

Chapter 7, Problem 27E

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Mechanical Behavior of Materials | (2nd Edition)

Step-by-step solution

Step 1 of 11

Show the calculation for the specimen under 1st failure load:

Express the characteristic flexure strength (maximum stress) in the outer most layer for three point bend test.

$$\sigma_{max} = \frac{3PS}{2bh^2} \dots\dots (1)$$

Here, failure load is P , height of bar is h , outer span is S , and breadth of bar is b .

Substitute 1,040 N for P , 5 mm for h , 10 mm for b , and 50 mm for L in Equation (1).

$$\begin{aligned}\sigma_{max} &= \frac{3(1,040 \text{ N})(50 \text{ mm})}{2(10 \text{ mm})(5 \text{ mm})^2} \\ &= \frac{156000 \text{ N}}{500 \text{ mm}^2} \\ &= 312 \frac{\text{N}}{\text{mm}^2} \times \frac{10^6 \text{ Pa}}{\text{N/mm}^2} \\ &= 3.12 \times 10^8 \text{ Pa}\end{aligned}$$

Comment

Step 2 of 11

Calculate the probability of survival $P_i(V_o)$ for i^{th} strength value for N specimen.

$$P_i(V_o) = \frac{N+1-i}{N+1} \dots\dots (2)$$

Here, total number of specimens tested is N , and rank of specimen is i .

Substitute 1 for i and 10 for N in Equation (2).

$$\begin{aligned}P_i(V_o) &= \frac{10+1-1}{10+1} \\ &= \frac{10}{11} \\ &= 0.909091\end{aligned}$$

Comment

Step 3 of 11

Calculate failure probability of $N+1$ strength intervals for N tests.

$$\begin{aligned}F_i(V_o) &= 1 - P_i(V_o) \\ &= 1 - \frac{N+1-i}{N+1} \\ &= \frac{N+1-(N+1-i)}{N+1} \dots\dots (3) \\ &= \frac{i}{N+1}\end{aligned}$$

Substitute 1 for i and 10 for N in Equation (3).

$$\begin{aligned}F_i(V_o) &= \frac{1}{10+1} \\ &= \frac{1}{11} \\ &= 0.09\end{aligned}$$

Calculate $\ln(\sigma) \dots\dots (4)$

Substitute $3.12 \times 10^8 \text{ Pa}$ for σ in Equation (4).

$$\begin{aligned}\ln(\sigma) &= \ln(3.12 \times 10^8 \text{ Pa}) \\ &= 19.55 \text{ Pa}\end{aligned}$$

Comment

Step 4 of 11

Calculate $\ln\left[\ln\left(\frac{1}{P_i(V_o)}\right)\right] \dots\dots (5)$

Substitute 0.9 for $P_i(V_o)$ in Equation (5).

$$\begin{aligned}\ln\left[\ln\left(\frac{1}{P_i(V_o)}\right)\right] &= \ln\left[\ln\left(\frac{1}{0.909091}\right)\right] \\ &= -2.35062 \text{ Pa}\end{aligned}$$

Comment

Step 5 of 11

Use spreadsheet and Equations (1), (2), (3), (4), and (5), calculate the characteristic flexural strength (σ , MPa), survival probability ($P_i(V_o)$), logarithmic flexural strength ($\ln(\sigma)$), failure probability ($F_i(V_o)$), and $\ln\left[\ln\left(\frac{1}{P_i(V_o)}\right)\right]$ for all the specimens as in Table (1).

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Comment

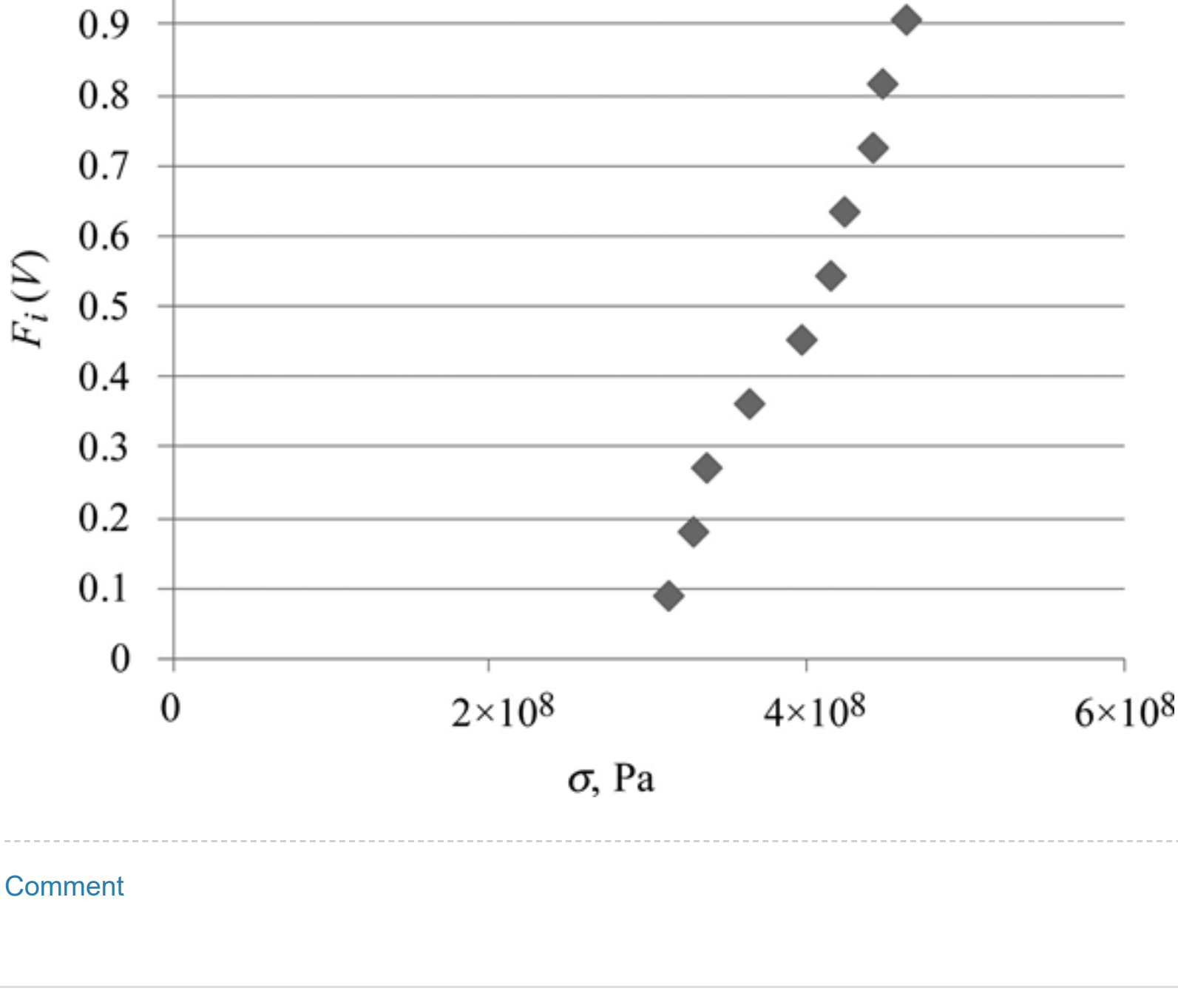
Step 6 of 11

i	Load, N	σ , Pa	$P_i(V_o)$	$F_i(V_o)$	$\ln(\sigma)$	$\ln\left[\ln\left(\frac{1}{P_i(V_o)}\right)\right]$
1	1040	3.12×10^8	0.90909	0.09091	19.5585	-2.3506
2	1092	3.27×10^8	0.81818	0.18182	19.6073	-1.6061
3	1120	3.36×10^8	0.72727	0.27273	19.6326	-1.1443
4	1210	3.63×10^8	0.63636	0.36364	19.7099	-0.7941
5	1320	3.96×10^8	0.54545	0.45455	19.7969	-0.5007
6	1381	4.14×10^8	0.45455	0.54545	19.8421	-0.2377
7	1410	4.23×10^8	0.36364	0.63636	19.8629	0.01153
8	1470	4.41×10^8	0.27273	0.72727	19.9046	0.26181
9	1490	4.47×10^8	0.18182	0.81818	19.9181	0.53342
10	1540	4.62×10^8	0.09091	0.90909	19.9511	0.87459

Comment

Step 7 of 11

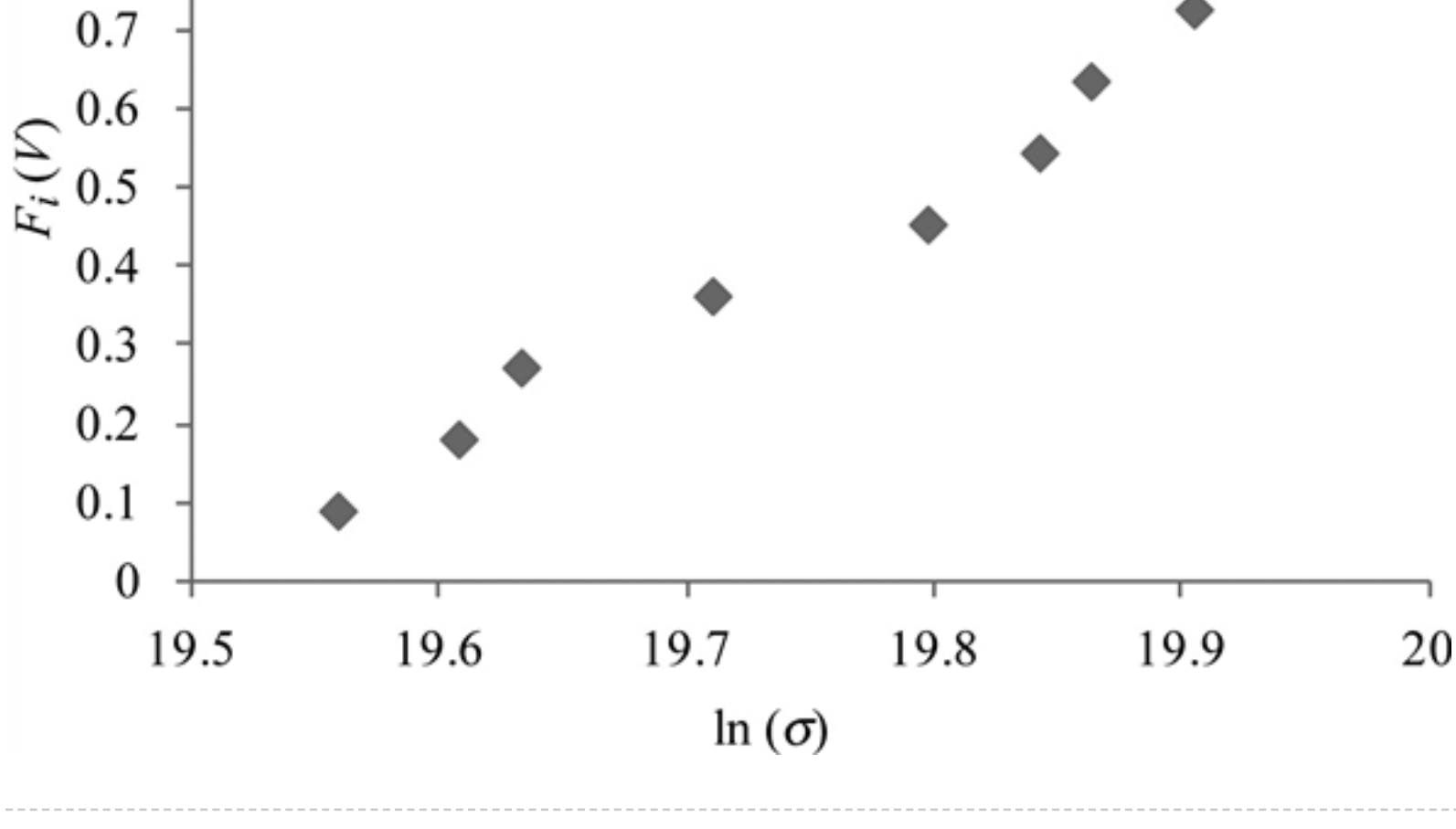
Show the graph between probability failure and sigma as in Figure (1).



Comment

Step 8 of 11

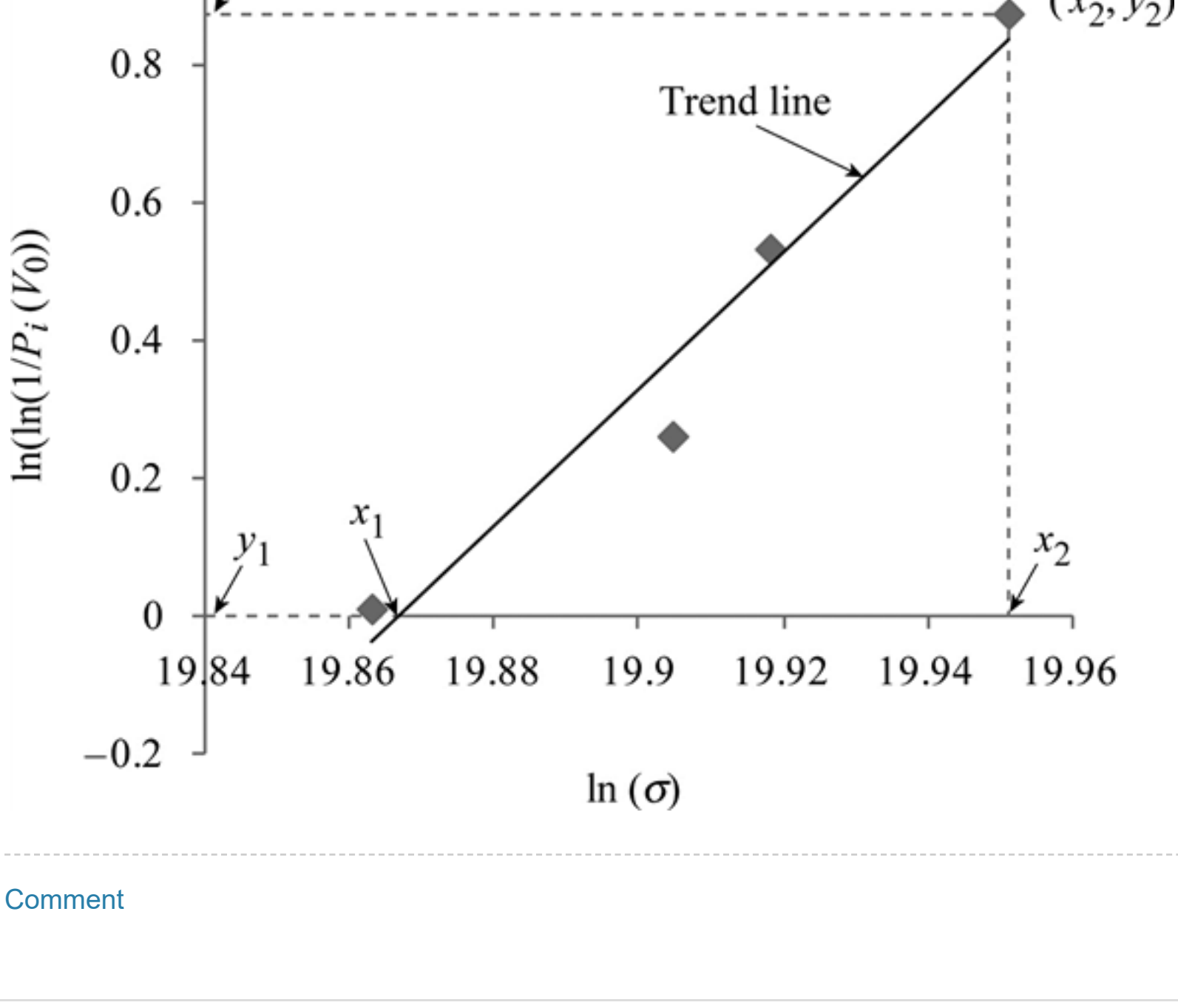
Show the plot between probability failure and flexural strength as in Figure (2).



Comment

Step 9 of 11

To obtain Weibull's modulus, find a slope using trend line plot between $\ln\left[\ln\left(\frac{1}{P_i(V_o)}\right)\right]$ and $\ln(\sigma)$ as in Figure (3).



Comment

Step 10 of 11

The Weibull's modulus for the specimen can be calculated by taking the slope from the plot between $\ln\left[\ln\left(\frac{1}{P_i(V_o)}\right)\right]$ and $\ln(\sigma)$ from Figure (3). The slope should be positive so choose the positive data from Table (1) between $\ln\left[\ln\left(\frac{1}{P_i(V_o)}\right)\right]$ and $\ln(\sigma)$.

Consider any two points to take the slope from the graph.

Comment

Step 11 of 11

Calculate the Weibull's modulus (m) for the specimen from Figure (3).

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

Substitute 0.9 for y_2 , 0 for y_1 , 19.95 for x_2 , and 19.86 for x_1 .

$$\begin{aligned}m &= \frac{0.9 - 0}{19.95 - 19.86} \\ &= 10\end{aligned}$$

From Table of typical values of the Weibull Modulus m for some material, select engineering ceramics as Al_2O_3 for the range of m as 5-10. Thus, the above calculated value of m is correct.

Hence, the Weibull's modulus (m) for the specimen is 10.

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