GLASGOW CALEDONIAN UNIVERSITY

SCHOOL OF ENGINEERING & BUILT ENVIRONMENT

ENGINEERING DESIGN & ANALYSIS 2 (M2H721926) – Torsion Theory

Tutorial

1. A standard torsion specimen has a uniform diameter of 6 mm. Under test, the values of torque against angle of twist obtained over a length of 75 mm were as follows:

Torque T (m	0	1.73	3.53	5.27	7.11
Angle of Twist θ (°)	0	1	2	3	4

(a) Plot a graph of torque vs. angle of twist and hence determine the modulus of rigidity of the specimen material.

(b) Determine the maximum shear stress in the specimen material when the torque is 2 Nm.

2. An aluminium alloy bar was tested in tension and torsion. The tension test on one portion of 20 mm diameter showed an extension of 0.34 mm with a load of 40 kN measured on a gauge length of 200 mm. The torsion test on a second portion of 14 mm diameter showed an angle of twist of 0.125 rad on a gauge length of 250 mm when the torque was 35 Nm. Find E and G for the material. **(74.7 GN/m^2; 18.6 GN/m^2)**

3. For phosphor-bronze the relation between the moduli of elasticity and rigidity may be taken as E = 2.6G. A tensile specimen of this material, of diameter 20 mm, extended by 0.075 mm on a gauge length of 50 mm when the load applied was 50 kN. What would be the angle of twist per metre length on a shaft of the same material (20 mm diameter) due to torque of 15 Nm? **(0.0234 rad or 1.34°)**

4. A hollow shaft of 50 mm internal diameter and 12 mm thick, twists through an angle of 1° in a length of 2 m when subjected to a torque of 1 kNm. Calculate the modulus of rigidity for the material. **(49.2 GN/m^2)**

5. The propeller shaft of an aircraft engine is steel tubing of 75 mm external and 60 mm internal diameter. The shaft is to transmit 150 kW at 1650 rev/min. The failing stress in shear for this shaft is 140 MN/m^2. What is the factor of safety? **(7.87)**

6. A hollow shaft is to transmit 2 MW at 40 rev/s. The external diameter is to be 1.3 times the internal diameter. The maximum torque maybe taken as 20 per cent greater than the average and the maximum shear stress is limited to 150 MN/m^2. Find the external diameter of the shaft. **(79.6 mm)**

7. A brass shaft of 6 mm diameter is tested in torsion. At the limit of proportionality the torque is 0.6 Nm and the angle of twist 1.13° on a gauge length of 250 mm. Calculate G for the brass.

(59.8 GN/m^2)

8. Calculate the maximum shear stress in a 6-mm diameter bolt when tightened by a force of 50 N at the end of a 150 mm spanner. What would be the corresponding stress in a 10-mm diameter bolt? **(177 MN/m^2; 38.1 MN/m^2)**

9. A gear wheel is keyed to a 50 mm diameter shaft by a square section key of width w mm and length 50 mm. The load on the wheel tooth amounts to 5 kN at a radius of 150 mm. If the shear stress in the key is to be twice the maximum shear stress in the shaft calculate the width w. **(9.85 mm)**

10. A solid circular shaft is connected to the drive shaft of an electric motor by a solid flanged coupling, the drive being taken through eight bolts, of 12 mm diameter, on a pitch circle diameter of 225 mm. The bolts carry the whole driving torque and are loaded in shear only. Calculate the shaft diameter if the maximum shear stress in the shaft is to be equal to the shear stress in the bolts. **(80.3 mm)**

11. A length of hollow steel shaft is used to drill a hole 3 km deep in rock. The power exerted is 180 kW and the speed of rotation of the drill is 60 rev/min. If the inner and outer diameters of the shaft are 150 mm and 175 mm respectively, calculate: **(a)** the maximum shear stress in the shaft; **(b)** the twist of one end relative to the other, in revolutions. $G = 84$ kN/mm^2. **(59.3 MN/m^2; 3.84 rev)**

12. A length of hollow steel shaft transmits 900 kW at 165 rev/min. The maximum shear stress is not to exceed 56 MN/m^2 and the inside diameter is to be 0.6 times the outside diameter. Determine: **(a)** the shaft diameters' **(b)** the shear stress at the *inner* surface of the shaft. **(106 mm; 176 mm; 33.7 MN/m^2)**

13. A turbine shaft is to transmit power at 4 rev/s. If the shaft is 1 m external diameter and 25 mm thick and the maximum shear stress permitted is 70MN/m^2 find the power transmitted. What is the diameter of the equivalent solid shaft and what is the percentage saving in weight of the hollow shaft over the solid? **(64 MW; 571 mm; 70.1%)**

14. Compare the torsional stiffness of a 25 mm diameter solid shaft with that of a hollow shaft of 40 mm diameter externally. Both shafts are to have the same length, same modulus of rigidity, and same mass. What is the internal diameter of the hollow shaft? **(1 : 4 12; 31.2 mm)**

15. Calculate the power which will be transmitted at 220 rev/min by a hollow shaft of 150 mm inside diameter and 50 mm thick, if the maximum shear stress is 70 MN/m^2. Find the percentage by which the shaft will be stronger if made solid instead of hollow and the external diameter is the same. **(4.32 MW; 14.88%)**

16. A hollow shaft driving a ship's screw is to carry a torque of 13 kNm and is to be of 150 mm diameter externally. Calculate the inside diameter if the maximum shear stress is not to exceed 40 MN/m^2. Calculate the angle of twist in degrees on a 5.5 m length and the *minimum* shear stress. G =84 GN/m^2 **(127 min; 2.02°; 339 MN/m^2)**

17. A hollow shaft of alloy steel is 12 mm outside diameter and 10 mm thick. It is to be coupled to a solid shaft of the same material, 100 mm diameter. If the length of the hollow shaft is 960 mm find the length of solid shaft to limit the *total* angle of twist to 2.7° under a torque of 20 kNm. **(958 mm)**