SM21
Torsion Testing Machine

All due care has been taken to ensure that the contents of this manual are accurate and up to date. However, if any errors are discovered please inform TQ so the problem may be rectified.

A Packing Contents List is supplied with the equipment. Carefully check the contents of the package(s) against the list. If any items are missing or damaged, contact your local TQ agent or TQ immediately.

TQ Education and Training Ltd
Products Division

PE/ajp/0298

CONTENTS

CONTENTS

SECTION 1.0 INTRODUCTION

The **SM21 Advanced Torsion Testing Machine** enables forward and reverse torsion tests on a range of sizes and lengths of specimens requiring test torques of up to 200 Nm (1750 lbf-in). Load is applied by a variable speed electric motor driving through a 5:1 belt drive and a 1200:1 reduction gearbox. The torque reaction is provided by a pendulum whose movement is measured by a linear potentiometer. The potentiometer is connected to a digital meter giving a readout calibrated in torque units (Nm or lbf-in). Input rotation is measured by a digital counter, one unit being equal to 0.3° of the input shaft rotation. The pendulum angle is measured by a scale and pointer. The twist of the specimen can be regarded as the difference between the angle of rotation of the input shaft and the pendulum angle*.

The test specimens are held at each end by sockets mounted on the input and pendulum shafts, various sizes being supplied to enable use of a variety of specimens. Although intended for testing larger specimens the machine can also be used for testing the smaller 6 mm/0.25" diameter specimens normally employed on the TecQuipment SM1 Torsion Machine. Accurate measurements of twist angle, and hence of strain can be obtained using the SM2 Torsiometer (small specimens only). The TecQuipment Torsiometers (SM21a and SM21b) can be supplied for use with specimens having hexagonal ends up to 24 mm A/F and also with the Avery-type specimens.

* This twist can be taken to be that over the total length of the specimen. For accurate work it is essential to use a torsiometer to measure the twist over a known gauge length. The TecQuipment SM21a Torsiometer is specially designed for this purpose.

SECTION 2.0 ASSEMBLY AND OPERATION

2.1 Assembly Instructions

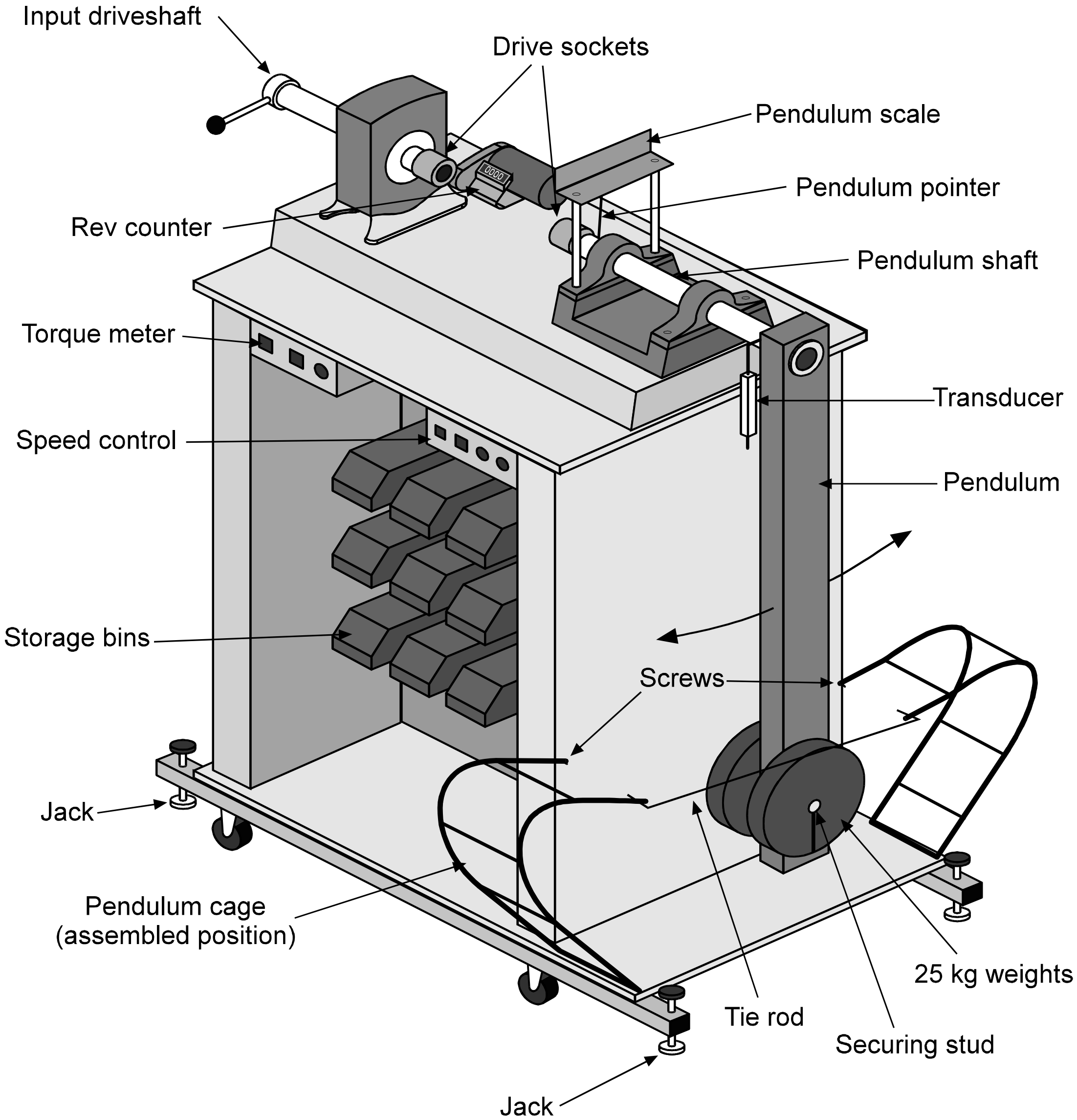

Figure 2.1 SM21 Torsion Testing Machine

The machine is despatched partly disassembled. Assemble on site referring to Figure 2.1 as follows:

1. Remove all loose items from their packing and check all items off against the Packing Contents list. **Note:** Do not discard any of the packing material until the machine has been completely assembled and tested.

2. Remove the two screws securing the two halves of the pendulum cage to the side of the cabinet. Swing the cage halves outwards and re-fit the screws to lock the cages in their outer position.

3. Fit the plated securing studs through the hole in the lower end of the pendulum and fit a washer and plain nut on the inner end.

4. Carefully slide one pendulum weight (slot downwards) over the stud and the locating peg behind the pendulum so that it rests on the stud. Fit the other weight similarly at the front and then lock both weights in position by fitting the dome nut and washer and tightening up.

5. Fit the tie rod into the holes in each end of the outer arms of the pendulum cages.

6. Slide the pointer onto the inner end of the pendulum shaft and clamp it in position with the thumb screw provided.

2.2 Operation

2.2.1 General Notes

(a) **Speed Control** - The motor will always start in the direction selected on the speed control. To change the direction of the motor stop the unit using the speed control, ensuring that the pendulum has stopped, and then select the opposite direction on the control.

> **Warning!**
> **Damage to the motor may result if the pendulum has not stopped swinging before changing direction.**

Note: This unit is fitted with a 3A fuse (spare fuses are supplied.)

(b) **Sockets** - Four hexagon sizes are supplied, three being 1/2" drive for which adaptors are provided. The sockets are intended for use with the following specimens:

3/16″ Whitworth: All 6 mm and ¼″ diameter specimens except cast iron.

12 mm AF: 6 mm and ¼″ diameter cast iron specimens (note: it may be necessary to remove rough edges from the hexagonal ends of some specimens).

17 mm AF: The larger specimens supplied with the rig, and for further optional experiments when these become available.

(c) **Torque Meter Calibration -** the torque meter is calibrated before leaving the factory and can be checked using the values stated on the label. Setting zero at zero pendulum angle and checking values at ±10 gives a reasonable check on calibration but there may be small zeroing errors. A more accurate check can be carried out by setting zero at –10 and checking that the value at +10 is double the value stated on the label.

2.2.2 Preparation for Use

1. Jack up the pendulum end of the rig using the two jacking screws in order to prevent movement of the rig due to any swinging of the pendulum during tests (This should occur only when a specimen fractures).

2. Connect the speed control and torque meter modules to a single phase mains supply and switch on[1].

3. Fit the appropriate sized sockets (and adaptors if required) to the input and pendulum shafts.

[1] The machine will be supplied to suit the voltage quoted when ordering the machine.

4. With the pendulum steady, set the torque meter to zero using the 'Set Zero' control at the rear of the meter unit and set the pointer to zero on the pendulum angle scale.

5. Withdraw the input shaft through the gearbox and insert the specimen in one of the sockets. Run the motor using the speed control until the second socket will slide onto the other end of the specimen. Ensure that the input shaft is pushed inwards as far as it will go before applying any load.

6. Slowly inch the motor until the torque meter reading just begins to change, then set the input revolution counter to zero by pressing the trip lever on the left.

2.2.3 Torsion Test to Failure

1. Use the motor to rotate the input shaft in increments of say 1.5° (i.e. 5 revs of the counter). At each value record the counter reading, the torque value and the pendulum angle. This can be carried out incrementally or continuously (constant strain rate).

2. Continue until the specimen has yielded, then increase the interval between readings to, say 6° (20 revs) and later to 15° (50 revs) or more if testing relatively ductile specimens. If strain rate is not considered important, the motor speed can be increased during these later stages of the test.

2.2.4 Other Tests and Analysis of Results

Other tests include demonstration of upper and lower yield strengths for normalised steel specimens, and demonstration of the Bauschinger effect and other effects relating to work hardening and heat treatment.

Such tests generally involve releasing the load, or reversing it. On the SM21 apparatus this is achieved simply by reversing the speed control module and running the motor until the desired condition is obtained.

If it is required to remove a strained specimen before fracture (for example for heat treatment), reverse the motor and run it until the pendulum angle falls to zero, and sockets become loose on the specimen. Then withdraw the sliding input shaft and remove the specimen.

Warning!
No attempt should be made to remove a specimen when under load.

SECTION 3.0 DESCRIPTION OF THE APPARATUS

3.1 Introduction

The TecQuipment Torsiometer Model SM21a is specially designed to fit onto the standard specimens supplied by TecQuipment for all of their torsion testing machines. This torsiometer can accommodate total strains of any magnitude due to the facility of being able to adjust the dial indicator drive. It can be used therefore to measure strains accurately in both the elastic and plastic regions.

3.2 Construction

A sectional arrangement of the TecQuipment Torsiometer Model SM21a is shown in Figure 3.1 to which reference should be made.

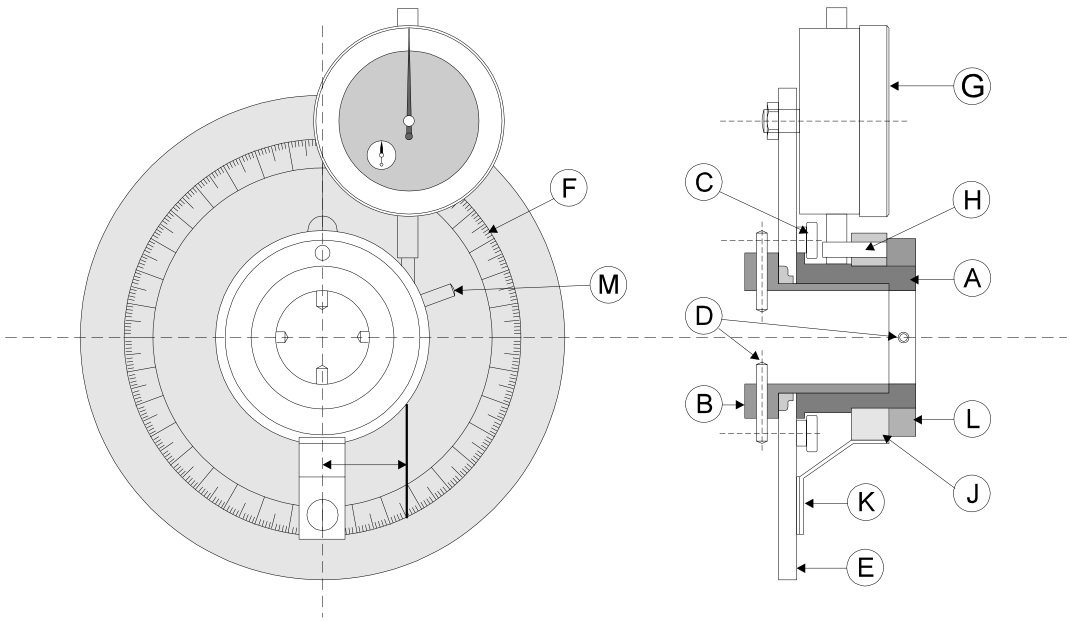

Figure 3.1 SM21a Torsiometer

The torsiometer consists basically of two cylindrical components A and B which are capable of relative rotation but are constrained against relative axial movement by two shoulder screws C. Each part, A and B, contains two diametrically opposite screws D which have 90 cone points. The screws in part A are short socket drive screws whilst those in B are much longer for ease of manipulation. These sets of screws are used to clamp the torsiometer to the specimen and set the gauge length to 50 mm.

Integral with component B is disc E carrying a scale F marked out in degrees. Dial gauge G is also attached to the disc E in such a position that its axis is 25 mm from the axis of the specimen.

The dial gauge plunger should rest on the flat portion of the rod H which is attached to ring J. Also attached to J is a cursor K which moves over the scale F. This assembly is held in position on component A by the locating ring L.

Note: In Figure 3.1 ring J is shown 90° out of position.

The locking screw M in ring J is used to set the zero position of the dial gauge (and the initial position of the cursor). It is also used to adjust the position of J during testing so as to accommodate large strain readings.

3.3 Use and Operation

3.3.1 Use

If it is merely required to demonstrate a torsion test a torsiometer is not essential: if, however, results of any scientific interest are required it is essential to use a torsiometer. Use of the TecQuipment Torsiometer Model SM21a will allow accurate measurements of strain to be obtained in both elastic and plastic regions. The modulus of rigidity can be determined accurately and accurate measurement of the work-hardening properties of a material can be made.

3.3.2 Attachment

The TecQuipment Torsiometer Model SM21a is attached to a specimen by threading the specimen through the centre of the torsiometer after unscrewing, but not removing, the four gripping screws D (two at each end).

Place the two segments corresponding to the specimen diameter in position as shown in Figure 2.2. Then, holding the torsiometer in the required position relative to the length of the specimen, tighten the two gripping screws so that the clearance between the segment and the specimen is the same for each segment.

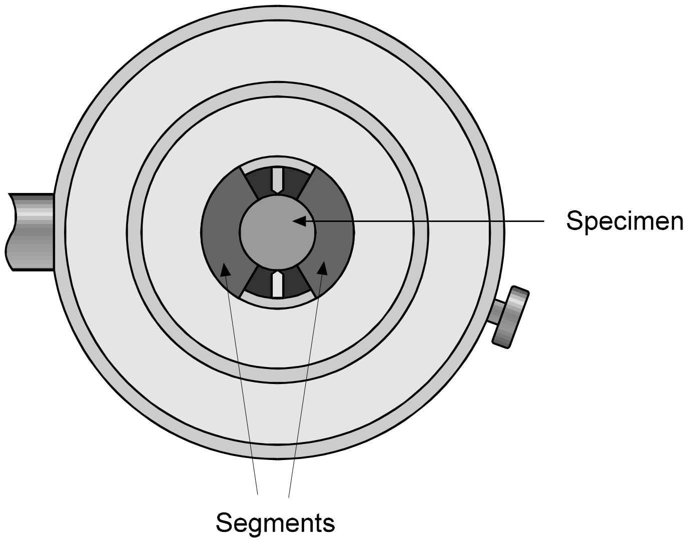

Figure 2.2 Torsiometer Segment Positions

After these two screws have been tightened tipping the whole assembly upside down will allow the segments to fall out of position. The segments should now be placed in the corresponding position at the other end of the torsiometer. Rotate this end so that the two sets of gripping screws are at 90° to each other and tighten up as before.

Remove the segments and insert the assembly in the torsion machine as described below.

3.3.3 Operation

The dial gauge is easier to read if the specimen is inserted into the machine with the end B of the torsiometer adjacent to the pendulum scale.

Withdraw the drive shaft to its full extent. Slide the end of the specimen into the drive socket attached to the pendulum shaft then push the drive shaft toward the specimen. At this stage it may be necessary to drive/inch the motor to line up the drive socket with the specimen. Slide the drive shaft so that the specimen is fully engaged by the drive socket.

The torsiometer is now ready for use. Should the full-scale deflection of the dial gauge be insufficient at the first clamp position of ring J, it may be adjusted to enable further readings to be taken by slackening the screw M and resetting the ring J. This does not disturb the clamping of the torsiometer in any way and allows continual adjustment throughout the test.

SECTION 4.0 THEORY

4.1 Twisting of a Solid Circular Bar into the Plastic Region

During transition from elastic to plastic behaviour there is no change in either the condition of equilibrium or the geometric conditions but there is a change in the shear-stress versus shear-strain relationship. Generally speaking, the stress-strain relationship changes from a linear to non-linear relationship at the torsional yield stress. For some materials there may be a second change back to a linear relationship with a much reduced slope when the shear-strain reaches values in excess of about twice the yield strain. The slope of this second linear portion is sometimes referred to as the work-hardening modulus or coefficient.

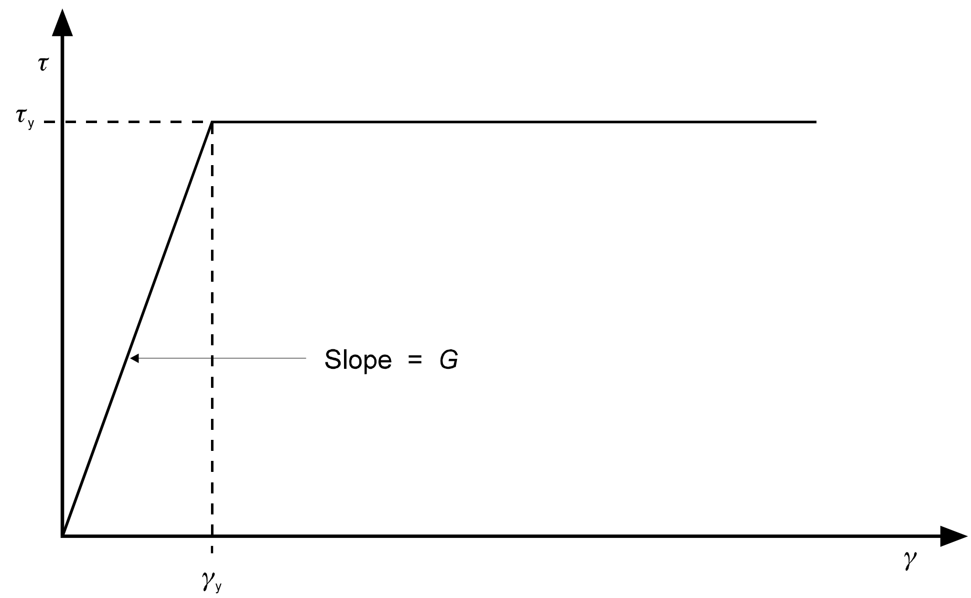

Figure 4.1 Graph of Shear-Stress versus Shear-Strain

When studying the theoretical behaviour of materials in the plastic region it is usual to commence by considering an elastic-perfectly plastic model. The shear-stress versus shear-strain curve for such a material is shown in Figure 4.1 in which τ_y is the yield shear stress and γ_y is the yield shear strain.

If a solid shaft of this ideal material is twisted progressively until it becomes 'fully plastic' the shear-stress distribution can be characterised at four distinct stages as shown in Figure 4.2. Figure 4.2(a) shows the stress distribution when all of the material is below the yield stress. Figure 4.2(b) shows the distribution when the outer fibres of the shaft just reach the yield stress; in this case the whole shaft is still elastic. Figure 4.2(c) shows the condition when the applied torque has caused yielding to a depth *h*, and Figure 4.2(d) shows 'full' plasticity. In the latter case of course there must remain a small elastic core which has an almost insignificant effect and for theoretical purposes, is ignored.

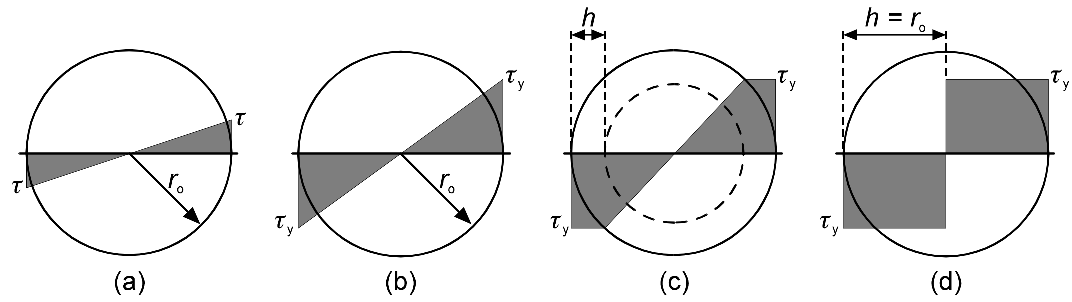

Figure 4.2 Shear-Stress Distribution Characteristics

4.2 Analysis

Consider case (b) of Figure 4.2. The torque required to produce this state is given by:

$$T_y = \frac{\tau_y J}{r_o} = \frac{\pi}{2}\tau_y r_o^3$$

(4-1)

The corresponding twist is:

$$\theta_y = \frac{\tau_y L}{G r_o}$$

(4-2)

where: L = length of shaft;
T_y = torque to produce yield stress at outer fibre;
θ_y = twist in radius over length of shaft L.

Now consider case (c) of Figure 4.2. The shear strain is still proportional to radius even for material strained plastically.

Let

$$r_o - h = r_y$$

then for $\theta > \theta_y$

$$\gamma = r\frac{d\theta}{dL} = r\frac{\theta}{L}$$

(4-3)

$$\therefore \quad r_y = \frac{L\gamma_y}{\theta} = \frac{r_o\,\theta_y}{\theta}$$

(4-4)

Equation (4-4) gives the depth of the yield surface for an angle of twist $\theta > \theta_y$. The shear-stress distribution is discontinuous at r and is given by two equations:

For $0 < r \leq r_y$

$$\tau = \tau_y.\frac{r}{r_y}$$

(4-5)

For $r_y \leq r < r_o$

$$\tau = \tau_y$$

(4-6)

Considering the equilibrium of the cross-section by equating the resisting torque due to the stress distribution to the applied torque. Then:

$$T = \int_r^{r_o} r\,\tau.2\pi r\,dr$$

$$= \int_0^{r_y} r\left(\frac{r}{r_y}\tau_y\right).2\pi r\,dr + \int_0^{r_y} r\,\tau_y.2\pi r\,dr$$

$$= \frac{2\pi}{3}\tau r_o^3\left(1+\frac{1}{4}\left(\frac{r_y}{r_o}\right)^3\right)$$

(4-7)

Substituting Equations (4-1) and (4-4) in Equation (4-7) we obtain:

$$T = \frac{4}{3}T_y\left(1 - \frac{1}{4}\left(\frac{\theta_y}{\theta}\right)^3\right)$$

(4-8)

Equation (4-8) is the non-linear t - θ relationship for twists greater than θ_y. For twists less than θ_y the usual elastic relationship holds viz:

$$T = \frac{GJ\theta}{L} = T_y\frac{\theta}{\theta_y}$$

(4-9)

From Equation (4-8) it is seen that if $\theta \rightarrow \infty$ then $T = \frac{3}{4}T_y$ i.e. the limit torque is 1.333 T. Substituting a value of $\theta = 3\theta_y$ into Equation (4-8) gives T = 1.32 T_y which indicates a rapid approach to the limit torque after yield occurs. Figure 4.3 shows a plot of T against θ using Equations (4-8) and (4-9).

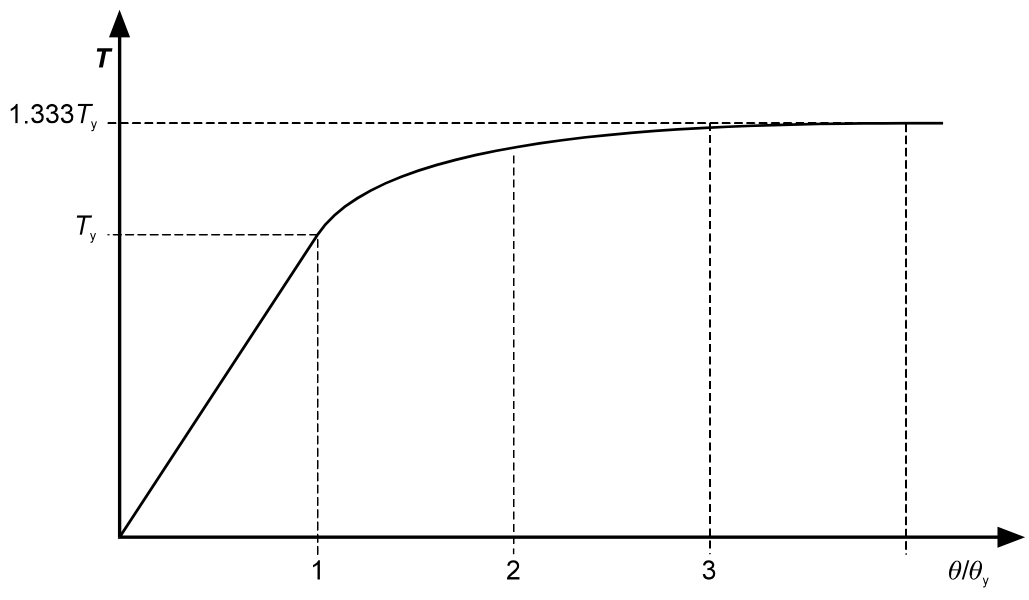

Figure 4.3 Graph of Torque versus Twist

4.3 Residual Stress

Suppose a shaft has been twisted to produce the shear-stress distribution shown in Figure 4.2(c). If the applied torque is maintained constant, then provided that effects of creep can be ignored (normally the case) the stress distribution remains the same.

If the applied torque is now reduced it is expected that the twist will also reduce which in fact occurs. Now, when a stressed material, particularly a metal, sheds load it does so elastically and usually with the normal modulus of elasticity (in this case the Modulus of Rigidity). This phenomenon coupled with the fact that the conditions of torsional equilibrium and the geometric constraints are unchanged causes the unloading line on the T - θ diagram to be parallel to the elastic loading line as shown in Figure 4.1. On reaching zero torque, it is seen, there is residual twist in the shaft which can be called the plastic twist for reasons which are obvious.

Since there is no externally applied torque to produce this twist, it must be due to internal (residual) stresses.

4.4 Residual Shear-Stress Distribution

An understanding of the residual shear-stress distribution is a steel shaft which has been overstrained can be obtained by considering superposition of an elastic stress distribution which would produce a torque equal and opposite to the applied torque.

In Figure 4.4(a) we have the stress distribution of Figure 4.2(c) due to torque $+T$; Figure 4.2(b) is the stress distribution (linear) which produces torque $-T$. Figure 4.4(c) is obtained by superposition of Figure 4.4(b) on Figure 4.4(a) and shows that, despite the fact that the resultant torque is zero, residual stresses exist at the central part of the shaft which are of the same sense as the original stresses, and at the outer part of the shaft of opposite sense as shown in Figure 4.4(d). Obviously since the resultant torque is zero then the resultant moment of the stress diagram about the axis of the bar is zero, i.e. the moment of area a and 0 is equal to the moment of area b about 0.

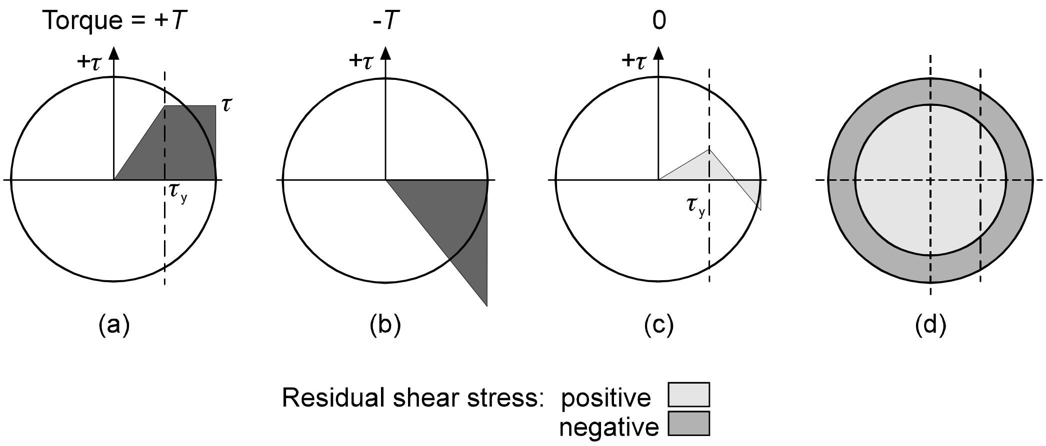

Figure 4.4 Shear-Stress Distribution

Note: If the 'negative' residual shear-stress intensity should exceed the yield shear-stress then the principle of superposition no longer holds because the behaviour becomes non-linear during the reverse stressing cycle. The application of Strain History Analysis then becomes necessary which is beyond the scope of this manual.

SECTION 5.0 EXPERIMENTAL PROCEDURE

5.1 Introduction

Before proceeding with experimental work two points must be carefully noted:

1. If accuracy is required it is not sufficient to measure deflection between the grips of a testing machine; it is essential to use an extensometer measuring deflection over an accurately specified gauge length. In the present case a torsiometer is required, e.g. TecQuipment SM21a or SM21b. Deflection between the grips of a machine may be used to demonstrate general behaviour and to obtain approximate values; sometimes this is all that is required.

   The obtaining of accurate results is time consuming and requires clear and careful logging of readings. It must be remembered that in destructive testing there is no opportunity to go back and check readings!

2. In torsion testing the observed readings are those of torque and twist. The results of scientific interest are those of shear-stress and shear-strain in particular the shear-stress versus shear-strain characteristics of the material. This is due to our interest in stress analysis for design purposes. If we merely require the torsional strength of a shaft we can apply torque to that shaft and measure the deflection over its length. In carrying out a tension test the assumption that the stress is uniform over the cross-section is from force to stress. In the case of the torsion of a solid circular shaft the stress varies directly as the radius; it is not a simple matter to convert from torque to shear-stress.

   One way in which this difficulty can be overcome is to use thin walled tubular specimens but these are expensive to produce and are prone to buckling when subjected to large plastic strains.

   For purposes of comparison what is usually done is to plot the **Nominal Shear-Stress versus Shear-Strain** curve.

5.2 Tests on Mild Steel

5.2.1 Residual Stresses

As was shown in Section 4.4 theory predicts that overstraining (i.e. straining beyond the yield point and then unloading) in torsion induces residual stresses in the torsion bar, shaft or specimen. In practice it is found that two types of residual stresses are induced:

1. Stresses in and between crystals due to deformation of the individual crystals. These stresses are called **textural stresses** and can be removed by low temperature heat treatment (200 - 300°C). If textural stresses are not removed they will cause displacement of distortion of components in service when they are released due to serve loading. Textural stresses are said, therefore, to be harmful.

2. The stresses distributed as indicated in Figure 4.4(d) are referred to as **body stresses** or **macro stresses** (Textural stresses could be referred to as **micro** stresses). The macro stresses affect the bulk of the material and are beneficial because they allow higher loading of components than would otherwise be possible without yielding taking place.

5.2.2 Testing in the Plastic Region

Figure 5.1 shows the torque versus twist characteristics obtained for a mild steel specimen (not normalised) tested in the TecQuipment SM21 Torsion Testing Machine using the TecQuipment SM21a Torsiometer.

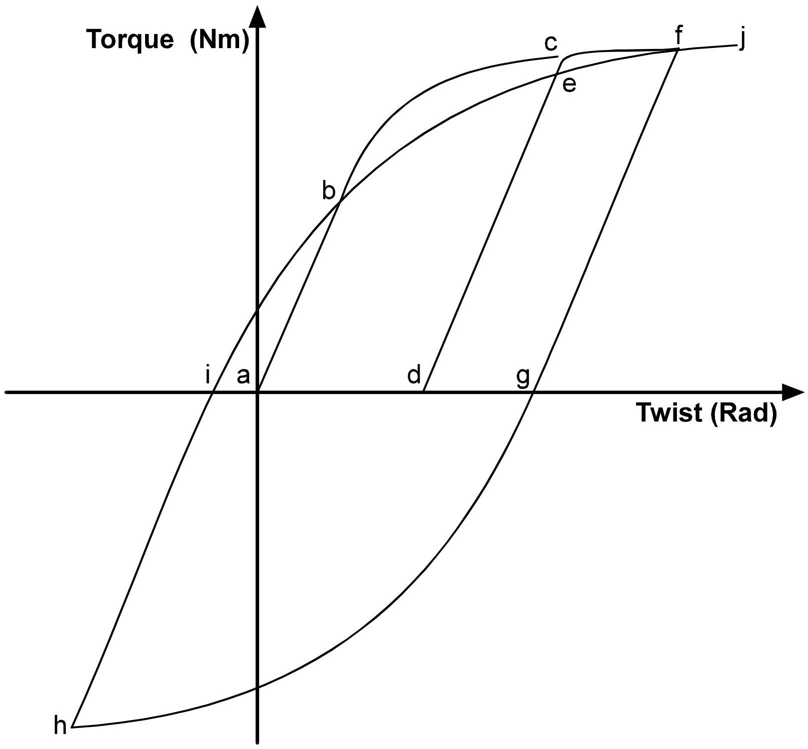

Figure 5.1 Torque versus Twist Characteristics

The initial load cycle is shown by the section (abc) in which (ab) is the elastic line and (bc) is the transition between the elastic limit and the limit torque (see Figure 4.3). In this case the limit torque is given by:

$$T_L = 1.5T_y \tag{5-1}$$

The modulus of rigidity will be given by:

$$G = \frac{L}{J}.\frac{dT}{d\theta} \tag{5-2}$$

within the range (a) to (b).

The unloading line (cd) is not shown but lies close to (de) and ends at (d). The residual twist, i.e. the plastic twist, is (ad) and therefore the residual strain, γ^1 is given by:

$$\gamma_r^1 = \frac{r.ad}{L}$$

(5-3)

at the outside fibres this becomes:

$$\gamma_{r_o}^1 = \frac{r_o.ad}{L}$$

(5-4)

Reloading takes place along (def). The portion (de) is parallel to the elastic line (ab) indicating that the presence of residual stresses does not affect the modulus of rigidity, however, they do affect the elastic limit raising it by approximately 35% in this case. (Mild steel is never used for prestressed torsion bars!). Note that the transition zone between the yield torque and the limit torque is now very short.

Unloading from (f) produces the line (fg) which is almost parallel to (ab). The residual twist at zero torque is (ag) and reverse loading produces the curve (gh). Note the shortness of the elastic portion in reverse loading and also that the torque at (h) is approximately equal to that at (f). Would it be expected that the limit torque would be the same for either direction of twisting?.

Unloading from (h) produces the line (hi) which is again almost parallel to (ab) and gives a residual twist at zero torque of (ai) which is negative relative to the previous residual twists (ad) and (ag).

Reversing the direction of the machine next allows the characteristic (ij) to be obtained again with only a very short elastic portion following reversal. Again, it is seen, the limit torque is unaltered and the points (bcf) and (j) form a continuous curve. This supports the theory that the limit torque is unaltered regardless of the way in which it is achieved.

5.2.3 Nominal Shear-Stress versus Shear-Strain

There is no need to replot the torque versus twist characteristic in order to obtain the nominal shear-stress versus shear-strain characteristic. All that is necessary us to scale the axes:

$$\tau = \frac{16T}{\pi d^3} \quad \mathrm{N/m^2}$$

(5-5)

where: T = Torque (Nm),
d = Diameter of specimen (m).

$$\gamma = \frac{d\theta}{2L}$$

(5-6)

where: θ = Twist (rad),
L = Gauge length (m).

5.2.4 Fluctuation of Results

It may be noticed during continuous straining in the plastic region that the readings on the torque meter fluctuate. This is due to the shearing action taking place within the specimen and is also evident on observing the very slight oscillation of the pendulum of the machine.

5.3 Other Experiments

5.3.1 Demonstration of Upper and Lower Yield Points

If a **normalised** mild steel specimen is tested it should be observed that an upper and lower yield point may be encountered. This is due to the fact that a higher stress is required to initiate yield than to propagate yield along the specimen. This phenomenon is illustrated in Figure 5.2 where, after initial yielding of the specimen, (point A) the load immediately fell to a lower value (point B). The strain was then reduced until the specimen was again in the elastic range (point C) but when re-loaded it yielded at the lower yield strength (point D) showing that, with normalised mild steel, yield propagates at the 'lower yield point' stress value.

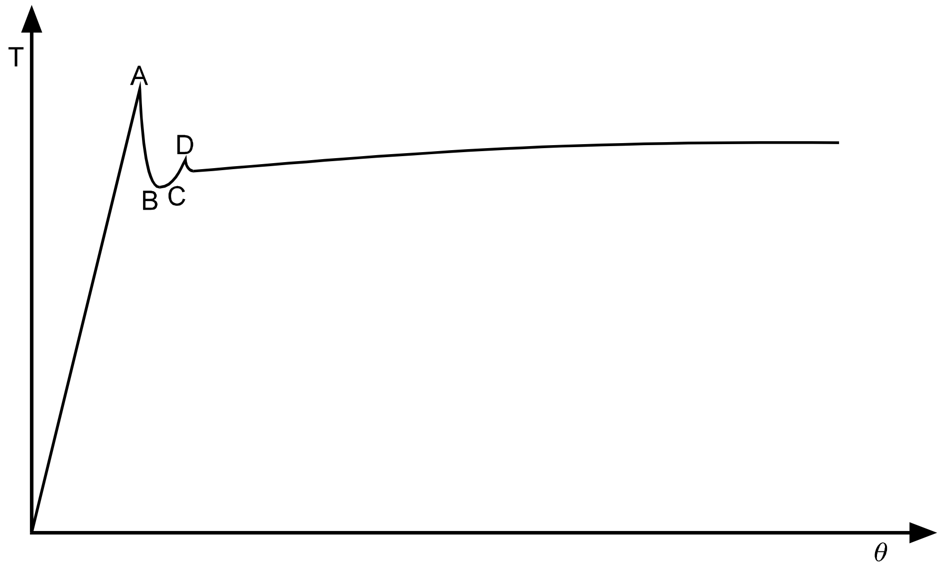

Figure 5.2 Yield Points

5.3.2 Nominal Shear-Stress versus Shear-Strain for Specimens of Different Diameters

In both elastic and plastic regions of torsional strain the shear-stress is related to the torque by:

$$\tau = \frac{kT}{d^3} \quad \textbf{(5-7)}$$

where k is a constant with a value of 16/π in the elastic region.

This value of k is used throughout a torsion test when plotting the nominal shear-stress against the shear strain. (The true shear-stress is less than the nominal shear-stress in the plastic region.)

Equation (5-7) can be justified by testing specimens of the same material but different diameters. Figure 5.3 shows the results of a series of three such tests. The curve a was obtained using a 5/32" diameter specimen, b and c were obtained from 7/32" and 1/4" diameter specimens respectively.

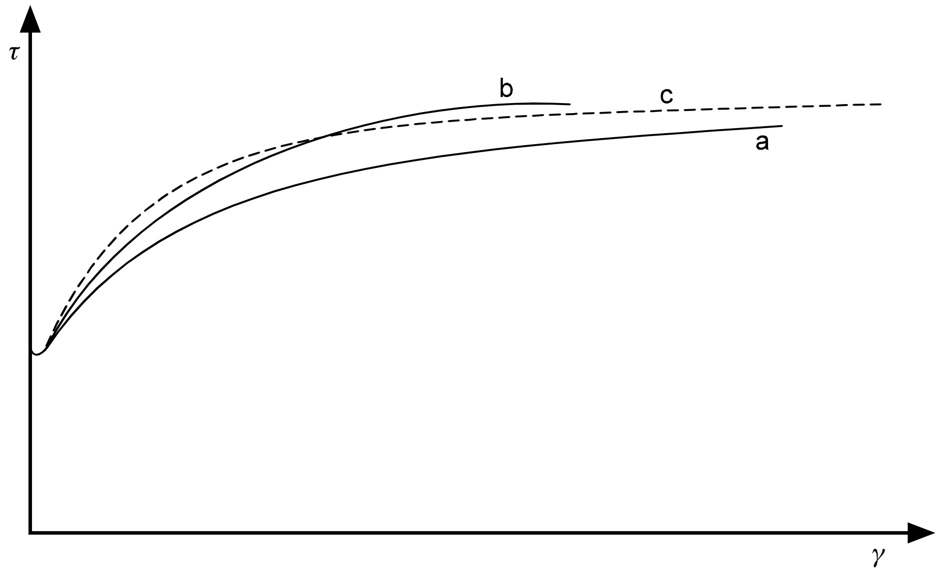

Figure 5.3 Comparison of Different Diameter Specimens

5.3.3 Tests of Thin Walled Specimens

The true shear-stress versus shear-strain curve for a material can be produced by testing a thin-walled tubular specimen. The main assumption is that the wall is thin enough to produce a uniform shear-stress distribution across it given by:

$$\tau = \frac{16 d_o T}{\pi\left(d_o^4 - d_i^4\right)}$$

where: t = wall thickness,
d_o = outer diameter,
d_i = inner diameter.

The bore must be smooth otherwise stress raisers will be present and give erroneous result and premature failure. Care must be taken not to distort the specimen when fitting the torsiometer.

Note: Hollow specimens are **not** provided as standard.

SECTION 6.0 ANCILLARY SPECIMENS AND EQUIPMENT

Range of Experiments

A wide range of tests on standard (solid) specimens of different materials can be carried out including:

1. Verification of the elastic torsion equation.
2. Determination of modulus of rigidity and yield shear stress.
3. Determination of upper and lower yield stresses for normalised steel specimens.
4. Investigation of the behaviour of materials under plastic deformation, the phenomenon of work hardening and the effect of varying strain rate.
5. Determination of modulus of rupture in torsion.
6. Reversed torsion tests to demonstrate the Bauschinger effect and the effects of residual body and textural stresses on torsional strength.
7. If heat treatment facilities are available various tests can be carried out to demonstrate the effect of heat treatment on residual stresses and torsional strength.

Additional specimens and ancillary equipment can be supplied to enable the Analysis of surface stresses in solid and hollow section specimens of various shapes.

Note: The use of a torsiometer (SM21a or b) is required for accurate determination of these quantities.

The SM21a mechanical torsiometer is primarily designed for accurate measurements in the elastic range and the initial stages of plastic deformation. As an alternative, the SM21b electronic torsiometer provides an accurate, continuous digital readout both for small strains in the elastic range and for twists of up to 5 revolutions as may be encountered in the plastic range. The outputs from this unit and the digital torque meter can be used to plot results automatically on an xy plotter or to provide outputs for a data logging system.

A wide range of standard (solid) test specimens are available in different diameters and materials. Special strain gauged solid and hollow section specimens of various shapes can be supplied to customers' requirements for stress analysis under loads in the elastic range. Additional ancillary equipment can also be supplied for heat treatment of specimens and to enable torsion tests at elevated temperatures. The specification of such equipment can be tailored to suit individual customer requirements.

APPENDIX: MACHINE SPECIFICATION

Max torque:	199.9 Nm (1999 lbfin)
Main gearbox ratio:	1200:1 Rated torque 240 Nm (2100 lbin)
Drive motor:	187 W, 3000 rev/min with 4:1 reduction gearbox
Maximum strain rate:	225°/min
Digital counter:	5 digit resettable type (1 revolution = 0.3)
Pendulum angle:	–30 to +30 in 0.5 divisions
Pendulum bob weights:	2 off 25 kg
Drive shaft ends:	19 mm (0.75″) square
Drive sockets:	3/16″ Whitworth; 12, 17 and 24mm A/F supplied as standard (two off each)
Speed (strain) control:	Thyristor drive with tachometer feedback and digital readout of strain rate
Torque meter:	TecQuipment E101 digital measuring system with three digit display and Nm/lbfin changeover switch

Optional Ancillaries

1. SM21a Mechanical Torsiometer: for use with specimens having ends up to 24mm A/F hex.
2. SM21b Digital Torsiometer: electronic version of SM21a complete with digital meter suitable for continuous reading up to 5 revolutions.
3. Additional ancillary equipment for heat treatment of specimens and testing at elevated temperatures can be supplied to customers' requirements.

Micrometers, rulers, etc are **not** supplied.

Services Required

Single-phase earthed AC mains electrical supply 220/240V or 110/120V 50/60Hz. Voltage to be specified on all orders.

Space Required

For satisfactory use of this equipment a floor area of approximately 1.5 m × 1.5 m (5 ft × 5 ft) is recommended.

Dimensions and Weights

Nett: 1100 mm (43″) × 1300 mm (41″) × 1550 mm (61″);
150 kg (330 lb)
Gross: (approximate; as packed for export) 1.2 m^3 (42 ft^3);
250 kg (550 lb).