Tabletop Mechanical Test Apparatus for Torsion Experimentation

Deliverable Name: Project Plan and Product Specification

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Abstract

This report identifies the basis for the project, the progress that has been made, and the steps that will be taken to complete the capstone. The Munitions Directorate at Eglin Air Force Base has the need to perform torsion tests. The task is to develop a table top torsion testing machine that can effectively perform these tests. The group has completed a Needs Assessment and developed a Gant Chart to help organize the steps that will be taken to complete the project. The next step is to generate a presentation introducing the project to the class. Following that will be further research on the performance specifications, design, and budget analysis.

1 Introduction

The project is to design a table-top sized torsion testing machine capable of efficiently testing a particular range of small specimen. The table top torsion tester will be able to assist with stress and strain analysis on a variety of materials. The Munitions Directorate at Eglin Air Force Base has a machine already in use at this time. Although this machine has high performance specifications, it is designed for much larger specimen. Consequently, there are a number of inaccuracies that develop during the testing of these smaller specimen. The table top torsion tester must perform these tests absent of these inaccuracies all while keeping the design within the given constraints.

2 Project Definition

2.1 Background Research

The Eglin Air Force Base's Munitions Directorate has done extensive research in the field of testing mechanical properties of materials commonly used in projectiles. They are interested in how different materials react under different loads to simulate different scenarios of diverse mediums that the munitions will be fired at. This being said, the group is constrained to the size of the specimens that they can generate. The reason for limited plate thickness is not a matter of cost, however it is a matter of geometry. When the Munitions Directorate is fabricating components of the munitions they use raw stock that is as close to final shape as possible to conserve waste material. In order to properly characterize the materials that ends up in a product they have to test similar geometry in order the get accurate results. A representation on how the Directorate gets their samples is shown below in Figure 1. (1)

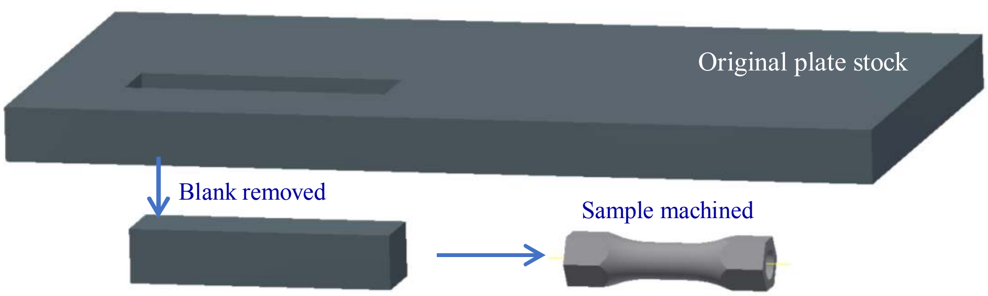

Figure1 Example of sample production from plate stock (1)

Since materials of interest are often in the form of thin sheets or plates, this makes the specimen that is generated relatively small, having dimensions roughly the size of a human thumb. The exact dimensions can be seen below in Table 1, and a drawing of the specimen can be found in Figure 2.

Table 2. Specimen Dimensions

Dimension	Measurement (mm)
Total Length	58.4
Gauge Length	12.7
Width	14.3
Inner Diameter	9.09
Fillet Radius	27.9
Hex Length	10.4

For most common torsion testing the specimen is roughly a foot long and roughly an inch in diameter. But, due to the constraint of the thickness of the plate that they are machining the specimens from; problems arise from using equipment that test more common (larger) sample sizes. These problems normally come in the form of electrical noise in the signals they are receiving from the sensors they have testing. There becomes a point at which the data has no meaning because the signal has been extrapolated beyond its limits, or it is experiencing a low Signal-to- Noise ratio(SNR). (2)

In its most simplest form the signal to noise ratio can be defined as the rms (root-mean-square) value of the voltage divided by the rms value of the noise. The higher this ratio is, the more accurate your results will be. As seen above in Figure 3 below, noise energy can be expressed over

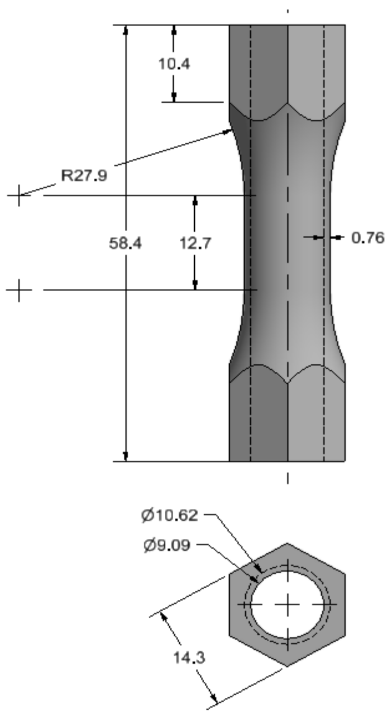

Figure 2: Given above are the actual dimensions of the samples given in millimeters. (1)

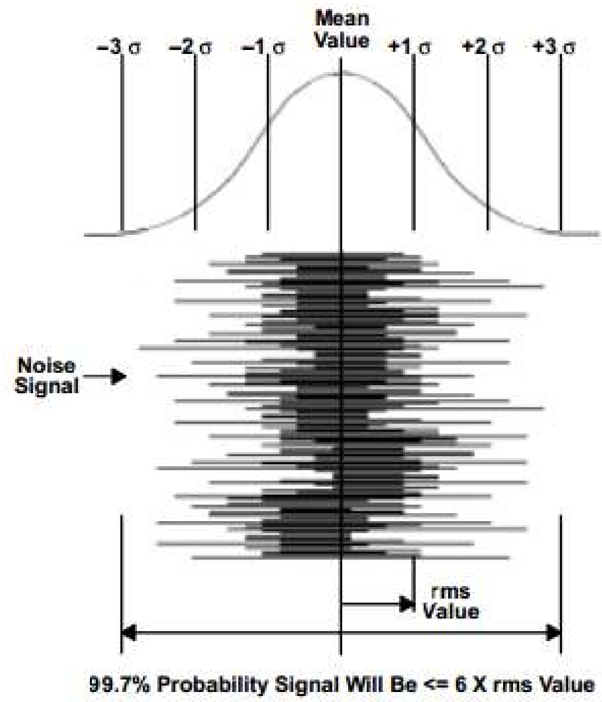

Figure 3: Gaussian Distribution of Noise Energy showing different standard deviations in relation to the mean value. (3)

the Gaussian Distribution of Noise Energy. In this case σ is the standard deviation of the Gaussian distribution and the rms value of the noise voltage and current. In this example data it is clear to see that when the data falls close to $\pm 1\sigma$ it is going to be fairly close to the mean value, which in this case is the true value from the signal. For this given data it will fall in $\pm 1\sigma$ 68% of the time. (3)

For material testing in the Munitions Directorate the accuracy of their data might be the difference in penetrating the target, or causing catastrophic damage to the surroundings, so the noise in their data needs to be minimized in their signal. Eglin is currently using a testing machine that only exerts roughly 2% of its total load capacity. This is due to the size and power of the machine that they are using to test the samples. Running at such a low torque causes the machine to send out an extremely small signal. In turn to actually understand, and see the signal the data has to be amplified, but since the data was taken from such a small range of the machine's ability; the data, once amplified, has a lot of noise.

To achieve a higher SNR Eglin has asked our group to design and build a much smaller, more accurate machine. This machine would run at roughly 20 to 40% of its capacity yielding data that would have much less noise associated with it the size and power of the machine. (1)

2.2 Need Statement

The Munitions Directorate at the Eglin Air Force Base is the sponsor for this project. Material testing is a crucial part in developing new and improved weapons and ammunition. Their current torsion-testing machine is unsatisfactory due to its massive size relative to certain specimens. For small specimens their current machine is highly inaccurate and wasteful.

"**The current torsion machine at the Eglin Air Force Base is inefficient and ineffective when testing small specimens.**"

2.3 Goal Statement & Objectives

In order to develop the proper machine that will satisfy Eglin Air Force Base's Munitions Directorate need, an overall goal statement and objectives were developed for the project.

"Design a more effective way of testing small specimens in free end torsion."

Objectives:

The objectives of this project include:

- Design a way to apply a torque to a material sample
- Measure the applied torsion to the sample
- Interfaces with existing 3D DIC system
- Construct small scale housing for the machine that can fit upon a tabletop
- Design a gripping mechanism that can hold cylindrical samples while testing and allows for axial linear motion
- Use materials that can be easily procured and machined
- Ensure that design is safe for operator

3 Constraints

From the background presentation delivered by the sponsor the following constraints for the project were developed:

- Max load on specimen to Max axial load ratio must be 20% or above. (Currently ~ 2.3%)
- Minimum of 50Nm axial loading by the machine
- Budget - $2,000 (Not including the motor)
- Max surface area of machine – 2ft x 3ft
- Must do monotonic (one direction), and cyclic (2 direction) Free-End Torsion Loading
- Free end has one degree of freedom (axial direction due to contraction/expansion of specimen)
- Must be compatible with the DIC

3.1 Design Specifications

Additionally, design specifications by the sponsor have been given. These specifications cover measurable design and engineering features of the final machine. The design specifications desired by the sponsor include:

- Max surface area of machine – 2ft x 3ft
- Minimum of 50Nm axial loading by the machine
- Max load on specimen to Max axial load ratio must be 20% or above. (Currently ~ 2.3%)
- Must be able to be moved by human (Max weight ~ 50lbs)
- Must have minimum strain rate of 1.5 degrees/s

3.2 Performance Specifications

Furthermore, performance specifications are expectations of performance during use. The performance specifications put forth by the sponsor are:

- Must be compatible with the DIC
- Must have digital or analog applied stress/force output
- Must be able to input desired cyclic displacement
- Lowest signal to noise ratio as possible

4 Methodology

Due to the scope of this project, the task of designing this torsion tester has been broken down into sections and presented in a Gantt chart which will be completed in a systematic manner that will ensure the design is finished by the deadline.

4.1 Schedule

The Gantt chart found in the Appendix shows schedule and course of action through the remainder of the semester. As the chart suggests, the first step in the design process is to do extensive background research on topics relating to our capstone project. There are a few main areas of study that must be inspected before initial designs can be produced, these include the method used to grip the samples, how the torque will be generated, what motors can potentially be used, and how the machine will measure and handle the data collected through the test. These points, as well as others will be researched to assist in the construction of the design. After doing a substantial amount of research, the project will move into the concept generation stage. During this time, initial designs will be brainstormed and produced by the team, and calculations will be performed to determine the requirements necessary to the design.

Once initial designs are produced, a single design must be selected to carry through to the CAD designing stage. To determine the best design, a house of quality matrix will be produced and each potential design will be compared to a set of standards that are set by the constraints and objectives of the project. This selection process will allow for a single design to be chosen so that CAD modeling can begin. A CAD assembly and drawings will be produced to ensure that the design meets the necessary specifications and so that machining of the parts can be done in the future.

After the CAD designing, a material analysis will be done to select the best material that can be used for the job. Using an FCOFV design approach, the design will be analyzed to be made out of the most cost effective material while still staying within the constraints of the project. Once a material is selected, a budget analysis will be conducted to ensure that all parts necessary can be procured while staying under budget. Vendors will be inspected and quotes will be collected to make sure the price of parts such as the motor or grips are reasonable and fair. Finally, the parts will be selected and ordered and any materials that must be machined will be sent to the machine shop.

4.2 Resource Allocation

Taking a look at the Gantt chart in the Appendix, each task has a specific amount of time allocated for it to ensure that all tasks have enough time to be completed. The background research will be conducted as a team, with each member responsible for being knowledgeable on all subject areas related to the design. It is imperative that all parties associated with the group are all familiar with the background information so that each member understands what is required to complete the design. Concept generation will also be done as a primarily team-oriented activity. Multiple potential designs will be produced by all members of the team and then a group discussion will occur so that feedback can be provided on each candidate. The calculations will also be conducted by the team as a whole to ensure accuracy of the results determined.

The design selection will also be done as a team, with the guidance and feedback of the sponsor to ensure that all avenues are considered. The quality matrix will be produced and each design will be compared so that a single design can be chosen. Once a design is chosen, a CAD model will be produced of the design. Logan McCall will take the lead on the CAD production, and will ensure that the drawings are produced within the time frame. Under the direction of Logan, the rest of the group will help to produce any CAD parts and drawings deemed necessary.

Once the CAD design is completed, the budget analysis will be conducted by Reggie Scott. The responsibilities of this analysis are to determine the cost of each part, allocate funding from the budget for each piece, and select vendors from which each part can be obtained. Once vendors are selected, the parts will be ordered and those that need machining will be sent to the machine shop.

Due to the scope of the project and the difficulties that are sure to be encountered with each step, each member of the team will be responsible for helping with all facets of the design procedure. Although Logan and Reggie will be taking the lead in two of the areas specified above, Brendan and Mark will also be assisting with each process as well.

5 Conclusion

This report identifies the basis for the project, the progress that has been made, and the process that will be done to produce the design. The Munitions Directorate at Eglin Air Force Base requires a torsion testing device that is capable of accurately testing small samples. The task is to develop a table top torsion testing machine that can efficiently perform these tests. The group has completed a Needs Assessment and developed a Gant chart that identifies the goals and requirements of the project, and to assist in the organization of the design procedure moving forward, respectively. In the immediate future, the group will begin working on a presentation to introduce the project to the class. In conjunction with working on the presentation, further background research will be conducted, preliminary designs will be produced, and initial calculations will be done so that a design may begin to be developed.

6 References

1. Flater, P. (2014). *Tabletop Torsion Test.* Eglin, FL: Air Force Research Laboratory.
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3. Carter, B. (2008). *Texas Instruments: Op Amp Noise Theory and Applications*. Retrieved September 22, 2014

7 Appendix

Gantt Chart