IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X
PP. 47-53
www.iosrjournals.org

Design and Development of Torsion Test Rig to Find Modulus of Rigidity on Universal Testing Machine

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Abstract: *Modulus of rigidity is an important property of materials and provides the right selection ,in the design of Engineering components . Conventional determination of the Modulus of rigidity of materials is carried out on torsion testing machine. In the present case a separate jig is prepared and used in UTM for the determination of modulus of rigidity. The results are compared and found to be narrow difference. This technique may be replaced the conventional torsion machine. In this method we may also reduce another equipment cost.*

Key words*: Special jig,* Modulus *of rigidity, Torsion testing machine, UTM.*

I. Introduction

The Universal Testing Machine (UTM) is used to test the tensile strength and compressive strength of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures. This is very true, but perhaps overly simplistic. There are varieties of terms in the industry that are used to refer to a UTM. The most common terms are “tensile tester”, “compression tester” and “bend tester”. There are also UTM that have been stripped of capabilities or marketed to a specific sector which have led to the development of specialized names such as “texture analyzer” for food, “top load compression tester” for packaging and pipe, and “peel tester” for adhesives, tapes, and labels. Today, a UTM can perform all of these tests and more. A UTM is a great multi-purpose instrument for an R&D lab or QC department. A UTM can perform various tests like tensile test, compression test, peel test, puncture test, bend test etc.

The setup and usage are detailed in a test method, often published by a standards organization. This specifies the sample preparation, sample fixing, gauge length (the length which is under study or observation), analysis, etc.The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips. Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen. Machines range from very small table top systems to ones with over 53 MN (12 million lbf) capacity.

To test the vehicle components such as bearings and pivots etc /the set was prepared and tested [1].Particularly to test small load composites are tested [2].To test the concrete structures an setup is prepared [3].FRP components are successfully tested by Mehran Ameli *et.al*[4].Steel metal components are tested by Qing yen *et.al*[5]. Shafts for torsion by UTM to reduce the cost.

1.1 TORSION:

In the field of solid mechanics, torsion is the twisting of an object due to an applied torque. Torsion is expressed in Newton per square meter (Pa) or pound per square inch (psi) while torque is expressed in Newton meters (N· m) or foot-pound force (ft· lbf). In sections perpendicular to the torque axis, the resultant shear stress in this section is perpendicular to the radius.

For shafts of uniform cross-section the torsion is:

$$\frac{T}{J} = \frac{G\theta}{l} = \frac{q}{r}$$

where:

- T is the applied torque or moment of torsion in N-m
- q is the maximum shear stress at the outer surface

- *J* is the torsion constant for the section. It is almost equal to the second moment of area. .
- *r* is the distance between the rotational axis and the farthest point in the section (at the outer surface).
- l is the length of the object the torque is being applied to or over.
- θ is the angle of twist in radians
- *G* is the shear modulus, also called the modulus of rigidity, and is usually given in gigapascals (GPa), lbf/in^2 (psi), or lbf/ft^2.
- The product *J G* is called the torsional rigidity .

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for a shaft with torsion, the properties are shear stress and angle of twist.
The shear stress at a point within a shaft under torsion is

$$q = \frac{T}{J} r$$

Note that the highest shear stress occurs on the surface of the shaft, where the radius is maximum. High stresses at the surface may be compounded by stress concentrations such as rough spots. Thus, shafts for use in high torsion are polished to a fine surface finish to reduce the maximum stress in the shaft and increase their service life.
The angle of twist can be found by using:

$$q = \frac{Tl}{GJ}$$

The project is focused all about conducting torsion test on a specimen using UTM. Since the UTM has no mechanism of performing torsion test, some apparatus is designed and manufactured to fix the specimen on the machine and load is applied. The observations are noted down and further calculations are made to get the torsion in the bar for each load applied.

1.2 Different types of Torsion Testing Machines:
There are large varieties of machines for all types of tests available today in the market. The accuracy level and the efficiency of the machines are improving tremendously from day to day. As of now the main torsion testing machines are classified based on

1. Operation
2. Position of the specimen
3. Control
4. Use Torsion machines description, their construction and their function is of little importance here.

1.3 Universal testing machine:
A Universal testing machine (UTM), also known as universal tester, is used to test the tensile strength and compressive strength of materials. The 'Universal' part of the name reflects that it can perform many standard tensile and compression tests on materials, components and structures. As many know about universal testing machine and its operation.

1.4 APPLICATIONS:
The following tests can be performed with it

1. Tension test
2. Compression test
3. Bending test

These are the main applications of UTM. But torsion test is performed on UTM in this project by designing and fabricating some of the mechanical components.

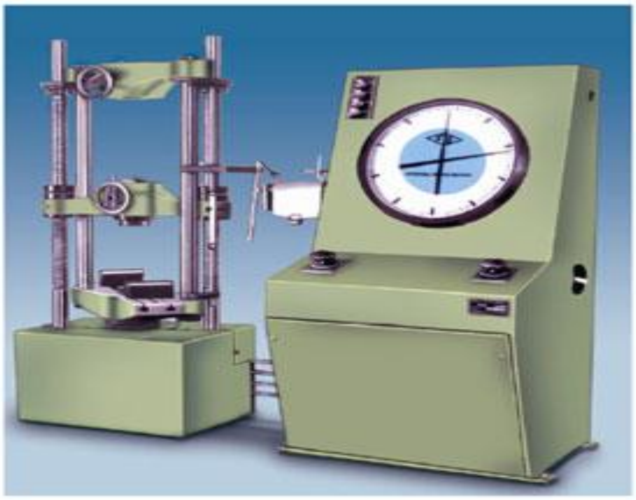


Fig.1: Universal Testing Machine to conduct torsion test

II. Experimental Design And Alignment Components Used For Torsion Test

- Metal bed or Base Plate
- Vertical plates
- T-slot
- Specimen
- Load applying pointer
- Spanner
- Bushes and nuts

All these components are designed in CATIA and manufactured using various industrial processes like turning, milling etc.

2.1 Alignment Metal Bed Or Vertical Plates:

- The metal bed or base plate is fixed to the universal testing machine above the T-slot by means of bushes and nuts. The design of bed and plates is carefully made by taking the measurements of the machine
- The slots for fixing the nuts are also accurately designed and manufactured
- The 2 vertical plates are designed one with a circular slot and the other with a square slot. The circular slot is made by hole drilling and the rectangular slot by gas cutting.

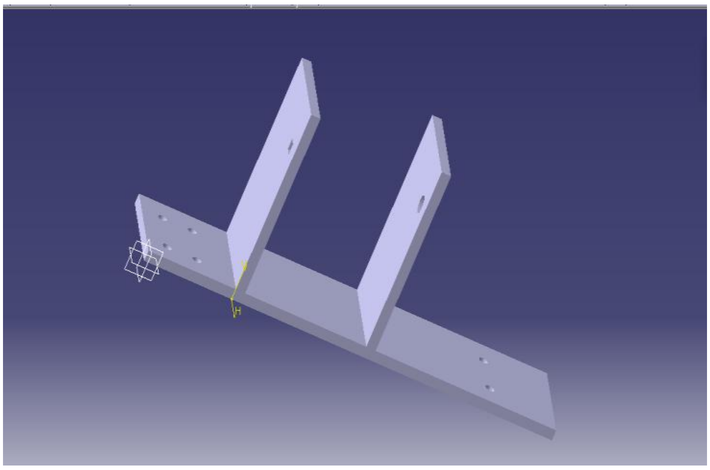


Fig 2: Torsion Test Jig Used In Universal Testing Machine

2.2 The specimen
Details:
- The specimen is made of mild steel(MS). It is a rod with circular cross section.
- The two ends of the specimen are designed in such a way that one end is fixed in one vertical plate with square slot Other end of the specimen is to hold the spanner.
- The end which holds the spanner is remained out of the space between vertical plates
- Only circular cross section of rod is between the vertical plates.

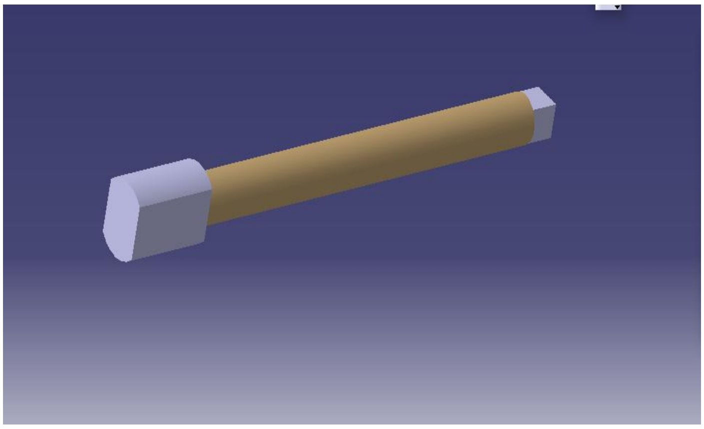
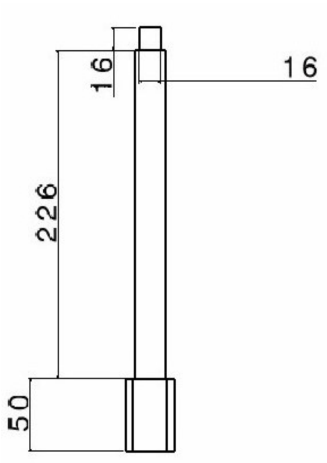
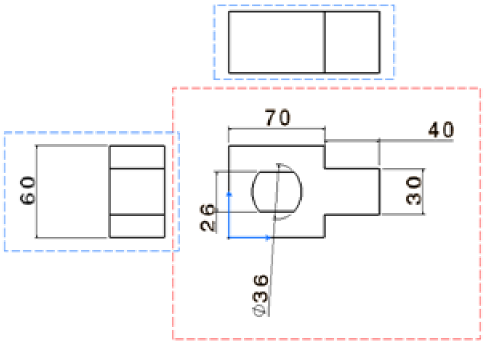


Fig. 3

2.3Design of specimen:



2.4 SPANNER
- The spanner is the most important component in the whole Equipment.
- It is of material EN8 manufactured using milling Operations.
- It is the component which takes the load and applies it on the specimen to bring torsion in it.
- One end of specimen is fixed with spanner for the load to be applied.
- The slot in spanner and end of specimen are designed identical except for 1mm clearance.



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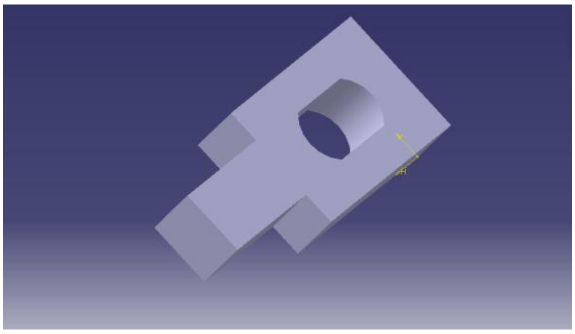

Fig. 6 Spanner

2.5 Method of testing

The metal bed is fixed to the UTM which has a T-slot by means of

- bushes and nuts.
- The vertical plates are already welded to the metal bed.
- The specimen is now inserted through the vertical plates to be in Position.
- The UTM is prefixed with a pointer for applying load on spanner.
- The spanner is fixed to one end of specimen.
- The metal bed is fixed in such a way that the load is applied exactly in the midpoint of the spanner.
- After observing the alignment carefully, a dial guage is fixed under the spanner to observe the deflection of spanner
- The metal bed is fixed to the UTM which has a T-slot by means of bushes and nuts.
- The vertical plates are already welded to the metal bed.
- The specimen is now inserted through the vertical plates to be in position.
- The UTM is prefixed with a pointer for applying load on spanner.
- The spanner is fixed to one end of specimen.
- The metal bed is fixed in such a way that the load is applied exactly in the midpoint of the spanner.
- After observing the alignment carefully, a dial guage is fixed under the spanner to observe the deflection of spanner
- Load is now gradually applied on the spanner with the help of sharp pointer.
- Since it is a hydraulic load we can easily operate and accurately increase the load.
- For every increase of load the deflection of dial guage is carefully noted down.
- After the values are noted down the machine is turned off.

Further calculations are made to find out the torsion in the specimen

S.No	Deflection (mm)	Load (k-N)	Cumulative difference of deflection (mm)	Cumulative difference of load (k-N)	Load per 0.1mm Deflection (k-N)
1.	0.33	4.16	0.3	0.16	0.0533
	0.6	4.32	0.2	0.32	0.16
	0.8	4.64	0.2	0.28	0.14
	1	4.92			
2.	1.2	5.8	0.2	0.32	0.16
	1.4	6.12	0.2	0.64	**0.32 (max)**
	1.65	6.76	0.3	0.72	0.24
	2	7.48			

Fig.4.The experimental set up on UTM during torsion testing of steel sample
The Experiment Conducted gave The Following Values:
Centre distance=41mm.
Centre to dial gauge pointer=61mm.
Specimen to plate distance=255mm.

III. Experiment Results

As shown in the table, the cumulative difference of load and deflection is calculated and the load per 0.1mm deflection is also calculated in each case.
And the maximum value of load per 0.1mm deflection is observed.
We go with further calculations taking this maximum value into consideration

Calculations:
From the table the maximum value of load per 0.1mm of deflection is 0.32 k-N.
We know that,
$T/J=G\theta/L$
Where,
T= TORQUE
J = POLAR MOMENT OF INERTIA
G = MODULUS OF RIGIDITY
θ = ANGLE OF DEFLECTION
l = SPECIMEN TO PLATE DISTANCE = 255 mm
We know that
T = torque = load$\times$offset

$= 0.32\times ((41\div 10^3)\times10^3 = 13.12$ N-m

$J = \pi d^4 / 32$ for this circular shaft

$= (3.14\times23^4)\div 32 \quad = 27459.40\ mm^4$

We know,

$r\,\theta = l$

$\Rightarrow \quad \theta = l / r$

$\Rightarrow \theta = 0.1 / 61$

$\Rightarrow \theta =$ 0.0016 radians or 0.092 degrees

Now,

$T / J = G\theta / L$

$\Rightarrow (13.12 \times 10^3) / 27459.40 = (G\times0.0016) / 255$

By solving the above equation, we get
G = $76148.7869\ N/mm^2$ or $0.76\times10^5\ N/mm^2$

Hence we calculated the value of G.
Results:
Therefore the modulus of rigidity of the specimen, which is made up of mild steel is
G = $76148.7869\ N/mm^2$ or $0.76\times10^5\ N/mm^2$

IV. Conclusions

Torsion test rig is performed on Universal testing machine and the elastic proportion of the specimen material is observed. From the observed values, we found the modulus of rigidity, i.e., G of the material. This experiment helped in the better understanding of material properties of the specimen and the working of UTM. It added one more function to the UTM. It improved our knowledge on design of mechanical elements in CATIA.By more accurate fabrication of the material, more accurate results can be obtained.

Acknowledgements:
The authors are thankful to the management of Sreenidhi Institute of Science and Technology for their encouragement and support for this project.

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