Multiple Choice Quiz

There are 13 correct answers in the following multiple choice questions (some questions have multiple answers that are correct). To attain a perfect score on the quiz, all correct answers must be given. Each correct answer is worth 1 point. Each omitted answer or wrong answer reduces the score by 1 point, and each additional answer beyond the correct number of answers reduces the score by 1 point. Percentage score on the quiz is based on the total number of correct answers.

18.1 Which of the following are bulk deformation processes (three correct answers): (a) bending, (b) deep drawing, (c) extrusion, (d) forging, (e) rolling, and (f) shearing?

Answer. (c), (d), and (e).

18.2 Which of the following is typical of the starting work geometry in sheet metal processes: (a) high volume-to-area ratio or (b) low volume-to-area ratio?

Answer. (b).

18.3 The flow curve expresses the behavior of a metal in which of the following regions of the stress-strain curve: (a) elastic region or (b) plastic region?

Answer. (b).

18.4 The average flow stress is the flow stress multiplied by which of the following factors: (a) n, (b) $(1+n)$, (c) $1/n$, or (d) $1/(1+n)$, where n is the strain-hardening exponent?

Answer. (d).

18.5 Hot working of metals refers to which one of the following temperature regions relative to the melting point of the given metal on an absolute temperature scale: (a) room temperature, (b) $0.2T_m$, (c) $0.4T_m$, or (d) $0.6T_m$?

Answer. (d).

18.6 Which of the following are advantages and characteristics of hot working relative to cold working (four correct answers): (a) fracture of workpart is less likely, (b) friction is reduced, (c) increased strength properties, (d) isotropic mechanical properties, (e) less overall energy is required, (f) lower deformation forces is required, (g) more significant shape changes are possible, and (h) strain-rate sensitivity is reduced?

Answer. (a), (d), (f), and (g).

18.7 Increasing strain rate tends to have which one of the following effects on flow stress during hot forming of metal: (a) decreases flow stress, (b) has no effect, or (c) increases flow stress?

Answer. (c).

18.8 The coefficient of friction between the part and the tool in cold working tends to be (a) higher, (b) lower, or (c) no different relative to its value in hot working?

Answer. (b).

Problems

Flow Curve in Forming

18.1 The strength coefficient = 550 MPa and strain-hardening exponent = 0.22 for a certain metal. During a forming operation, the final true strain that the metal experiences = 0.85. Determine the flow stress at this strain and the average flow stress that the metal experienced during the operation.

Solution: Flow stress $Y_f = 550(0.85)^{0.22}$ = **531 MPa.**

Average flow stress $\bar{Y}_f = 550(0.85)^{0.22}/1.22 =$ **435 MPa.**

18.2 A metal has a flow curve with strength coefficient = 850 MPa and strain-hardening exponent = 0.30. A tensile specimen of the metal with gage length = 100 mm is stretched to a length = 157 mm. Determine the flow stress at the new length and the average flow stress that the metal has been subjected to during the deformation.

Solution: $\varepsilon = \ln(157/100) = \ln 1.57 = 0.451$
Flow stress $Y_f = 850(0.451)^{0.30} =$ **669.4 MPa.**
Average flow stress $\bar{Y}_f = 850(0.451)^{0.30}/1.30 =$ **514.9 MPa.**

18.3 A particular metal has a flow curve with strength coefficient = 35,000 lb/in^2 and strain-hardening exponent = 0.26. A tensile specimen of the metal with gage length = 2.0 in is stretched to a length = 3.3 in. Determine the flow stress at this new length and the average flow stress that the metal has been subjected to during deformation.

Solution: $\varepsilon = \ln(3.3/2.0) = \ln 1.65 = 0.501$
Flow stress $Y_f = 35{,}000(0.501)^{0.26} =$ **29,240 lb/in^2.**
Average flow stress $\bar{Y}_f = 35{,}000(0.501)^{0.26}/1.26 =$ **23,206 lb/in^2.**

18.4 The strength coefficient and strain-hardening exponent of a certain test metal are 40,000 lb/in^2 and 0.19, respectively. A cylindrical specimen of the metal with starting diameter = 2.5 in and length = 3.0 in is compressed to a length of 1.5 in. Determine the flow stress at this compressed length and the average flow stress that the metal has experienced during deformation.

Solution: $\varepsilon = \ln(1.5/3.0) = \ln 0.5 = -0.69315$
Flow stress $Y_f = 40{,}000(0.69315)^{0.19} =$ **37,309 lb/in^2.**
Average flow stress $\bar{Y}_f = 40{,}000(0.69315)^{0.19}/1.19 =$ **31,352 lb/in^2.**

18.5 Derive the equation for average flow stress, Eq. (18.2) in the text.

Solution: Flow stress equation [Eq. (18.1)]: $Y_f = K\varepsilon^n$
$\bar{Y}_f$ over the range $\varepsilon = 0$ to $\varepsilon = \varepsilon$ is given by $\int K\varepsilon^n\, d\varepsilon = K \int \varepsilon^n\, d\varepsilon = K\varepsilon^{n+1}/\varepsilon(n+1) = \boldsymbol{K\varepsilon^n/(n+1)}$

18.6 For a certain metal, the strength coefficient = 700 MPa and strain-hardening exponent = 0.27. Determine the average flow stress that the metal experiences if it is subjected to a stress that is equal to its strength coefficient *K*.

Solution: $Y_f = K = 700 = K\varepsilon^n = 700\varepsilon^{27}$
ε must be equal to 1.0.
$\bar{Y}_f = 700(1.0)^{.27}/1.27 = 700/1.27 =$ **551.2 MPa**

18.7 Determine the value of the strain-hardening exponent for a metal that will cause the average flow stress to be 3/4 of the final flow stress after deformation.

Solution: $\bar{Y}_f = 0.75\ Y_f$
$K\varepsilon^n/(1+n) = 0.75\ K\varepsilon^n$
$1/(1+n) = 0.75$
$1 = 0.75(1+n) = 0.75 + 0.75n$
$0.25 = 0.75n$ $\quad$ $\boldsymbol{n = 0.333}$

18.8 The strength coefficient = 35,000 lb/in^2 and strain-hardening exponent = 0.40 for a metal used in a forming operation in which the workpart is reduced in cross-sectional area by stretching. If the average flow stress on the part is 20,000 lb/in^2, determine the amount of reduction in cross-sectional area experienced by the part.

Solution: $\overline{Y}_f = K\varepsilon^n/(1+n)$
$20{,}000 = 35{,}000\ \varepsilon^4/(1.4)$
$1.4(20{,}000) = 35{,}000\ \varepsilon^4$
$28{,}000/35{,}000 = 0.8 = \varepsilon^4$
$0.4 \ln \varepsilon = \ln (0.8) = -0.22314$
$\ln \varepsilon = -0.22314/0.4 = -0.55786$
$\varepsilon = 0.5724$
$\varepsilon = \ln(A_o/A_f) = 0.5724$
$A_o/A_f = 1.7726$
$\boldsymbol{A_f = A_o/1.7726 = 0.564A_o}$

18.9 In a tensile test, two pairs of values of stress and strain were measured for the specimen metal after it had yielded: (1) true stress = 217 MPa and true strain = 0.35, and (2) true stress = 259 MPa and true strain = 0.68. Based on these data points, determine the strength coefficient and strain-hardening exponent.

Solution: Solve two equations, two unknowns: $\ln K = \ln \sigma - n \ln \varepsilon$
(1) $\ln K = \ln 217 - n \ln 0.35$
(2) $\ln K = \ln 259 - n \ln 0.68$
(1) $\ln K = 5.3799 - (-1.0498)n = 5.3799 + 1.0498\ n$
(2) $\ln K = 5.5568 - (-0.3857)n = 5.5568 + 0.3857\ n$
$5.3799 + 1.0498\ n = 5.5568 + 0.3857\ n$
$1.0498\ n - 0.3857\ n = 5.5568 - 5.3799$
$0.6641\ n = 0.1769$ $\qquad$ $\boldsymbol{n = 0.2664}$
$\ln K = 5.3799 + 1.0498\ (0.2664) = 5.6596$ $\qquad$ $\boldsymbol{K = 287}$ **MPa**

18.10 The following stress and strain values were measured in the plastic region during a tensile test carried out on a new experimental metal: (1) true stress = 43,608 lb/in^2 and true strain = 0.27 in/in, and (2) true stress = 52,048 lb/in^2 and true strain = 0.85 in/in. Based on these data points, determine the strength coefficient and strain-hardening exponent.

Solution: Solve two equations, two unknowns: $\ln K = \ln \sigma - n \ln \varepsilon$
(3) $\ln K = \ln 43{,}608 - n \ln 0.27$
(4) $\ln K = \ln 52{,}048 - n \ln 0.85$
(3) $\ln K = 10.6830 - (-1.3093)n = 10.6830 + 1.3093\ n$
(4) $\ln K = 10.8600 - (-0.1625)n = 10.8600 + 0.1625\ n$
(5) $10.6830 + 1.3093\ n = 10.8600 + 0.1625\ n$
$1.3093\ n - 0.1625\ n = 10.8600 - 10.6830$
$1.1468\ n = 0.1769$ $\qquad$ $\boldsymbol{n = 0.1543}$
$\ln K = 10.6830 + 1.3093\ (0.1543) = 10.885$ $\qquad$ $\boldsymbol{K = 53{,}374}$ **lb/in^2**

Strain Rate

18.11 The gage length of a tensile test specimen = 150 mm. It is subjected to a tensile test in which the grips holding the end of the test specimen are moved with a relative velocity = 0.1 m/s. Construct a plot of the strain rate as a function of length as the specimen is pulled to a length = 200 mm.

Solution: The following values are calculated for the plot:
At L = 150 mm, strain rate $\dot{\varepsilon} = 0.1/0.15 = 0.667\ s^{-1}$
At L = 160 mm, strain rate $\dot{\varepsilon} = 0.1/0.16 = 0.625\ s^{-1}$
At L = 170 mm, strain rate $\dot{\varepsilon} = 0.1/0.17 = 0.588\ s^{-1}$
At L = 180 mm, strain rate $\dot{\varepsilon} = 0.1/0.18 = 0.555\ s^{-1}$
At L = 190 mm, strain rate $\dot{\varepsilon} = 0.1/0.19 = 0.526\ s^{-1}$
At L = 200 mm, strain rate $\dot{\varepsilon} = 0.1/0.20 = 0.500\ s^{-1}$

18.12 A specimen with 6.0 in starting gage length is subjected to a tensile test in which the grips holding the end of the test specimen are moved with a relative velocity = 1.0 in/sec. Construct a plot of the strain rate as a function of length as the specimen is pulled to a length = 8.0 in.

Solution: The following values are calculated for the plot:
At L = 6.0 in, strain rate $\dot{\varepsilon}$ = 1/6.0 = 0.1667 sec^{-1}
At L = 6.5 in, strain rate $\dot{\varepsilon}$ = 1/6.5 = 0.1538 sec^{-1}
At L = 7.0 in, strain rate $\dot{\varepsilon}$ = 1/7.0 = 0.1429 sec^{-1}
At L = 7.5 in, strain rate $\dot{\varepsilon}$ = 1/7.5 = 0.1333 sec^{-1}
At L = 8.0 in, strain rate $\dot{\varepsilon}$ = 1/8.0 = 0.1250 sec^{-1}

18.13 A workpart with starting height h = 100 mm is compressed to a final height of 50 mm. During the deformation, the relative speed of the plattens compressing the part = 200 mm/s. Determine the strain rate at (a) h = 100 mm, (b) h = 75 mm, and (c) h = 51 mm.

Solution: (a) strain rate $\dot{\varepsilon}$ = 200/100 = **2.0 s^{-1}**

(b) strain rate $\dot{\varepsilon}$ = 200/75 = **2.667 s^{-1}**

(c) strain rate $\dot{\varepsilon}$ = 200/51 = **3.922 s^{-1}**

18.14 A hot working operation is carried out at various speeds. The strength constant = 30,000 lb/in^2 and the strain-rate sensitivity exponent = 0.15. Determine the flow stress if the strain rate is (a) 0.01/sec (b) 1.0/sec, (c) 100/sec.

Solution: (a) $Y_f = C(\dot{\varepsilon})^{m}$ = 30,000(0.01)$^{.15}$ = **15,036 lb/in^2**

(b) Y_f = 30,000(1.0)$^{0.15}$ = **30,000 lb/in^2**

(c) Y_f = 30,000(100)$^{0.15}$ = **59,858 lb/in^2**

18.15 A tensile test is performed to determine the strength constant C and strain-rate sensitivity exponent m in Eq. (18.4) for a certain metal. The temperature at which the test is performed = 500°C. At a strain rate = 12/s, the stress is measured at 160 MPa; and at a strain rate = 250/s, the stress = 300 MPa. (a) Determine C and m. (b) If the temperature were 600°C, what changes would you expect in the values of C and m?

Solution: (a) Two equations: (1) 160 = $C(12)^m$ and (2) 300 = $C(250)^m$
(1) ln 160 = ln C + m ln 12 or ln 160 - m ln 12 = ln C
(2) ln 300 = ln C + m ln 250 or ln 300 - m ln 250 = ln C
(1) and (2): ln 160 - m ln 12 = ln 300 - m ln 250
5.0752 – 2.4849 m = 5.7038 – 5.5215 m
(5.5215 – 2.4849)m = 5.7038 – 5.0752
3.0366 m = 0.6286 **m = 0.207**
(1) C = 160/(12)$^{0.207}$ = 160.1.6726 = 95.658
(2) C = 300/(250)$^{0.207}$ = 300/3.1361 = 95.660
Averaging these values, **C = 95.659**

(b) If temperature were 600°C, the strength constant C would decrease and the strain-rate sensitivity exponent m would increase.

18.16 A tensile test is carried out to determine the strength constant C and strain-rate sensitivity exponent m for a certain metal at 1000°F. At a strain rate = 10/sec, the stress is measured at 23,000 lb/in^2; and at a strain rate = 300/sec, the stress = 45,000 lb/in^2. (a) Determine C and m. (b) If the temperature were 900°F, what changes would you expect in the values of C and m?

Solution: (a) Two equations: (1) 23,000 = $C(10)^m$ and (2) 45,000 = $C(300)^m$
45,000/23,000 = 1.9565 = $(300/10)^m = (30)^m$

ln 1.9656 = m ln 30

0.67117 = 3.4012 m **m = 0.1973**

(1) $C = 23000/10^{0.1973} = 23000/1.5752 = 14{,}601.4$

(2) $C = 45000/300^{0.1973} = 45000/3.0819 = 14{,}601.4$ **C = 14,601.4**

(b) If temperature were decreased to 900°F, the strength constant C would increase and the strain-rate sensitivity exponent m would decrease.