

Chapter 6, Problem 21E

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Mechanical Behavior of Materials | (2nd Edition)

Step-by-step solution

Step 1 of 8

a)

Express the Johnson Cook equation for stress (σ).

$$\sigma = \left(\sigma_0 + K \varepsilon^n \right) \left(1 + C \ln \frac{\dot{\varepsilon}}{\dot{\varepsilon}_0} \right) \left[1 - \left(\frac{T - T_r}{T_m - T_r} \right)^m \right] \quad \dots\dots (1)$$

Here, yield stress is σ_0 , constant is K , true strain is ε , exponent constant is n , constant parameter is C , material constant parameter is m , reference strain rate is $\dot{\varepsilon}_0$, strain rate is $\dot{\varepsilon}$, melting temperature is T_m , reference temperature is T_r , and ambient temperature is T .

From the graph of stress versus strain curve, select the yield stress value corresponding to the temperature of 77 K and strain value 0 as 700 MPa .

Substitute 700 MPa for σ_0 , 1120 MPa for K , 0 for ε , 0.25 for n , 0.007 for C , 10^{-4} s^{-1} for $\dot{\varepsilon}$, $3 \times 10^{-4} \text{ s}^{-1}$ for $\dot{\varepsilon}_0$, 1 for m , 77 K for T_r , 298 K for T , and 1600 K for T_m .

$$\sigma = \left(700 \text{ MPa} + (1120 \text{ MPa})(0)^{0.25} \right) \left(1 + 0.007 \ln \frac{10^{-4} \text{ s}^{-1}}{3 \times 10^{-4} \text{ s}^{-1}} \right) \left[1 - \left(\frac{298 \text{ K} - 77 \text{ K}}{1600 \text{ K} - 77 \text{ K}} \right)^1 \right]$$
$$= \left\{ \left(700 \text{ MPa} \left(\frac{10^6 \text{ MPa}}{1 \text{ MPa}} \right) + (1120 \text{ MPa})(0)^{0.25} \right) \right\}$$
$$= \left\{ \left(1 + 0.007 \ln \frac{10^{-4} \text{ s}^{-1}}{3 \times 10^{-4} \text{ s}^{-1}} \right) \left[1 - \left(\frac{298 \text{ K} - 77 \text{ K}}{1600 \text{ K} - 77 \text{ K}} \right)^1 \right] \right\}$$
$$= 593.8 \times 10^6 \text{ Pa} \left(\frac{1 \text{ MPa}}{10^6 \text{ MPa}} \right)$$
$$= 593.8 \text{ MPa}$$

Comment

Step 2 of 8

Use spreadsheet to calculate the stress value at temperature of 77 K, 173 K, 473 K, and 1473 K as in Table (1).

ε	σ (Pa)			
	77 K	173 K	473 K	1473 K
0	593822110	633770899	802476551	7121189554
0.1	1128111249	1.204E+09	1.525E+09	1.3528E+10
0.2	1229202556	1.312E+09	1.661E+09	1.4741E+10
0.3	1296986162	1.384E+09	1.753E+09	1.5554E+10
0.4	1349421057	1.44E+09	1.824E+09	1.6182E+10
0.5	1392770723	1.486E+09	1.882E+09	1.6702E+10
0.6	1430029803	1.526E+09	1.933E+09	1.7149E+10
0.7	1462884301	1.561E+09	1.977E+09	1.7543E+10
0.8	1492385754	1.593E+09	2.017E+09	1.7897E+10
0.9	1519238045	1.621E+09	2.053E+09	1.8219E+10
1	1543937486	1.648E+09	2.086E+09	1.8515E+10

Comment

Step 3 of 8

Plot the stress-strain curve at temperature of 77 K, 173 K and 473 K, as in Figure (1).

Comment

Step 4 of 8

Plot the stress-strain curve at temperature of 1473 K as in Figure (2).

Comment

Step 5 of 8

b)

Calculate the stress value (σ) using Johnson Cook equation at the strain rate and temperature of $3 \times 10^{-4} \text{ s}^{-1}$ and 77 K.

Substitute 700 MPa for σ_0 , 1120 MPa for K , 0 for ε , 0.25 for n , 0.02 for C , $3 \times 10^{-4} \text{ s}^{-1}$ for $\dot{\varepsilon}$, $3 \times 10^{-4} \text{ s}^{-1}$ for $\dot{\varepsilon}_0$, 1 for m , 77 K for T_r , 298 K for T , and 1600 K for T_m in Equation (1).

$$\sigma = \left\{ \left(700 \text{ MPa} + (1120 \text{ MPa})(0)^{0.25} \right) \left(1 + 0.02 \ln \frac{3 \times 10^{-4} \text{ s}^{-1}}{3 \times 10^{-4} \text{ s}^{-1}} \right) \right\}$$
$$= \left\{ \left[1 - \left(\frac{298 \text{ K} - 77 \text{ K}}{1600 \text{ K} - 77 \text{ K}} \right)^1 \right] \right\}$$
$$= \left\{ \left(700 \text{ MPa} \left(\frac{10^6 \text{ MPa}}{1 \text{ MPa}} \right) + (1120 \text{ MPa})(0)^{0.25} \right) \right\}$$
$$= \left\{ \left(1 + 0.02 \ln \frac{3 \times 10^{-4} \text{ s}^{-1}}{3 \times 10^{-4} \text{ s}^{-1}} \right) \left[1 - \left(\frac{298 \text{ K} - 77 \text{ K}}{1600 \text{ K} - 77 \text{ K}} \right)^1 \right] \right\}$$
$$= 598.4 \times 10^6 \text{ Pa} \left(\frac{1 \text{ MPa}}{10^6 \text{ MPa}} \right)$$
$$= 598.4 \text{ MPa}$$

Comment

Step 6 of 8

Use spreadsheet to calculate the stress value at strain rate and temperature of $3 \times 10^{-4} \text{ s}^{-1}$ and 77 K, 173 K, 473 K, and 1473 K as in Table (2).

ε	σ (Pa)			
	77 K	173 K	473 K	1473 K
0	598424163	638682551	808695652	7176377953
0.1	1136853982	1.213E+09	1.536E+09	1.3633E+10
0.2	1238728734	1.322E+09	1.674E+09	1.4855E+10
0.3	1307037655	1.395E+09	1.766E+09	1.5674E+10
0.4	1359878915	1.451E+09	1.838E+09	1.6308E+10
0.5	1403564536	1.498E+09	1.897E+09	1.6832E+10
0.6	144112370	1.538E+09	1.947E+09	1.7282E+10
0.7	1474221486	1.573E+09	1.992E+09	1.7679E+10
0.8	1503951572	1.605E+09	2.032E+09	1.8036E+10
0.9	1531011965	1.634E+09	2.069E+09	1.836E+10
1	1555902823	1.661E+09	2.103E+09	1.8659E+10

Comment

Step 7 of 8

Plot the stress-strain curve at temperature of 77 K, 173 K and 473 K at strain rate of $3 \times 10^{-4} \text{ s}^{-1}$ as in Figure (3).

Comment

Step 8 of 8

Plot the stress-strain curve at temperature of 1473 K at strain rate of $3 \times 10^{-4} \text{ s}^{-1}$ as in Figure (4).

Comment

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