Product Development 1

Introduction to
Mechanical Engineering Design

Spring 2023

Failure Theories

Sample problem 1

Suppose that the shaft in Sample Problem 2 from PPT-06 is redesigned by halving the length dimensions. Using the same material and design factor as in that problem, find the new shaft diameter.

Sample problem 2

A 1020 CD steel shaft is to transmit 20 hp while rotating at 1750 rpm. Determine the minimum diameter for the shaft to provide a minimum factor of safety of 3 based on the maximum-shear-stress theory.

Sample problem 3

A 20-mm-diameter steel shaft, made of AISI 1035 HR steel, transmits power while rotating at 400 rev/min. Assume any bending moments in the shaft to be relatively small compared to the torque. Determine how much power, in units of kW, the shaft can transmit with a static factor of safety of 1.5 based on

(a) the maximum-shear-stress theory.

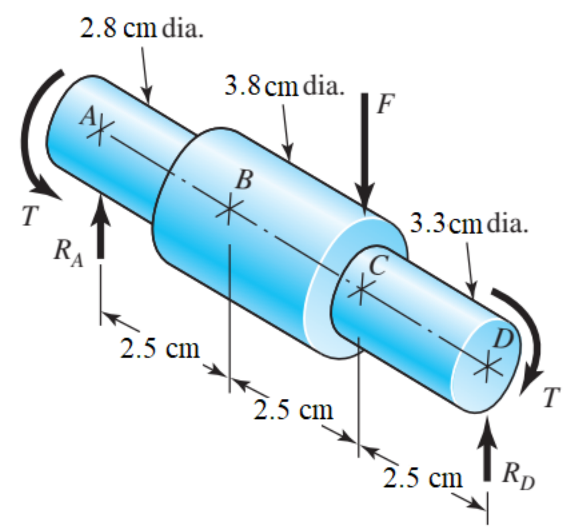
(b) distortion-energy theory.

Sample problem 4

A round shaft supports a transverse load of F = 66.7 kN and carries a torque of T = 790 N·m, as shown in the figure. The shaft does not rotate. The shaft is machined from AISI 4140 steel, quenched and tempered at 204°C. Document the location of the critical stress element and how you determined that element to be critical. Do not assume transverse shear stress is negligible without proving it. Then,

(a) determine the minimum factor of safety based on yielding according to the maximum shear-stress theory.

(b) determine the minimum factor of safety based on yielding according to the distortion-energy theory.

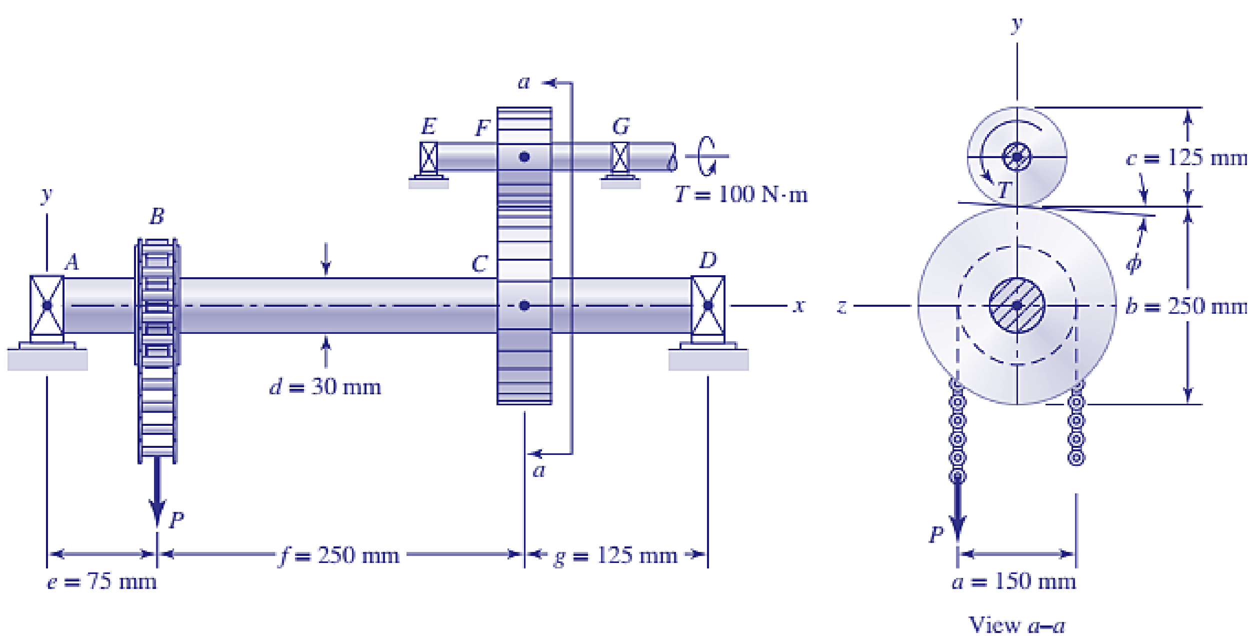


Sample problem 5

(I) A torque T = 100 N · m is applied to the shaft EFG, which is running at constant speed and contains gear F. Gear F transmits torque to shaft ABCD through gear C, which drives the chain sprocket at B, transmitting a force P as shown. Sprocket B, gear C, and gear F have pitch diameters of a = 150, b = 250, and c = 125 mm, respectively. The contact force between the gears is transmitted through the pressure angle $\phi = 20°$. Assuming no frictional losses and considering the bearings at A, D, E, and G to be simple supports, locate the point on shaft ABCD that contains the maximum tensile bending and maximum torsional shear stresses. Combine these stresses and determine the maximum principal normal and shear stresses in the shaft.

Sample problem 5, Cont.

(II) Build upon the results of the problem above to determine the minimum factor of safety for yielding. Use both the maximum-shear-stress theory and the distortion-energy theory, and compare the results. The material is 1018 CD steel.



Sample problem 6

A cold-drawn AISI 1015 steel tube is 300 mm OD by 200 mm ID and is to be subjected to an external pressure caused by a shrink fit. Using the distortion-energy theory, determine the maximum pressure that would cause the material of the tube to yield.

Sample problem 7

(I) A pin in a knuckle joint carrying a tensile load F deflects somewhat on account of this loading, making the distribution of reaction and load as shown in part (b) of the figure. A common simplification is to assume uniform load distributions, as shown in part (c). To further simplify, designers may consider replacing the distributed loads with point loads, such as in the two models shown in parts d and e. If a = 12.7 mm, b = 19.05 mm, d = 12.7 mm, and F = 4.45 kN, estimate the maximum bending stress and the maximum shear stress due to V for the three simplified models. Compare the three models from a designer's perspective in terms of accuracy, safety, and modeling time.

Sample problem 7, Cont.

(II) Build upon the results of this problem (Part I) to determine the factor of safety for yielding based on the distortion-energy theory for each of the simplified models in parts c, d, and e of the figure. The pin is machined from AISI 1018 hot-rolled steel. Compare the three models from a designer's perspective in terms of accuracy, safety, and modeling time.