MSMA Lateral Loading Device

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Progress Report

Document

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1.0 Abstract

This report will provide a brief review of the Magnetic Shape Memory Alloy (MSMA) Lateral Loading Device Project. First the problem identification, project description, and previously proposed design will be reviewed. This design comprises of the Honeywell Model 11 force sensor and the Ultramotion Digit NEMA 17 Stepper actuator. Then this document will cover the client requested secondary design. This secondary design consists of the Honeywell Model 11 force sensor and either the THORLABS PAS015 Piezo-Actuator or the THORLABS PAZ015 Piezo-Actuator. The difference between these two options are that the PAS015 does not have a built in feedback control, whereas the PAZ015 does. As the client makes a decision on which design to go forth with, there are specific tasks that the team can move forward with. The Gantt chart will then be presented as well as the duties of each team member.

2.0 Project Description

At the Northern Arizona University, Dr. Constantin Ciocanel is experimenting with a MSMA, which exhibits strain under a magnetic field. The mechanical properties of this material are not well known, and it is Dr. Ciocanel's goal to find them. Using an Instron machine, Dr. Ciocanel and his graduate student loads the selected material vertically, while applying a magnetic field horizontally, seen in **Fig. 2.1** and **Fig. 2.2**. However, this experimental set up leaves an entire third dimension unexplored.

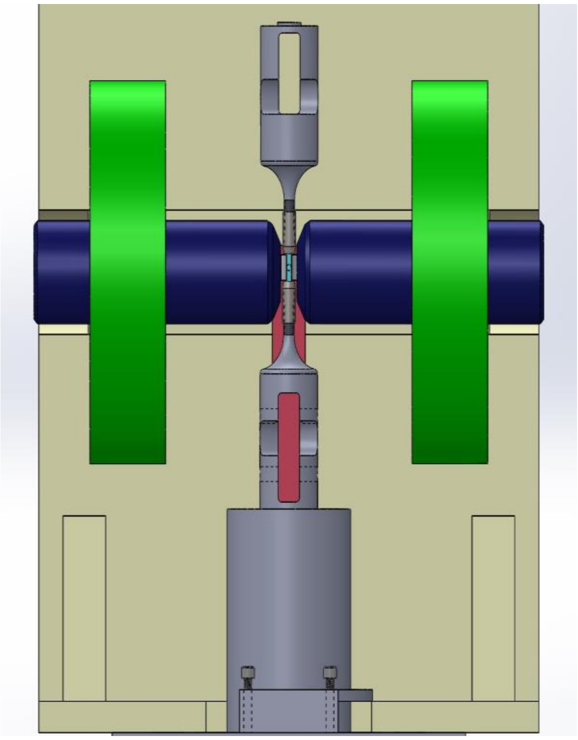


Figure 2.1: Close up of Instron machine

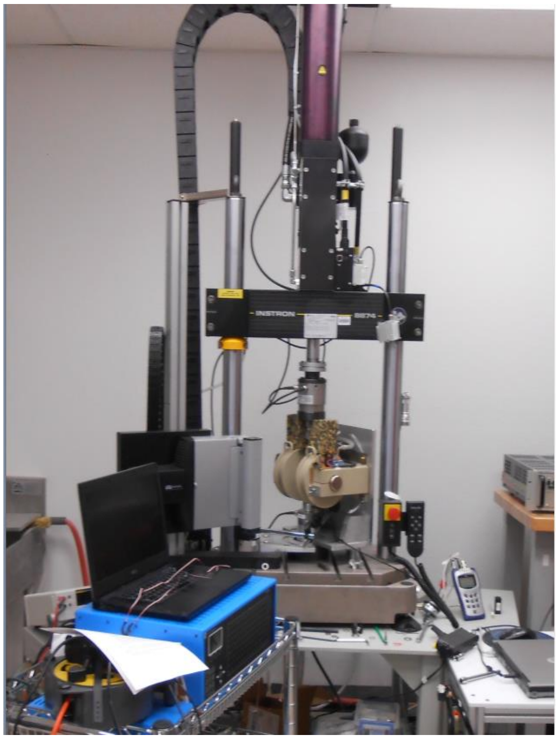


Figure 2.2: Full Instron machine

In order to run tests which result in accurate data, a piece of equipment needs to be designed that will facilitate the testing process in a third dimension. This equipment is required to be effective, cost efficient, and precise. It must also be able interface with the already existing equipment. In order to meet these goals the following set of constraints were set:

1. Full cost under $2,500: This includes all the parts and materials used within the design.
2. Capable of applying a force greater than or equal to 75 N: The actuator must apply a constant force ranging from 0 to at least 75 N. This force is required to get a complete understanding of the MSMA material properties during testing.
3. The materials used must be non-magnetic: The apparatus has high powered electro dipoles creating a powerful electric field. Therefore, the material selected must be resist the magnetism and function normally.
4. The width of the material in contact with the MSMA must be no greater than 10 mm: The distance between the electro dipoles is 10 mm. If our design has a width greater than the specified value it will not be able to make contact with the MSMA.
5. The height of the material in contact with the MSMA must be no greater than 12 mm: The distance between the grips that hold the MSMA in the testing apparatus during maximum material compression is 12 mm. The design must be equal to or less than the specified value to make contact with the MSMA and allow for a force to be applied.
6. Able to be installed by two individuals: On average two individuals will be working within the lab at any given moment. Therefore, the design must be such that two lab workers could install or uninstall the device for testing purposes. This will apply limits on the designs size and weight.

3.0 Design Concepts

Due to the small space within the testing environment, it was decided that there was only one basic design that could be implemented. Within this basic design there were however two main variable components. This decision was reached at the beginning of the design process, it became evident that each design apparatus was too similar in their setup to deem separate designs. Therefore the designs for the overall concept generation were split into two main categories: sensing devices and actuating devices. These two categories are completely different in their functionality and allow for a large range of options to select from when selecting the final design. The basic overall design with the two variable devices can be seen in **Fig. 3.1** below. The basic design works by placing the actuator and sensor an undecided distance from the MSMA, allowing for more design and size options to this problem.

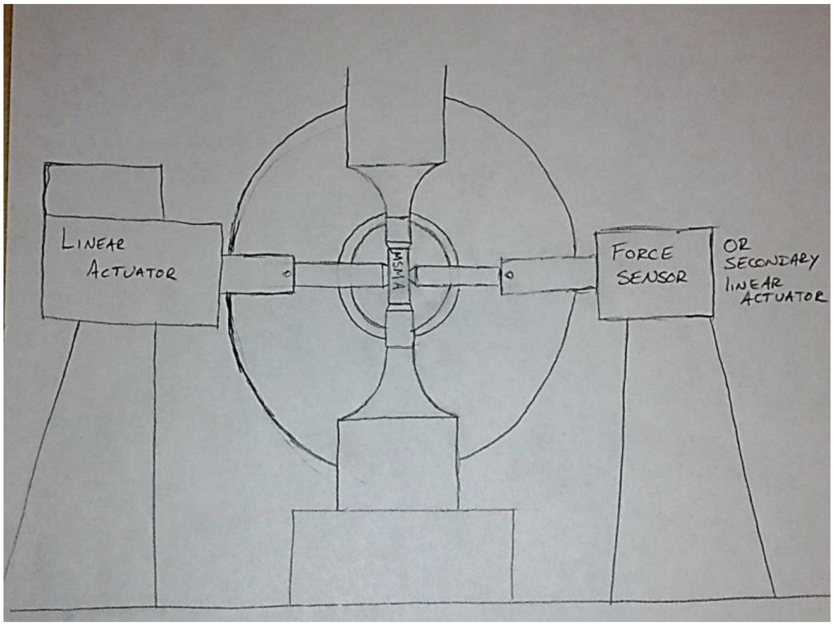


Figure 3.1: Initial System Design

3.1 Force Sensing

Force sensors come in a variety of types and parameters. The maximum displacement that the MSMA will have will be 0.18 mm. For the type of sensing that will need to happen, the force sensor will have to be extremely sensitive. However, as the precision increases in a product, so does the cost. It will be imperative that middle is met between the cost and the precision. The force sensor will need to be small in size because it will be located on the backside of the MSMA, the side with the least area to work with. It will also have to be small so that the sensor can be easily removed, as Dr. Ciocanel performs a variety of tests on the specimens of MSMAs.

There are a variety of types of force sensors that will be applicable for these constraints. Piezoelectric sensors provide a high precision. However, they are very expensive. Strain gages are another viable option because of their size as well as their sensitivity. Force sensing resistors are like strain gages in principle. Their difference is that force sensing resistors have a lower precision.

3.2 Actuators

The actuation that will need to happen is very precise since the maximum displacement that will happen is 0.18 mm. Although the actuator will be located in front of the MSMA, the space will still be limited. Much like the force sensor, as the actuator becomes more precise, the cost increases. Some actuators need a special feedback controller which is another cost addition.

There are four types of actuators that are applicable to the current description: electromechanical, hydraulic, pneumatic, and piezoactuators. Electromechanical actuation devices come in a variety of force increments. Since the force needed is at most 200 N and the maximum displacement is 0.18 mm, finding electromechanical actuators that fit into the design description will be difficult. Hydraulic actuators require many hoses as well as a supply for the hydraulic fluid. The pneumatic actuators are easy to find and the simplest in design. The piezoactuators are the most expensive, since they use multiple stacks of piezoelectric materials. These, however, are the most precise because piezoelectrics are very precise in nature.

4.0 Previously Proposed Design

Upon further analysis of product costs and ease of manufacturing it became apparent that a strain gauge would be the only viable option for force sensing giving the current budget. For actuation it was found that the best option would be an electromechanical design. From there the following products were selected. The force sensor product is a Honeywell Model 11 Subminiature Tension/Compression Load Cell [3]. As for the actuators, the Ultra Motion Digit NEMA 17 Stepper was selected [5].

The following mounting setup was proposed using the electromechanical actuator as seen in **Fig 4.1**. This design uses a cylindrical tower design, where each tower would have a threaded end and screw directly into the existing Instron base plate. A circular base would then be attached to the top of the actuator tower to provide a suitable area for the actuator mounting system. Again, the MSMA is held by the Material Testing Fixtures [1] and is compressed by the add-ons of the actuator and force sensor. The tower on the back side, which supports the load cell is still undergoing differing design considerations.

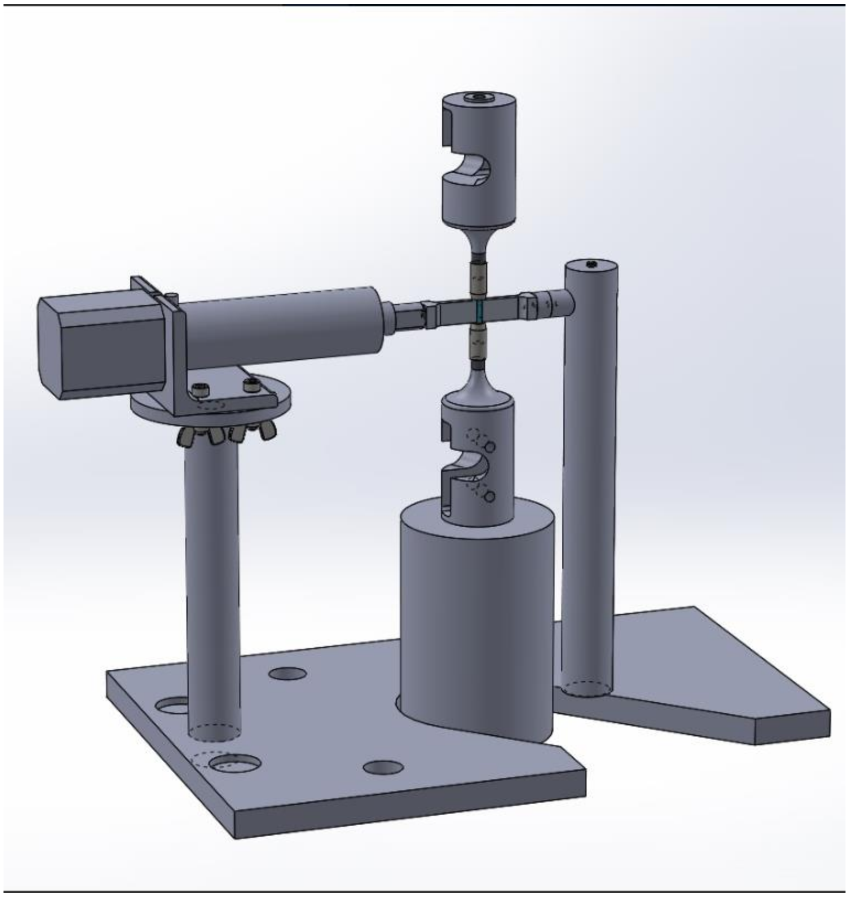


Figure 4.1: Solidworks Model of Electromechanical Mounting Design [1] [3] [4]

5.0 Secondary Design

For the secondary design the setup is essentially the same; however the ThorLabs PAS015 Modular Piezoelectric Actuator [4] will replace the Ultra Motion Digit actuator. Both actuating products are about seven inches in length and have similar diameters. With this change, it will be necessary to slightly alter the design of the support to accommodate the different geometry of the actuator. However the overall look of the supporting system will be the same. The main difference in these two products is how they are controlled. The ThorLabs actuator uses a Piezo controller to connect to LabView while the Digit will use a stepper drive. This design has a higher resolution and allows for better programmability within LabView. Another possible option considered is the ThorLabs PAZ015 Actuator [4] which is the same as the PAS series but also has positional feedback control. The cost of the actuator and driver are at least double that of the Digit. The cost breakdown is looked at more closely in the next section.

6.0 Cost Comparison

The Honeywell Model 11 Subminiature Tension/Compression Load Cell is the selected load cell. This product is currently owned by the client and has been approved for application in this device. Its cost will therefore be removed from the total cost breakdown. In addition, the manufacturing for all parts of the mounting system will be performed by the members of our team. This will occur in Northern Arizona University's Manufacturing Shop, under appropriate supervision. Thanks to this, manufacturing costs will not need to be added in the total cost of production. Listed in **Table 4.1** below is the compared cost breakdowns for each design.

Component	**EM**	**PE1**	**PE2**	**Cost**
Digit NEMA 17 Stepper	X			$620.00
ST5-S Stepper Drive	X			$360.00
THORLABS PAS015 Piezo-Actuator			X	$1463.48
T-Cube Piezo Controller		X	X	$595.00
THORLABS PAZ015 Piezo-Actuator		X		$1933.85
T-Cube Strain Gauge Reader		X		$545.00
Power Supply		X	X	$105.00
Model 11 Load Cell*	X	X	X	$771.00
6061 Al Rod, 1" Diameter, 3' Length	X	X	X	$19.34
6061 Al, ¼" x 6" x 3'	X	X	X	$35.46
Flathead Screw, 5 pack	X	X	X	$5.24
Wing Nuts, 25 pack	X	X	X	$7.21
Socket Head Cap Screw, 25 pack	X	X	X	$5.61
Set Screw, 25 pack	X	X	X	$3.76
Total Cost	**$1056.62**	**$3255.47**	**$2240.10**	

Table 4.1: Cost Comparison

The cost comparison shows that either the Ultramotion Digit or ThorLabs PAS series would be within the previously allotted budget. While the ThorLabs PAZ series would put the project slightly over budget. The reason for the breakdown of the PAZ series is that the client specifically stated that he would like the team to look into that product. Using the cost comparison, the team will approach the client and allow him to cast the final decision regarding the product used. All the products are capable of meeting the project requirements, so it is up to the client's preference.

7.0 Project Planning

The tasks for this project have been distributed among the five team members. The full team will collaborate on the choice of actuator, obtaining materials, testing, and any needed redesign. From there the remaining tasks were delegated to a leader and second, to ensure quality completion. Matthew and Cody will be in charge of ordering materials and products. Thaddeus and Joy will finish designing the supports and mounting in SolidWorks. Jonathan and Matthew will machine the parts in the machine shop in building 98C. Thaddeus and Matt will complete the assembling and building necessary during the testing and redesigning phase. Cody and

Jonathan will be in charge of programming a LabView file for the force feedback portion of the design. All of these tasks have been organized into three main tasks: Finishing Design and Order Parts, Assemble Setup, and Build Programming and Testing. These tasks, and their allocated times, were organized using Microsoft Project. The Gantt chart for this allocation can be seen in the Appendix A, **Fig A.1**.

8.0 Conclusion

This project entails designing and building a system which will laterally load an MSMA in order to assist Dr. Ciocanel in testing this material. The chosen design was narrowed to the Digit and PAS series actuators. Due to new technologies involved with MSMA specimens the lateral dimension does not deform. Due to this the client has required more time to consider which actuator he would like to pursues. The decision is whether the client would like a more stable force application or if he would like to spend more money for an obsolete technology. In order to maintain a consistent force, a Honeywell Model 11 Subminiature Tension/Compression Load Cell will be used to measure the amount of force applied. Coupled with a well-built program using LabView, this information will be feed back to the actuator, causing it to adjust accordingly. The load cell support structure is currently undergoing design changes. The remaining tasks include purchasing the products and materials, machining the parts, building the LabView code, testing, and any redesign needed. These tasks have been distributed to the team members.

9.0 References

[1] Garcia, Matt, Randy Jackson, Jeremy Mountain, Qian Tong, and Hui Yao. *Material Testing Fixture*. *Material Testing Fixture*. Dr. Ciocanel, 2012. Web. 15 Nov. 2013. <http://www.cefns.nau.edu/capstone/projects/ME/2013/DFMTM/index.html>.

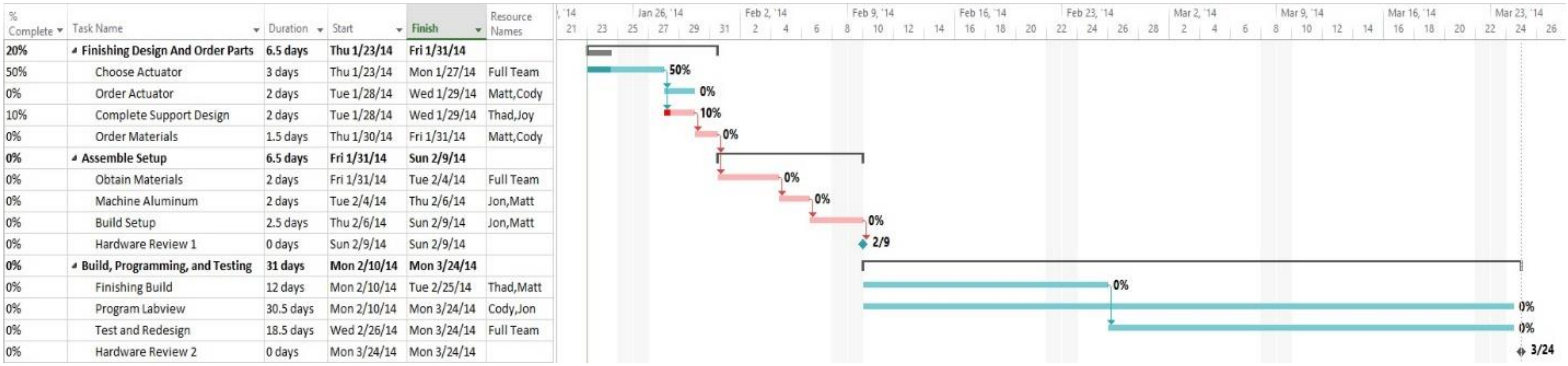
[2] Leo, Donald J. Engineering Analysis of Smart Material Systems. Hoboken, NJ: John Wiley & Sons, 2007.

[3] "Model 11." *Model 11*. Honeywell International Inc, 2013. Web. 6 Nov. 2013.

[4] "Replaceable Tip Piezo Actuators." *Thorlabs*. N.p., n.d. Web. 15 Jan. 2014.

[5] "The Digit." *http://www.ultramotion.com/products/digit.php*. Ultra Motion. Web. 1 Dec. 2013.

10.0 Appendices



% Complete	Task Name	Duration	Start	Finish	Resource Names
20%	**◢ Finishing Design And Order Parts**	**6.5 days**	**Thu 1/23/14**	**Fri 1/31/14**	
50%	Choose Actuator	3 days	Thu 1/23/14	Mon 1/27/14	Full Team
0%	Order Actuator	2 days	Tue 1/28/14	Wed 1/29/14	Matt,Cody
10%	Complete Support Design	2 days	Tue 1/28/14	Wed 1/29/14	Thad,Joy
0%	Order Materials	1.5 days	Thu 1/30/14	Fri 1/31/14	Matt,Cody
0%	**◢ Assemble Setup**	**6.5 days**	**Fri 1/31/14**	**Sun 2/9/14**	
0%	Obtain Materials	2 days	Fri 1/31/14	Tue 2/4/14	Full Team
0%	Machine Aluminum	2 days	Tue 2/4/14	Thu 2/6/14	Jon,Matt
0%	Build Setup	2.5 days	Thu 2/6/14	Sun 2/9/14	Jon,Matt
0%	Hardware Review 1	0 days	Sun 2/9/14	Sun 2/9/14	
0%	**◢ Build, Programming, and Testing**	**31 days**	**Mon 2/10/14**	**Mon 3/24/14**	
0%	Finishing Build	12 days	Mon 2/10/14	Tue 2/25/14	Thad,Matt
0%	Program Labview	30.5 days	Mon 2/10/14	Mon 3/24/14	Cody,Jon
0%	Test and Redesign	18.5 days	Wed 2/26/14	Mon 3/24/14	Full Team
0%	Hardware Review 2	0 days	Mon 3/24/14	Mon 3/24/14	

Figure A.1: Updated Gantt Chart for Spring 2014