Operation Manual

Team 13

Tabletop Torsion Machine

Members:

Brendan Keane – bmk10c

Logan McCall – lgm12b

Reginald Scott – rbs09

Mark Swain – mas10h

Faculty Advisor:

Dr. Simone Hruda

Sponsor:

Mr. Philip Flater

Air Force Research Laboratory

Instructor:

Dr. Gupta

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ABSTRACT

This report is meant to be a reference to the user when operating the tabletop torsion tester. In this document, the user may find everything necessary to operate and maintain all aspects of the machine. The user may also find a brief explanation of the fundamental principles used by all torsion testers in this manual. Additionally, the user may find assembly information, operation instructions, product specification, troubleshooting guidelines, maintenance requires/suggestions, and finally the spare parts included with the machine.

ACKNOWLEDGMENTS

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The group would also like to thank the members of the FAMU-FSU College of Engineering Machine Shop for their great work on the fabrication of the parts necessary to complete the design. Finally, the team would like to thank the FAMU-FSU College of Engineering and Mechanical Engineering Department for providing the facilities that allowed for the completion of this design.

1. Introduction

Material testing is an essential part of designing new and improved products. It ensures reliability, efficiency, and safety. Knowing how a material acts under certain conditions allows engineers to create an optimal design. Without proper material testing an idea would never become reality. 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. They have a need for smaller, tabletop torsion testing machine. A smaller machine will lead to more accurate data when testing small specimens. These small specimens are used in order to test materials that are similar to the geometry of the product in the field. The data that will be gathered from the new machine will more accurately characterize the materials and how they react under torsional loads. This will result in more accurate models and simulations used by the AFRL.

In general, there are 4 major components of a torsion machine. These components include load generation, load application, load measurement and housing or frame. Additionally, the Air Force sponsor has requested that the free end of the specimen has 1 degree of freedom in the axial direction. This will ensure accurate results even if the specimen expands or contracts during testing. An AC gear motor and variable frequency drive (VFD) are being used in order to generate the load required to twist the specimen. The specimen will be held in place using two 6-jaw chucks. A strain rosette will be placed on the transmitting shaft in order to output the applied load on the specimen. Finally, the frame will be made out of steel and will utilize a 2 rail ball bearing guide in order to allow the free end to have 1 degree of freedom in the axial direction.

This is the operation manual for the tabletop torsion machine that has been designed and manufactured by the team. This manual takes the user through each component of the torsion machine and answers any question he/she might have. Someone with little or no experience will be able to operate the machine by referencing this manual. The end of this manual contains troubleshooting and maintenance information that is essential to the long life of the machine.

2. Background and Literature Review

The Munitions Directorate at Eglin Air Force Research Laboratory (AFRL) has tasked the team with designing and building a small scale torsion tester that can be used in their labs to help characterize different materials. The AFRL currently uses a torsion tester that is roughly three meters in length, to test samples that are no greater than eight centimeters longs. Due to the large size of the machine in comparison to the samples being tested, the data collected from testing on the current apparatus is not ideal. Therefore, a smaller testing machine will be proved to the AFRL which will allow for more accurate results, while taking up much smaller space in the lab.

To further understand the task assigned to the group, the fundamentals of torsion testing will be discussed in detail. A torsion test measures the strength of a material against a twisting force. This is a very common test which is used to determine how a specimen of a specific material will interact when subjected to a torque. Through these laboratory tests, the behavior of these materials under specific loading conditions can be characterized, and although the geometries may change from test to real world application, important characteristics of the material can be determined which are independent of geometry.

In a typical torsion test, the specimen is gripped on both ends firmly so that no slippage may occur during the experiment. Then, once the specimen is secured, a motor and gear drive is used to apply a torque. One end of the specimen remains stationary during testing, while the other is rotated by the motor. The twist experienced by the specimen is recorded. By using the twisting information as well as the applied torque, many material properties can be determined.

The data collected from a torsion test can be represented in a shear stress vs. shear strain plot like the one shown in Figure 1. The shear stress applied to the specimen can be determined by using the equation

$$\tau = \frac{M_T r}{J} \tag{1}$$

where M_T is the torsional moment applied, r is the radius of the sample, and J is the polar moment of inertia. The shear strain applied can be calculated with

$$\gamma = \frac{r\theta}{L} \tag{2}$$

where θ is the angle of twist, and L is the length of the sample.

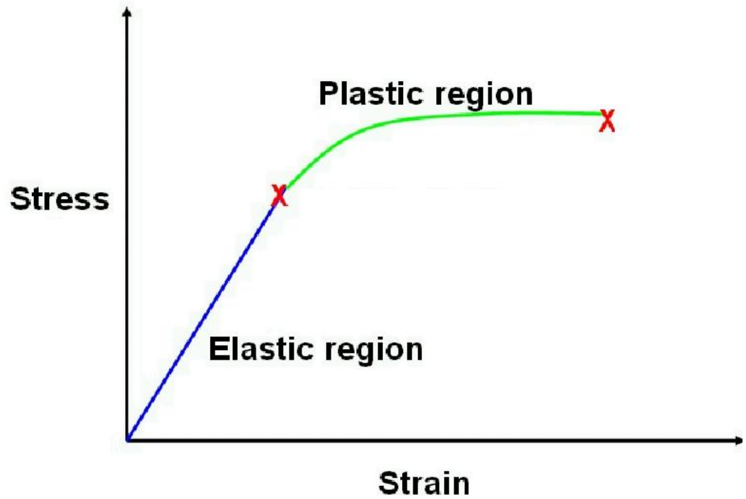


Figure 1: Example of a shear stress vs. shear strain plot for a sample undergoing a torsion test

In the elastic region of the plot, there is a linear relationship between the shear stress and shear strain experienced by the sample. This linear relationship leads to the determination of the shear modulus, G, of the material which can be determined using the equation

$$G = \frac{\tau}{\gamma} \tag{3}$$

When undergoing torsion, brittle and ductile materials will fail in different ways. A brittle specimen will break along surfaces 450 to the shaft axis. However, a ductile material fails along a plane of maximum shear, resulting in a fracture surface on a plane perpendicular to the shaft axis. [1]

3. Functional Analysis

It is important for the user to understand the different components of the torsion machine and how they work. Figure 2 below shows a functional analysis diagram of the machine. This diagram breaks down the machine into 5 major components and explains how each part accomplishes its required task. When all of these components work together the user is able to complete an accurate torsion test on a specimen.

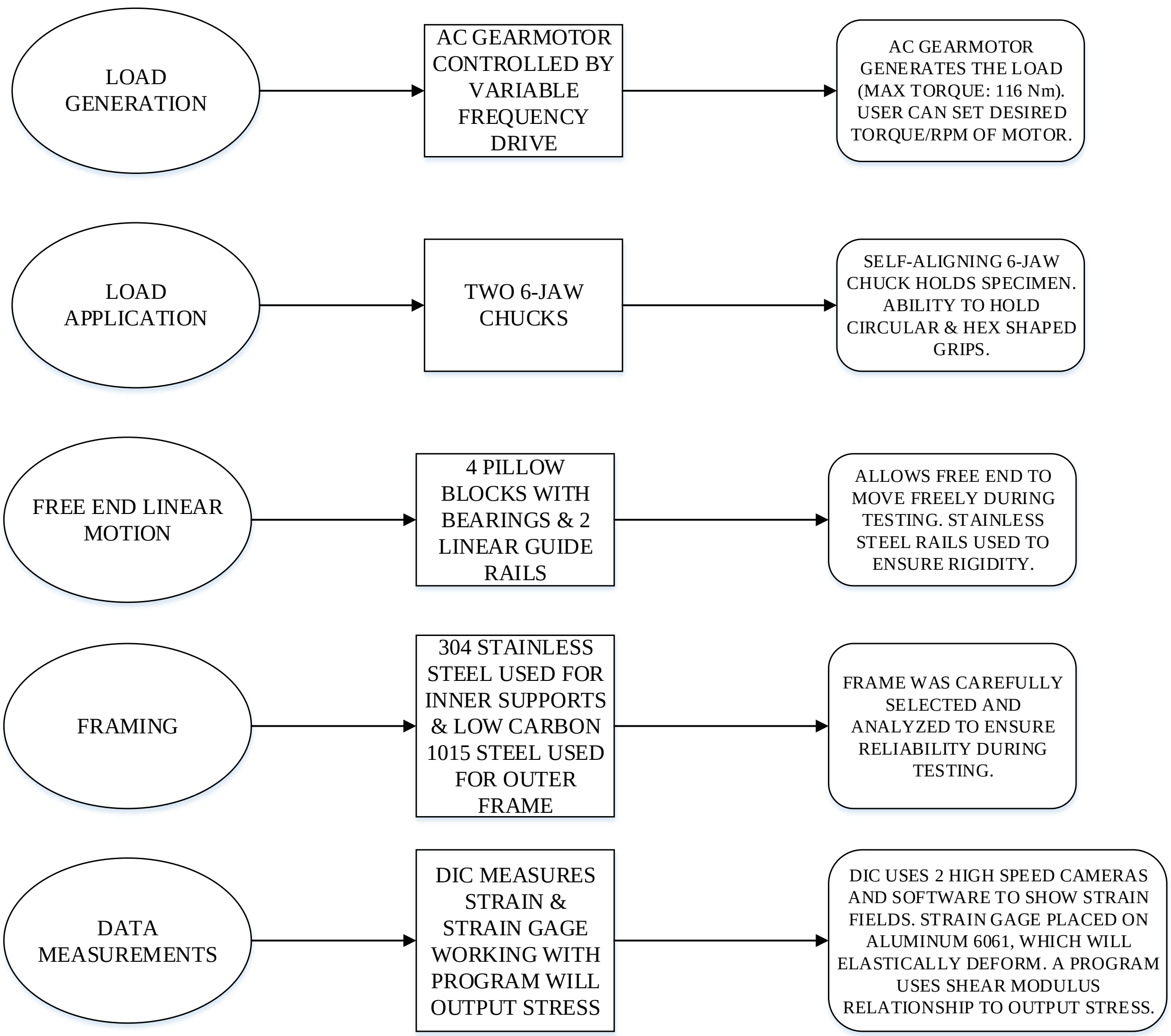


Figure 2: Function analysis of torsion machine

4. Product Specification

One of the main benefits of this torsion tester is its small size. Figure 3 shows the major dimensions of the machine. It should be noted that similar torsion testers on the market are much larger than this one. As a result, this tester has the ability to be easily moved by two people if necessary and can fit onto a standard table.

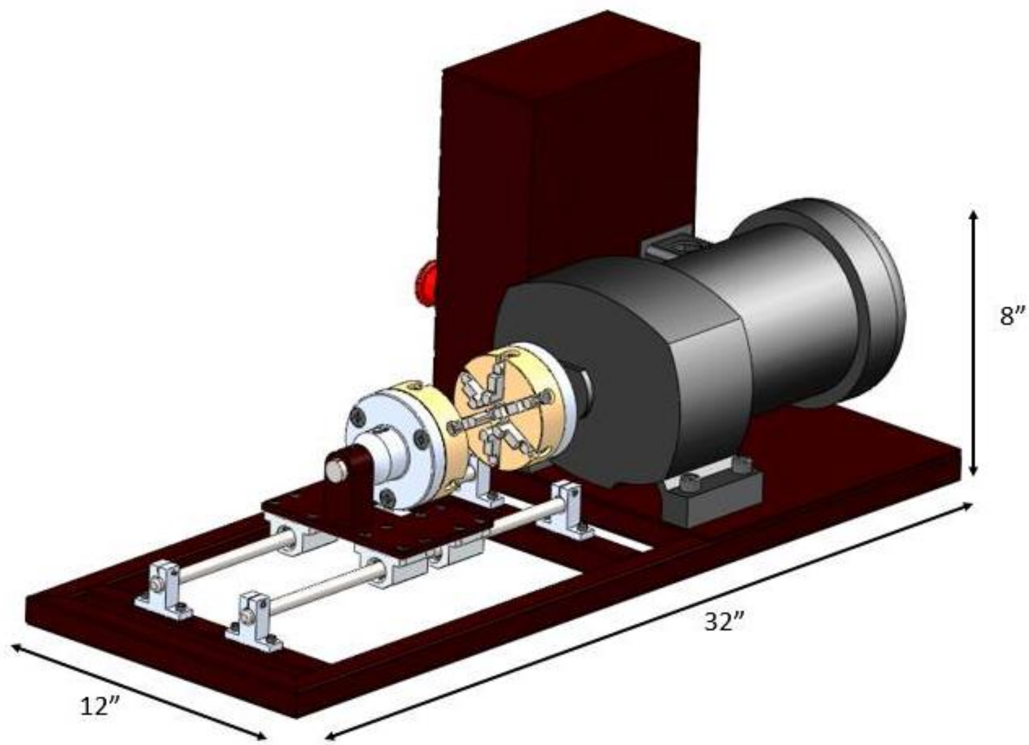


Figure 3: CAD rendering of torsion machine with dimensions

The motor information can be found in figure 4 below. This picture contains all of the important characteristics of the motor. For more motor information please reference the motor manual provided with the torsion tester. This motor is rated to have a maximum output of 116 Nm, which was more than adequate for this design which required an output of around 100 Nm.

For information regarding the VFD properties, please reference the manual provided with the torsion tester, or it can be found online at:
https://www.automationdirect.com/static/manuals/gs2m/gs2m.html.

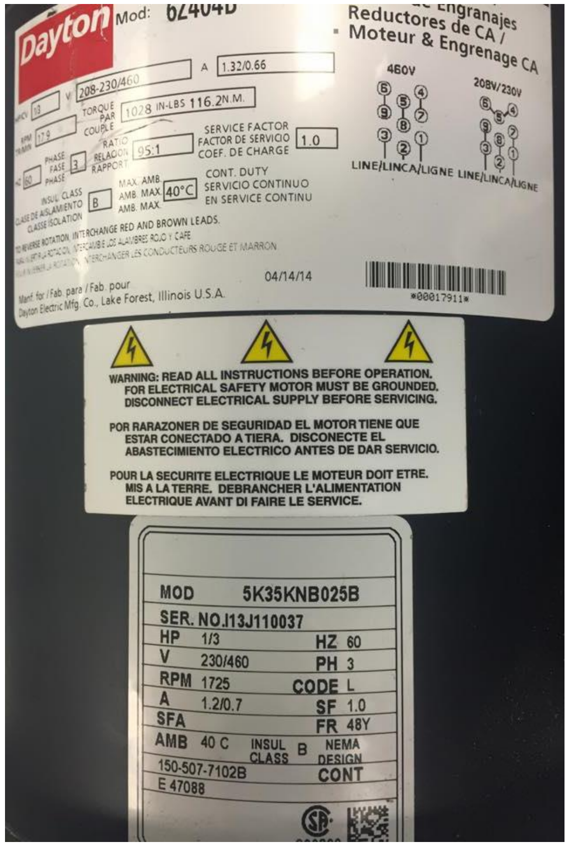


Figure 4: Motor baseplate information

This torsion tester has been design to test specimens with the geometries found in Table 1. These samples are quite small, with a total length of less than 60 mm, however the machine is capable of handling specimens that are up to 180 mm in length. The diameter of the specimens tested is limited by the size of the chucks. The specimens must also have a geometry that will not require greater than the torque applied by the motor, so hollow small specimens are recommended.

Table 1: 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

5. Assembly

Figure 5 is a 3D CAD rendering of the overall design. Figure 6 shows the overall assembly of the torsion tester in a simpler 2D CAD rendering with labels.

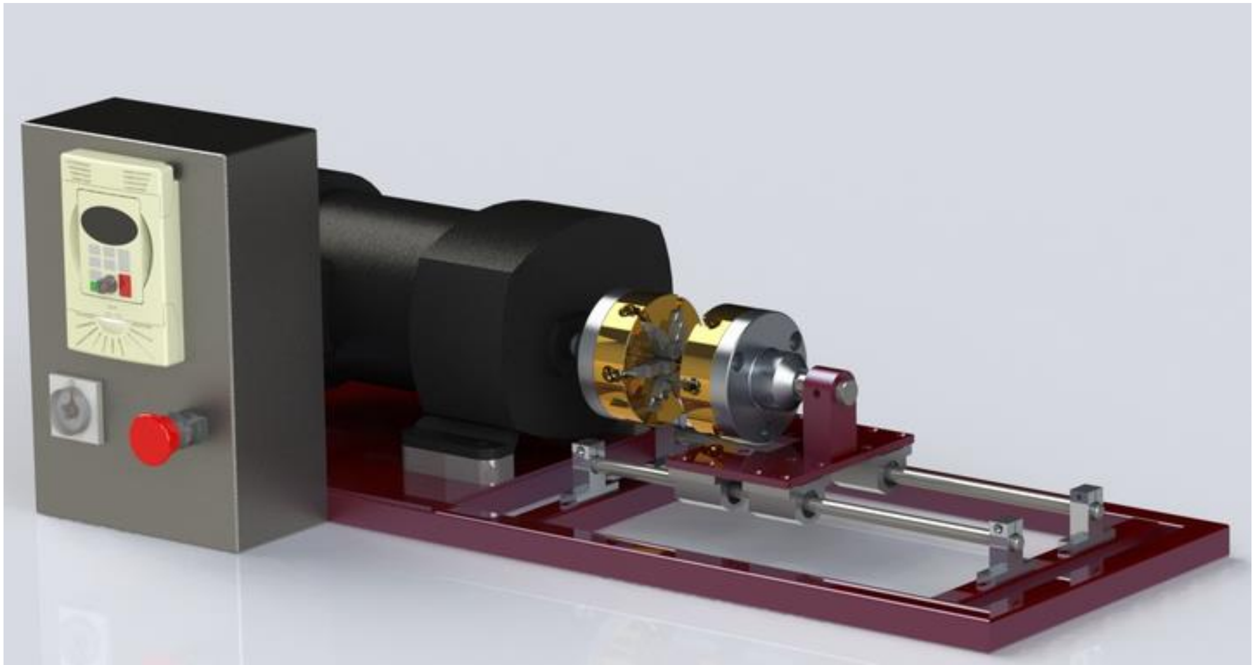


Figure 5: 3D CAD rendering of the tabletop torsion machine

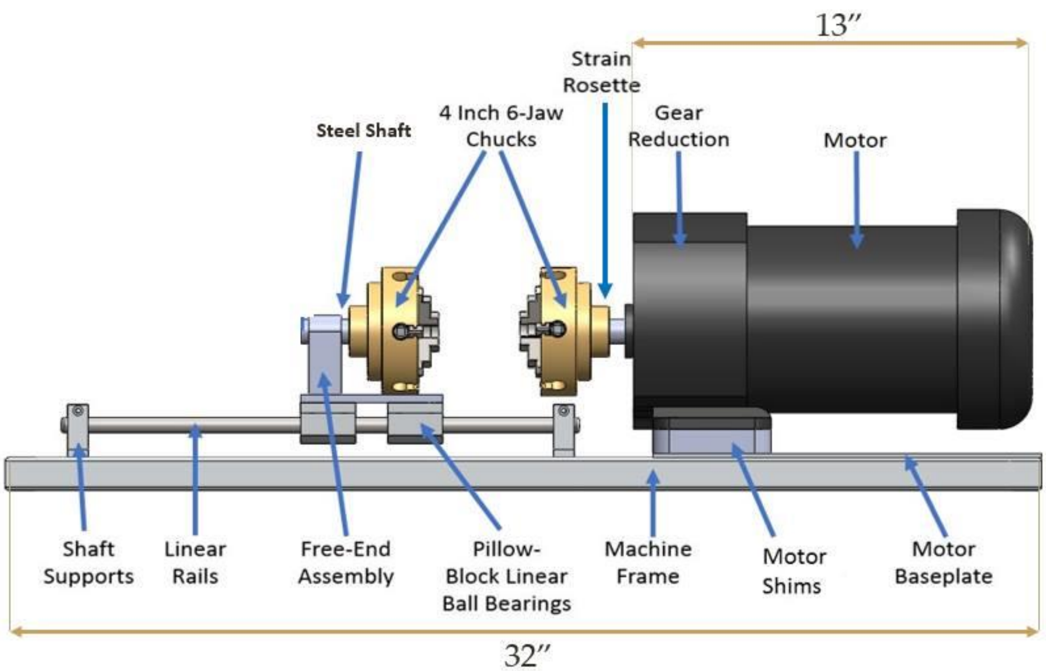


Figure 6: Side view of torsion machine with labels

The free end of the machine was custom and therefore a critical part of the machine. For this reason, its assembly on its own can be found in figure 7.

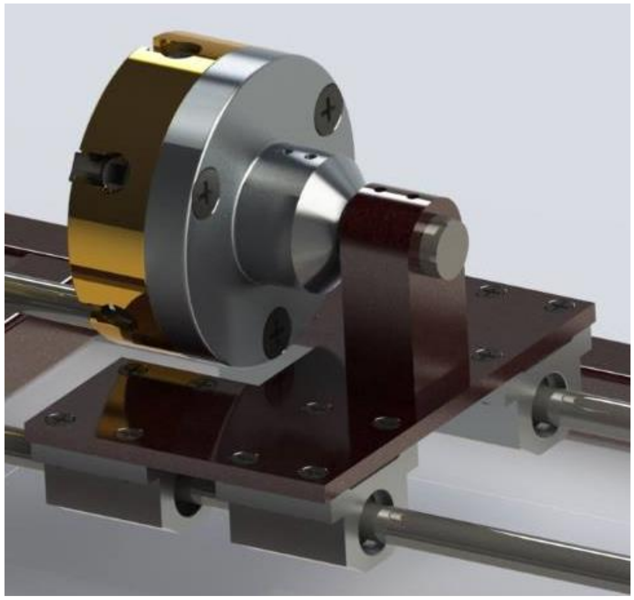


Figure 7: Free end assembly

Figure 7: Free end assembly

6. Operation Instruction

It should be noted the machine must be hooked up to an electrical outlet rated for 120V. Following are the steps needed to operate the torsion tester. It is recommended that the user uses safety goggles while using the machine.

For power supply to VFD wiring setup, refer to Chapter 2, Section 8 of the VFD User Manual provided.

To wire the VFD to the motor make the following connections:

White (VFD) → Motor wires 3 & 9

Red (VFD) → Motor wires 2 & 8

Black (VFD) → Motor wires 1 & 7

Ground (VFD) → Green screw in motor wire housing

To perform a torsion test follow these steps:

1. Perform necessary maintenance checks
2. Clamp machine to table
3. Loosen chucks with key provided to allow for specimen placement
4. Tighten chuck attached to motor shaft first using key (do not exceed grip length)
5. Slide free end chuck to cover specimen grip and tighten
6. Plug VFD into electrical outlet
7. Using VFD keypad, insert required program settings from motor baseplate
8. Set potentiometer to desired RPM/torque
9. Click green RUN button on VFD to begin test
10. Watch specimen closely and click red STOP button once desired failure point is reached
11. Use key to open chucks and remove sample
12. Fully close chucks after removing sample
13. Perform final maintenance checks recommended in this manual

7. Troubleshooting

Although the torsion tester was designed to have a high reliability, it is always possible for something to go wrong during operation. This section is meant to be a tool for the user in case something goes wrong with the machine.

VFD not turning ON

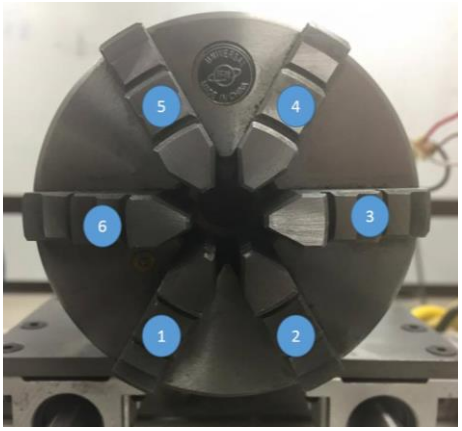
- Make sure electrical plug is in outlet
- Make sure all wiring is correct and securely fastened
- For more complex problems with the VFD please refer to chapter 6 in the VFD manual provided

Sample is slipping

- Use proper tightening key to tighten the chucks
- If using cylindrical grips try using another grip geometry such as hex grips
- Induce friction on sample grips by scratching grip surfaces

Chuck is locked in position (unable to turn key)

- Fully loosen scroll and remove all teeth
- Replace teeth in order as shown below
- Insert teeth separately by watching for gap in scroll to pass while turning



Free end is not moving smoothly on linear rails

- Check that rails are aligned and perfectly straight
- Grease rails

Free end chuck is moving during testing

- Tighten down set screws

High motor temperature (motor is hot to the touch)

- Turn off machine for at least an hour

Motor shaft is not spinning

- Check that connections between motor and VFD are secure

8. Regular Maintenance

As with any machine, this torsion tester requires some maintenance from time to time.

VFD and motor

- Please refer to chapter 6 section 2 for monthly and annual inspection directions in the VFD manual to ensure optimal performance
- Also refer to motor manual for more information

Coupler

- Before and after testing, check couplers for any sort of deformation which may include cracking, warping, and/or shearing

Chucks

- Regularly check teeth for any deformations
- Fully open and close teeth before use to ensure proper alignment of teeth
- Refer to chuck manual provided with machine for more information

Free end

- Regularly check that the set screws are fully tightened

Linear rails

- Check all fasteners before use to ensure proper alignment
- Apply grease as needed to rails

Frame

- Perform a visual check of frame and welds for structural integrity before use
- Ensure all fasteners are fully tightened before testing

9. Spare parts

For any major part replacement please reference the bill of materials provided for the part number and vendor. The torsion tester comes with 2 chuck keys, and some extra fasteners which are listed below.

- 8 10-32 x 5/8 Button Head Socket Cap Screw
- 8 #10 Flat washer SAE
- 16 10-32 x 3/4 Flat Head Socket Cap
- 16 10-32 Hex Nut with Lock Washer
- 4 7/16-14 x 2 Socket Head Cap Screw
- 4 7/16-14 Nylon Insert Lock Nut