Tabletop Mechanical Test Apparatus for Torsion Experimentation

Team Number: 13

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Abstract

This report introduces the project and defines why the Munitions Department is in need of an improved torsion testing machine. The current torsion machine being used by the Munitions Department is intended for use with large specimens and is inaccurate while testing small specimens. Therefore they require a smaller, tabletop torsion machine that can be used to accurately test their small specimens. Within the group, duties have been allocated to each group member and a code of conduct was produced to ensure that all members are held accountable for their work. The team has met with both the faculty advisor and sponsor to open lines of communication and collaboration. Moving forward the next step for the group is to continue background research and produce preliminary designs.

1 Introduction

Materials are the building blocks of our physical world. From a designer's standpoint, knowing the limitations of the materials is of the utmost importance. There is always the trial and error route of constructing a mechanism or specimen and putting it to use until it fails, but this would prove to be extremely costly. A better route would be to develop a method to test these materials by allowing it to endure the same loads it will when it is put to purpose. The sponsor in need is Eglin Air Force Base's Munitions Department. The purpose of this testing is to understand how these materials act under certain torsional conditions. These torsional loads are tested the most in this sector. A huge machine is on site with extreme loading capabilities. This can be great for war heads, missiles, and other large items. But for small samples, the big robust machine is a bit overkill and leaves a lot of room for improving the efficiency of each test. This creates a need for a much smaller machine that is still capable of running torsion tests effectively while improving the overall efficiency of the process.

2 Project Definition

2.1 Background research

The Eglin Air Force Base's Munitions Department 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. Due to budget constraints the research lab can only purchase stock material up to a certain thickness, then from this stock they machine out their specimens as shown below in Figure 1.

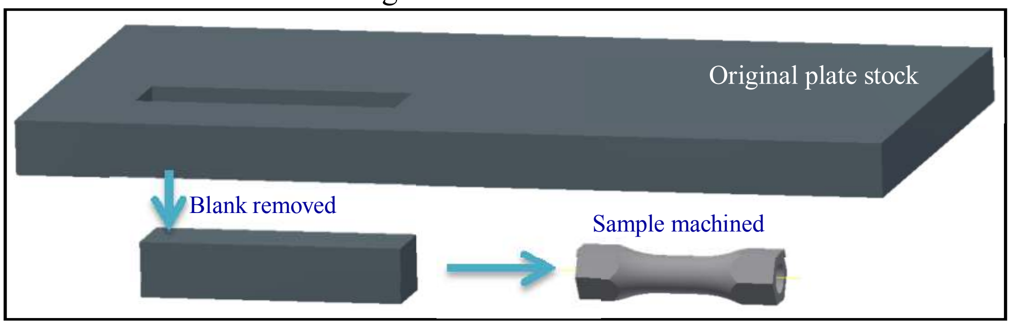

Figure1: Example case where test sample is machined from plate stock (1)

Since materials of interest are often in the form of thin sheets or plates, this make the specimen that is generated realatively 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 specimen from, problems arise from using equipment that are normally testing more common sample sizes. These problems normaly 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 simplist 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

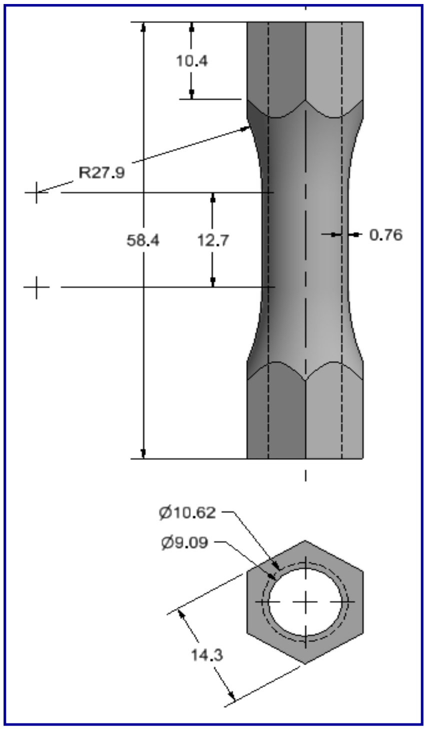

Figure 2: Given above are the actual dimensions of the samples given in milimeters. (1)

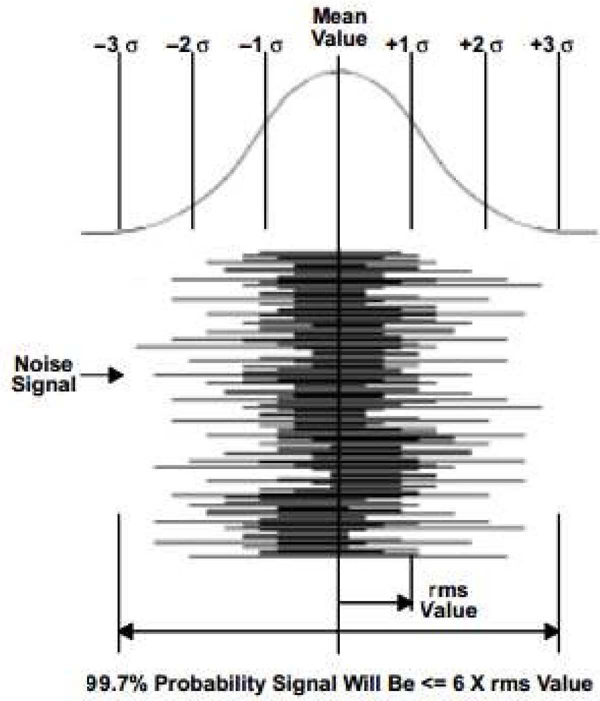

Figure 3: Gaussian Distribution of Noise Energy showing different standard deviations in relation to the mean value. (3)

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 department 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 Department 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

"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

2.4 Constraints

- Max load on specimen to Max axial load ratio must be 20% or above. (Currently ~ 2.3%)
- Minimum of 50N*m axial loading by the machine
- Budget - $2000 (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

2.5 Methodology

The goal of this project is to produce a small-scale torsion testing machine for the Eglin Air Force Base's Munitions Department which is compatible with their 3D DIC system. This project incorporates a number of different ideas and possible mechanisms to accomplish this goal, so a certain methodology must be formulated so that decisions can be made. The first step of the process is to expand our knowledge on the underlying principles of this project. First we must:

- Research other torsion testing devices
- Understand the torsional effects on cylindrical specimens
- Research techniques used to grab and hold cylindrical specimens
- Research the 3D DIC system being utilized in conjunction with our machine

After a literary review is performed, we must:

- Produce multiple potential designs
- Construct a decision matrix
- Evaluate each design and select one for prototyping

Once a design is selected, the prototyping will begin. This process will include:

- Build the design using CAD software
- Simulate moving parts of design using software
- Evaluate computer model to ensure working performance
- Purchase and machine necessary materials
- Assemble prototype
- Test prototype with samples provided by Eglin Air Force Base's Munitions Department
- Analyze data
- Make any necessary adjustments to ensure a fully operational design
- Develop a user manual with operating instructions

Once these requirements are met, the design will be considered complete and ready for use at the Eglin Air Force Base's Munitions Department.

3 Conclusion

The Munitions Department at Eglin Air Force Base has a need for a torsion testing machine that will be used for small scale specimens. The testing machines that the Munitions Department have been using in the past are intended to be used for large specimens, and when used on small samples they are not accurate enough. This is a result of a low signal to noise ratio that accompany these large testing machines, so therefore the Munitions Department has requested a smaller torsion testing machine for the small samples. The group will proceed with the assistance of the faculty advisor and sponsor, and will follow a certain methodology to ensure that all aspects of the design are accounted for and our sponsor is satisfied with the results. Moving forward, the next report will outline the project plan and the specifications of the design so that progress can be made on prototyping a design.

4 References

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