School of Engineering & Built Environment

MEng/BEng(Hons) in:

Mechanical-Electronic Systems Engineering
Mechanical & Power Plant Systems
Electrical Power Engineering
Computer-Aided Mechanical Engineering

Module: Engineering Design & Analysis 2
(Module No. M2H721926)

Theory of Torsion: A Summary

Eur Ing **Professor M. Macdonald** BSc MSc PhD CEng FIMechE FIES FHEA
Department Engineering
Room M203A
T: 0141 331 3540
E: mmd3@gcu.ac.uk

GLASGOW CALEDONIAN UNIVERSITY

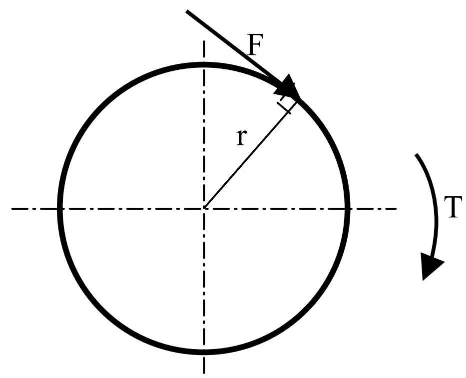
SCHOOL OF ENGINEERING & BUILT ENVIRONMENT

ENGINEERING DESIGN & ANALYSIS 2 (M2H721926) – Torsion Theory

Torque

Torque is defined as the turning or twisting effect of a force about a point around which it rotates. Referring to the figure, the torque T produced by the tangentially acting force F is the product of the force and the radius r at the point of force application, i.e.

$$T = F.r \quad \text{(Nm)}$$



Power and Torque

If a shaft transmits power at rotational speed of *N* (rev/min), the torque *T* (Nm) carried by the shaft is given by:

Power = work done by torque per second

= torque x angular speed

$$\therefore \quad P = \frac{2\pi N T}{60} \text{ (W)}$$

Alternatively, since $\omega = \frac{2\pi N}{60}$, then the transmitted power can be calculated from $P = T\omega$

Theory of Torsion

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{r}$$

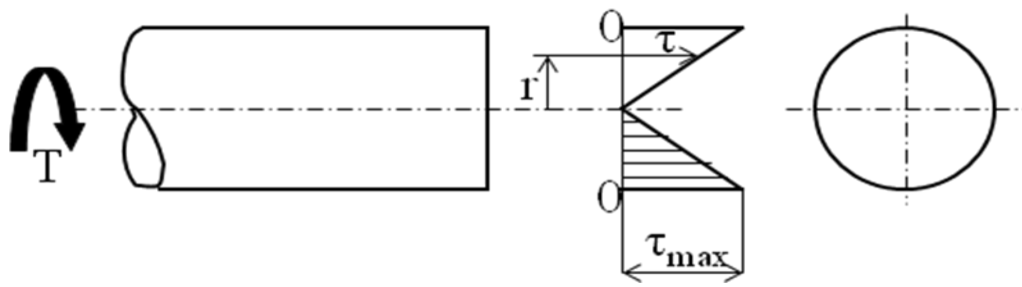
Other useful arrangements of this formula are as follows:

$$\tau = \frac{T\,r}{J}, \qquad \theta = \frac{T\,L}{G\,J} \qquad \text{and} \qquad \text{stiffness} = \frac{T}{\theta} = \frac{GJ_p}{L}$$

Note: $J = \dfrac{\pi d^4}{32}$ for a solid shaft, $J = \dfrac{\pi(d_2^{\,4} - d_1^{\,4})}{32}$ for a hollow shaft and $J = 2\pi r^3 t$ for a thin-walled shaft or tube.

Some important points should be noted –

1. The angle of twist θ varies *directly* with length *l*.
2. Since $\tau = Tr/J$, for a given torque *T* the shear stress τ is proportional to the radius *r*. Thus the maximum shear stress occurs at the outside surface where $r = d/2$, and the shear stress at the centre of the shaft is zero. The figure shows the variation of τ across a diameter.



Variation of τ with Radius r.