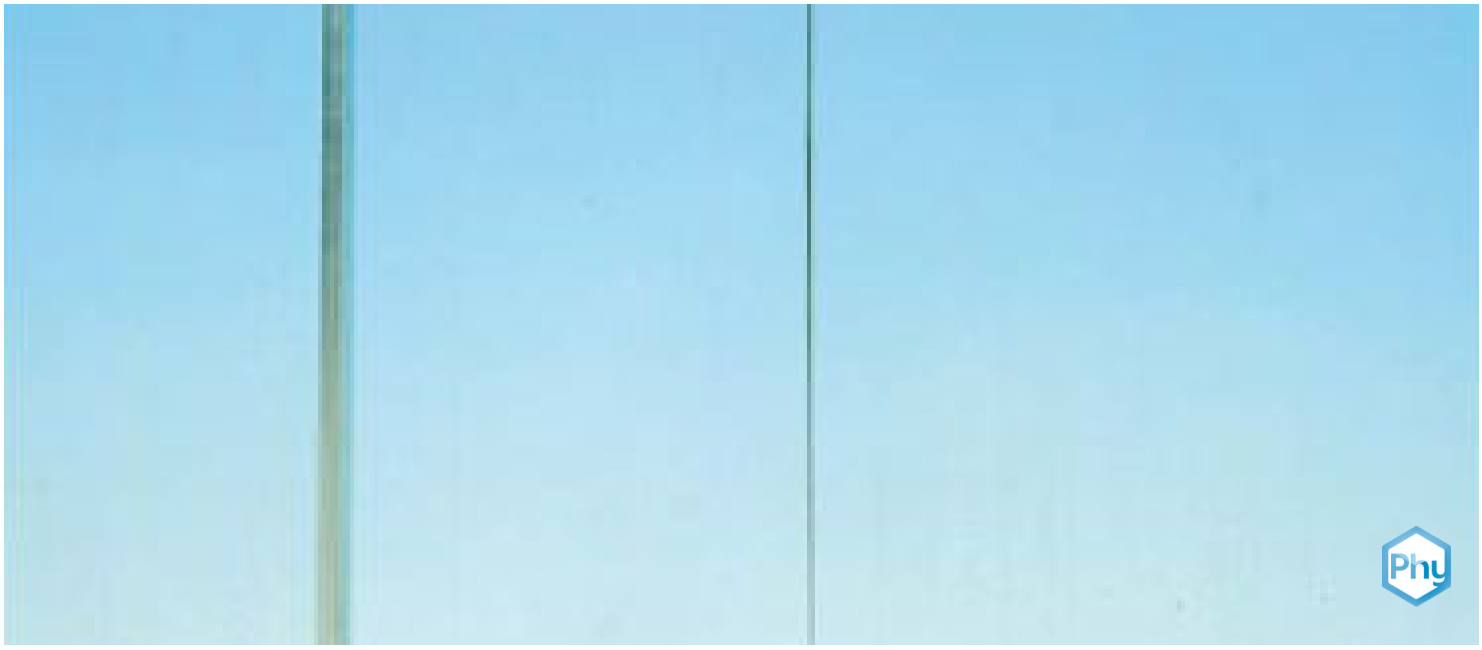
Mechanical hysteresis



Physics > Mechanics > Fabric & material properties

Applied Science > Engineering > Applied Mechanics > Statics

Applied Science > Engineering > Materials Science > Mechanical Properties

Applied Science > Medicine > Biomechanics

Difficulty level	Group size	Preparation time	Execution time
easy	2	45+ minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/60104b5e8b903a00038a52a9

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General information

Application

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Fig.1: Experimental set-up

Torge is used in many mechanical fields, such as the transportation industry, etc. As such the understanding of the dependancies of torge to rotational frequency, etc. is very important.

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Other information (1/2)

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Prior knowledge

The prior knowledge for this experiment is found in the Theory section.

Main principle

The relationship between torque and angle of rotation is determined when metal bars are twisted. The hysteresis curve is recorded.

Other information (2/2)

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Learning objective

The goal of this experiment is to determine the relationship between torque and angle of rotation.

Tasks

1. Record the hysteresis curve of steel and copper rods.
2. Record the stress-relaxation curve with various relaxation times of different materials.

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Theory (1/2)

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If forces act on a solid body, it is deformed, e.g. with shear stresses, shear deformations will occur. The Hooke's law range is characterised by the linear relationship between stress and torsion. With solid bodies, there is generally a range adjacent to the Hooke's law range, in which there is no longer a linear relationship between stress and deformation, but in which the deformation is still reversible to some extent. The limit of this range is called the yield point. The deformation becomes plastic if the stresses become greater than the yield point. The deformation of the bar is then not completely reversed, even in the stress-free condition. Since the phenomena of plasticity result from displacements of atoms, temperature and time have an influence. According to Hooke's law, the relationship between the stress U and the deformation H is given by

$\tau = \sigma \cdot \gamma$

where T is the shear modulus.

Theory (2/2)

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In the plastic range, a simple relaxation theorem approximately applies.

$\frac{d_\tau}{d_t} = \sigma \frac{d_\gamma}{d_t} - \frac{\tau}{\lambda}$

M being the relaxation time. Thus, if the deformation is kept constant, the stress U after time t is

$\tau = \tau_0 e^{-t/\lambda}$

if U_0 was the initial stress.

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Equipment

Position	Material	Item No.	Quantity
1	Torsion apparatus	02421-00	1
2	Torsion rod, steel, l = 500 mm, d = 2 mm	02421-01	1
3	Torsion rod, Al, l = 500 mm, d = 2 mm	02421-02	1
4	Torsion rod, Al, l = 400 mm, d = 2 mm	02421-03	1
5	Torsion rod, Al, l = 300 mm, d = 2 mm	02421-04	1
6	Torsion rod, Al, l = 500 mm, d = 3 mm	02421-05	1
7	Torsion rod, Al, l = 500 mm, d = 4 mm	02421-06	1
8	Torsion rod, brass, l = 500 mm, d = 2 mm	02421-07	1
9	Torsion rod, Cu, l = 500 mm, d = 2 mm	02421-08	1
10	Spring balance,transparent, 1 N	03065-02	1
11	Spring balance,transparent, 2 N	03065-03	1
12	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1
13	Support base DEMO	02007-55	1
14	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
15	Support rod, stainless steel, 750 mm	02033-00	1
16	Right angle boss-head clamp	37697-00	1
17	Right angle clamp expert	02054-00	2

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Setup and Procedure

Setup and Procedure

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The experimental set-up is arranged as shown in Fig. 1. The spring balance acts at right angles to the lever. The measured force or moment and the angle which establishes itselfs are plotted. Except with steel, the elastic limit is very quickly reached, so that the measurements should be carried out either continuously or interrupted by uniform relaxation intervals. For reproducible curves, the torsion bars must not have any kinks or other deformations. In contrast to magnetic hysteresis, in which the crystal structure of the magnetic material is generally unchanged, in the case of mechanical hysteresis a direct relationship is to be found between deformation and moment as a function of time or temperature.

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Evaluation

Results (1/3)

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If metals are loaded into the plastic range and the material is allowed to relax, it subsequently finds itself again in the Hooke's law range with a new equilibrium position.

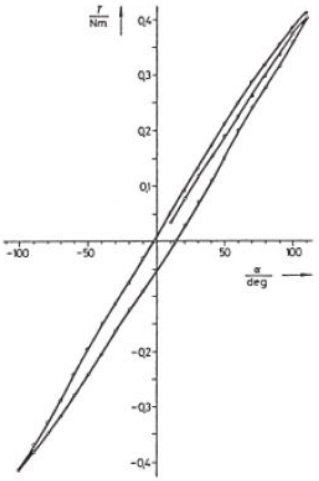

Fig. 2: Mechanical hysteresis curve for the torsion of a steel bar of 2 mm diameter and 0.5 m long. The branch which starts from the origin is called the virgin curve.

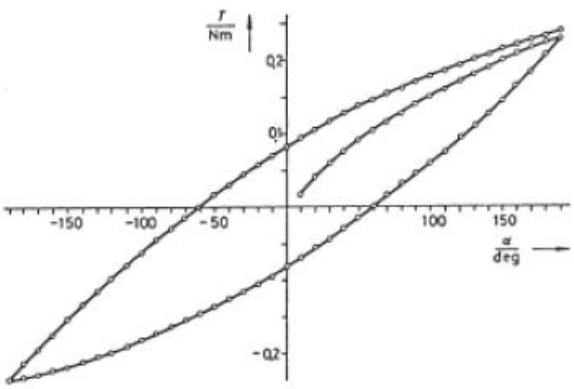

Fig. 3: Mechanical hysteresis curve for the torsion of a copper rod of 2 mm diameter and 0.5 m long.

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Results (2/3)

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Since, in the torsion of bars, the deformation of the outer layers of the bar is greater than that of the inner layers, from certain angle Bcr onwards the outermost layer will reach the yield point. With deformations beyond Bcr, a thicker outer layer will reach the plastic range, while the inner layers are still in the elastic range.

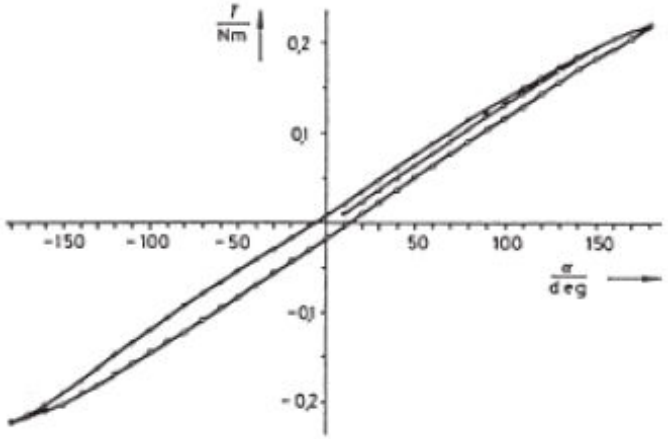

Fig. 4: Mechanical hysteresis curve for the torsion of an aluminium rod of 2 mm diameter and 0.5 m long.

Results (3/3)

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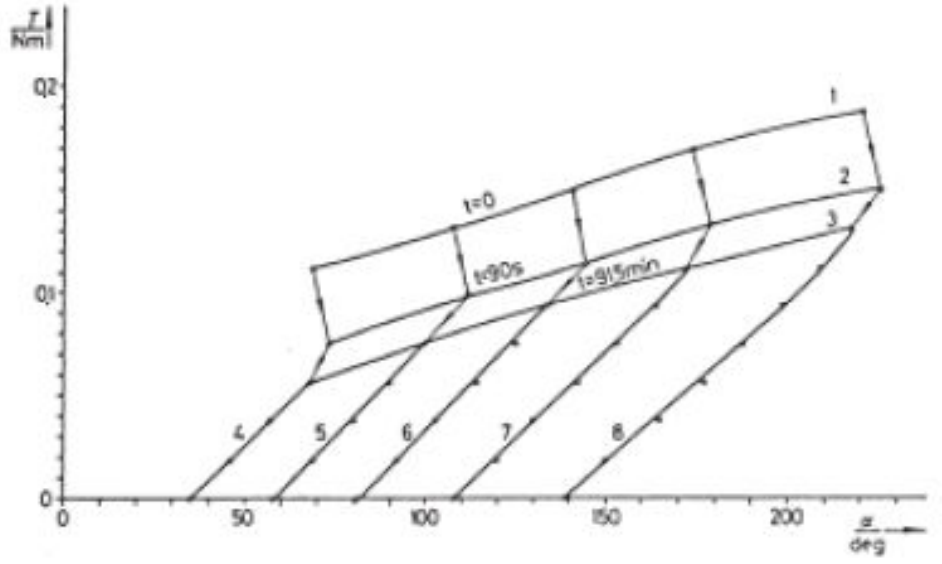

Fig. 5: Relaxation in the torsion of a copper rod of 2 mm diameter and 0.5 m long. The reading times between curves 1 and 2 lie about 90 seconds apart, those be-tween 2 and 3 about 90 minutes. After this recovery process, the bars were unloaded and the curves 4 to 8 were obtained.

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