Torsion Tester Redesign

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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April 2024

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ABSTRACT

The purpose of our project was to redesign the torsion tester for the MET2073L Strength of Materials Laboratory. Our main objectives were to reduce to a single operator electronic measurement of the load and axial deflection and explore electronic motors instead of manual load application. The previously designed torsion tester required multiple users to successfully operate, had aged and unreliable measurements devices, and was previously not automated. The goal of our project was to create an automated testing system that resulted in a more user-friendly experience for the students and faculty that work in the lab.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The current torsion testing in the MET2073L Strength of Materials Laboratory is dated and relies on two users to keep the system in balance. The system needs to be redesigned. In the new system, the following items should be improved (1) reduced to a single operator (2) electronic measurement of the load and axial deflection and (3) explore electronic motors instead of manual load application.

BACKGROUND

Torsion is the act of twisting due to applied torque on a piece of material. A torsion tester is able to determine the following material properties: maximum torque, torsional strength, torsional shear stress, modulus of elasticity in shear, and the breaking angle of specimen. The purpose of a torsion tester is to "simulate real life service conditions and to check product quality for products." (2) Torsion testers can be either uniaxial or multi-axis, the tests needs are taken into consideration to know which one is needed. The uniaxis tests for tensile strength, while the multi-axis does compression and torsion. There are three types of torsion testing that are failure, proof, and operational.(2) A failure test will run until the material breaks, having the machine record when the failure was and at what strength. A proof test is to test a specific torque load on the material, this is over a set period of time too. Operational torsion test takes the condition that the material is under in an application and measures the material's performance. (3) Torsion Tester machines are used to simulate real world conditions materials may have to face, checking the quality of the material. Some application that utilizes torsion tests are biomedical products, automotive components, torsion springs, screws, fasteners, rods, and shafts. (5) With the age of the current torsion tester for the Strength in Materials lab at University of Cincinnati, comes with lower accuracy. This is one of the reasons why professors want us to create a new tester. Another reason that there is a need for a new torsion tester is because the current one requires two operators and professors believe that with one operator the accuracy will increase. This project will also help add new technologies into the machine, helping make the torsion tester operated by one operator.

RESEARCH

SCOPE OF THE PROBLEM

The previously designed torsion tester required multiple users to successfully operate, had aged and unreliable measurements devices, and was previously not automated. The goal of our project was to create an automated testing system that resulted in a more user-friendly experience for the students and faculty that work in the lab. This project is important because it exposes the students to automated systems that they will experience in the real world on co-op, as well as, like previously mentioned, create a more user-friendly experience in the lab that reduces potential problems that came with the old design.

CURRENT STATE OF THE ART

While the torsion tester used in the strength of materials lab is not designed for heavy loads, most existing torsion testers are used for industrial applications. Zwick manufactures floor standing torsion testers called TorsionLine that have torsion drives ranging from 20 Nm to 2,000 Nm. (1) They are exceptionally large machines that have many applications that include but are not limited to, plastics, bone screws, camshafts, and many more. Each model also has an electronically interlocked safety device attached to prevent accidents from occurring while the machine is running. Information regarding the accuracy of their torsion testers was unavailable at the time of research.

Figure 1: Zwick TorsionLine 20/200/500

In addition to Zwick, another state-of-the-art torsion tester that is commonly used is Instron. They also manufacture many models of torsion testers, ranging up to 5,60 Nm (4). Their torsion testers are used in many biomedical applications which includes bone screws, syringes and needles. Their testers are also used in automotive and aerospace applications which can include switches, torsion springs, and fasteners. (4) Each of their models have multiple safety features that prevent the operator from injuring themselves or others during use. These include interlocked enclosures and interlocked chuck guards in the more advanced models. Unlike the Zwick models, Instron manufactures tabletop torsion testers, as seen below. The load weighing accuracy of both tabletop models is +/- 0.5%. (4)

Figure 2: Instron MT MicroTorsion Testing System

Along with Zwick and Instron, another instance of state-of-the-art torsion testers can be seen in the company Tinius Olsen. Similarly to the Instron model, Tinius Olsen makes a tabletop model instead of a floor-based model. Their machines have a capacity range of 1,000 Nm to all the way up to 30,000 Nm. (6) Some of their machines also have adjustable section slides, making their machines flexible in the length of materials they are able to test. The specifications state that their torque measurement accuracy is +/- 0.5%, their position measurement accuracy is +/- 0.1%, and their speed accuracy is also +/- 0.1%. (6) These specifications indicate that these models are very accurate and reliable for the operator and produce very little errors.

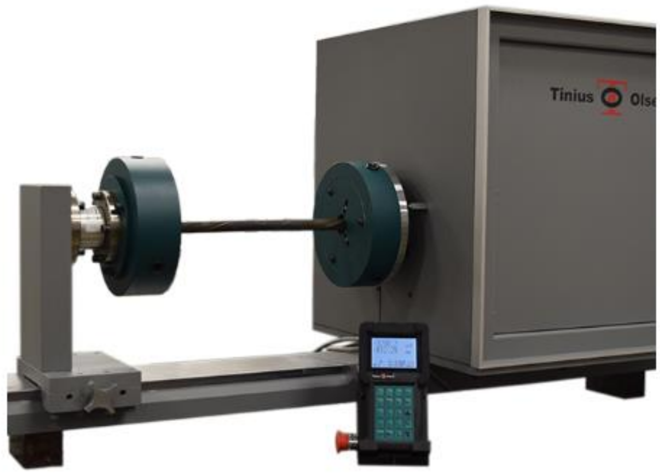


Figure 3: Tinius Olsen Torsion Tester

Finally, our last state of the art comparison is the current torsion tester in the strength of materials lab. This tester is not as accurate as some of the previously mentioned technologies but is still able to accurately record data as needed in the lab. It is a tabletop system that has the primary application of testing the torsion in various metal specimens provided by the lab instructors. The readings are determined by the torsiometer and a digital counter.

Figures 4 & 5: University of Cincinnati current torsion tester

END USER

The end user for this instrument is for teaching labs and can be used in an educational setting where testing values are relatively low, and precision is not extremely high compared to industrial applications.

CONCLUSIONS AND SUMMARY OF RESEARCH

In conclusion, torsion testers are used so that engineers are able to simulate the conditions a specific material will encounter in the real-world application. After completing research, it was found that there are various applications for torsion testing and are applicable by different standards. Some of the various industries that utilize torsion testing are the following: Biomedical, automotive, and manufacturing fields. With the different fields that use torsion testing, each field abides different standards. In our application we will look closely at the manufacturing field. After researching various state of the art torsion testers, a conclusion was reached that the current system used by the university is slightly dated but can be improved by incorporating various aspects we discovered in these products, such as improved accuracy in data collection, replacing manual pieces of equipment, and a more concise tabletop footprint. The end users will be University of Cincinnati students and faculty, in the Mechanical and Materials Engineering department. With the completion of this project, the gap between old technology and modern technology will meet in the middle, making the machine more accurate. The benefit of University of Cincinnati allowing their 5th year engineering students to create a torsion tester, rather than buying a new machine, is allowing their engineering students to use what they have learned in the classroom and apply it for their senior design project.

CUSTOMER FEATURES

After interviewing various professors about the current torsion tester used in the lab, a common conclusion was reached. The priority of deliverables was agreed upon by all interviewed professors and is as follows: reduce the need for 2 operators, implement a load cell along with an electronic measuring system, and replace the current hand wheel with an electric motor. These previously mentioned deliverables are weighted the highest, except the electric motor. Secondary deliverables were also established in our house of quality and are as follows: low cost, easily assembled, and high reliability (see Appendix A).

PRODUCT OBJECTIVES

A load cell transducer will be implemented into the machine as a way to measure torque. This way it will take away the need to level the load bar, and this will also take away the need for two operators to one operator. The relative weight for the number of operators is 9.6. A way to get the machine to be low cost will be to utilize some of the current testing system in the redesign. After making the House of Quality the relative weight of cost came out to be 10.7. The redesign will also be easily assembled by reusing existing parts and limiting the number of additional parts, with a relative weight being 12.1. The frame of the machine will be cut down in order to create room for the load cell and to make the size of the machine smaller, after creating the House of Quality size came out with a relative weight of 8.6. The need for an electric motor will be explored in order to eliminate the need for the operators to deliver manual load, with this not being the top priority the relative weight came out to be 5.0.

QUALITY FUNCTION DEPLOYMENT

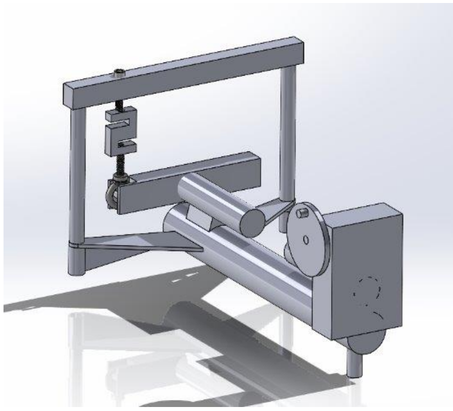
- Reduce the need of two operators to one operator:
    - The current machine needs two operators to keep the load bar completely level, due to compliance of the torque load meter.
- Electric measurement:
    - The electric measurement will be able to measure load and axial deflection. A load cell will help make measurements electric.
- Electric motor:
    - Rather than having a manual load application a motor should be utilized. This is not a high priority for this project.
- Low-cost:
    - Keeping the project very low-cost will help the university save money.
- Easily assembled:

    - If there are less parts that need to be assembled, it will help the project be low-cost and easy to assemble.
- Shorter height of machine:
    - A shorter height is wanted to allow for easy assembly of the load cell. The extra height will not be required and will save space.

See Appendix A for House of Quality

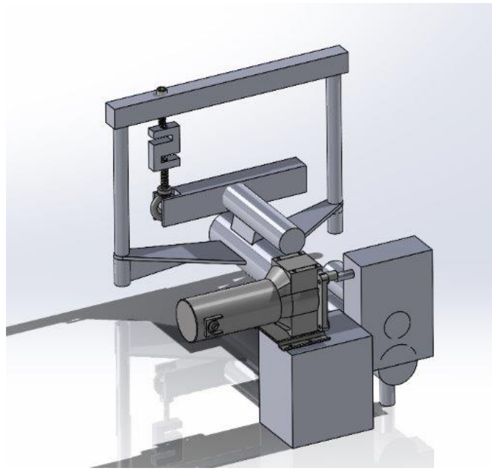
DESIGN

Concept 1:



For concept 1, the current torsion tester has a torque load meter, it will be replaced with a load cell. This way the need for two operators is reduced to one operator. With the load cell there will be a digital measuring system connecting to it, this will give the measurements for torque. For this concept the hand crank that is currently on the machine now is going to be saved, by doing this the cost of the project will be lower. The machine's height is also lowered to help add the load cell.

Concept 2:



For the second concept, the load cell will still be utilized to replace the torque load meter. With having a load cell, a digital measuring system will be used to give the measurements to the students and professors using the machine. On the current torsion tester, a hand crank is used, from the interviews the group conducted an electric motor was requested to replace the hand crank. The height of the new machine is still going to be lower than the current machine, to help with the load cell.

Due to the fact that our project was a redesign and was not designed from start to finish, there was little design analysis to be completed. The machine's loading conditions are nearly identical to those that existed before the redesign took place. The addition of the motor was the only significant change that required additional in-depth design analysis. Because our project was already built and we reused many of the same components in the redesign, we did not have any significant factors of safety of concern.

The following components required calculations before they were selected: side supports of the frame, motor, and the pinion and drive gear. Our initial stress calculations indicated that if we were to order new material for the side supports, the material would require a minimum ultimate tensile strength of 63.8 ksi. This led us to choose 1018 cold drawn carbon steel for the side supports. After surveying various past professors that have taught the lab, it was determined that the minimum required torque was 400 lbf-in. The machine also requires a low rotation speed in order to carefully observe the specimen. We then determined that the motor needed to spin at a rate of 4.5 RPM and would need a torque rating of 250 lbf-in. Because low speed and high gearing ratios result in an increase in torque, it was not required that the motor torque be higher than 400 lbf-in before gearing. After completing our gearing calculations, we selected a 16-tooth pinion and an 86-tooth drive gear. This resulted in a final torque rating of 1338.75 lbf-in, which is well above the required 400 lbf-in requirement. The final design did not include the previously mentioned gears because of the internal gear box that was discovered during disassembly of the machine. Instead, we selected a combination of spider couplings to use direct drive instead of a gearing connection for the motor.

See below for a detailed view of the bill of materials.

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Part	Quantity	Price/Part	Total Cost
Tension Force S Beam Load Cell Sensor with digital force gauge	1	$219.00	$219.00
Steel Rods (side supports)	2	$63.26	$126.52
Rectangular Steel Bar (top beam)	1	$14.05	$14.05
Motor	1	$327.65	$327.65
Torsiometer	1	$2,733.33	$2,733.33
Eyebolt (1/2"-13)	1	$25.19	$25.19
Hex Bolts	1	$8.62	$8.62
Hex Screw	1	$2.98	$2.98
Pinion	1	$43.10	$43.10
Gear	1	$45.77	$45.77
3600 rpm Hytrel Rubber Spider Coupling	1	$54.33	$54.33
Flexible Shaft Couple	1	$24.19	$24.19
Flexible Shaft Couple	1	$19.26	$19.26
Daq Board (USB-6001)	1	$304.00	$304.00
Total Cost:	$3947.99		

In Senior Design 2, our proposed budget was around $4,000. We did not account for some of the parts that were needed for the project. One of these parts were the daq board, this brought our total cost up closer to the proposed budget. In the end, we were able to stay under budget for our project.

SCHEDULE, PROPOSED /ACTUAL

For Senior Design II, our key dates are listed below.

- Design concepts on Solidworks: End of October 2023
- Finish Solidworks design complete: November 2023
- Design review: December 2023
- Building: January 2024
- Start testing: February 2024
- Finished product: March 2024/ Beginning of April 2024
- Expo: April 2024
- Presentation: April 2024

For Senior Design III, for some of our tasks we were a little behind on. This is due to material ordering and receiving took a little longer than expected. The task of disassembling the current torsion tester didn't take us as long as we expected. This allowed us to make time up for assembling the new torsion tester.

SUSTAINABILITY AND MATERIAL USAGE

Since we were using parts that were on the existing torsion tester, we were able to effectively use material. Cutting the amount of material needed to a small amount. Some material wasn't used due to not knowing we could reuse some of the parts that were currently on the torsion tester. That was due to ordering material before we were able to take the torsion tester apart.

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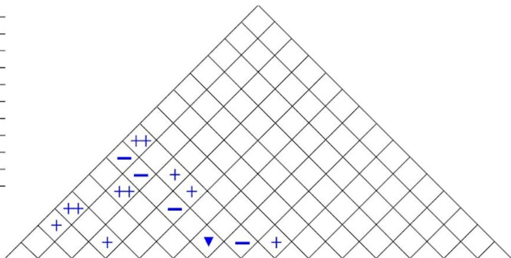
APPENDIX A

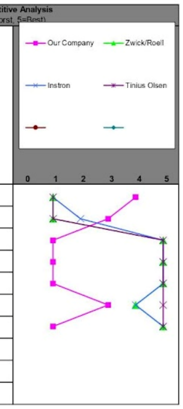
Title: Senior Design 1 - Torsion Tester House of Quality
Author: Anna Krizsa and Alexandra Mitchell
Date: 9/28/2023
Notes:



Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Our Company	Zwick/Roell	Instron	Tinius Olsen		
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	▼	▼	▲	▲	▼	x	x												
				Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Cost (Dollars)	Accuracy (Percentage)	Size (ft.)	Number of parts	Life (years)	User success rate	Number of operators	Motor (yes/no)	Torque (Over 200 lb.in)												
1	9	10.0	0.1	Low cost	Θ			O				▲								4	1	1	1		
2	9	15.0	0.2	Easily Assembled			O	Θ												3	1	2	1		
3	9	15.0	0.2	Operated by one operator	▲					Θ	Θ									1	5	5	5		
4	9	20.0	0.2	Electronic measurement	▲	Θ				O										1	5	5	5		
5	9	5.0	0.1	Electric motor	▲		O	▲				Θ								1	5	5	5		
6	9	15.0	0.2	Reliability					Θ	O		▲								3	4	4	5		
7	9	20.0	0.2	Load cell	▲		O			▲			Θ							1	5	5	5		
8																									
9																									
10																									

Competitive Analysis (0=Worst, 5=Best)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Target or Limit Value															
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	4	7	6	6	8	7	0	0	3						
Max Relationship Value in Column	9	9	3	9	9	9	9	9	9						
Weight / Importance	150.0	180.0	120.0	170.0	135.0	260.0	135.0	70.0	180.0						
Relative Weight	10.7	12.9	8.6	12.1	9.6	18.6	9.6	5.0	12.9						

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