Spring 2025 Exam 2

Department of Mechanical Engineering Technology

Time: 75 minutes

This exam consists of 5 pages (including this page).

Do NOT open this exam until you are instructed to do so.

When you are finished, turn in all your materials to the instructor:

- This exam
- The equation sheet
- Your crib sheet

Section 1: Multiple Choice (4 points each, 40 points total)

1. In a fatigue failure analysis, the S-N curve represents the relationship between:
    - Stress and strain under static loading
    - Alternating stress and number of cycles to failure
    - Stress intensity factor and crack growth rate
    - Temperature and time under creep conditions
2. In a beam subject to pure bending, which type of stress is experienced along the length of the beam?
    - Shear stress
    - Normal stress
    - Torsional stress
    - Hoop stress
3. The endurance limit of a material is defined as:
    - The maximum stress it can withstand indefinitely without failure
    - The maximum strain it can undergo without permanent deformation
    - The critical stress at which fracture occurs in a single load event
4. Which of the following factors can affect the endurance limit?
    - Surface finish
    - Size of the component
    - Operating environment (corrosive, high temperature, etc.)
    - All of the above
5. Which of the following is true about Goodman and Morrow fatigue failure criteria?
    - Both ignore the mean stress in fatigue calculations
    - Goodman is more conservative than Morrow
    - Morrow is more conservative than Goodman
    - Neither can be used to estimate the fatigue life of a specimen.
6. The fatigue strength of a material after 10 million cycles is known as the:
    - Endurance limit
    - Ultimate strength
    - Yield strength
    - Safety factor
7. What is the endurance limit of a material?
    - The maximum stress a material can withstand before permanent deformation occurs.
    - The magnitude of a completely reversed stress cycle that can be applied to the material indefinitely without failure, theoretically.
    - The stress at which a material will begin to creep over time.
    - The minimum stress required to initiate crack propagation in a material.

8. A spring has 6 active coils, and the ends are squared and ground. What is the total number of coils? (See table below.)
    - 4
    - 6
    - 7
    - 8

Type of Spring Ends				
Term	**Plain**	**Plain and Ground**	**Squared or Closed**	**Squared and Ground**
End coils, N_e	0	1	2	2
Total coils, N_t	N_a	$N_a + 1$	$N_a + 2$	$N_a + 2$
Free length, L_0	$pN_a + d$	$P(N_a + 1)$	$pN_a + 3d$	$pN_a + 2d$
Solid length, L_s	$d(N_t + 1)$	dN_t	$d(N_t + 1)$	dN_t
Pitch, p	$(L_0 - d)/N_a$	$L_0/(N_a + 1)$	$(L_0 - 3d)/N_a$	$(L_0 - 2d)/N_a$

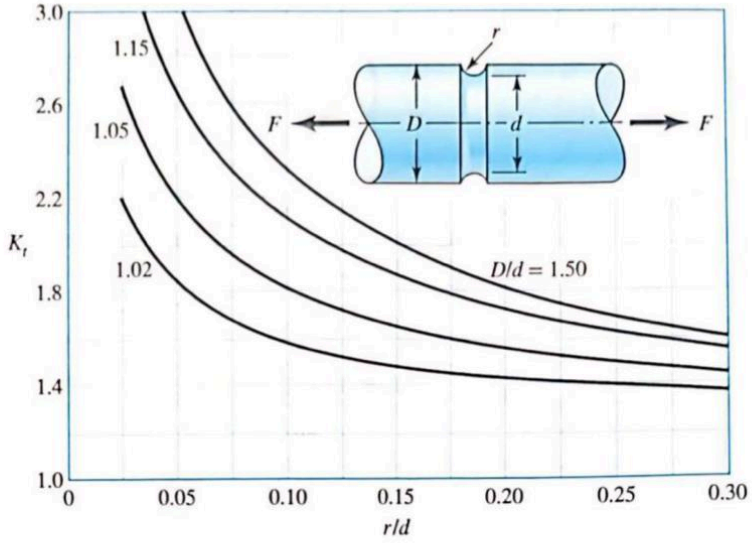
9. Shear failure of a key across its width can be caused by:
    - Excessive friction during normal operation
    - Excessive torque transmission from the shaft to the hub.
    - High lubricant pressure inside the hub
    - Loss of contact between the key and keyway
10. Which of the following best describes the role of shot peening in spring design?
    - It increases the spring stiffness by altering the wire diameter
    - It introduces compressive residual stresses to improve fatigue resistance
    - It hardens the surface of the spring to resist corrosion
    - It roughens the surface to improve the coefficient of friction.

Section 2: Problem-Solving (20 points each, 60 points total)

11. A cylindrical shaft with a groove is subjected to a fluctuating axial load with a mean stress of 100 MPa and an alternating stress of 200 MPa. The dimensions of the shaft as pictured are D = 40 mm, d = 38 mm, r = 3 mm. The fully corrected endurance limit is 300 MPa, the yield strength is 400 MPa and the ultimate tensile strength is 700 MPa. Using the Goodman criterion, determine the factor of safety guarding against fatigue failure. Show all calculations.

Figure A–15–13

Grooved round bar in tension. $\sigma_0 = F/A$, where $A = \pi d^2/4$.



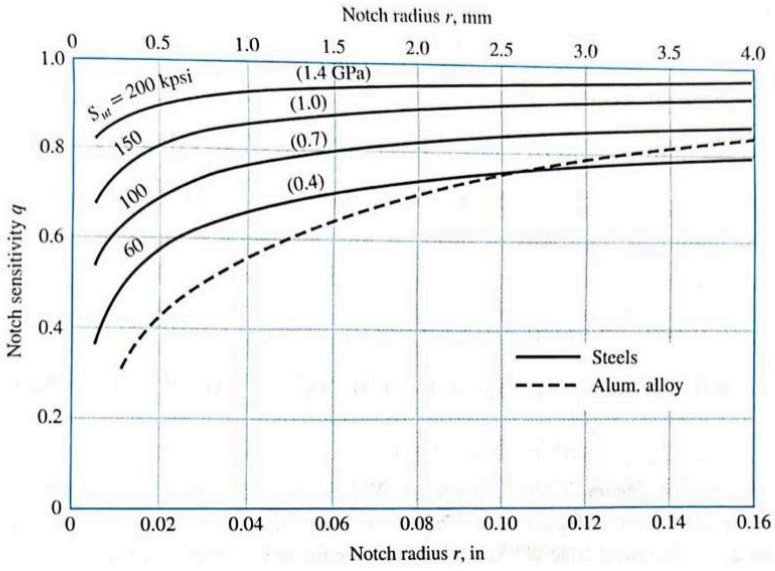


Figure 6–26

Notch-sensitivity charts for steels and UNS A92024-T wrought aluminum alloys subjected to reversed bending or reversed axial loads. For larger notch radii, use the values of q corresponding to the r = 0.16-in (4-mm) ordinate. Source: Sines, George and Waisman, J. L. (eds.), *Metal Fatigue*, McGraw-Hill, New York, 1969.

12. A grooved round bar has dimensions D = 9.2 mm, d = 8 mm, r = 1.5 mm. The bar is not rotating, and the axial load cycles from 5kN in compression to 10 kN in tension. The bar is at room temperature, and 90% reliability is desired. The bar is made of hot-rolled AISI 1018 steel with S_{ut} = 400 MPa and S_y = 220 MPa. Determine the fully corrected endurance limit, S_e.

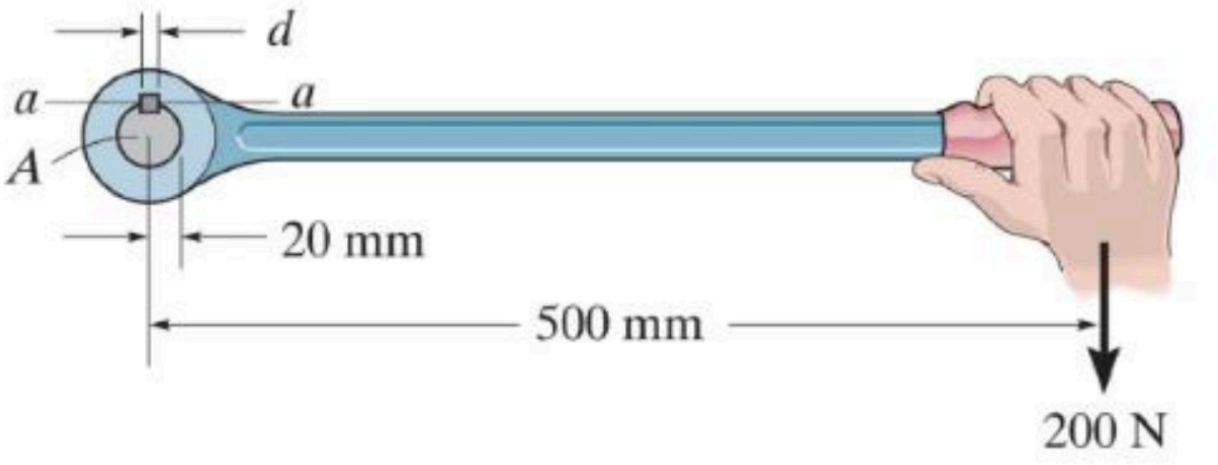
13. A compression spring in a mechanical assembly is subjected to cyclic loading, varying from 100 N to 500 N. The spring material is music wire (A228) with a diameter of 3 mm and the spring is unpeened. The outer diameter of the spring coil is 27 mm. Find:
    a. The endurance limit of the spring wire, S_{se}, using the Goodman criterion with Zimmerli data.
    b. The midrange (τ_m) and alternating (τ_a) components of shear stress for the spring.
    c. The factor of safety for infinite life using the Goodman failure criterion.

Table 10-4: Constants for Estimating Minimum Tensile Strength of Common Spring Wires

Material	ASTM No.	Exponent *m*	Diameter, in	*A*, kpsi · in^m	Diameter, mm	A, Mpa · mm^m	Relative Cost of Wire
Music wire*	A228	0.145	0.004 to 0.256	201	0.10 to 6.5	2211	2.6
OQ&T wire†	A229	0.187	0.020 to 0.500	147	0.5 to 12.7	1855	1.3
Hard-drawn wire‡	A227	0.190	0.028 to 0.500	140	0.7 to 12.7	1783	1.0
Chrome-vanadium wire§	A232	0.168	0.032 to 0.437	169	0.8 to 11.1	2005	3.1
Chrome-silicon wire‖	A401	0.108	0.063 to 0.375	202	1.6 to 9.5	1974	4.0
302 Stainless wire#	A313	0.146	0.013 to 0.10	169	0.3 to 2.5	1867	7.6 to 11
		0.263	0.10 to 0.20	128	2.5 to 5	2065	
		0.478	0.20 to 0.40	90	5 to 10	2911	
Phosphor-bronze wire**	B159	0	0.004 to 0.022	145	0.1 to 0.6	1000	8.0
		0.028	0.022 to 0.075	121	0.6 to 2	913	
		0.064	0.075 to 0.30	110	2 to 7.5	932	

Bonus Problem (10 points)

A lever is attached to a shaft with a square key as shown. The force applied to the lever is 200 N. The key is 25 mm long, and it is made of 1018 CD steel with Sy = 370 MPa and Sut = 440 MPa.



Determine the minimum dimension “d” required to ensure safe operation of the key. Use a safety factor of *n* = 1.2.