is necessary to secure the specimen to the pushrod. After looking at some of the design options that were available to us, we decided that to proceed with using a screw to secure the specimen to the pushrod. In tension the max load that would be applied to the specimen would be about 18 N. In order to secure the specimen a few factors have to be considered. On the next page, in **Figure 10: Free Body Diagram**, an image of the forces seen by this type of loading is shown.

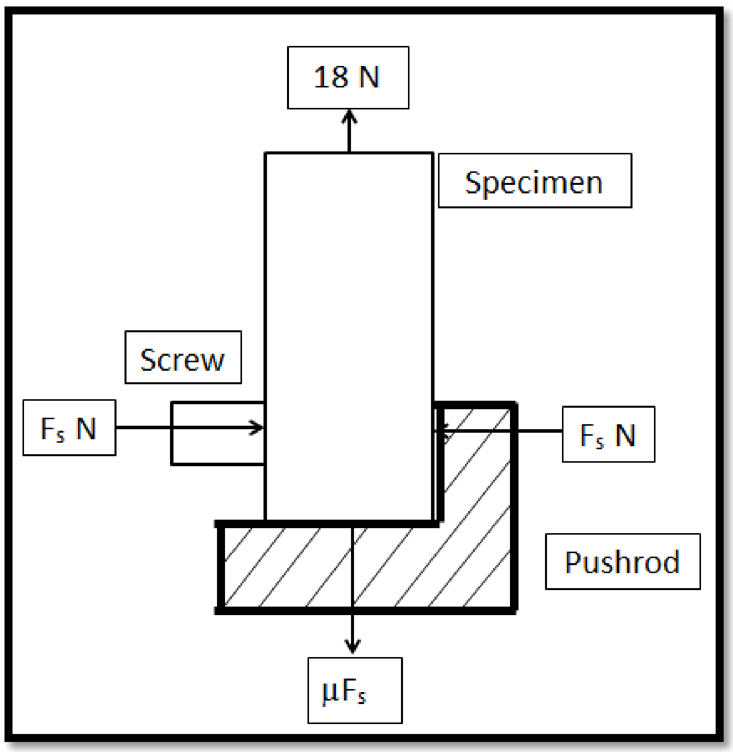

Figure 10: Free Body Diagram

As seen in this diagram, F_s is the normal force applied by the screw to the specimen. Taking into account the frictional component, we find that the following equations are useful in helping to determine the required forces.

$$\sum F_y = 18\text{N} - \mu F_s = 0 \quad \textbf{(4)}$$

$$F_s = \frac{18}{\mu}\text{N} \quad \textbf{(5)}$$

After finding the coefficients of friction for the different types of material we were able to calculate the different forces that will be seen. Below in **Table 8: Screw Forces**, a table of forces and their corresponding coefficients of friction are shown.

Table 8: Screw Forces

Force	Friction
120.0	0.15
36.0	0.50
21.2	0.85
15.0	1.20
11.6	1.55
9.5	1.90

As can be seen in this table, the max force than any type of screw needs to apply to secure the specimen was found to be 120 N. For the rest of the calculations, we assume the max force to be 120 N.

To continue the analysis of the screw, it is necessary to ensure that the threads will not strip the pushrod when subjected to this force. After looking at the different screw types that are available, we decided that the best screw type for this application would be an M3 x 0.5 x 6mm screw. This is a standard metric screw size that has a major thread diameter of 3mm and a pitch of 0.5mm. In order to calculate the stresses seen by the pushrod and the screw the following equations were used.

Internal Threaded Shear Area

$$A_s = \pi \cdot n \cdot l_e \cdot D\left(\frac{1}{2n} + 0.57735(D - dp)\right) \quad \textbf{(6)}$$

External Screw Shear Area

$$A_n = \pi \cdot n \cdot l_e \cdot dr\left(\frac{1}{2n} + 0.57735(dp - dr)\right) \quad \textbf{(7)}$$

The variables in these equations are defined below

p = Pitch

$n = \frac{1}{p}$ = Number of threads per inch

l_e = Fastener thread engagement

D = Major diameter of internal thread

dr = Minor diameter

dp = Pitch diameter

Using equations **(6)** and **(7)**, along with the dimensions of a M3 x 0.5 x 6 mm screw, the results for the shear area were calculated and are shown below in **Table 9: Shear Results**.

Table 9: Shear Results.

D [mm]	dr [mm]	Le [mm]	dp [mm]	p [mm]	External Area [mm^2]	Internal Area [mm^2]
3.000	2.385	3.500	2.567	0.500	**18.623**	**32.986**

We then performed an analysis of the different types of materials that we could use for the screws. We chose to analyze two of the screws with the lowest coefficients of friction. In this analysis we chose to look at brass and nylon screws. On the next page, in **Table 10: Stresses**, the results of the calculation for each screw are shown.

Table 10: Stresses

	Nylon Type 66			**Brass**		
	Yield Str. [MPa]	**Force [N]**	**Coeff. Friction**	**Yield Str. [MPa]**	**Force [N]**	**Coeff. Friction**
	45	120	0.15	130	51.43	0.35
External Thread Force to Fail [N]	838.1			2421.0		
Internal Thread Shear to Fail [N]	8081.6			8081.6		

As we can see in this table, the force required to strip the internal threads is about 8 [kN]. This result means that both of the screws will strip before stripping the pushrod threading. This is exactly what is desired as we do not want to damage the pushrod itself.

Next we look at the cross-sectional area on which the screw will apply force. Below in **Figure 11: Sectional View**, and **Figure 12: Tip**, a cross-sectional view of the area where the force is applied, and a model view of the tip, are shown.

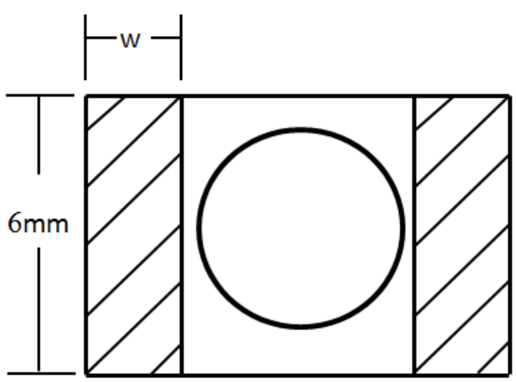

Figure 11: Sectional View

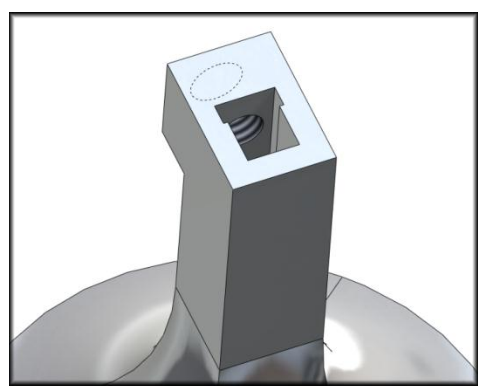

Figure 12: Tip

In these views, we show the smallest area over which the force is applied. The wall thickness *w* can be varied from 0.5mm to 1.25mm.

Below, in **Table 11: Wall Stresses**, we see the results of calculating the stress over these two areas.

Table 11: Wall Stresses

M3 x 0.5 x 6mm	Break Fixture	
Wall 'w'	**Stress MPa**	**FS**
0.50	20.00	12.1
0.55	18.18	13.3
0.60	16.67	14.5
0.65	15.38	15.7
0.70	14.29	16.9
0.75	13.33	18.1
0.80	12.50	19.3
0.85	11.76	20.5
0.90	11.11	21.7
0.95	10.53	22.9
1.00	10.00	24.1
1.05	9.52	25.3
1.10	9.09	26.5
1.15	8.70	27.7
1.20	8.33	28.9
1.25	8.00	30.1

As seen in **Table 11: Wall Stresses**, the stresses seen over this area range from 8–20MPa. Although initially surprising, the factors of safety that correspond to these stresses, range from 12–30. These values match our expectations given the magnitude of the forces that are seen and the strength of the aluminum.

4.5 Cost Analysis

After we looked at different references, we were able to create a table of the cost of the different materials. There are six types of metals that are listed in the table along with the associated costs. They are Copper, Silver, Lead, Magnesium, Aluminum Alloy and Platinum. We created a scale to describe the price, ranging from 1 – 9, where 9 is the lowest cost. Below in **Table 12: Material Cost**, we show the different materials and costs.

Table 12: Material Cost

Material	$/lb	Description	Scale
Copper	3-3.5	A little Expensive	4
Silver	30-32	Too expensive	2
Lead	2.3-3.0	A little Expensive	5
Magnesium	2-2.6	A little Expensive	6
Aluminum Alloy	0.6-0.9	Inexpensive	9
Platinum	50-60	Too Expensive	1

As can be seen from this table, Aluminum alloy is the most inexpensive material that meets our requirements

Next, we analyzed the different types of aluminum alloy, 1000 series to 7000 series. After comparing the costs of the different materials, we found little variation in the cost, about $3 - $3.5 per kilogram. Because of similar pricing, it is important to look at the different material composition. For instances, the aluminum 1000 series is 99% pure aluminum while the 7000 series is made from zinc. The material that best suits our needs was Aluminum 6061-T6 for the main components of our design. On the next page, in **Table 13: Alloy Pricing**, the costs and compositions of the different aluminum alloys are shown.

Table 13: Alloy Pricing

Aluminum Alloy	Alloyed Component	Price: $/kg
1000 Series	Pure 99%	2.6-4
2000 Series	Copper	2.5-4.2
3000 Series	Manganese	3.5-3.6
4000 Series	Silicon	3.0-5
5000 Series	Magnesium	2.5-3.5
6000 Series	Magnesium Silicon	2.5-3.5
7000 Series	Zinc	2.5-5.5

After looking for different types of screws, there were two main types of screws. The two types of screws we will focus on will be brass and nylon. By comparing the costs, we find that the brass is much more expensive than the nylon. Below in **Table 14: Screw Pricing**, the cost of each screw is shown.

Table 14: Screw Pricing

Screw	Price / piece [$/piece]
Brass	0.1-1
Nylon	0.005-0.006

5. Final Design

After speaking with our client we have settled on the design with which we will move forward. The designs which were initially chosen in our decision matrix changed after speaking with Dr. Ciocanel. One problem with the clamp tip design was that the tip did not fit between the magnetic coils. The space between these magnets would have been about 20mm, which is much too large. Because of this we were forced to rethink the design of the tip. After looking at the decision matrix and some of the options that were available, we decided to make modifications to the screw tip design. Rather than using four screws to secure the specimen we designed a new tip that only employed the use of one screw. A model of this new design is shown below in **Figure 13: Final Tip**.

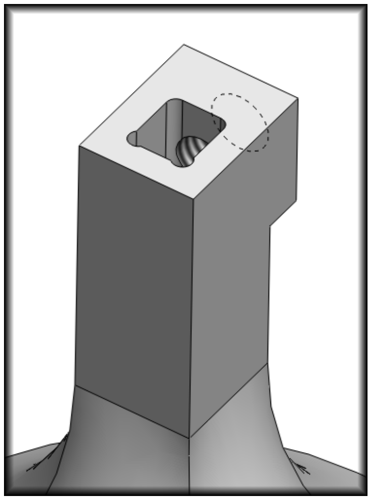

Figure 13: Final Tip

This design allows for axial alignment as well as tension tests. This design also ensures that the tip will fit between the small widths of the magnets.

The base design also did not quite meet the constraints that we were working with. Because of this we looked at one of other designs called the Base Sleeve. This design uses the existing alignment of the force analyzer to align the pushrod. A screw is used to secure the sleeve to force analyzer. Below is a section view and regular view of this base design located in **Figure 14: Base Sleeve**, and **Figure 15: Sectioned Base**.

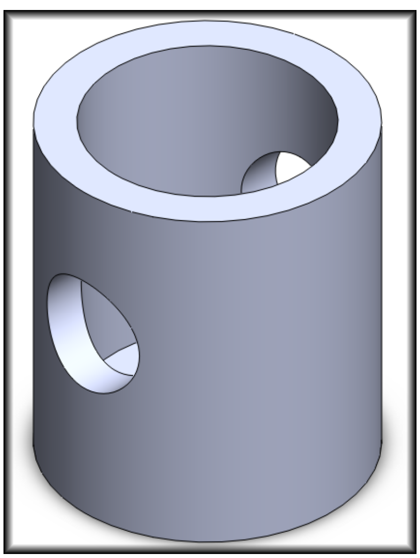

Figure 14: Base Sleeve

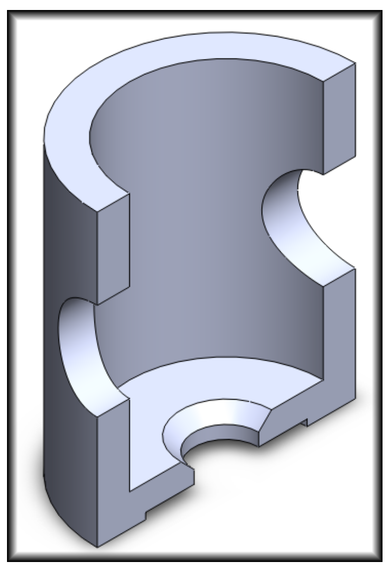

Figure 15: Sectioned Base

This design ensures that the base will be axially aligned. It also allows for tension and compression testing. A detailed view of these designs can be found in **Appendix 3: Drawings**.

These designs will be cost effective and ensure that all of constraints are met. The material that we are looking to make the components is primarily Aluminum 6061 – T6. We have also considered looking at Titanium. Titanium has a yield strength of about 880 [MPa] as opposed to aluminum which has a yield strength of about 245 [MPa]. This would ensure that the no yielding would occur during testing. Titanium is much more costly than the aluminum, but it is non-magnetic and would meet our requirements.

6. Future Tasks

Next semester, the main task will be to build and test prototypes of our designs. In order to be ready to build and test prototypes, we must first consult with our client for design feedback. Once our client has approved our designs we can begin the building phase. In order to build our parts we will be in contact with the machine shop to figure out what machines we will need to use, and what files, tools, and assistance we will need when using the machines. Our parts will mainly be made in CNC machines, lathes, and mills. We are also looking into using a rapid prototyping machine to make our designs. The particular system we are looking at is called Fused Deposition Modeling (FDM), which lays downs beads of hot plastic. This material fuses together to form the final product.

Once each prototype has been built, we can begin testing them. In order to test them and make sure they work properly, each component in the design must be able to mate flawlessly with the other components. Next, we will need to make sure that each part can be placed on or into the machine testing environment. Once the parts can be mated with each other and the testing machine, we can begin to run trials, making sure that they stay in place during actual testing.

After each prototype is build, we will perform analysis to ensure that all requirements are met. If a prototype does not, we will redesign and rebuild the flawed part. This process will be repeated until a design is achieved that meets all the requirements and objectives.

7. Project Plan

7.1 Fall Semester

The final Gantt chart for Fall Semester can be found in **Appendix 1: Fall 2012 Timeline**. Our preliminary tasks included meeting with our client to learn about the project, current issues that needed to be resolved, and to look at the machine up close. After understanding the problem, we then proceeded to generate ideas. We began with separate ideas for the tip of the pushrod and the way it attaches to the base where the force analyzer is located. With each new design, we would schedule a meeting with our client to discuss our ideas and ask for feedback. Each design was changed multiple times throughout the semester, and will likely continue to change as the next semester progresses. Once designs were updated, analysis was performed on each design. This analysis helped us gain a better understanding of how each design would meet, or not meet our design criteria.

7.2 Spring Semester

A rough plan has been laid out for the spring semester as well and can be found in **Appendix 2: Spring 2013 Timeline**. The majority of the work next semester has been allotted to building and testing our designs. Before we can proceed with the building however, we must first understand the manufacturing processes involved in designs of this scale. Once we have a firm grasp of the manufacturing process, we will begin to build our designs. After each design is built, we will then need to test and analyze them to make sure they meet our customer's requirements, as well as our engineering targets. The building and analysis of each design will continue and be repeated until a final design is achieved. This design will meet all of the customer's requirements as well as our engineering targets.

8. Conclusion

8.1 Introduction

Our project is to design a new test fixture for a Magnetic Shape Memory Alloy (MSMA). The current testing fixtures are causing fatigue failure in the specimens which is undesirable. These testing fixtures will operate in the presence of a magnetic field due to the nature of specimens. Because the specimens are extremely rare and expensive, axial alignment is one of the most critical components of this project. The project is to create a new fixture that is able to perform both tensile and compressive tests on the MSMA specimens.

8.2 Objectives and Constraints

The objectives for this project are to design a new material testing fixture. One of the most important objectives is to keep the specimen axially aligned. This will prevent the specimen from developing fatigue cracks and catastrophically failing.

For this project, we have defined seven constraints must meet. These constraints are listed below:

1) **Specimen size:** The specimen size is (3 x 3 x 20) mm.
2) **Exposed length:** There must be at least 6mm of exposed specimen for the camera to monitor.
3) **Fixture must not damage specimen:** The fixture cannot bite into the material causing damage.
4) **Fixture must be non- magnetic:** The magnetic field of the fixture must not interfere with the applied magnetic field.
5) **The distance between magnets:** The space between the magnets when the specimen is located can be no more than 10mm.
6) **Magnetic field:** The applied magnetic field varies from (0.5 ~ 1.0) Tesla (T).
7) **Axial Alignment:** It is crucial that the specimen be axially loaded.

8.3 Concepts Generation, Selection, and Final Design

During the concepts generation, we came up with two tip designs and three base designs: The Clamp Tip, Screw Tip, Adjustable Base, Base Sleeve and Collar Base. After talking with our client, some issues were discovered and we were forced to modify the designs. By considering the Selection Matrix and the advisement from our client, we came up with our final design. Altogether, this design will contain eight components:

1. Base Sleeve x 2
2. Securing Pin x 2
3. Pushrod / Tip x 2
4. Set Screw x 2

Below in **Figure 16: Full Assembly**, a model of our full design is shown. This image contains all the components in our design oriented in the actual final configuration.

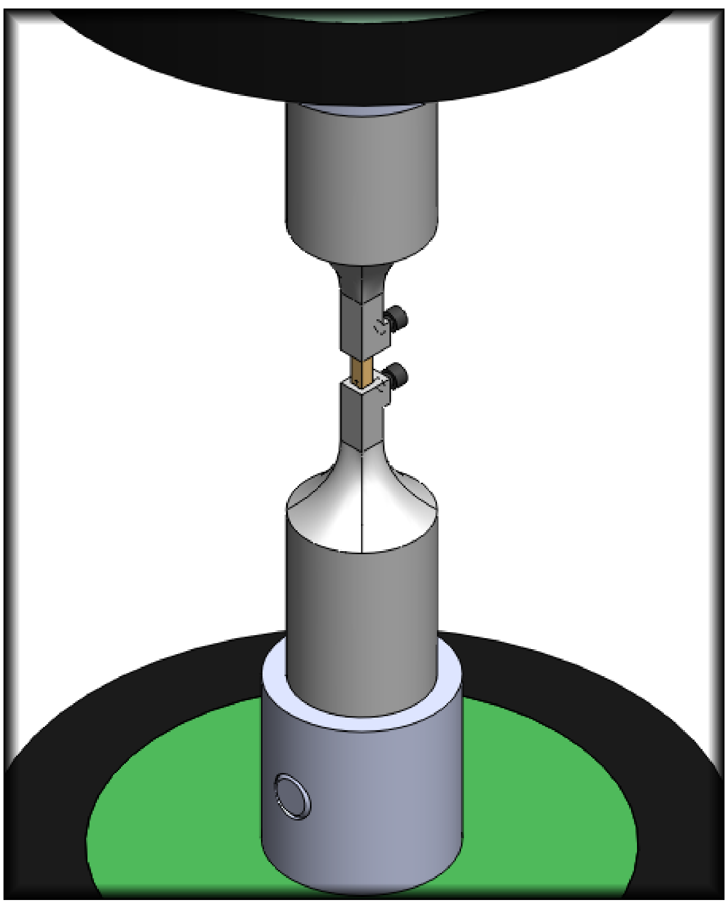

Figure 16: Full Assembly

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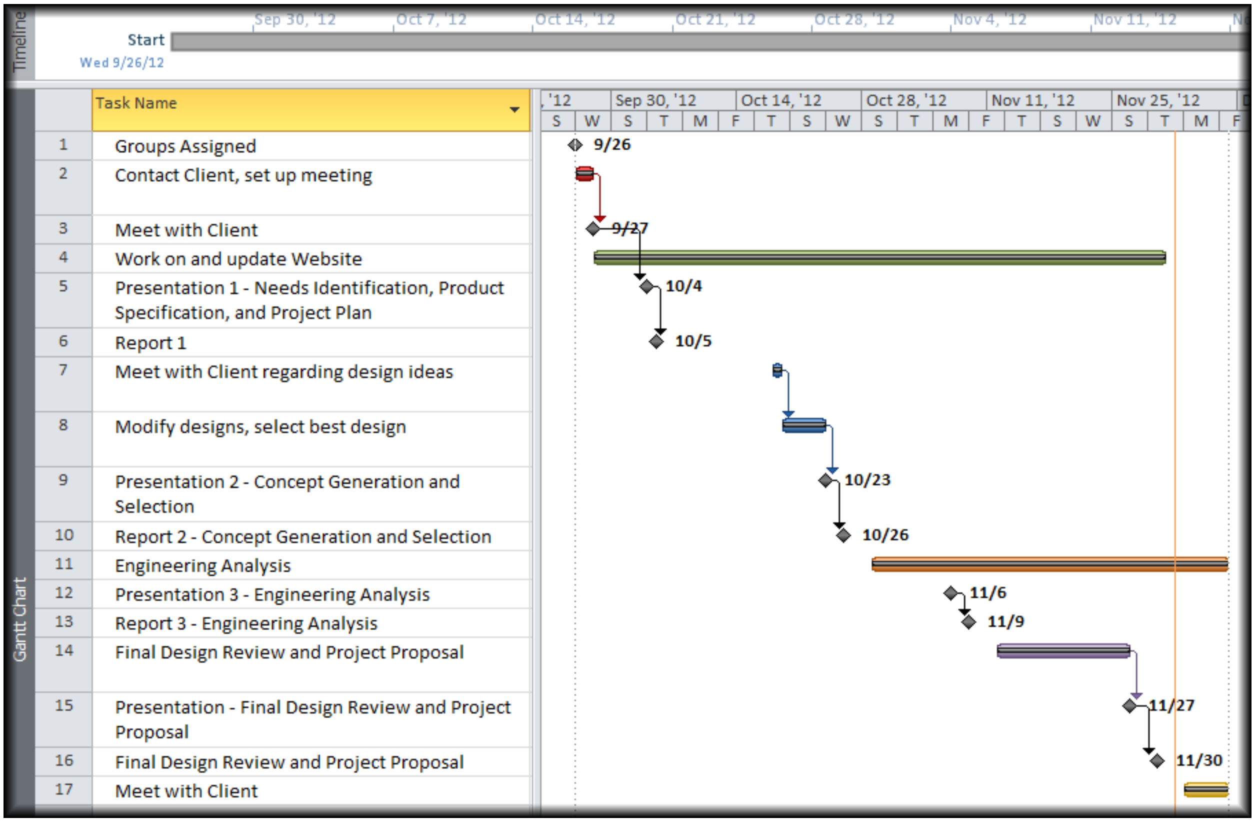
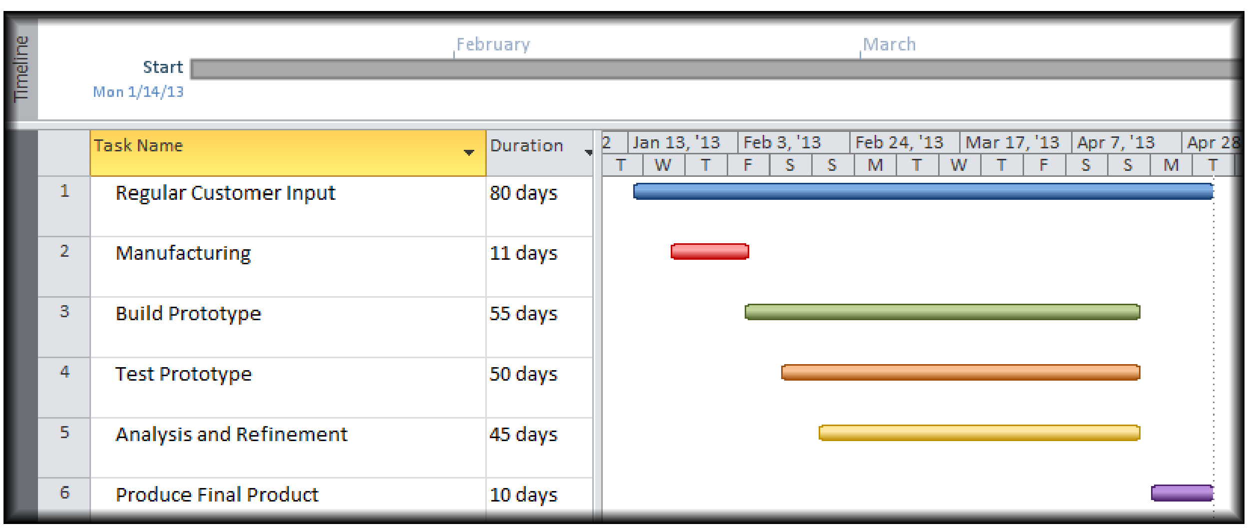
Dr. John Tester

Dr. Constantin Ciocanel

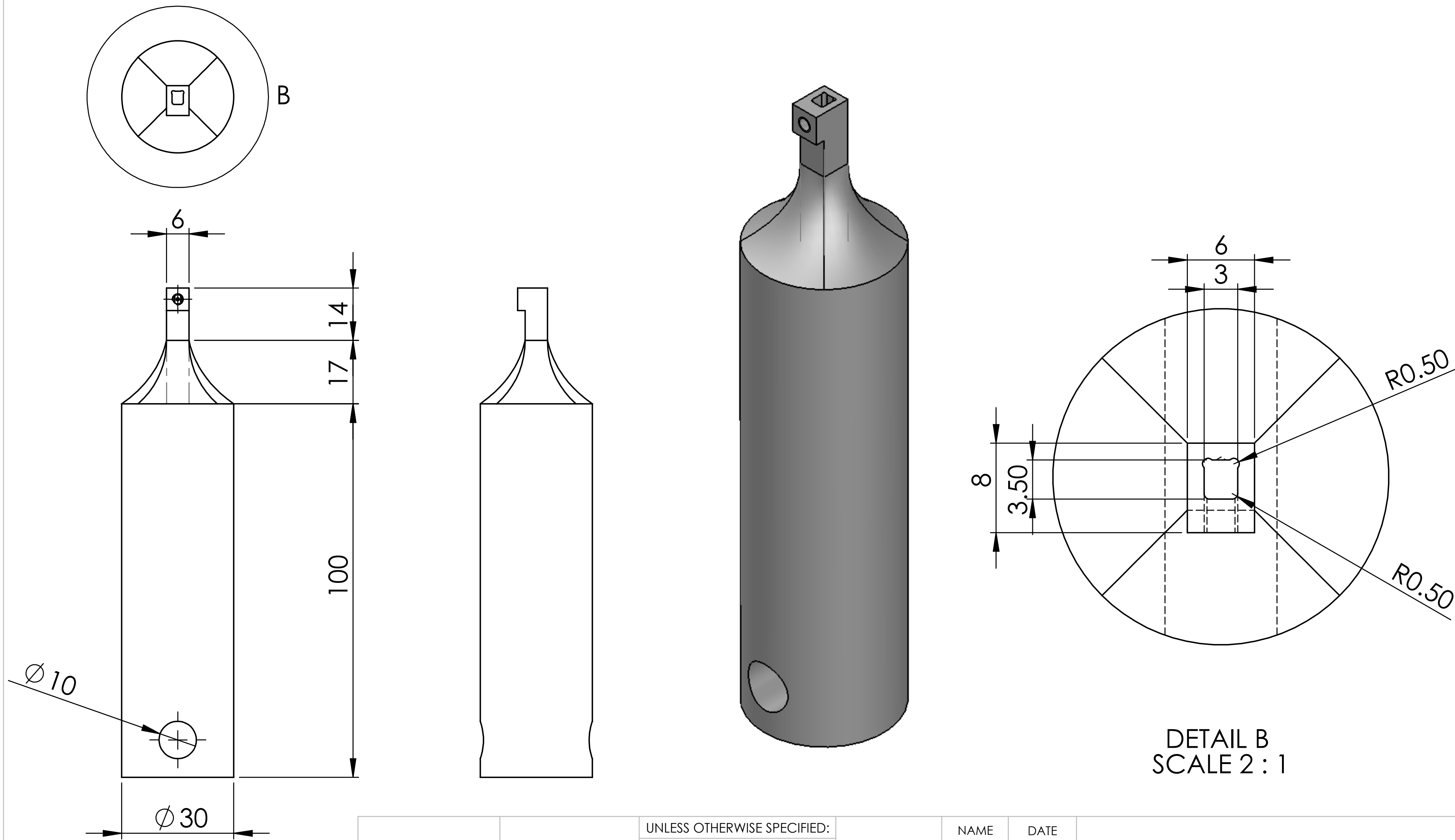
Appendix 1: Fall 2012 Timeline



Appendix 2: Spring 2013 Timeline



Appendix 3: Drawings



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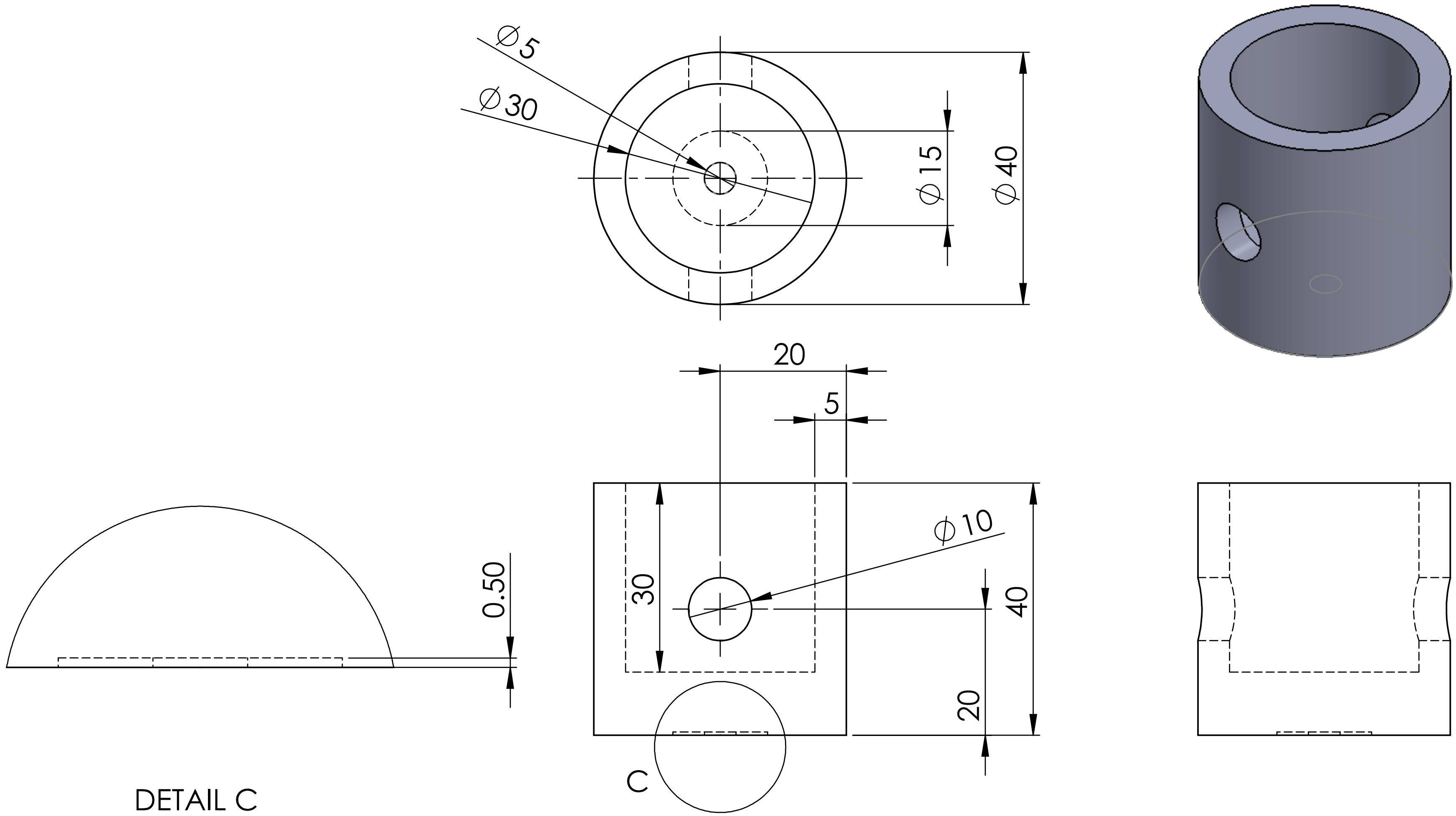

DETAIL C
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ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
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INTERPRET GEOMETRIC TOLERANCING PER:

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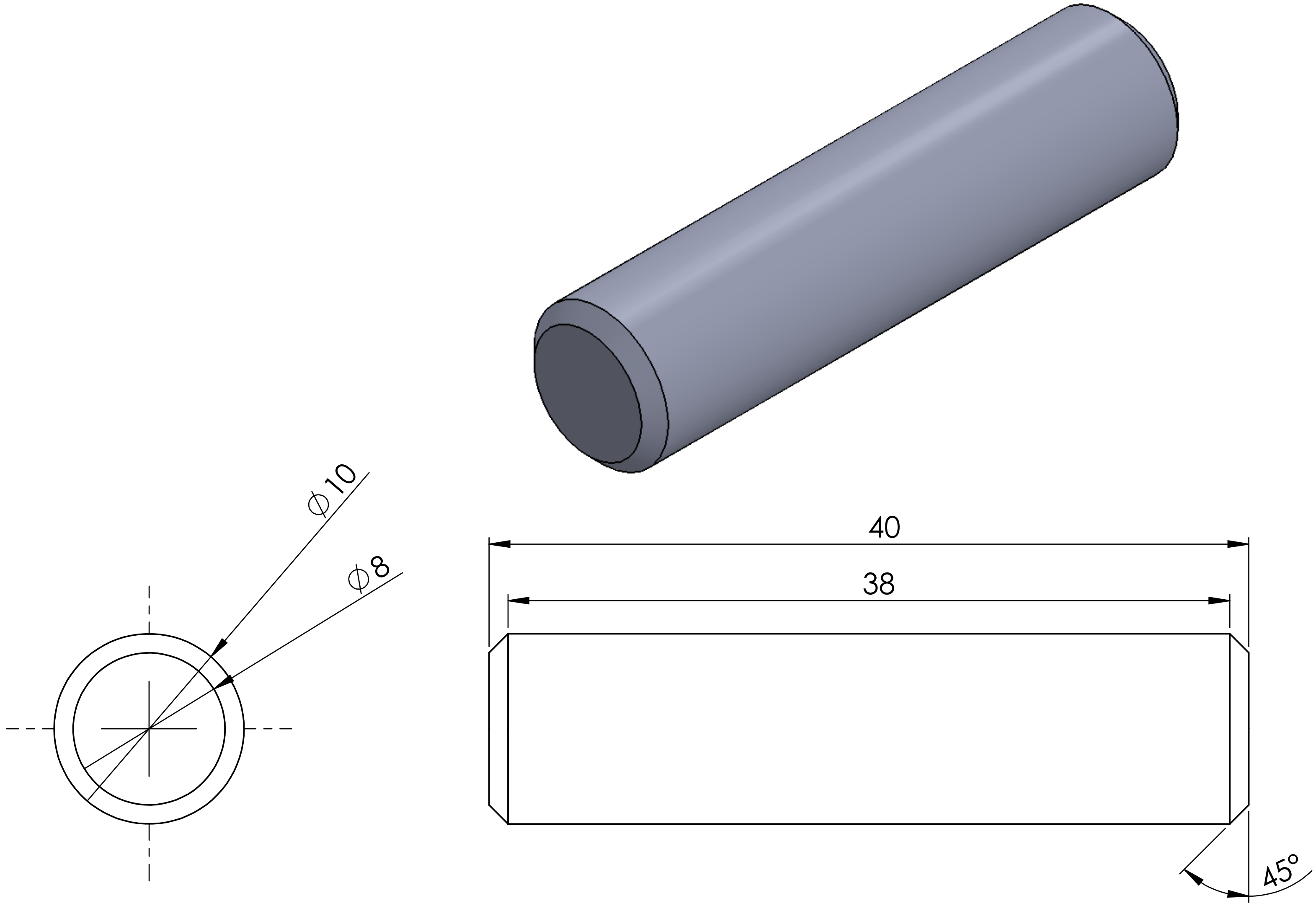

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

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TITLE:

SIZE	DWG. NO.	REV
A	pin	

SCALE: 2:1 WEIGHT: SHEET 3 OF 3

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