Machine Design - 1

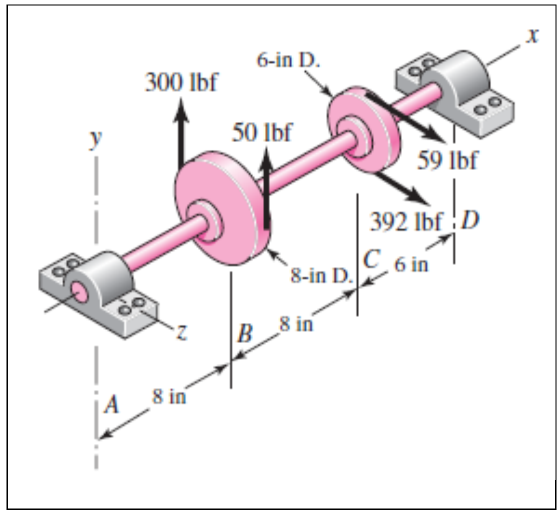
The figure shows a shaft mounted in bearings at A and D and having pulleys at B and C. The forces shown acting on the pulley surfaces represent the belt tensions. The shaft is to be made of AISI 1035 CD steel.

(a) **(15 points)** Draw shear and bending moment diagrams of the loading conditions for both the XY and XZ planes.

(b) **(20 points)** What is the maximum net bending moment, and where does it occur (point B or point C)?

(c) **(30 points)** Assuming a shaft diameter of 1 inch, what is the bending stress at that point? What is the shear stress at that point?

(d) **(35 points)** Using maximum shear stress (MSS) failure theory, *determine the minimum shaft diameter* to avoid yielding with a design factor of 2.



Potentially useful equations:

Moment of Inertias

Shape	*Ix*	*Iy*	*J*
Rectangle	$bh^3/12$	$bh^3/12$	$\frac{bh}{12}(b^2+h^2)$
Triangle	$bh^3/36$	$bh^3/36$	$\frac{bh}{12}\left(\frac{b^2+h^2}{18}\right)$
Circle	$\pi d^4/64$	$\pi d^4/64$	$\pi d^4/32$

Stresses

Normal Stresses			*Shear Stresses*	
Axial	Tensile	$\sigma = \frac{F}{A}$	Torsional	$\tau = \frac{Tr}{J}$
	Compression	$\sigma = \frac{F}{A}$	Transverse (Flexural)	$\tau = \frac{VQ}{Ib}$
Bending		$\sigma = \frac{Mc}{I}$		Q=Ay

Principle stresses	$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} +/- \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + {\tau_{xy}}^2}$	$\tan 2\phi = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$

Problems

Max. and min. shear stresses	$\tau_{1,2} = +/- \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$	
Von-Mises stresses	$\sigma' = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$	

Deterministic ASTM Minimum Tensile and Yield Strengths for Some Hot-Rolled (HR) and Cold-Drawn (CD) Steels [The strengths listed are estimated ASTM minimum values in the size range 18 to 32 mm ($\frac{3}{4}$ to $1\frac{1}{4}$ in). These strengths are suitable for use with the design factor defined in Sec. 1–10, provided the materials conform to ASTM A6 or A568 requirements or are required in the purchase specifications. Remember that a numbering system is not a specification.] *Source:* 1986 SAE Handbook, p. 2.15.

1 UNS No.	2 SAE and/or AISI No.	3 Processing	4 Tensile Strength, MPa (kpsi)	5 Yield Strength, MPa (kpsi)	6 Elongation in 2 in, %	7 Reduction in Area, %	8 Brinell Hardness
G10060	1006	HR	300 (43)	170 (24)	30	55	86
		CD	330 (48)	280 (41)	20	45	95
G10100	1010	HR	320 (47)	180 (26)	28	50	95
		CD	370 (53)	300 (44)	20	40	105
G10150	1015	HR	340 (50)	190 (27.5)	28	50	101
		CD	390 (56)	320 (47)	18	40	111
G10180	1018	HR	400 (58)	220 (32)	25	50	116
		CD	440 (64)	370 (54)	15	40	126
G10200	1020	HR	380 (55)	210 (30)	25	50	111
		CD	470 (68)	390 (57)	15	40	131
G10300	1030	HR	470 (68)	260 (37.5)	20	42	137
		CD	520 (76)	440 (64)	12	35	149
G10350	1035	HR	500 (72)	270 (39.5)	18	40	143
		CD	550 (80)	460 (67)	12	35	163
G10400	1040	HR	520 (76)	290 (42)	18	40	149
		CD	590 (85)	490 (71)	12	35	170
G10450	1045	HR	570 (82)	310 (45)	16	40	163
		CD	630 (91)	530 (77)	12	35	179
G10500	1050	HR	620 (90)	340 (49.5)	15	35	179
		CD	690 (100)	580 (84)	10	30	197
G10600	1060	HR	680 (98)	370 (54)	12	30	201
G10800	1080	HR	770 (112)	420 (61.5)	10	25	229
G10950	1095	HR	830 (120)	460 (66)	10	25	248