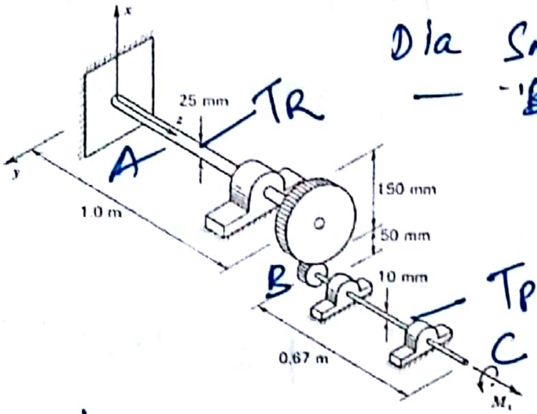
Name: [redacted] Roll no. [redacted]

Department of Aerospace Engineering, Indian Institute of Technology, Madras.

AS 2010: Basic strength of materials. Quiz 9

1. For the assembly shown, determine the maximum torque M_t that may be applied before the shear stress of 275 MPa is reached in either shaft. The shafts are made of steel, with $G = 70$ GPa.



Dia Smaller gear → dp
— " Bigger — → dR

Torque ratio

$T = F \times (d/2)$

$T_P = F \times (d_P/2)$;

$T_R = F \times (d_R/2)$;

$\frac{T_P}{T_R} = \left(\frac{d_P}{d_R}\right) = \frac{50}{150} = 1/3$; $T_P \times 3 = T_R$

where F is, force exerted by small gear. ~~which we had~~

Now, calculating max shaft Torque, under the given max shear stress, 275×10^6 ~~M~~Pa.

$\frac{\tau}{r} = \frac{T}{J}$;

J – Polar inertia
r – radius of shaft
T – Torque.
τ – Shear stress.

$$\tau = \frac{16T}{\pi d^3}$$.

case-I So, for Smaller shaft, BC,

$$\tau_P = \frac{16 \times T_P}{\pi (0.01)^3}$$;

$$T_P = 53.99 \text{ N-M}$$ — ①

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Case-II Bigger Shaft, AB

$$\tau_R = \frac{16 T_R}{\pi d_R^3} = \frac{16 \times 3 \times T_P}{\pi (0.025)^3}$$

$$\boxed{T_P = 281.23 \text{ N.m}} \quad \text{— (2)}$$

Take min $(T_P, T_R) = 54$ N-m.

if we take 281.23; $d = ?$

$$T = \frac{\pi}{16} \tau d^3 ; \quad 281.23 = \frac{\pi}{16} \times 275 \times 10^6 \times d^3$$

$$\boxed{d = 17.33 \text{ mm}}$$

Shaft BC, should have to greater than ($d = 17.33$)

So, maximum Torque can be applied is 54 N-m

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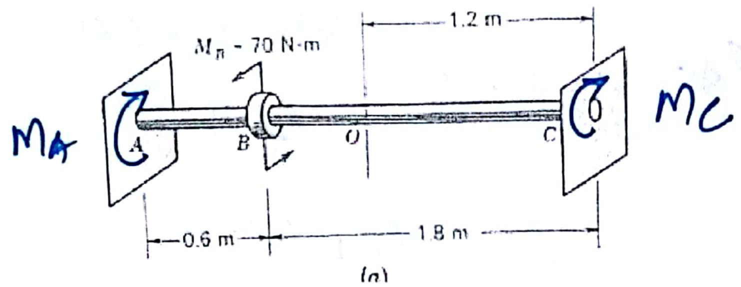
2. A couple of 70 N-m is applied to a 25 mm diameter aluminium alloy ($G = 27$ GPa) shaft as shown. The ends A and C of the shaft are built in and prevented from rotating. What is the angle through which the central cross-section of the shaft at O rotates?



Take moment equilibrium.

$$\boxed{M_A + M_C = 70} \quad \text{— (I)}$$

Geometric compatibility; rotation @ point B will be equal in magnitude & direction,

$$\boxed{\theta_{AB} = \theta_{BC}}.$$

Torsion equation ; $\frac{T}{J} = \frac{\tau}{r} = \frac{C\theta}{L}$.

$$\theta = \left(\frac{T.L}{J.C}\right);$$

$$\frac{M_A . l_{AB}}{J.C} = \frac{M_C \times l_{BC}}{J.C}.$$

$$\boxed{\frac{M_A}{M_C} = \frac{1.8}{0.6} = 3} \quad \text{— (II)}$$

from (I) & (II)

$M_A + M_A/3 = 70$; $M_A = \frac{3}{4} \times 70$

& $M_C = \frac{70}{4}$

So, rotation @ point O, is

θ_A. $\theta_{OC} = \frac{M_C \times l_{CO}}{G \cdot J}$

$= \frac{70/4 \times 1.2}{27 \times 10^9 \times \frac{\pi}{32} \times (0.025)^4}$

$\theta_{OC} = 0.02028$ radian.

$\theta_{OC} = 1.16°$.