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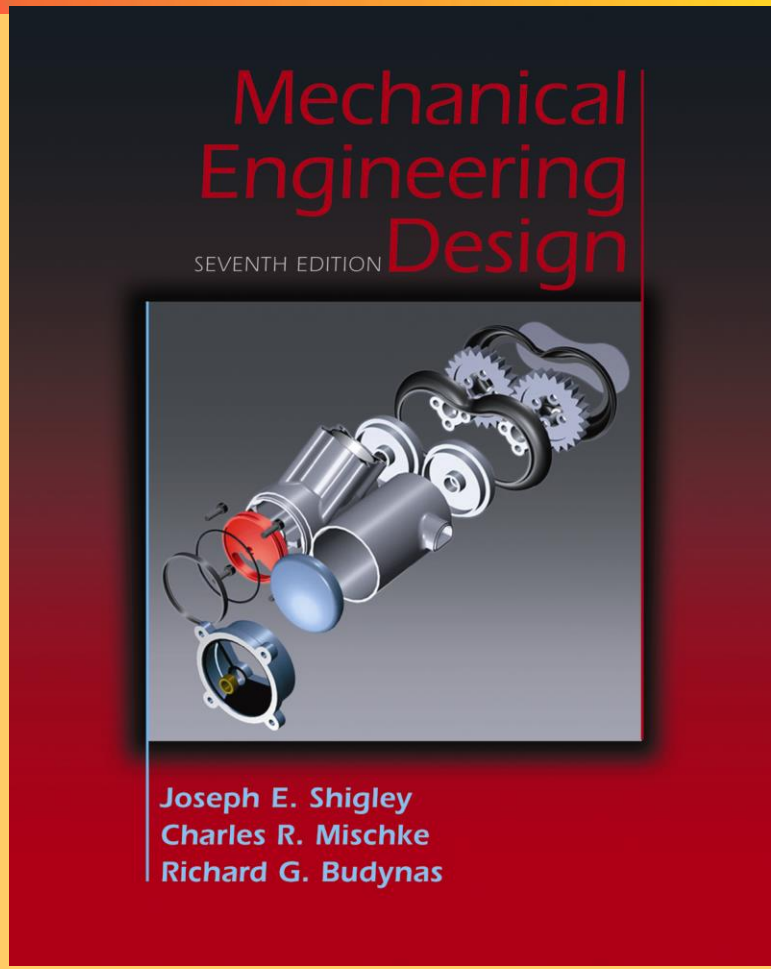
Chapter 3

Materials

Mechanical Engineering Design

Seventh Edition



Shigley • Mischke • Budynas

Static Strength

$$\varepsilon = \frac{l_i - l_0}{l_0} \qquad \varepsilon = \frac{A_0 - A_i}{A_i}$$

$$\sigma = \frac{P}{A_0} \qquad \varepsilon = \int_{l_0}^{l_i} \frac{dl}{l} = \ln \frac{l_i}{l_0}$$

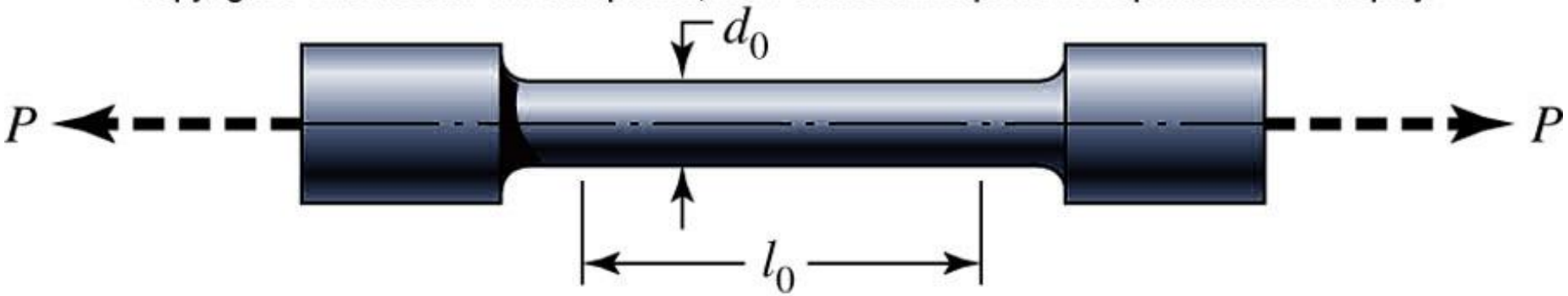


Fig. 3.1 A typical tension test specimen. Some of the standard dimensions used for d_0 are 2.5, 6.25, and 12.5 mm. Common gauge lengths l_0 used are 10, 25, and 50 mm.

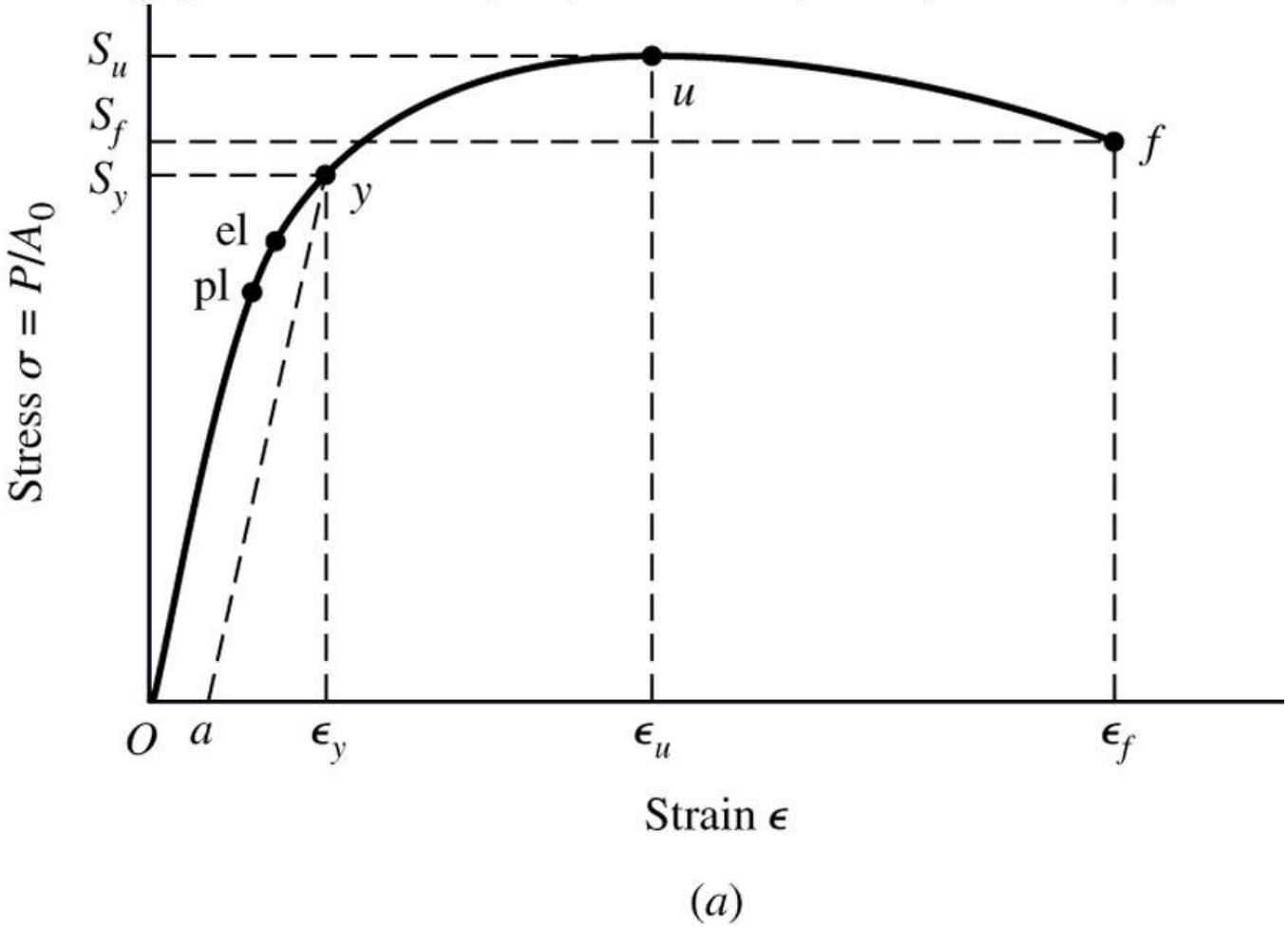


Fig. 3.2a Stress-strain diagram obtained from the standard tensile test of a ductile material.

Fig 3.3 Tension specimen after necking.

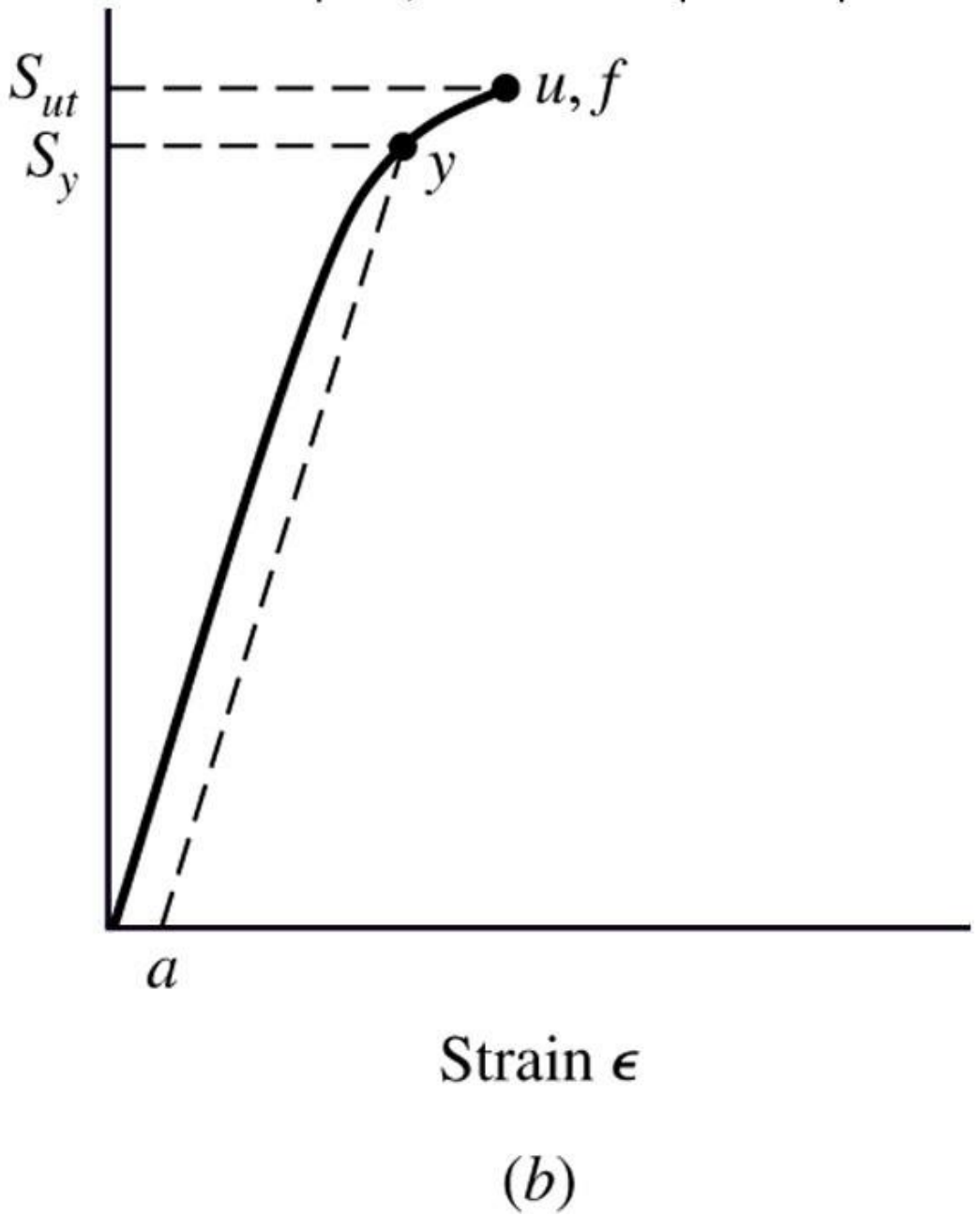


Fig. 3.2b Stress-strain diagram obtained from the standard tensile test of a brittle material.

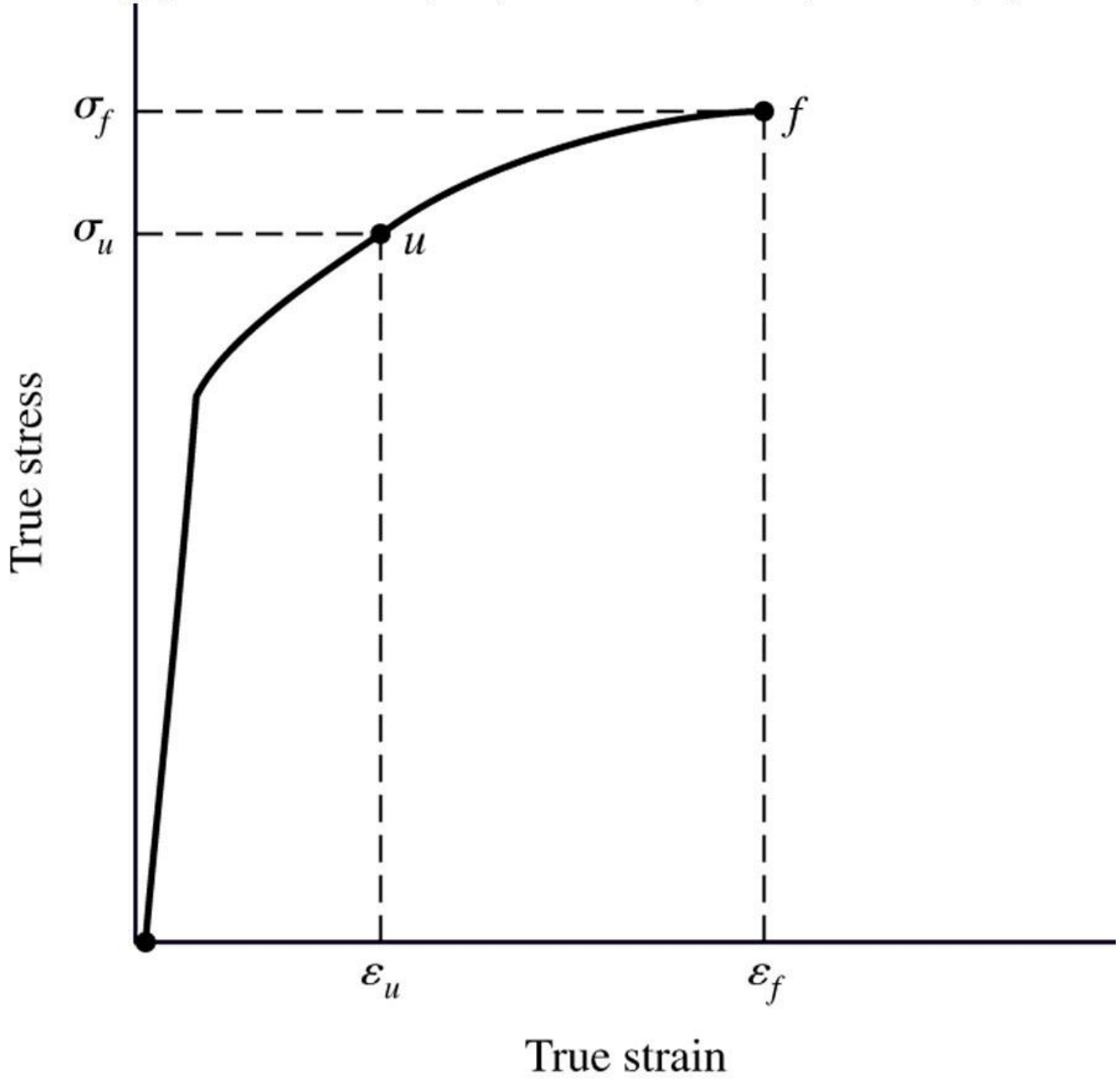
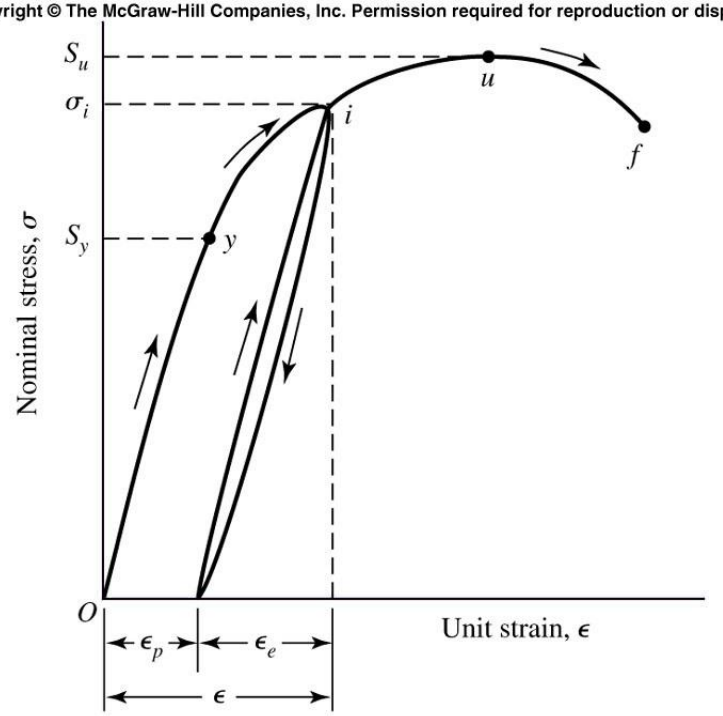


Fig 3.4 True stress-true strain diagram plotted using Cartesian coordinates.

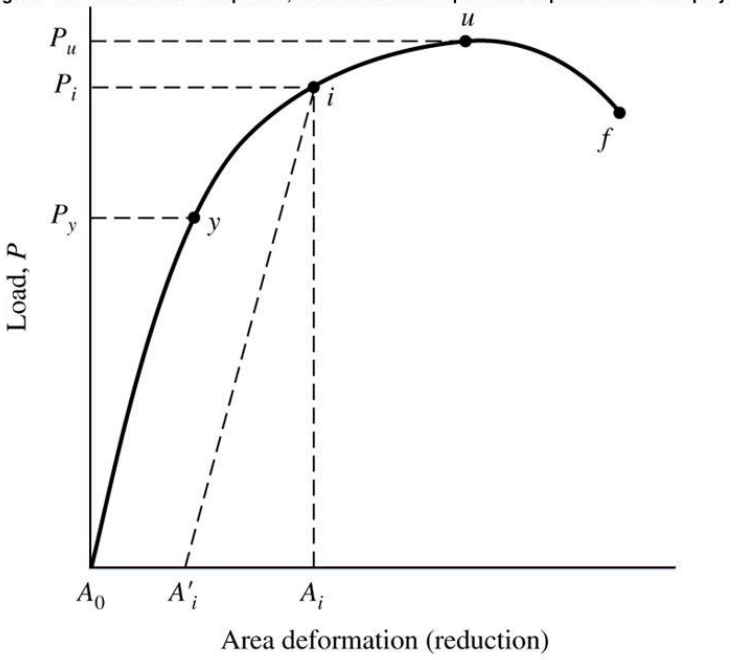
Strength and Cold Work

Cold working is the process of plastic straining below the recrystallization temperature in the plastic region of the stress-strain diagram.



(a)

Fig 3.5a Stress-strain diagram showing unloading and reloading at point *i* in the plastic region.



(b)

Fig. 3.5b Analogous load-deformation diagram.

$$W = \frac{A_0 - A_i'}{A_0} \approx \frac{A_0 - A_i}{A_0} \qquad A_i' = A_0(1-W)$$

$$S_u' = \frac{P_u}{A_i'} = \frac{S_u A_0}{A_0(1-W)} = \frac{S_u}{(1-W)} \qquad \varepsilon_i \le \varepsilon_u$$

$$S_y' = \frac{P_i}{A_i'} = \sigma_0 \varepsilon_i^m \qquad P_i \le P_u$$

$$S_u' \approx S_y' \approx \sigma_0 \varepsilon_i^m \qquad \varepsilon_i \le \varepsilon_u$$

Hardness

The resistance of a material to penetration by a pointed tool is called hardness.
Rockwell hardness test : diamond indenter; scales A, B, C; R_B=50.
Brinell hardness test : ball indenter; H_B
For 111 data pairs of carbon and low-alloy wrought steels

$$S_{ut} = 3.41(1, 0.041)\bar{H}_B \quad \text{MPa}$$

$$(S_{ut})_{0.99} = 3.10\bar{H}_B \quad \text{MPa}$$

Data from 72 tests of gray cast iron, the minimum strength

$$S_u = 1.58H_B\text{-}86 \quad \text{MPa}$$

SAE minimum strength

$$S_u = 1.6375H_B\text{-}110 \quad \text{MPa}$$

Impact Properties

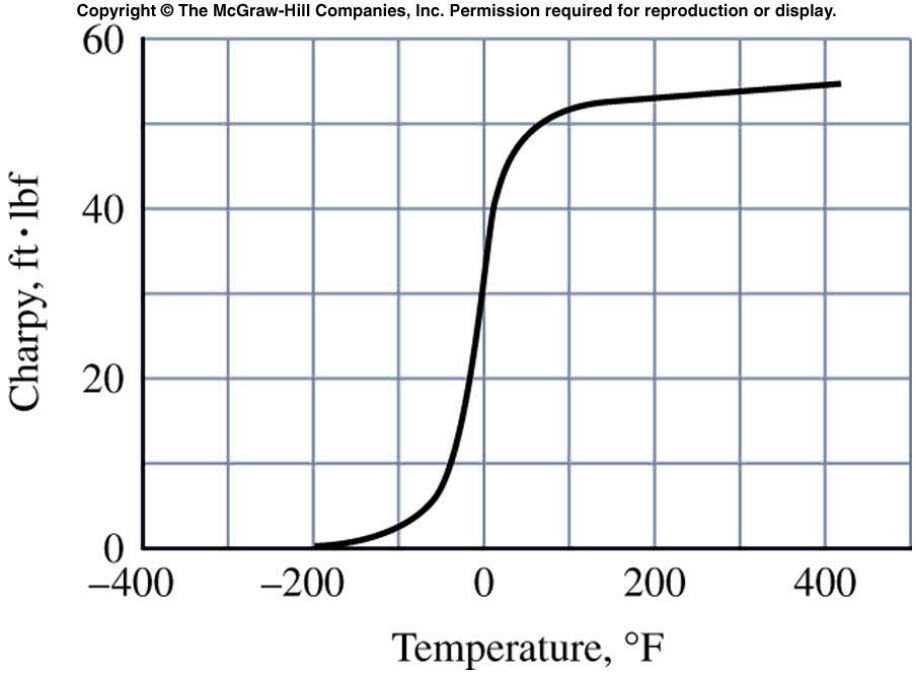


Fig 3.6 A mean trace shows the effect of temperature on impact values.

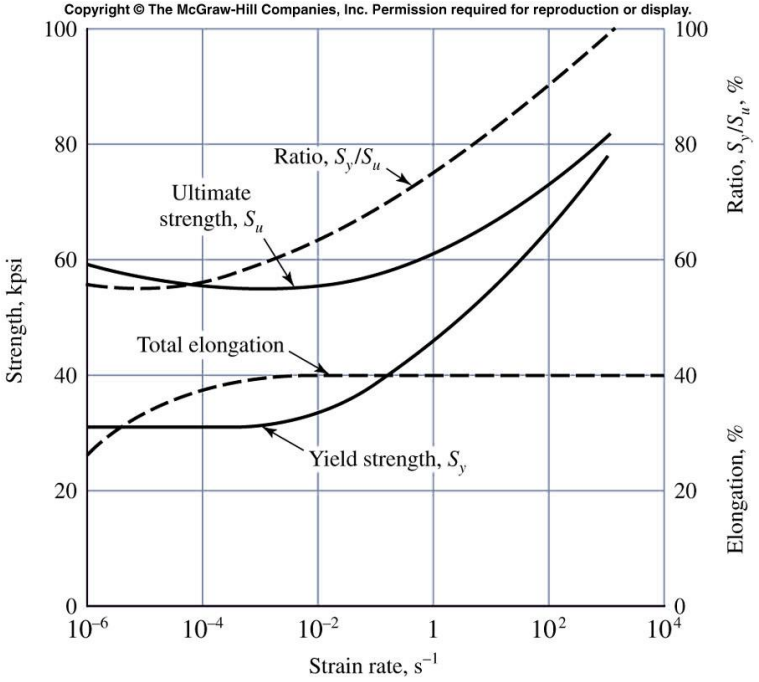


Fig. 3.7 Influence of strain rate on tensile properties.

Temperature Effects

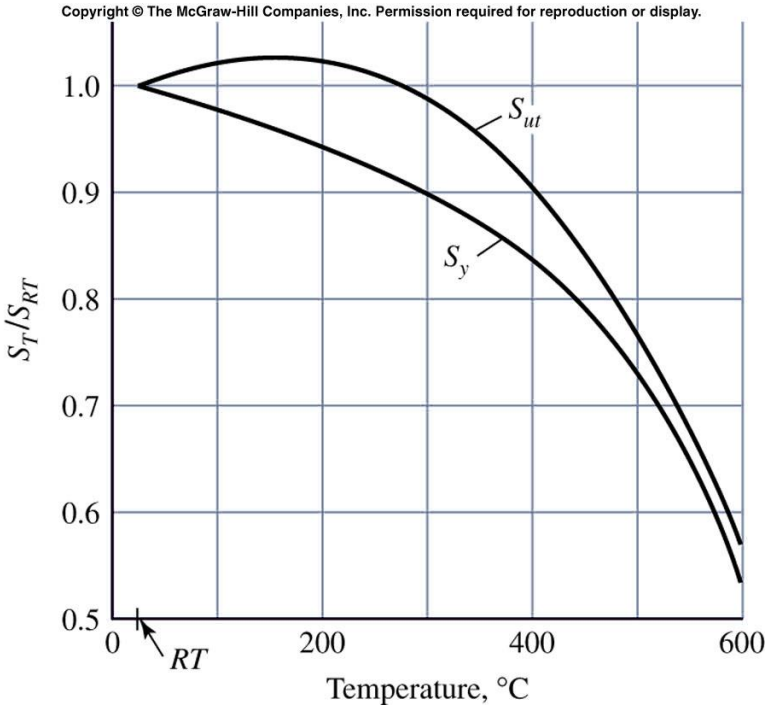


Fig. 3.8 A plot of the results of 145 tests of 21 carbon and alloy steels showing the effect of operating temperature on the yield strength S_y and the ultimate strength S_u.

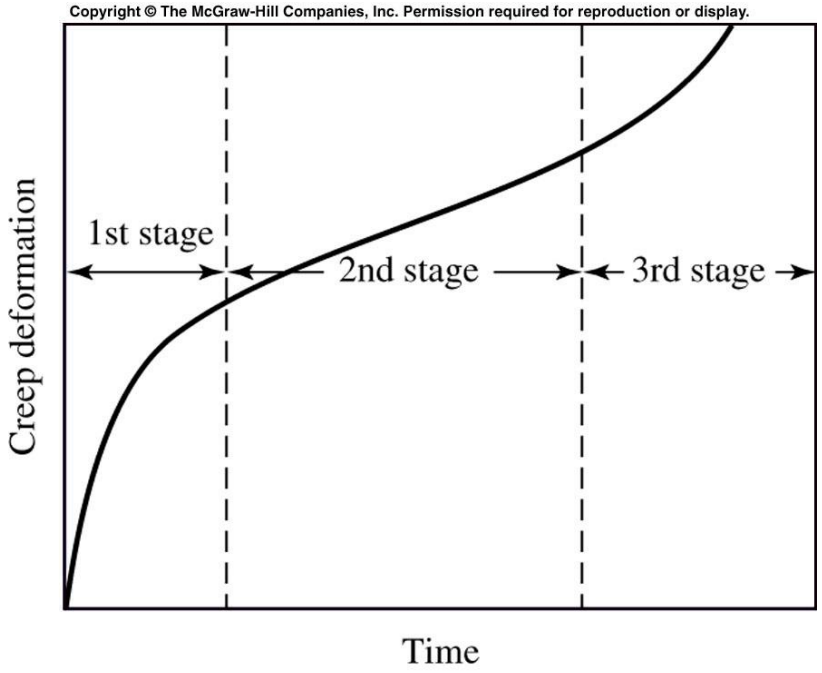


Fig. 3.9 Creep-time curve.