Restated Project Plan and Scope

Group 13
Tableop Torsion Machine

Members:
Brendan Keane – bmk10c
Logan McCall – lgm12b
Reginald Scott – rbs09
Mark Swain – mas10h

Advisor:
Dr. Simone Hruda

Sponsor:
Mr. Philip Flater
Air Force Research Laboratory

Instructors:
Dr. Gupta

1/26/2015

Contents

Figures

Tables

Abstract

The Air Force Research Laboratory Munitions Directorate at Eglin Air Force Base does thorough material testing for their products. A major material test they utilize is the torsion test. Their current machine is very large and is ineffective when testing small specimens. They have a need for a smaller, tabletop torsion tester that can generate at least 60 Nm of applied torque and stay within a budget of $2000. A smaller machine will produce much more accurate measurements when testing small specimens. After receiving all of the needs and constraints from the Air Force sponsor, multiple potential designs for the machine were created. The final design utilizes an AC motor with a controller to generate the torque. However, the project scope has been reevaluated and has changed slightly. The sponsor and team have decided to go with a VFD in order to control the motor. This option was deemed more cost effective and within the scope of the mechanical engineering team. CAD drawings for each part have been made and have undergone FEA in order to ensure quality. The parts and potential vendors are in the process of being finalized so final purchase orders can be made. After the parts are received, any necessary machining will be done and assembly of the machine will begin. A program will also be used to output the applied load on the specimen. Throughout the course of this project the team has learned many lessons due to the challenges faced.

I. Introduction

A. Project Overview

Material testing is an essential part of designing new and improved products. Knowing how a material acts under certain conditions allows engineers to create an optimal design. The Air Force Research Laboratory (AFRL) Munitions Directorate at Eglin AFB is currently testing materials to use with their products. These products range from warheads to the frame of a fighter jet. In order to ensure optimal performance and user safety, many material tests are performed. The current torsion machine at Eglin AFB is very large and is only effective when testing large specimens. Therefore, early in the fall semester, the group was tasked to develop a table top torsion testing apparatus for the AFRL at Eglin Air Force Base. The AFRL is interested in testing very small samples of aluminum and titanium alloys in torsion. The initial constraints of the project were to produce a torsion testing apparatus that can fit upon a table, be able to perform monotonic and cyclic loading, and build this apparatus while staying within a budget of $2,000. Initially, these constraints appeared manageable, but once the design began to come to fruition, some changes to the constraints were necessary. After consulting the sponsor and advisor of the group and discussing the challenges faced with the design, it has been determined that cyclic loading may not be viable for two reasons. The first reason is that the programming required to control a motor to be able to do cyclic loading is outside the skillset of the team. Although the group has a basic understanding of programming, the required coding necessary to generate such an effective control of the torque, rpm, and other characteristics of the motor was deemed too difficult and would delay the completion of the design. The other reason that cyclic loading has been deemed noncritical to the design is because of the constrictions of the $2,000 budget. After doing a rigorous budgetary examination of the components necessary for the design, it was determined that purchasing a motor and motor controller that can perform the cyclic loading was cost prohibitive. However, because the original design criteria set by the sponsor requested cyclic loading, the team will ensure that the final build will be adaptable in the event that the sponsor would like to replace the motor and controller selected with pieces that will allow for the cyclic loading.

With cyclic loading no longer being a high priority constraint, the design has been changed to fit within budget and can be produced by the team on time. The new design will still utilize many of the components discussed in the previous semester, with the exception of the variable frequency drive(VFD) and a steel frame. The motor and VFD setup will still allow for maximum repeatability and accuracy. The user will be able to set the desired rpm and applied torque. Additionally, the team has decided to move forward with a steel frame instead of aluminum due to its higher strength.

B. Constraints and Specifications

From the background information delivered by the sponsor, constraints have been created and put on this project. These constraints have been reevaluated by both the team and the sponsor, and a few of the constraints have been changed. Most notably of these changes is that now the machine is no longer required to perform cyclic loading. The remaining constraints are:

- Max torsional load on specimen to max load ratio must be 20% or above. (Currently ~ 2.3%)
- Minimum of 60Nm axial loading by the machine
- Budget - $2,000
- Max surface area of machine – $1m^2$
- Free end has one degree of freedom (axial direction due to contraction/expansion of specimen)
- Must be compatible with the digital image correlation (DIC)

The success of this project will be based on how well the final design abides by the constraints and specifications placed on it. It is expected that not every aspect will be perfect but as long as the machine is able to deliver acceptable results as decided by the sponsor, it will be successful. From these constraints and specifications, the following Needs Statement was developed:

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

C. Major Challenges and Obstacles from Last Semester

Throughout the course of last semester the team faced many challenges. The major challenge was deciding how the team was going to generate the torque needed to break the titanium specimen. At first, the team was overwhelmed with this idea because titanium is a very strong material. However, after talking to some faculty members and having team meetings the team originally decided to go with a programmable DC motor working with LabVIEW. At first, this idea seemed plausible and as long as a strong enough motor was chosen the project would work. However, after some time the team came to the conclusion that we did not have enough knowledge about programming and controlling motors to go this route. The team also found out that this method would not fit into our budget. At this point, the team was worried about completing the project on time because so much time and effort was put into this idea. After talking more about it and doing more research on motor control the team came up with the idea of using a VFD to control the motor. A proposal was made and presented to the sponsor and was ultimately accepted. This method fits within the budget of the project, is far less complex, and will deliver satisfactory results.

Another challenge the team faced last semester was choosing a proper material for the frame. At first, the team decided to go with a hollow aluminum frame for the machine because FEA done in solid works showed it would be strong enough. The team also liked the fact that aluminum was relatively cheap and light weight. However, after presenting the poster board at the end of last semester several professors questioned why we were using aluminum instead of steel. They said aluminum did not have a high enough stiffness to ensure an acceptable factor of safety and was not preferred by machinists to work with and weld. After a group meeting and talking to more professors the team made the change to go with a steel frame. This was a last minute change and required finding the right steel to use and proper vendor. This was a difficult task to accomplish because team members were getting ready to leave for vacation. The team was able to get all the information needed for purchase orders right before the break.

The challenges and results from last semester have taught the team very valuable lessons. The main lesson taken away is to always weigh all of the possible ideas and talk to anyone who has previous experience on the matter. Although choosing a method quickly may seem to be acceptable, it may not end up bring the best choice in the long run and can cause delays on the success of the project. From now on, the team has decided to run every new idea by the sponsor and advisor before any change is done to the design or project. The team will also always try to think of any better or more cost effective way of doing this project. This will include having more team meetings and talking to other people who have the proper knowledge on the subjects.

II. Design Changes by Category

A. Design Overview

In this section, the components chosen for each part of the design: load generation, load application, load measurement, linear motion, and housing will be discussed. However after hitting some obstacles with the load generation design, the method of control for the motor has been changed to reduce cost and simplify the build. Also, after further testing it was decided that a steel housing would be more appropriate for this build over an aluminum one.

B.1 Load Generation

In order to generate the load necessary for this tabletop torsion apparatus, the original plan was to use a DC motor with a certain motor controller which would allow for both monotonic and cyclic loading to be performed. However, after doing a thorough cost analysis as well as speaking with the sponsor, it was decided that an AC gear motor with a Variable Frequency Drive (VFD) was the most reasonable method to generate the necessary load for this tester. Unfortunately, this method will make it difficult to perform cyclic and loading. The motor selected, which is detailed down below, will not be able to perform the necessary back and forth motion at a quick enough frequency to perform the necessary test. The VFD would be able to control a motor to do cyclic loading, but would require significant programming to create the necessary load patterns required for cyclic loading. These components were selected because they are both cost effective and will be able to perform the monotonic loading required of the machine. Care will be taken while constructing the design to ensure that if at a later date a more capable motor was available to replace the one selected for this project, the rest of the apparatus would be adaptable to that motor.

B.2 Load Application

It is important that a proper gripping mechanism is chosen in order to achieve the highest accuracy possibly. The grip must not allow for any slip or off axis loading. For this design, a 6-tooth chuck has been selected as the most effective method for gripping the samples. The 6-jaw operates on the same principles as a 3-jaw chuck, but provides more surface area which will allow for greater gripping power to hold the sample.

B.3 Load Measurement

The torsion tester will be used in conjunction with the DIC (Digital Image Correlation) that is provided by the Sponsor in order to determine the strain present in the sample during testing. Strain gauges will also be provided by the sponsor for measuring the stress applied to the sample.

B.4 Linear Motion

As discussed previously in the constraints, the free end of the torsion tester must allow for 1 degree of axial freedom during testing. This is to permit the specimen to expand or contract while loading is applied to produce the most accurate results possible. For this design, the free end will be placed on a 2 rail ball bearing system. This platform will let the free end smoothly translate back and forth with minimal friction.

B.5 Housing

After performing a material selection process for the construction of the housing, the material selected for this build was aluminum. However, after speaking with faculty and considering other factors in the fabrication of the housing, it was determined that steel was the optimal material for this design. Steel will provide an extra factor of safety that will allow for the torsion tester to withstand all potential forces and torques applied to the frame. Steel is also easier to machine and weld for the machinists that were consulted in the shop, and although the steel is slightly more costly than aluminum, the added benefits of the safety factor and ease of fabrication are considered to be worth the extra cost.

B.6 Optimal Build

The optimal build with all components can be found in Figure 1. All components in the CAD model have been built to scale, so the final product will look very similar to this design.

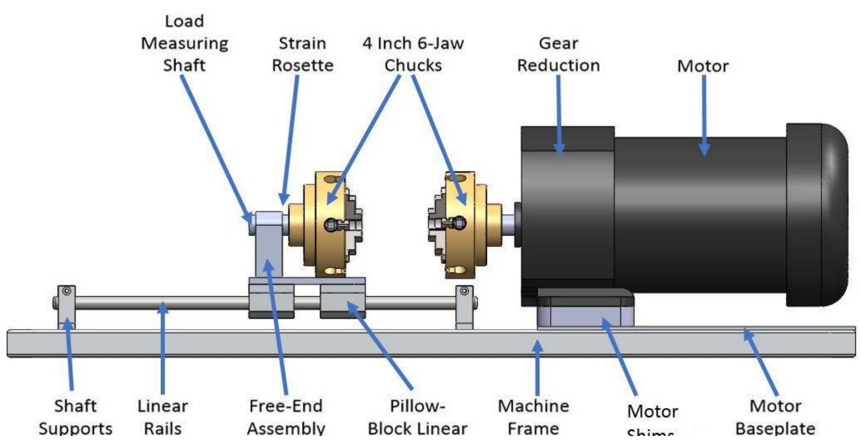

Figure 1 CAD model of optimal build

B.7 Programming Considerations

Last semester, the original design for this project included a fully programmable DC motor working with LabVIEW. This would require an interactive user interface on a computer. The user interface would allow the user to choose the type of loading and load amount desired. This route has proven to be very costly due to the many components needed to hook up a DC motor to a computer while allowing control and feedback. Additionally, the team consists of only mechanical engineers with limited knowledge and experience with programming and controlling. For these reasons, completing the project on time and within

budget seems unrealistic. In order to avoid this problem, an alternative has been brought to attention. This alternative is using a variable frequency drive (VFD) and motor. This route requires minimal programming and is much more cost effective. This method will still allow the user to input the desired motor rpm and applied torque.

III. Lessons Learned

While working on this project, the team has learned many things that can be used in the real world. For most, speaking in front of large crowds can be a very difficult experience, however the presentations performed in this class have provided ample practice to help the group prepare for these real world situations. The team has been exposed to many of the intricacies of the design process through this project as well. For example, the team has made the mistake of believing that every little piece of the design had been figured out but would stumble upon a problem that the design did not account for, sending us back to the drawing board. The group has learned that it must be thorough down to the smallest detail while still producing results in a timely manner. Lastly, one of the most important lessons the group has learned is how to conduct themselves in a professional manner throughout this entire process. We as a group represent not only ourselves, but the College of Engineering and the AFRL with this design, and it is imperative that everything from our first presentation to the open house that we produce results and carry ourselves in an appropriate manner.

IV. Procurement

The components and their respective cost as well as other important information is tabulated below. As the table suggests, the majority of the cost is due to the motor as well as the VFD which will be used to control the motor. Fortunately, none of the sensing components such as the strain gauges need to be purchased by the group because the AFRL has all the materials necessary for those areas of the design. Most of the pieces of the design are being purchased through Grainger.com, which does not charge taxes or shipping costs to the College of Engineering while also giving a healthy discount to the College.

The purchase order for the chucks has already been submitted, and the rest of the orders will be placed within the next few days. It is expected that all parts will be received by the end of January.

Table 1. Components List with Supplier, Price, and Part Number

Part	**Part Number**	**Price**	**Supplier**
Motor	6Z404	601.56	Grainger.com
VFD	GS2-10P5	166.00	AutomationDirect.com
Motor Shims 0.75” stock	2HHP8	9.05	Grainger.com
Motor Baseplate 0.125” sheet	3DRT8	14.84	Grainger.com
Free end Baseplate 0.25” sheet	3DRU7	22.59	Grainger.com
Rails 0.5” thick	2HXB4	2 @ 30.10 each	Grainger.com
Pillow Blocks 0.5”	2CNL6	4 @ 41.83 each	Grainger.com
Shaft support 0.5”	2CNU7	4 @ 25.99 each	Grainger.com
Long support tube 0.125” thick	3DRR5	2 @ 19.71 each	Grainger.com
Small thick support 0.25” thick	4YUL5	47.48 each	Grainger.com
4” 6-Jaw Chuck	2276	2 @ 174.95 each	LittleMachineShop.com

V. Project Management

The Gantt chart in Figure 2 shows the breakdown of the schedule for the Spring semester. There is about 2 weeks allotted for the parts that are being ordered to come in. After receiving the components and materials, the stock materials that must be machined will be sent to the shop for fabrication. While waiting on the machined parts, the team will focus on getting the motor to run correctly with the VFD. A final review of the physical design will be performed to determine what sorts of nuts, bolts, and miscellaneous things are necessary to complete the construction of the design. Then the machine will be assembled. After assembly, the team will use the strain gauges and electrical equipment provided by the AFRL to setup and calibrate the stress measurements. The final days will be used to test and troubleshoot the machine and also produce a user manual for the AFRL to use when operating the machine.

The team will work together on most of the tasks shown below. Due to Logan's experience with the machine shop, he will take the lead on getting all parts machined. The rest of the team is going to work together on how to control the VFD and motor. Then the whole group will work together to assemble the apparatus, and conduct testing.

	Task Name	Duration	Start	Finish
1	Procurement of Parts	14 days	Tue 1/13/15	Fri 1/30/15
2	Send stock materials to shop for machining	11 days	Fri 1/30/15	Fri 2/13/15
3	Calibrate Motor and Controller	16 days	Fri 1/30/15	Fri 2/20/15
4	Review Physical Design	4 days	Mon 2/16/15	Thu 2/19/15
5	Assemble Machine	11 days	Fri 2/20/15	Fri 3/6/15
6	Setup of Strain Gauges	5 days	Mon 3/9/15	Fri 3/13/15
7	Test/Troubleshoot Machine	15 days	Mon 3/16/15	Fri 4/3/15
8	Produce User Manual	5 days	Mon 3/30/15	Fri 4/3/15
9	Final Testing	1 day	Fri 4/3/15	Fri 4/3/15

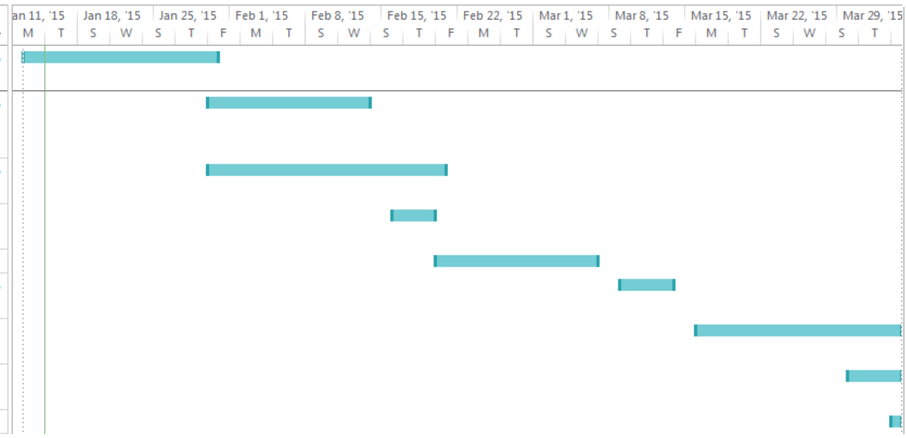

Figure 2 Gantt Chart for Spring Semester

VI. Conclusion

The Munitions Directorate at Eglin Air Force Base presented the team with the task of producing a more effective torsion testing machine. The new torsion testing machine must satisfy geometric constraints as well as functional constraints that were provided by our sponsor. After conducting background research, 5 categories of interest were developed; load generation, load application, linear motion, sensors, and housing. Multiple concepts were generated for the critical components and were compared using decision matrices to select the optimal design. The optimal design was constructed from the highest ranking components in each category. At the beginning of this semester the overall project scope and definition was reevaluated. Due to time, budget, and skill constraints the team has decided to use an AC motor that is controlled by a VFD. The VFD allows the user to simply manipulate the voltage sent to the motor and requires minimal programming. This route will ensure an acceptable final design that will be completed on time and within budget.

As stated last semester, two 6-jaw chucks will be used to grip the specimen. Orders for these chucks have been made. A 2 rail ball bearing guide will be used in order to account for the free-end. The team has prepared the purchase order for these and will be ordering them soon. The sponsor will be providing the strain rosette sensors needed for this project. This allows the team to use the money originally allocated for sensors for another part of the design. It also saves time looking for a proper and reliable vendor since the sensors must be of high quality. Finally, the team chose to go with steel for the housing and frame for the machine. The frame will have a hollow rectangular cross section in order to reduce the mass and cost of the overall machine. Using steel instead of aluminum will yield a higher factor of safety and reduce deflection in the frame.

The team expects to finish this project on time and within budget. This was made possible by the decision to go with the VFD and AC motor. The sponsor has approved the new final design and purchase orders set by the team.