FAMU/FSU College of Engineering
Department of Mechanical Engineering

Needs Assessment

Team #20

High Cycle Fatigue of Electroactive Membranes

Submitted to: Dr. Gupta & Dr. Helzer, ME Senior Design

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Abstract

There is insufficient data on the mechanical fatigue of electroactive membranes. This project is to design and build a mechanical fatigue mechanism to test the membranes. This mechanism will allow the fatigue to be quantified and valuable data to be gathered on these membranes. Currently the team has brainstormed various designs to accomplish this task. Further analysis on these designs will be conducted to better choose the best design. This will include theoretical analysis of the performance before a prototype is constructed. The best materials, motors, and sensors for the design will be chosen. The final design will be implemented onto the MTS (Materials Testing System) machine and tested for functionality and performance.

1 Introduction

Currently electroactive membranes are being studied for implementation onto robot legs to provide more efficient mobility. Little research has been performed on the fatigue of electroactive membranes [1]. Dr. William Oates and Dr. Jonathon Clark are sponsoring our team to build this machine to test specimens that they have been developing in the past couple of years. This project's goal is to develop a high cycle test mechanism to quantify the fatigue of these membranes so the design can be optimized. The project requires the fatigue mechanism to be implemented onto the MTS machine to simultaneously measure membrane loads and displacement. The frequency of the fatigue and the stroke distance will be able to be varied. The contact information and individual roles for the group is shown below in Table 1. Any questions should be directed to the team.

Table 1. Group Contact Information

Role	**Name**	**Email**
Team Leader	Adriane Guettler	aeg12b@my.fsu.edu
Financial Advisor	Nicholas Dawkins	nsd06@my.fsu.edu
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2 Project Definition

2.1 Background Research:

This project is to develop a machine to test high fatigue cyclic loading on electro-active membranes. Dr. Clark in the STRIDe lab has previously built a robot that functions similar to that of a cockroach, known either as “Sprawlita” or “iSprawl”. Figure 1, shown below, shows the current iSprawl platform. This robot at one point in time was the fastest robot per body length when it was running around on flat surfaces. At this point in time Dr. Clark is directing his attention towards making the robot be able to run or walk on multiple types of surfaces, and potentially be able to jump from certain heights. This is where Dr. Oates’ research comes into play, he researches smart materials. He and his researchers have been working to develop a membrane that can be implemented into the iSprawl robot. An example of the membrane and a schematic of the set-up of the membrane can be seen below in Figures 2 and 3. The membrane is made of VHB 4910 which is an adhesive tape which produces a great strain and elastic energy density [2].This allows the material to be very compliant. This membrane will be added to each one of the six legs and may be used alone of in pairs stacked together on one leg. Our team has been given the task to build a machine or mechanism that can be used in Dr. Oates lab to test the fatigue on various membrane specimens that have been created. The machine also must be able to adapt to testing on membrane at a time versus testing a stack of them, as they may be used in this manner on the robot.

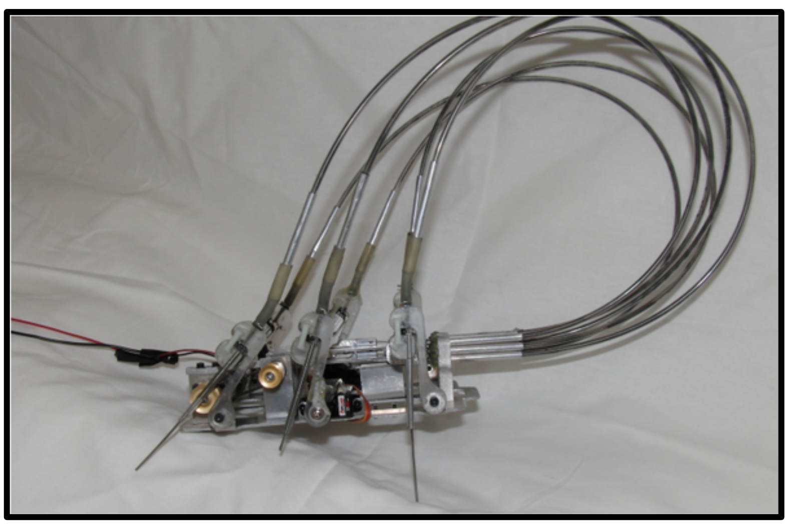
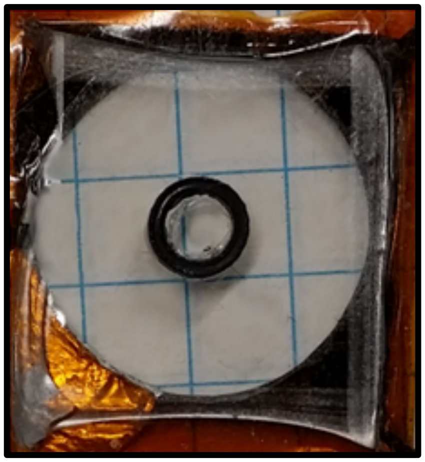


Figure 1: The image above is the current iSprawl platform that the membrane will be implemented onto. The robot is a 0.3 kg hexapod that is able to run at 2.5 ms^{-1}. [3]



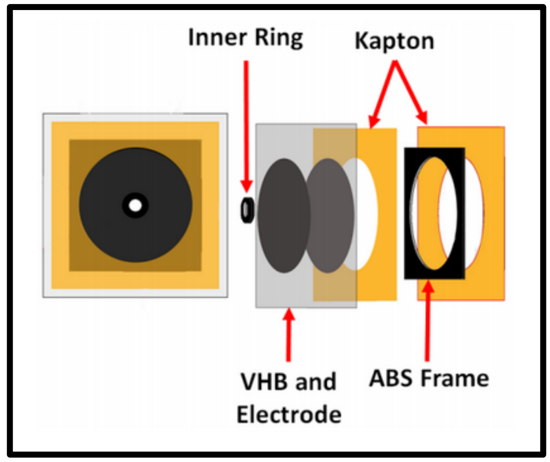


Figure 2 and 3: The figure on the left is an actual sample of the membrane. The figure on the right is a schematic of the setup of how the membranes are assembled. [3]

Previous work on the machine, which our team is in charge of designing and constructing, has not been completed. Much of the background information, in regards to the reasoning behind implementing this membrane on the robot comes from a thesis paper published by a graduate student from the FAMU-FSU College of Engineering named Jason Newton. Newton describes that his work "focuses on the development process of a dielectric elastomer based variable stiffness mechanism as a replacement for traditional springs on a legged hexapedal robot." [3] The idea behind this comes from how biological systems rather than mechanical ones operate, "biological systems show reliance upon their capability to adapt limb stiffness as a means to achieve dynamically similar locomotion over a wide range of terrains." [3]

2.2 Need Statement:

The purpose of this project is the design and implementation of a fatigue mechanism for electroactive membranes in a MTS machine. There is insufficient data on the fatigue behavior for electroactive membranes. It is desired to optimize the design of the membrane to handle repeated mechanical cycling over a range of frequencies and displacement.

There is a lack of information on the fatigue of electroactive membranes.

2.3 Goal Statement & Objectives:

Goal Statement: Design and build a device that produces high cycle sinusoidal mechanical fatigue of electroactive membranes.

Objectives:

- Accurately measure the fatigue placed on the specimen
- Produce various frequencies of cycling
- Produce varying stroke distances to displace the membrane
- Allow for tracking of the displacements controlled by the fatigue machine
- Measure the load associated with the stroke by implementing with the MTS machine

2.4 Constraints:

- System should be a tabletop mechanism that is mounted to the MTS machine
- Fatigue machine must have a 10mm stroke to displace the membrane
- System must be able to produce frequencies ranging from 0.1 to 100 Hz
- System should produce consistent functionality for various specimens
- Overall design should be completed within the budget (to be defined after further analysis)

2.5 Methodology:

For our goals to be achieved, we will come up with a system that can run the specimen through a standard fatigue test but also be able to count how many oscillations occur. Additionally, we will take measurements of the MTS machine so that our device can accurately mount onto it while staying sturdy with minimal vibrations and movement.

To come up with the type of system we would like to implement for the fatigue testing, we will develop multiple designs and create a decision matrix comparing each option. When we conclude the type of system that we want, we will make technical drawings of the entire system that fit to the dimensions of the MTS machine. Once the drawings are completed, they will help us determine what types of materials and parts we will need to start building the system. Before building a prototype though, we will consider making a design simulation using computer software to determine if we should move forward to a physical prototype. If the next step is to move forward with a prototype, materials will be collected and machining and assembly will follow. Some sample runs will be made once the prototype is completed to determine competency and accuracy in measurements. If everything is acceptable and up to par, if time permits, experiments can be carried out to determine the best fatigue material that could be implemented in the actual robotic legs.

2.6 Schedule:

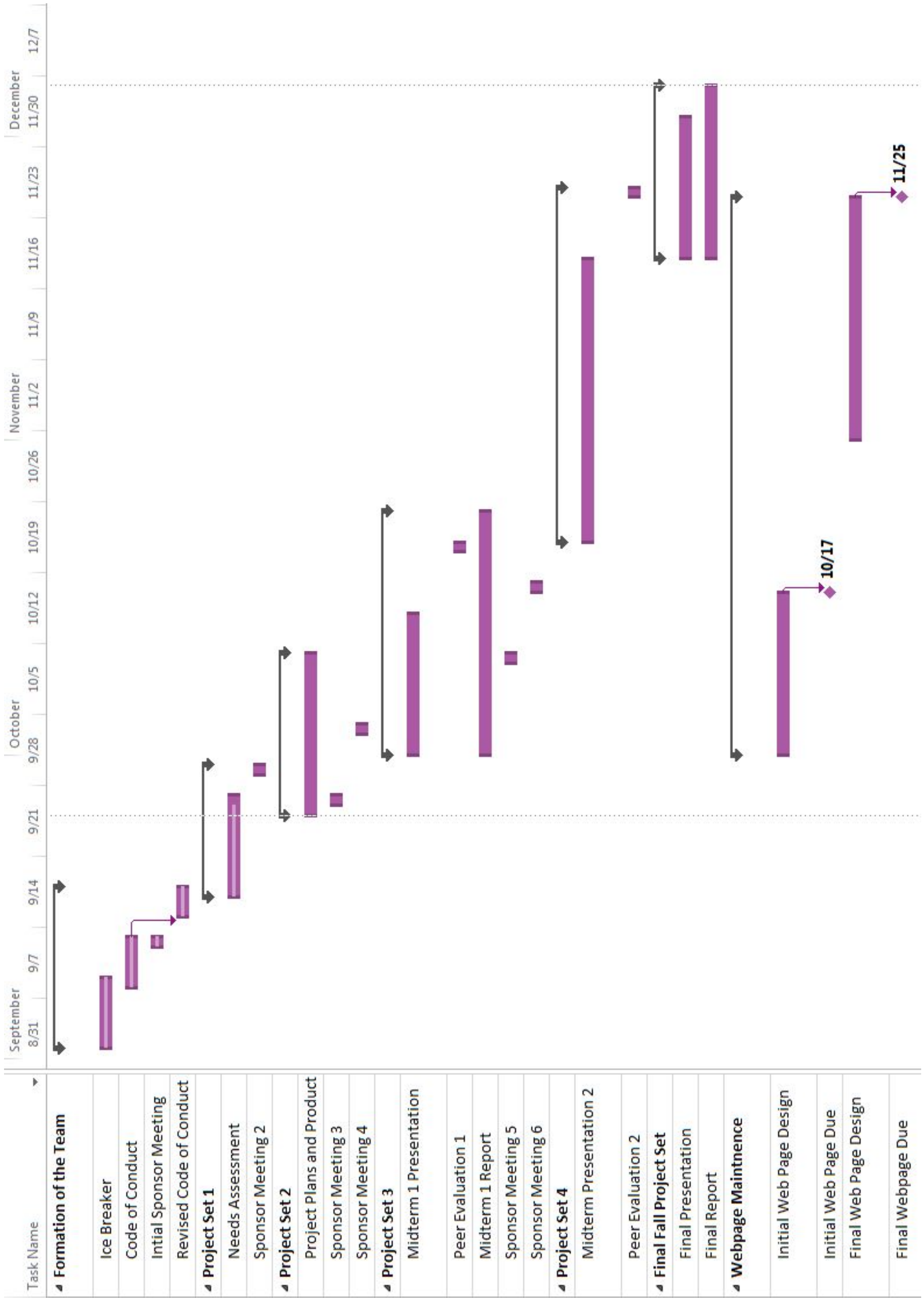


Figure 4. Gantt Chart

3 Conclusion

This project is driven by the lack of information on the fatigue of electroactive membranes. By the end of the spring semester 2015, the team shall have completed the objectives stated and shall accomplished the task ahead. These tasks include devising a fatigue mechanism that provides sufficient data on the fatigue behavior of the electroactive membrane. The fatigue mechanism shall be attached to the MTS machine. The mechanism should have adjustable frequency of cycling and stroke distances to displace the membrane. Tracking of displacement and load shall also be implemented by using the MTS machine. Near future work includes developing plausible designs and analyzing these designs to begin construction of the mechanism.

4 References

[1] Oates, William and Jonathan Clark. “High Cycle Fatigue of Electroactive Membranes.” Florida A&M/Florida State University, 2014. Print.

[2] Kofod, Guggi, Peter Sommer-Larsen, Roy Kornbluh, and Ron Pelrine. "Actuation Response of Polyacrylate Dielectric Elastomers." *Journal of Intelligent Materials Systems and Structures* 14.12 (2003): 787-93. Web.

[3] Newton, Jason. "Design And Characterization Of A Dielectric Elastomer Based Variable Stiffness Mechanism For Implementation Onto A Dynamic Running Robot." Thesis. Florida State University - College Of Engineering, 2014. Print.