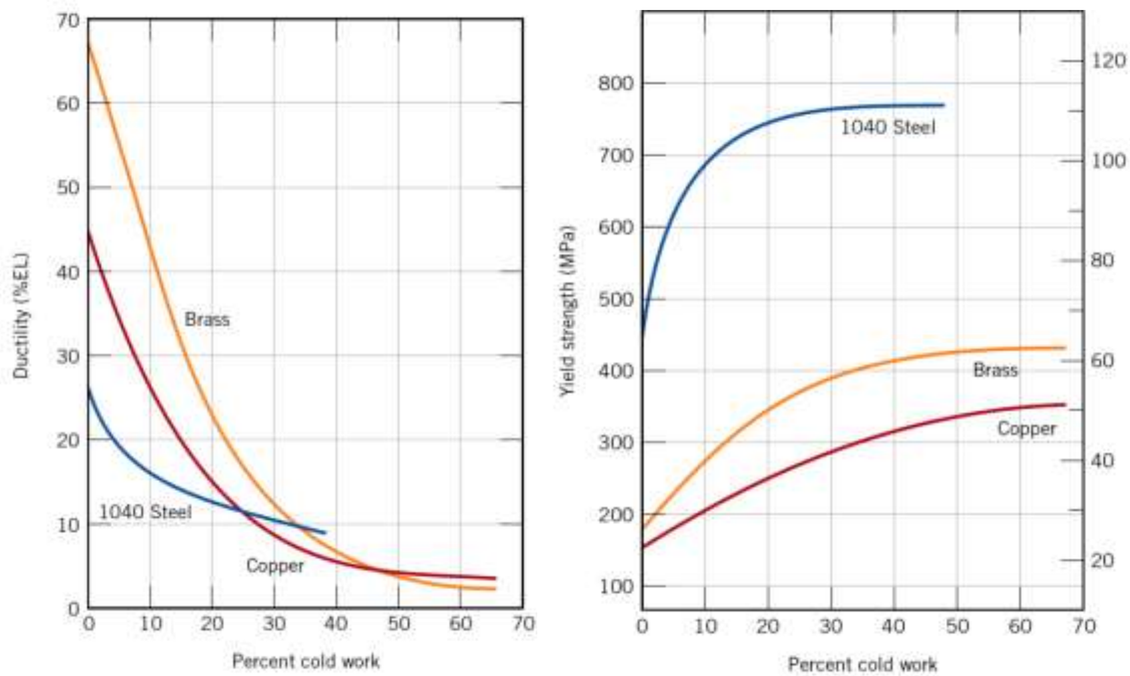
07/12/2022

METE 230 (SEC 5) FUNDAMENTALS OF MATERIALS SCIENCE AND ENGINEERING

HOMEWORK II

Q1 (10 points). Find the ductility of 1040 steel after cold rolling, by which the thickness of the billet was reduced and the rectangular cross-sectional area has increased from 30 cm x 10 cm to 32 cm x 12 cm. Calculate the ductility and yield strength of this material after the cold-working.



Q2 (10 points). How does strengthening occur in metals? What are the main strengthening mechanisms?

Q3 (10 points). Consider a single crystalline metal oriented such that the angle between the tensile axis and normal to the slip plane and slip direction are 35° and 60°, respectively. If the critical resolved shear stress is 6 MPa, will 11.6 MPa cause the single crystalline to yield?

Q4 (10 points) The average grain diameter of an iron material was measured as a function of time at 850 °C, as shown the table below.

Time (min)	Average grain diameter (μm)
30	10
120	18

(a) Calculate the original grain diameter.

(b) What will be the grain size after 300 mins of annealing at this temperature?

Q5 (10 points). A structural component in the form of a wide plate will be fabricated from an alloy steel having a plane strain fracture toughness of 101 MPa $m^{1/2}$ and a yield strength of 890 MPa. If the design stress is 510 MPa and the value of Y is 1.0;

(a) Determine the critical flaw size.

(b) If the flaw size detection resolution of an apparatus is 2.7 mm, can the critical flaw be detected?

Q6 (10 points). A steel plate is 300 mm wide and 6 mm thick. There is a 25 mm-long crack along each edge. If K_{IC} = 85 $MPa^{1/2}$ and Y=2.1:

(a) Calculate the force required to propagate the crack at the remaining 250 mm across the width of the plate.

(b) Calculate the force required to break the plate in tension if there were no crack. Assume that the fracture strength is 700 MPa.

Q7 (15 points). The table below shows the Charpy impact test data at different temperatures.

Temperature (°C)	Impact Energy (J)
30	80
20	79
10	74
0	60
-10	40
-20	25
-30	15
-40	10
-50	7
-60	5

(a) Plot the data as impact energy vs. temperature.

(b) Determine the ductile-to-brittle transition temperature (using the average of max and min impact energies).

(c) This material will be used at the outer parts of the submarines which can be exposed to the temperatures down to -35 °C. Is this material suitable for this application? If the fracture occurs during service, what type of fracture would it be?

Q8 (15 points). The fatigue data for an alloy steel are provided below.

Stress amplitude (MPa)	Cycles to failure
500	$5x10^3$
475	$9x10^3$
450	$3x10^4$
425	$8x10^4$
400	10^5
380	$5x10^5$
350	10^6
350	$5x10^6$
350	$5x10^7$

(a) Plot S-N curve using the data in the table.

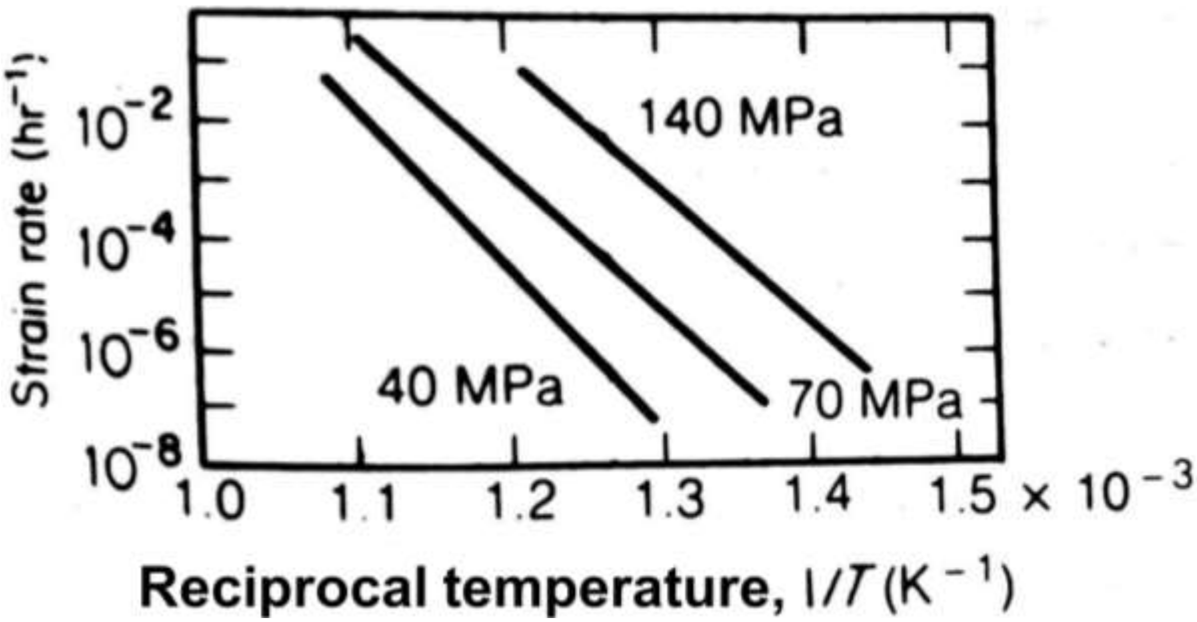
(b) What is the fatigue life for the stress amplitude of 410 MPa?

(c) This material will be used for an application which imposes fatigue stress of an amplitude of 300 MPa. How often should I check this material to avoid from fatigue failure?

Q9 (10 points). Steady state creep rate can be expressed by;

$$\dot{\varepsilon}_S = B\sigma^n e^{-Q/kT}$$

Apply this realtionship to the creep of a steel support rod in a boiler operating at 540 °C. The rod is stressed in tension to 40 MPa and its creep elongtion **must not exceed 10 %**. Using the data below, evaluate the constants in creep equation and estimate the lifetime of the rod.



DUE: 17/12/2022 – 11.59 pm.