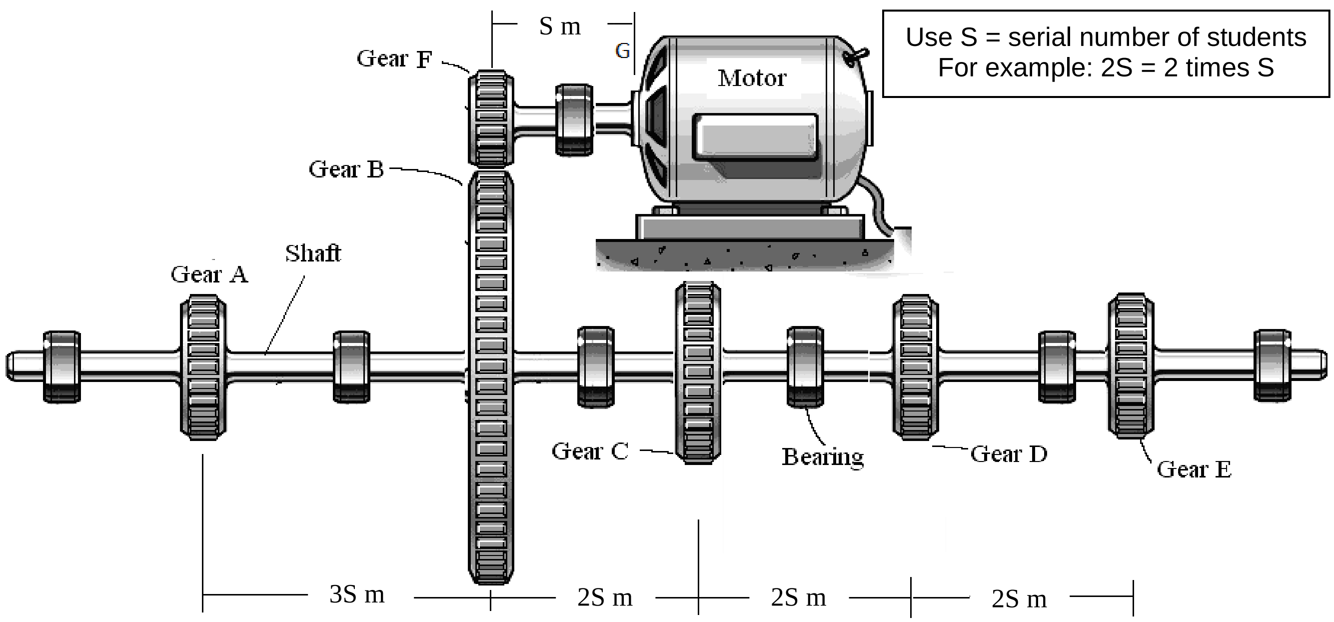
RYERSON UNIVERSITY
Department of Civil Engineering
CVL420: Strength of Materials II
MID-TERM EXAMINATION (Summer 2020)

Date: July 16, 2020

Answer all TWO Questions S: Serial number of students Time: 2 hour

Question 1 (25 Marks)

The motor shown in Fig. 1 supplies power P (= 700S kW) at 120 rpm through solid steel motor shaft GF (having a diameter of 200S mm) to the gear F. Gears A, C, D and E supply powers to four machines. The torques delivered by gear A, gear C and gear E to the machines are 7.18%, 3.59% and 3.59%, respectively of the torque delivered to gear B from gear F. Shaft ABCDE is also made of steel (having modulus of rigidity G = 75 GPa). The shaft part AB is solid having a diameter of 200S mm while shaft part BCDE is hollow (with an outside diameter of 200S mm and a thickness of 30S mm). The diameters of gears F and B are 300S mm and 1500S mm, respectively.



Use S = serial number of students
For example: 2S = 2 times S

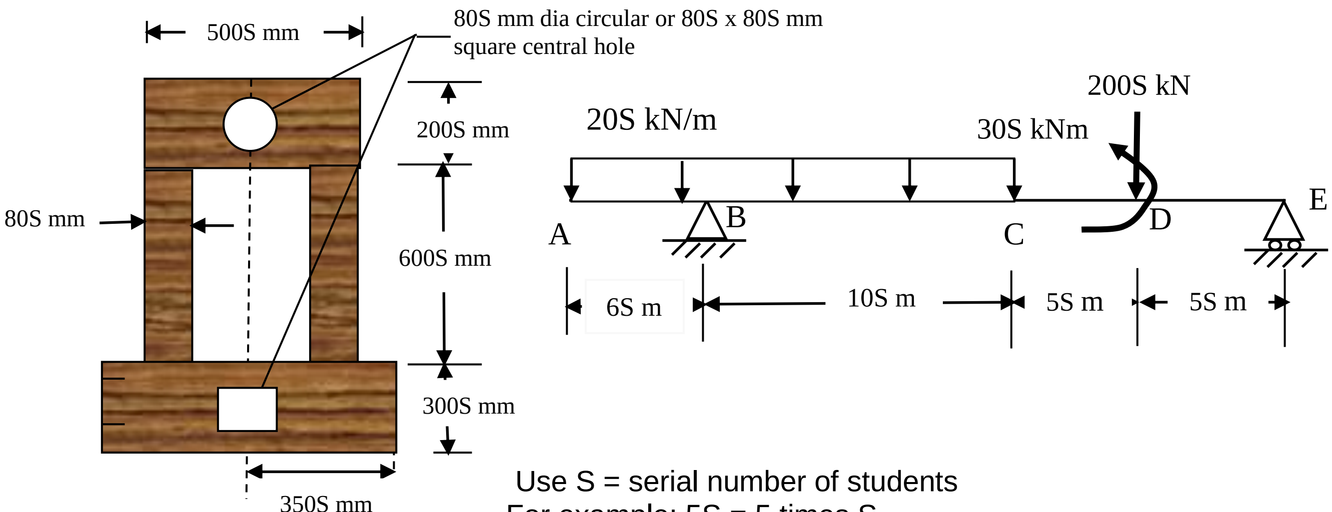
Fig. 1

- Determine the friction force between gear F and gear B. Draw the torque diagram of the whole shaft system. Determine the maximum torsional shearing stresses in shaft GF and ABCDE. Also determine the rotation of gear E relative to G and the rotation of gear E relative to A. What would be the length of the shaft AB if the rotation of gear A relative to gear E is limited to 0.015 radian? If the gear F is jammed, what will be stress in shaft AB? **(0.5+1.5+4.5 + 2.5 + 2 +1.0 = 12 Marks)**
- If a semi-circular groove of radius (= 10% of the shaft diameter) is introduced in the shaft FG after removing a thickness (= 10% of the shaft diameter) from the surface. Find the % torsional stress increase due to introduction of groove in the shaft. **(3 Marks)**
- If the circular shaft ABCDE is transformed into solid rectangular shaft (Depth = 2.0 times of width) having the same cross-sectional area, calculate the rotation of gear A relative to gear E and also the maximum shear stress in the shaft. If the shear strength of steel is 200 MPa, find the factor of safety. **(4 +1 = 5 Marks)**
- Determine the torsional stress in shaft DE, if it is transformed into thin walled hollow circular section with 2S mm thick wall (having the same outer diameter of 200S mm). If the shear strength of steel is 200 MPa, will it be safe? Find the rotation of Gear D with respect to E. Calculate also the shear flow in the thin-walled shaft DE. **(3 + 1 +1 = 5 Marks)**

Question 2 (25 Marks)

A beam made of four pieces of timber is loaded and supported as shown in Fig. 2. The support B is a pin and E is a roller.

- Write an equation for determining the moment in the part BC of the beam using point B as origin. Draw the shear force and the bending moment diagrams for the beam. **(4 Marks)**
- Find location of neutral axis (NA) of beam cross-section & moment of area about NA. (**4 Marks)**
- Find the maximum flexural stresses and draw the variation of flexural stress across the cross-section at the point of maximum moment in the beam. Determine the tension and compression forces derived from flexural stresses and also the corresponding resisting moment. Comment on the relationship between tension and compression forces as well as applied maximum moment and resisting moment stating the accuracy, assumptions and limitations of the flexural stress formula. **(5 + 4.5 + 2.5 = 12) Marks)**
- Determine the dimensions of a rectangular beam (use depth = 3 times the width) for part AB, if the maximum bending stress capacity of the beam material is 12 MPa using a factor of safety of 2.0. **(3 Marks)**
- Show the tension-compression state of stress along the length of the beam and explain how we this information is used in reinforced concrete beam design. **(2 Marks)**



Use S = serial number of students
For example: 5S = 5 times S

Fig. 2

FORMULA SHEET

Torsional Stress & Angle of Twist

- $\theta = \frac{TL}{GJ}$
- $\tau = \frac{Tc}{J}$
- $\theta = \sum_{i=1}^{n} \frac{T_i L_i}{G_i J_i}$
- $J = \frac{\pi c^4}{2}$
- $G = \frac{\tau}{\gamma}$
- $T = \frac{\tau . J}{c}$

Stress Concentration in Circular Shafts K = Kt

$$\tau_{\max} = K\frac{Tc}{J}$$

h/r	r/d	Kt	D/d	r/d	Kt
1	0	1.7	1.0	0	3.0
	0.2	1.42		0.05	1.4
	0.4	1.3		0.10	1.2
	0.6	1.2		0.15	1.15
	0.8	1.1		0.20	1.10
2	0	3.0	2.0	0	3.0
	0.2	2.2		0.05	2.1
	0.4	1.6		0.10	1.7
	0.6	1.4		0.15	1.5
	0.8	1.3		0.20	1.4

Torsion of Noncircular Sections

- $\tau_{\max} = \frac{T}{\alpha a^2 b}$
- $\theta = \frac{TL}{\beta a^3 bG}$

b/a	α	β
1.0	0.208	0.1406
1.2	0.219	0.1661
1.5	0.231	0.1958
2.0	0.246	0.229
2.5	0.258	0.249
3.0	0.267	0.263
4.0	0.282	0.281
5.0	0.291	0.291
10.0	0.312	0.312
∞	0.333	0.333

Torsion of Thin-Walled Tubes – Shear Flow

$$\tau_{\text{avg}} = \frac{T}{2tA_m}$$

$$\phi = \frac{TL}{4A_m^2 G}\oint\frac{ds}{t}$$

Power Transmission

$Power = \frac{dW_k}{dt} = T\frac{d\phi}{dt} = T\omega$

$\omega = \frac{2\pi N}{60}$ *Where N is in* (rpm),

Power in (Watt); 1 Watt = 1Nm.s

Elastic Flexure Formula

- $\sigma = \frac{My}{I}$
- $\sigma_{\max} = \frac{Mc}{I} = \frac{M}{S}$
- $I = \frac{bh^3}{12}$; $I = \frac{\pi R^4}{4}$

$I_{x'} = I_c + d_x^2 A$

1 MPa = 1 N/mm^2

1 GPa = 1000 MPa