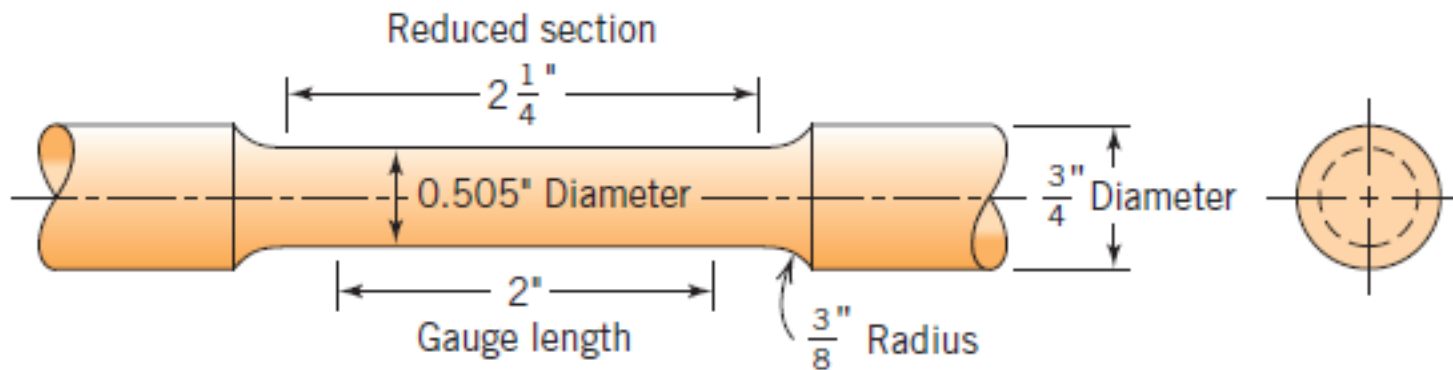




# Propriedades Mecânicas

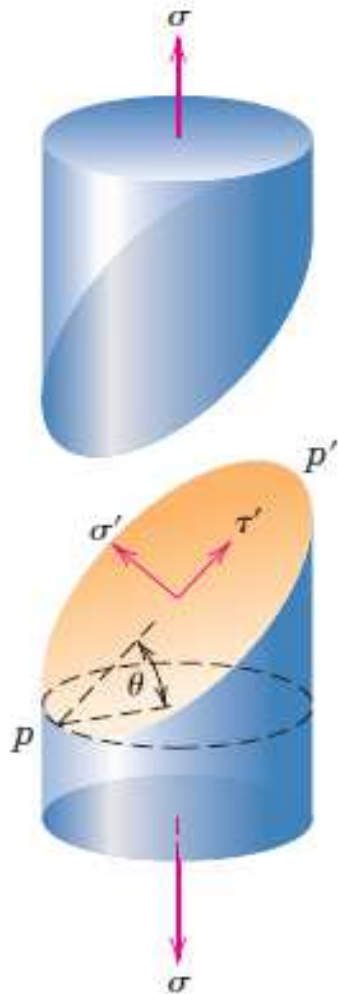
# [ Ensaio de Tração ]



$$\sigma = \frac{F}{A_0}$$

$$\epsilon = \frac{l_i - l_0}{l_0} = \frac{\Delta l}{l_0}$$

# [ Tração ]



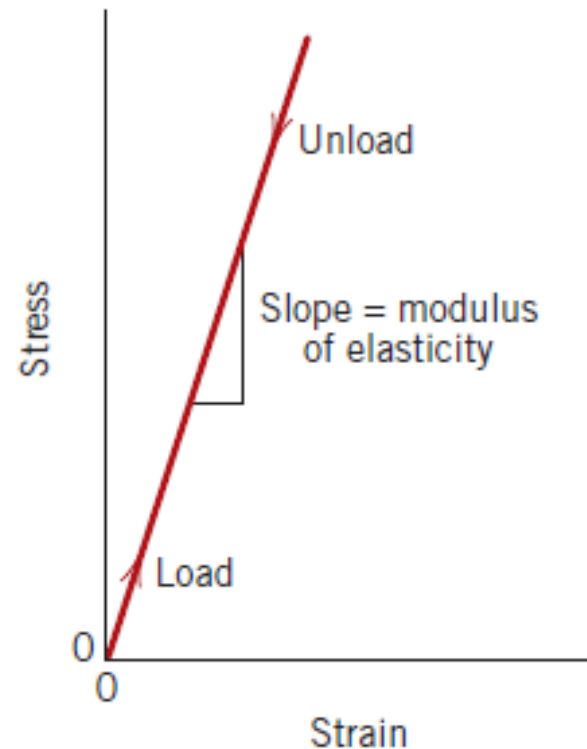
$$\sigma' = \sigma \cos^2 \theta = \sigma \left( \frac{1 + \cos 2\theta}{2} \right)$$

$$\tau' = \sigma \sin \theta \cos \theta = \sigma \left( \frac{\sin 2\theta}{2} \right)$$

# [ Deformação elástica ]

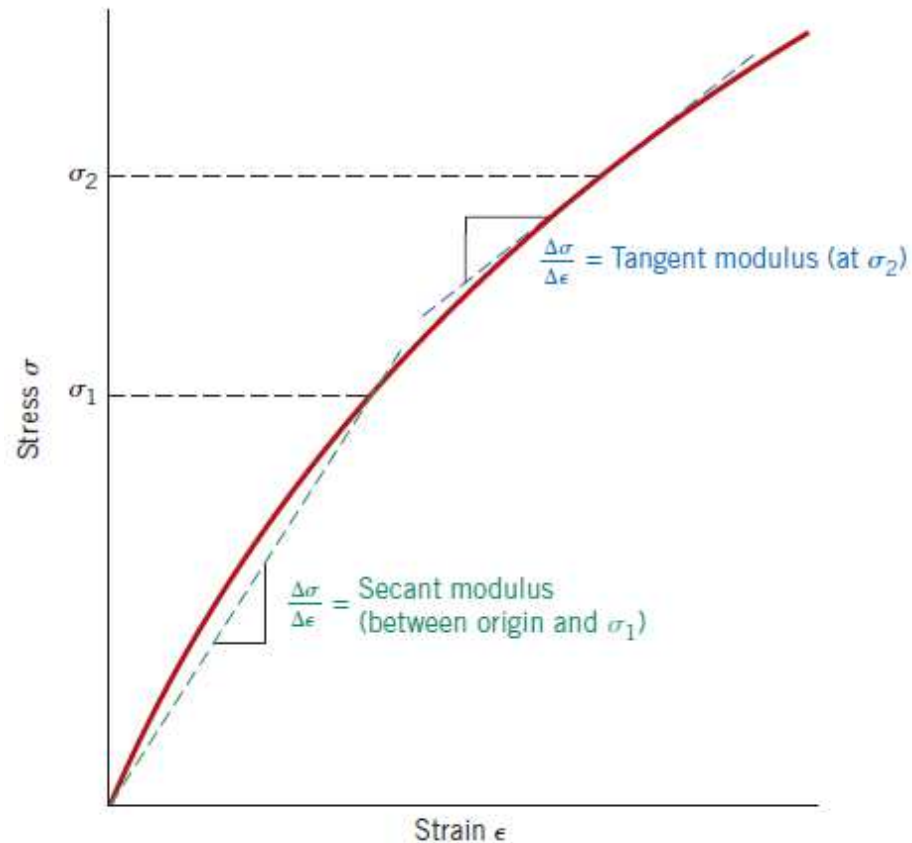
- Regime elástico linear (lei de Hook)

$$\sigma = E\epsilon$$

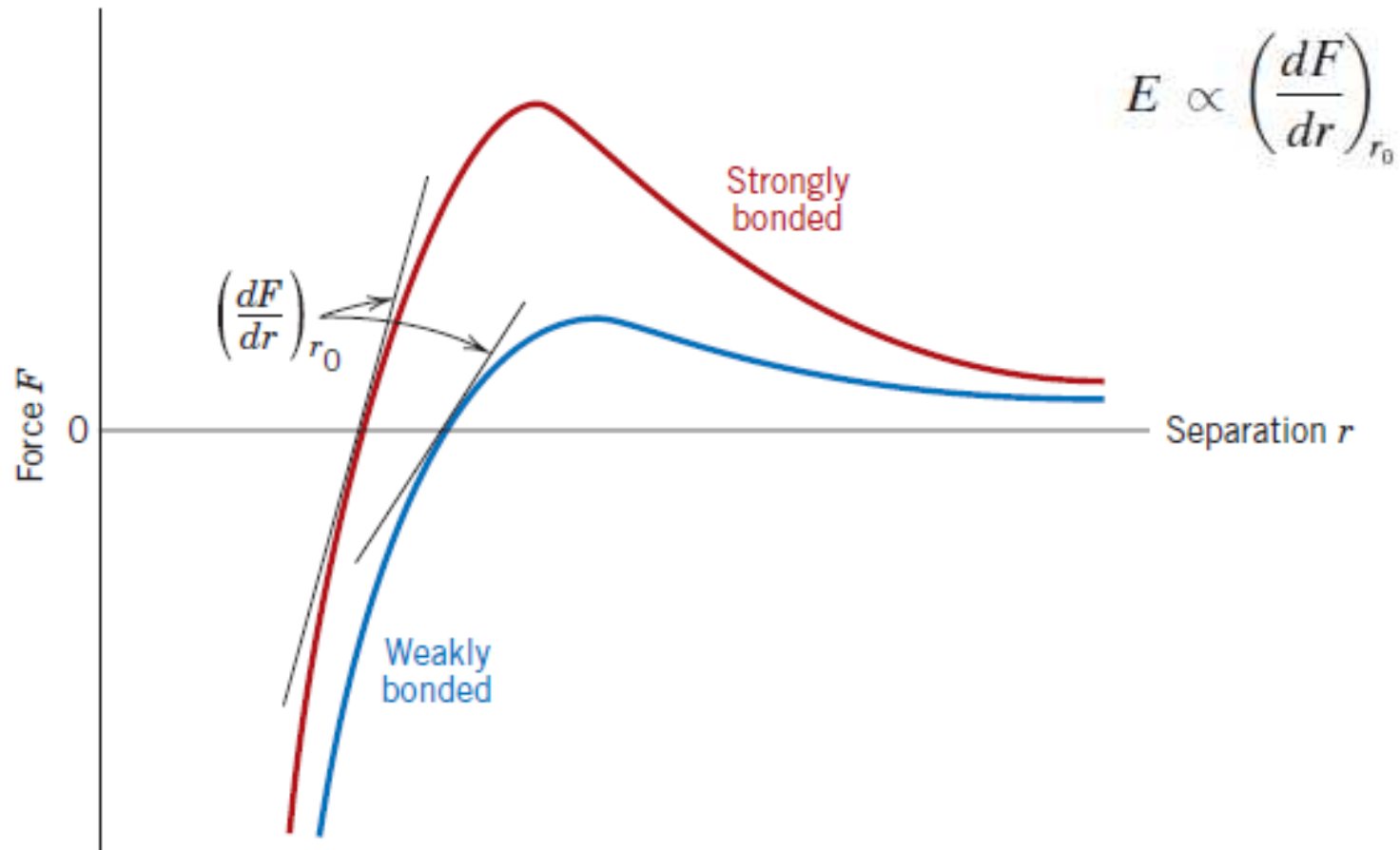


# [ Deformação elástica ]

- Regime elástico não linear



# Origem do módulo de elasticidade



# [ Outras propriedades elásticas ]

- Módulo de cisalhamento

$$\tau = G\gamma$$

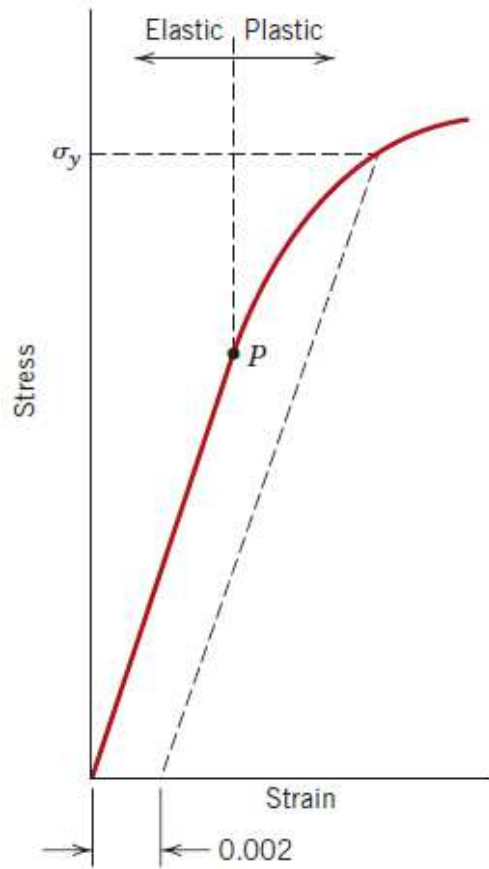
- Razão de Poisson

$$\nu = -\frac{\epsilon_x}{\epsilon_z} = -\frac{\epsilon_y}{\epsilon_z}$$

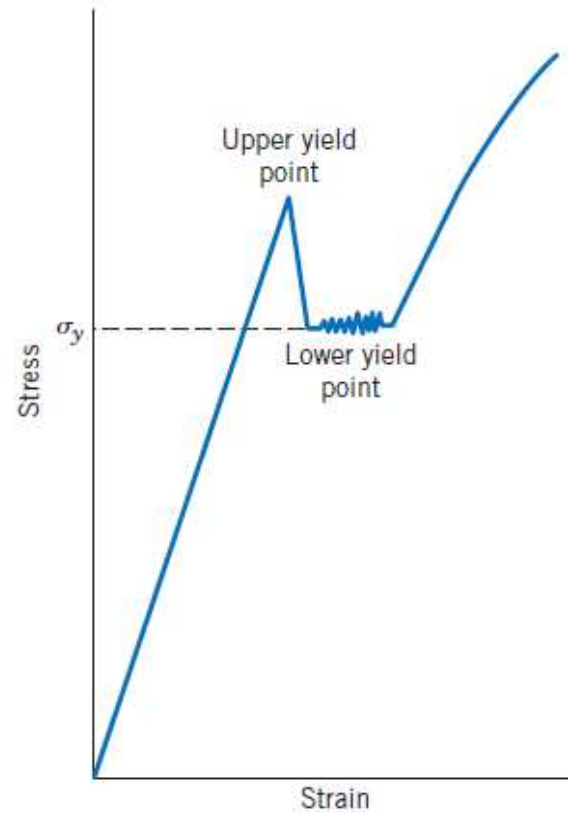
- p/ material isotrópico

$$E = 2G(1 + \nu)$$

# [ Deformação plástica ]



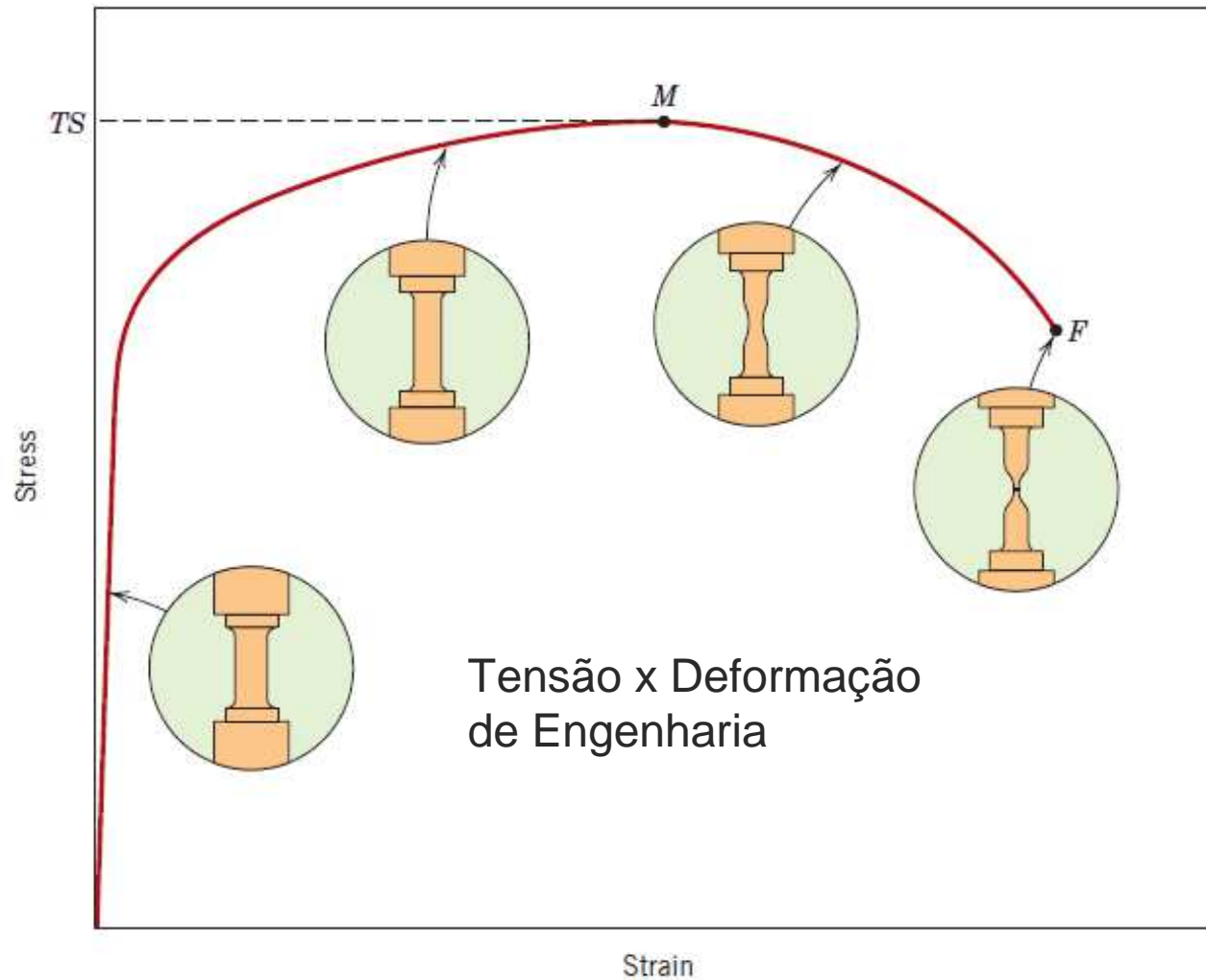
Limite não definido



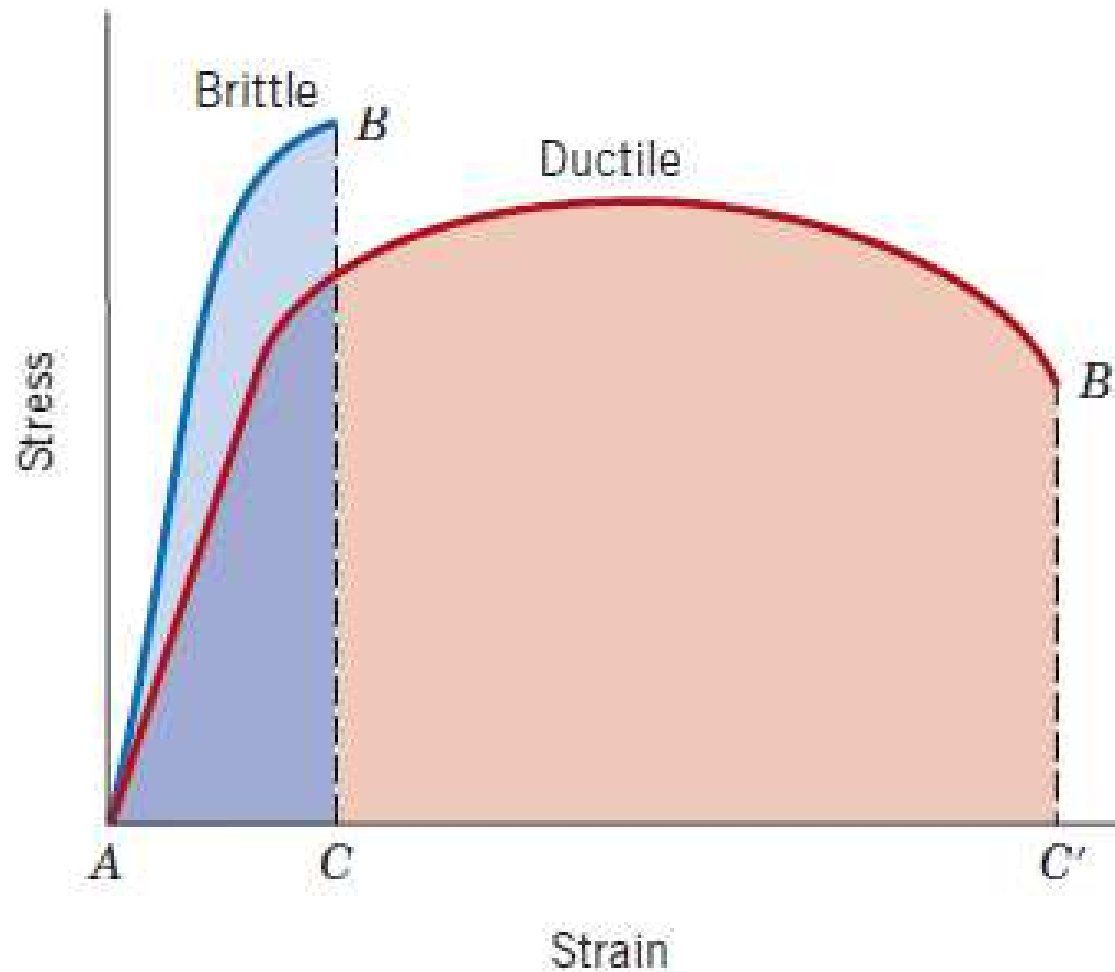
Limite bem definido



# Tensão x Deformação p/ um metal típico



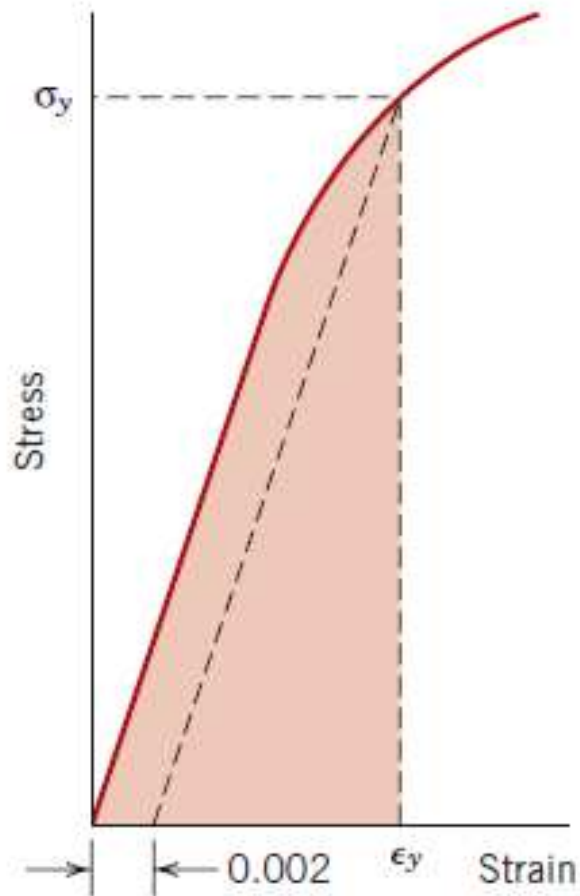
# [ Ductilidade ]



$$\%EL = \left( \frac{l_f - l_0}{l_0} \right) \times 100$$

$$\%RA = \left( \frac{A_0 - A_f}{A_0} \right) \times 100$$

# [ Resiliência ]

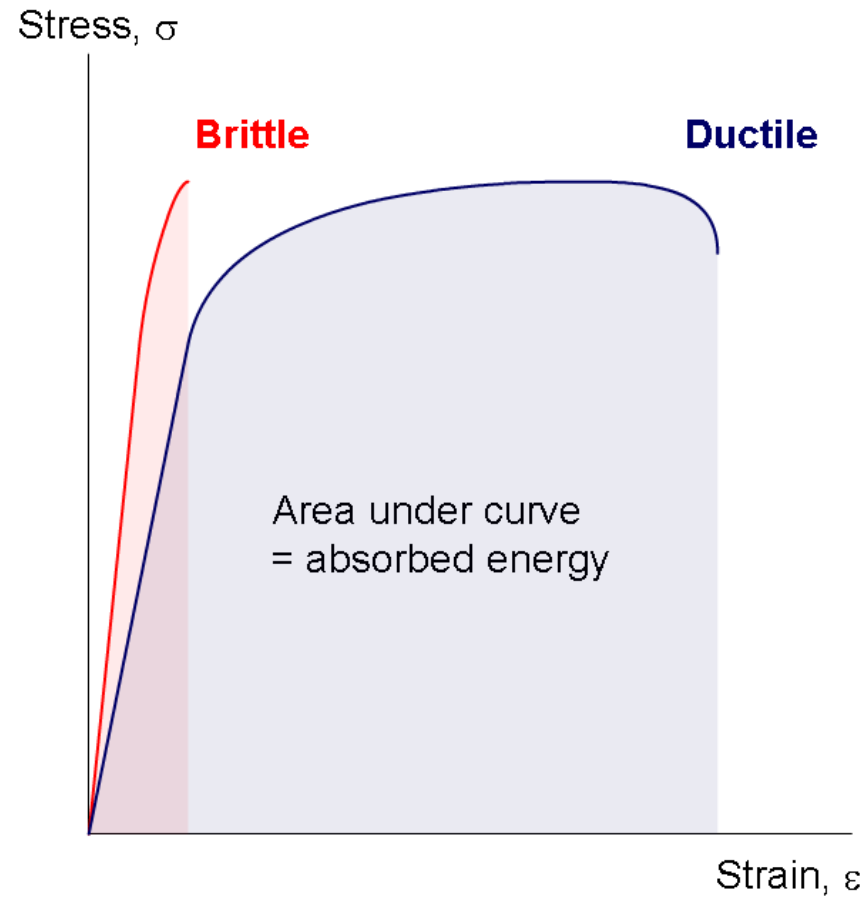


$$U_r = \int_0^{\epsilon_y} \sigma d\epsilon$$

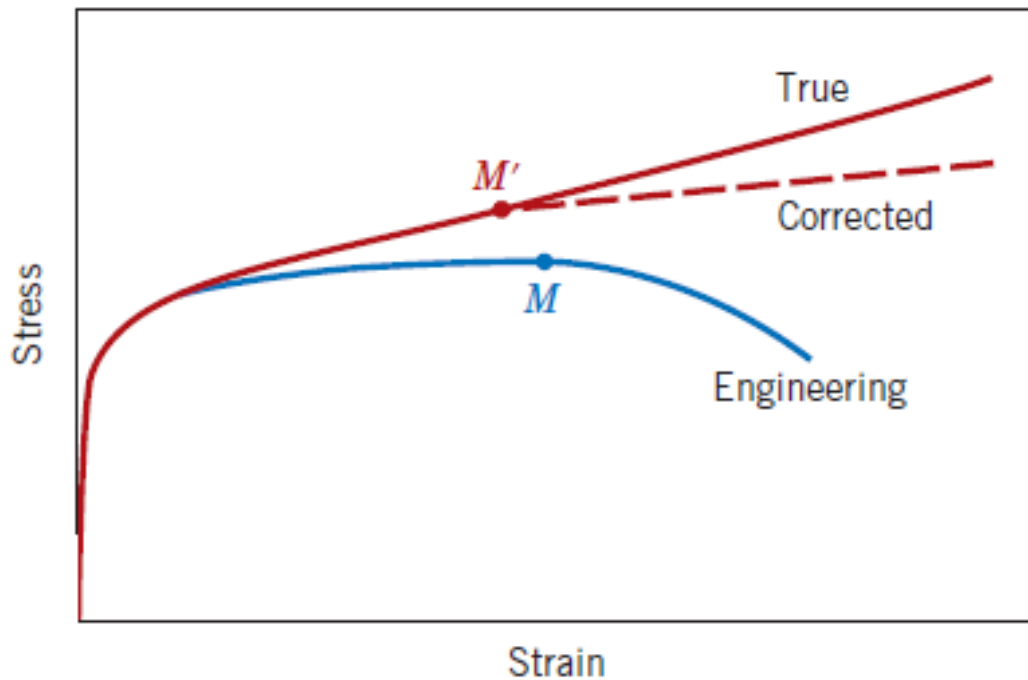
$$U_r = \frac{1}{2} \sigma_y \epsilon_y$$

$$U_r = \frac{1}{2} \sigma_y \epsilon_y = \frac{1}{2} \sigma_y \left( \frac{\sigma_y}{E} \right) = \frac{\sigma_y^2}{2E}$$

# [ Tenacidade ]



# Tensão e Deformação Verdadeiras em Tração



p/ metais:  $\sigma_T = K\epsilon_T^n$

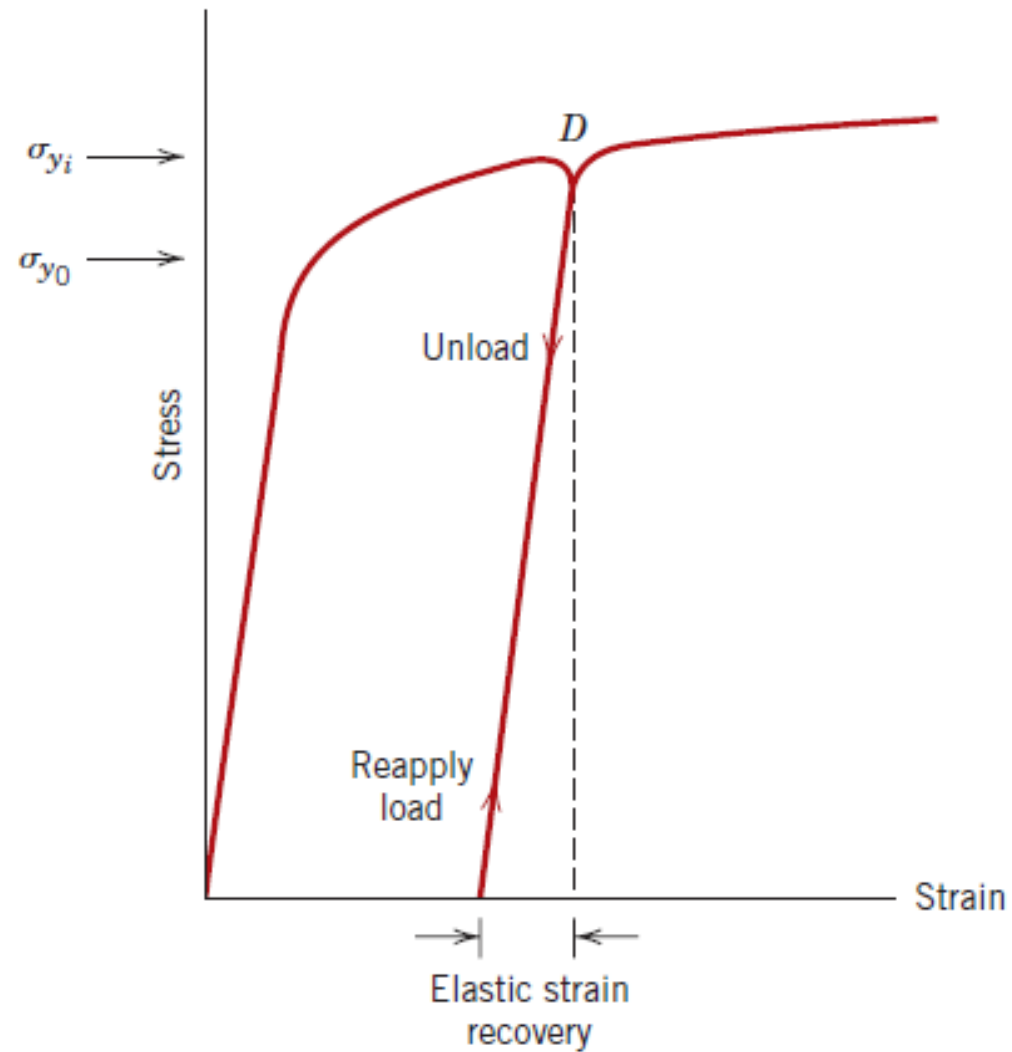
$$\sigma_T = \frac{F}{A_i}$$

$$\epsilon_T = \ln \frac{l_i}{l_0}$$

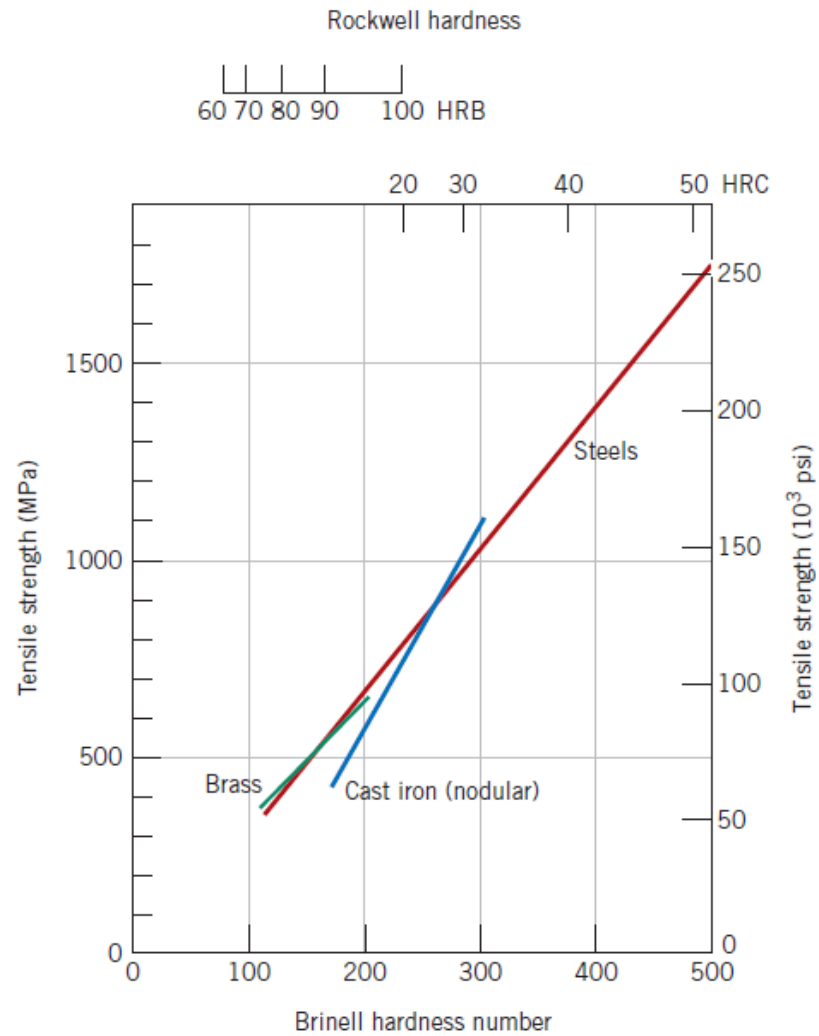
$$\sigma_T = \sigma(1 + \epsilon)$$

$$\epsilon_T = \ln(1 + \epsilon)$$

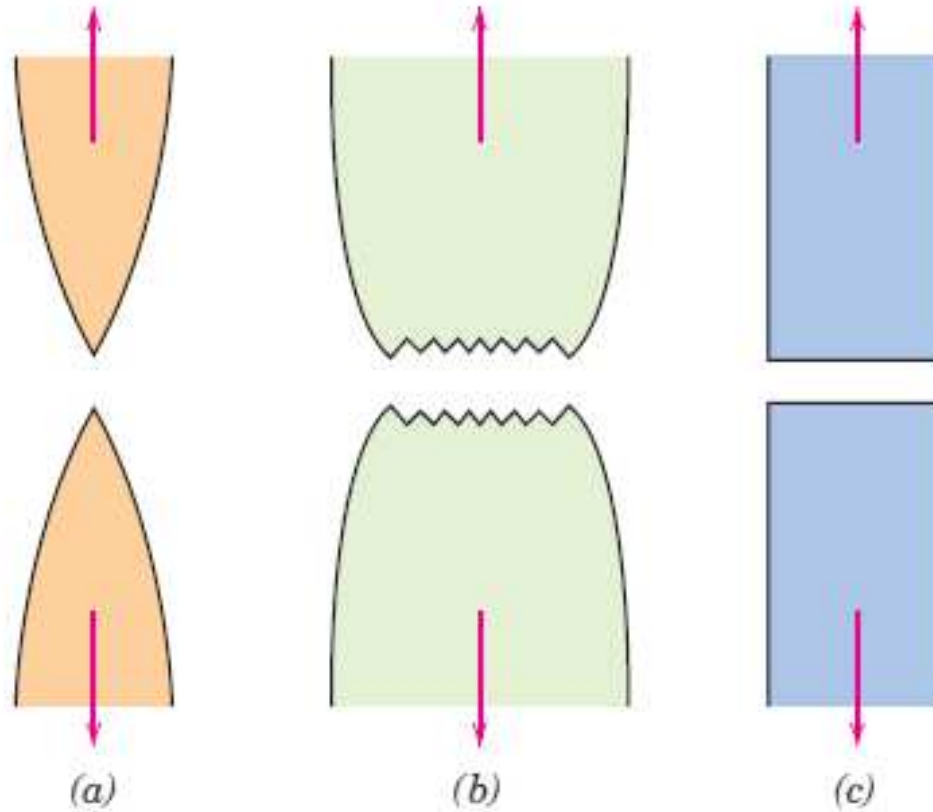
# [ Encruamento de metais ]



# [ Durezza ]

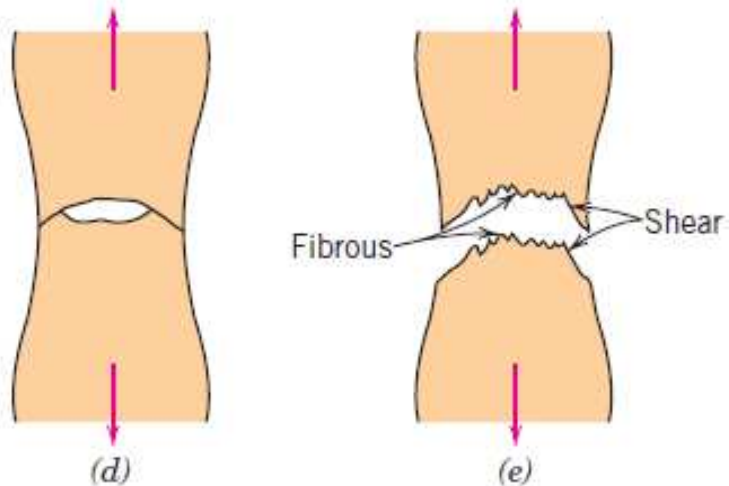
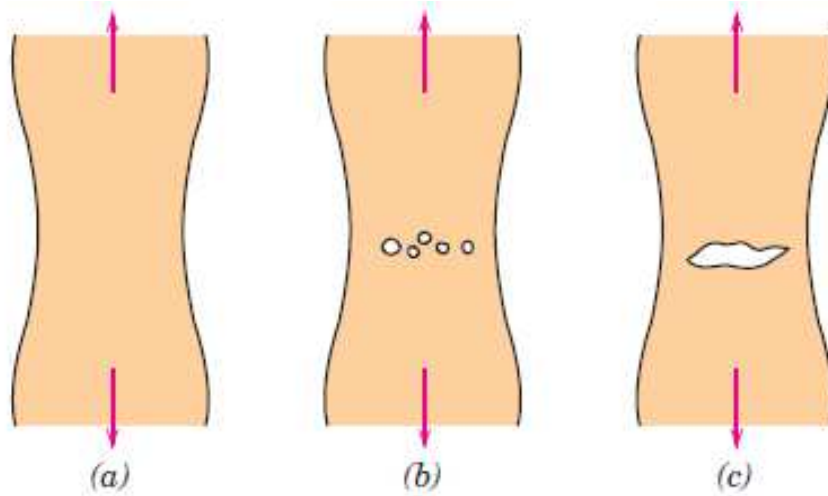


# [ Fratura dúctil ou frágil ]

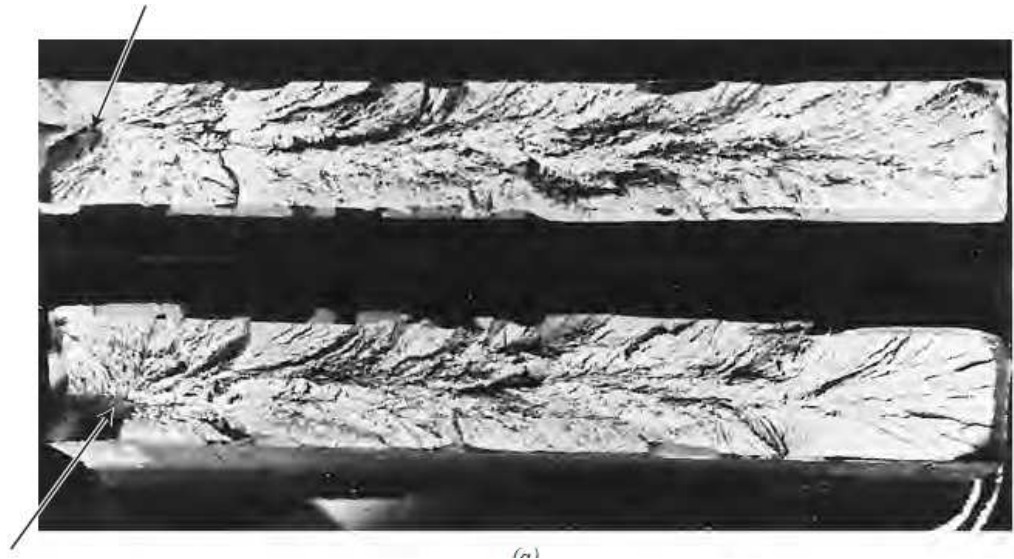




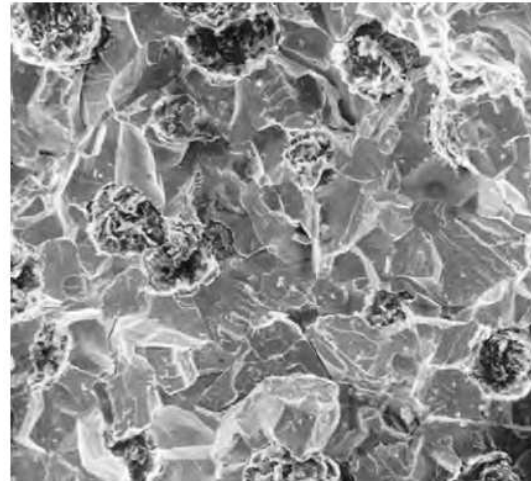
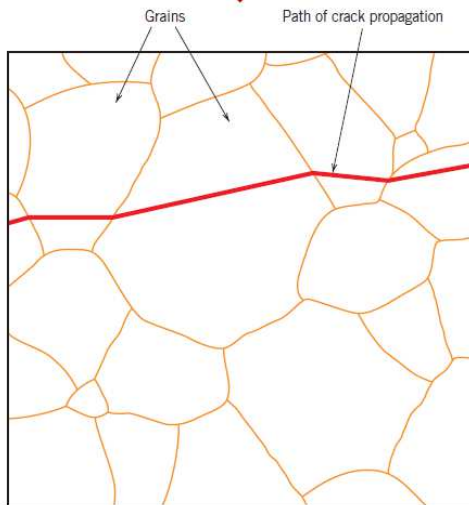
# [ Fratura “taça – cone” (dúctil) ]



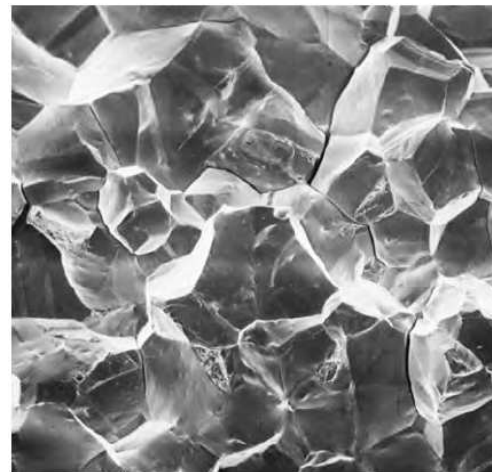
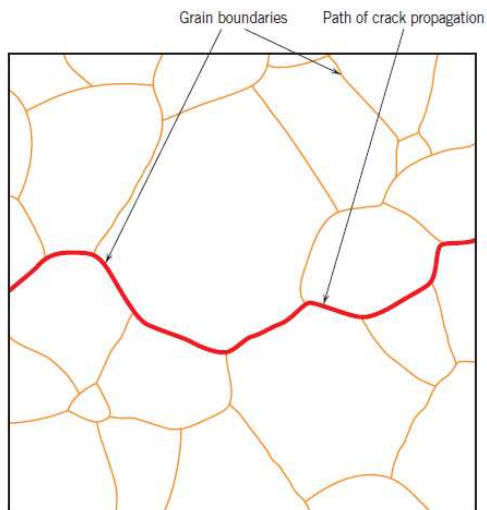
# [ Fratura frágil ]



# Fratura Transgranular e Intergranular

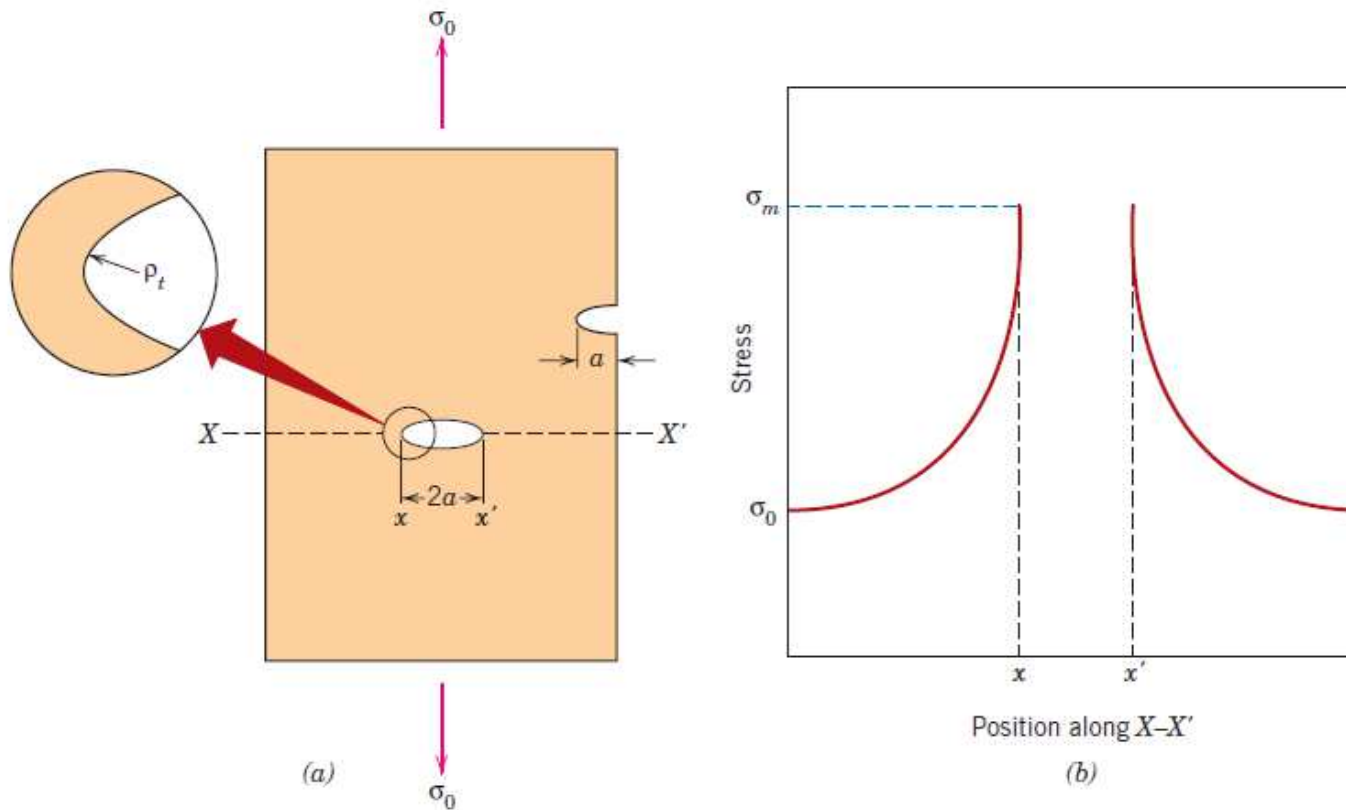


Transgranular



Intergranular

# [ Concentração de tensão ]

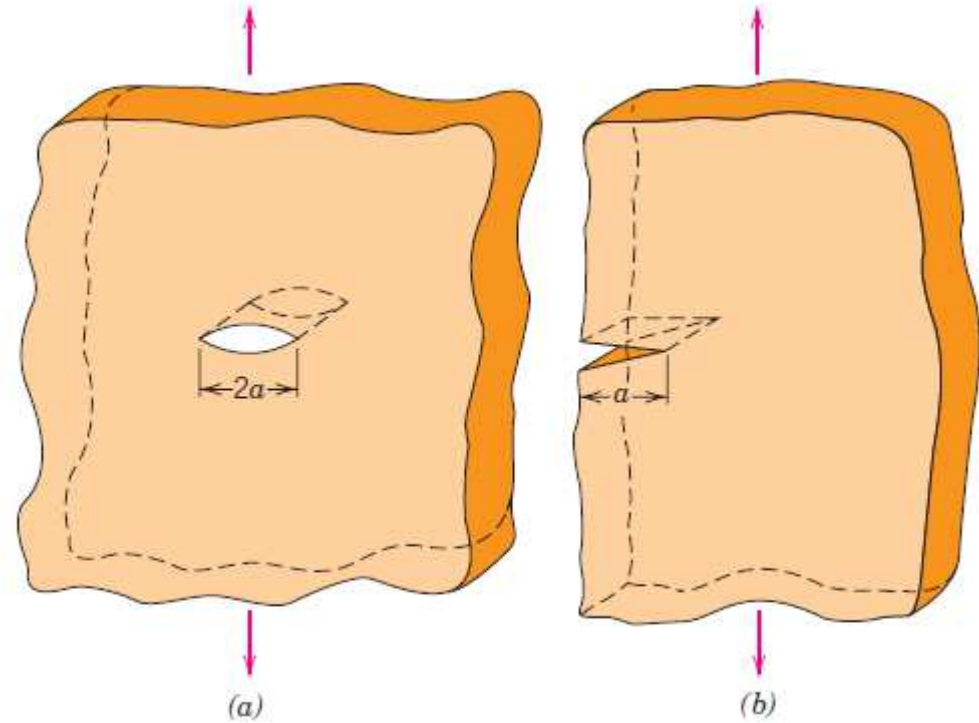


$$\sigma_m = 2\sigma_0 \left( \frac{a}{\rho_t} \right)^{1/2} \quad K_t = \frac{\sigma_m}{\sigma_0} = 2 \left( \frac{a}{\rho_t} \right)^{1/2}$$

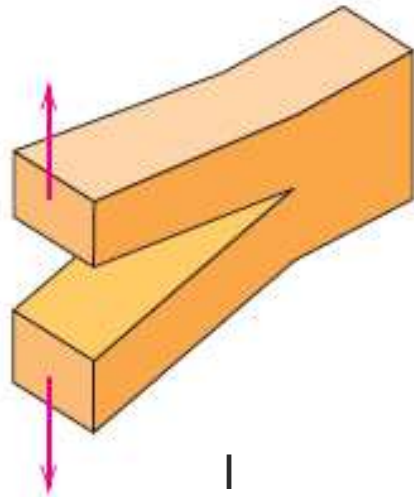
# [ Tenacidade à fratura ]

$$\sigma_c = \left( \frac{2E\gamma_s}{\pi a} \right)^{1/2}$$

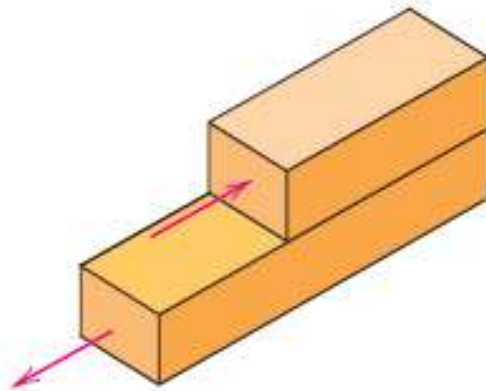
$$K_c = Y\sigma_c \sqrt{\pi a}$$



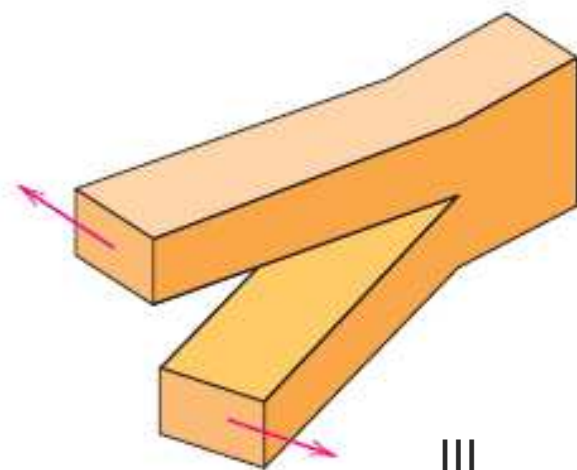
# [ Modos de fratura ]



I



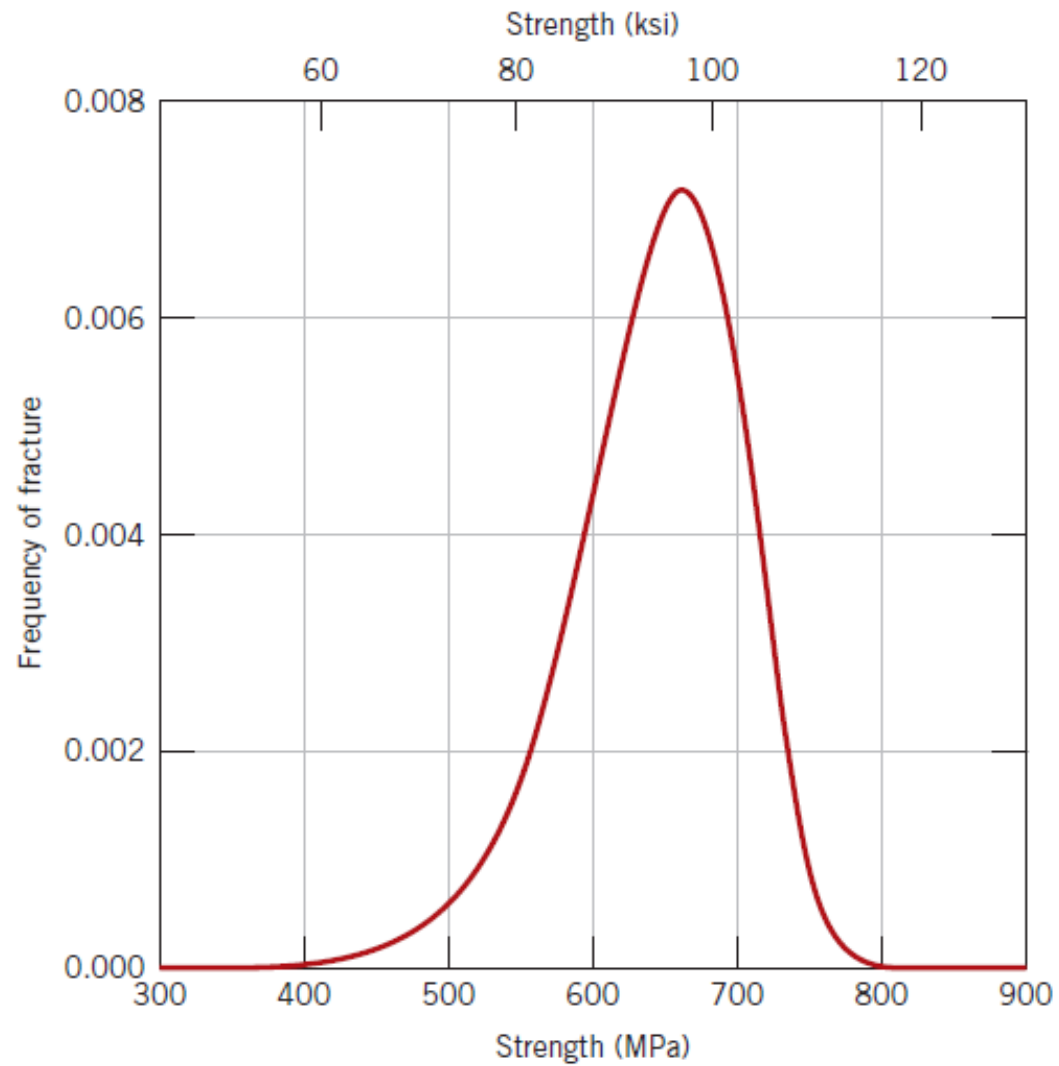
II



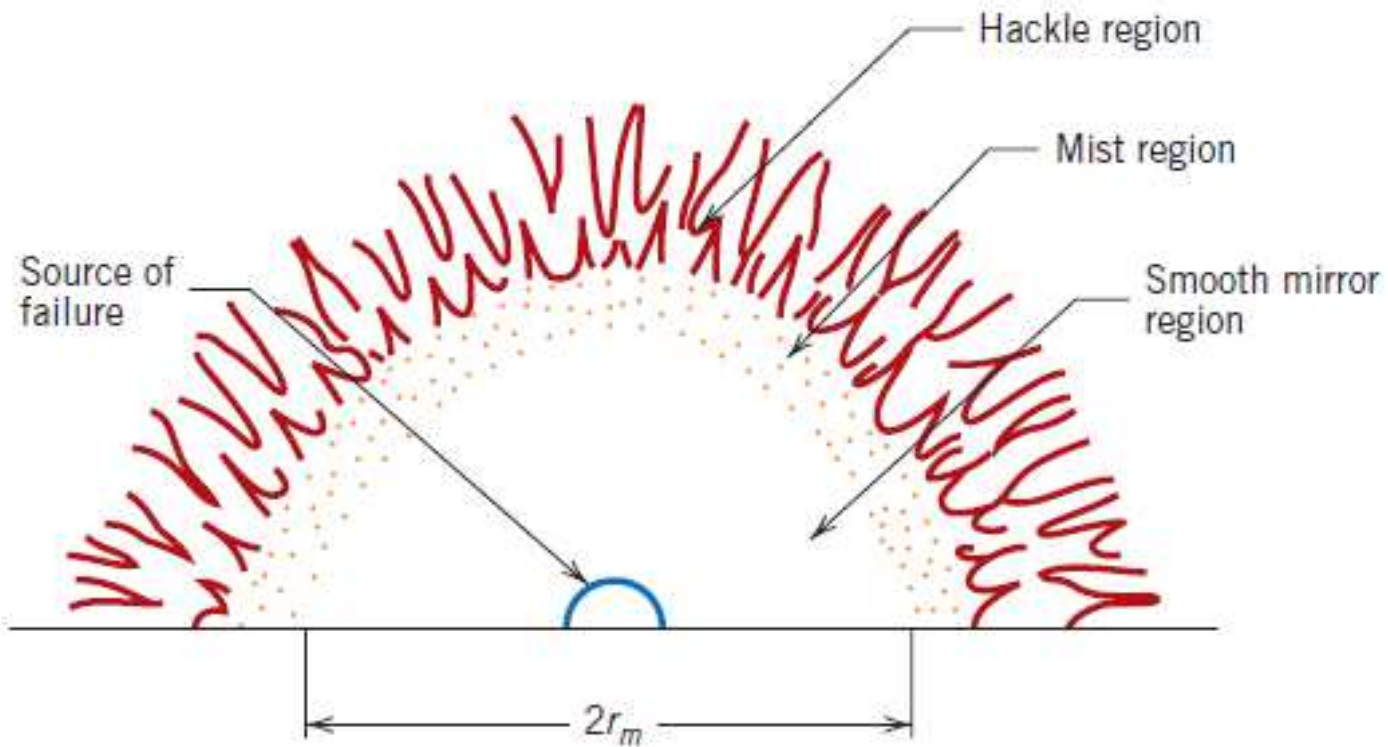
III

$$K_{Ic} = Y\sigma\sqrt{\pi a}$$

# [ Distribuição estatística ]

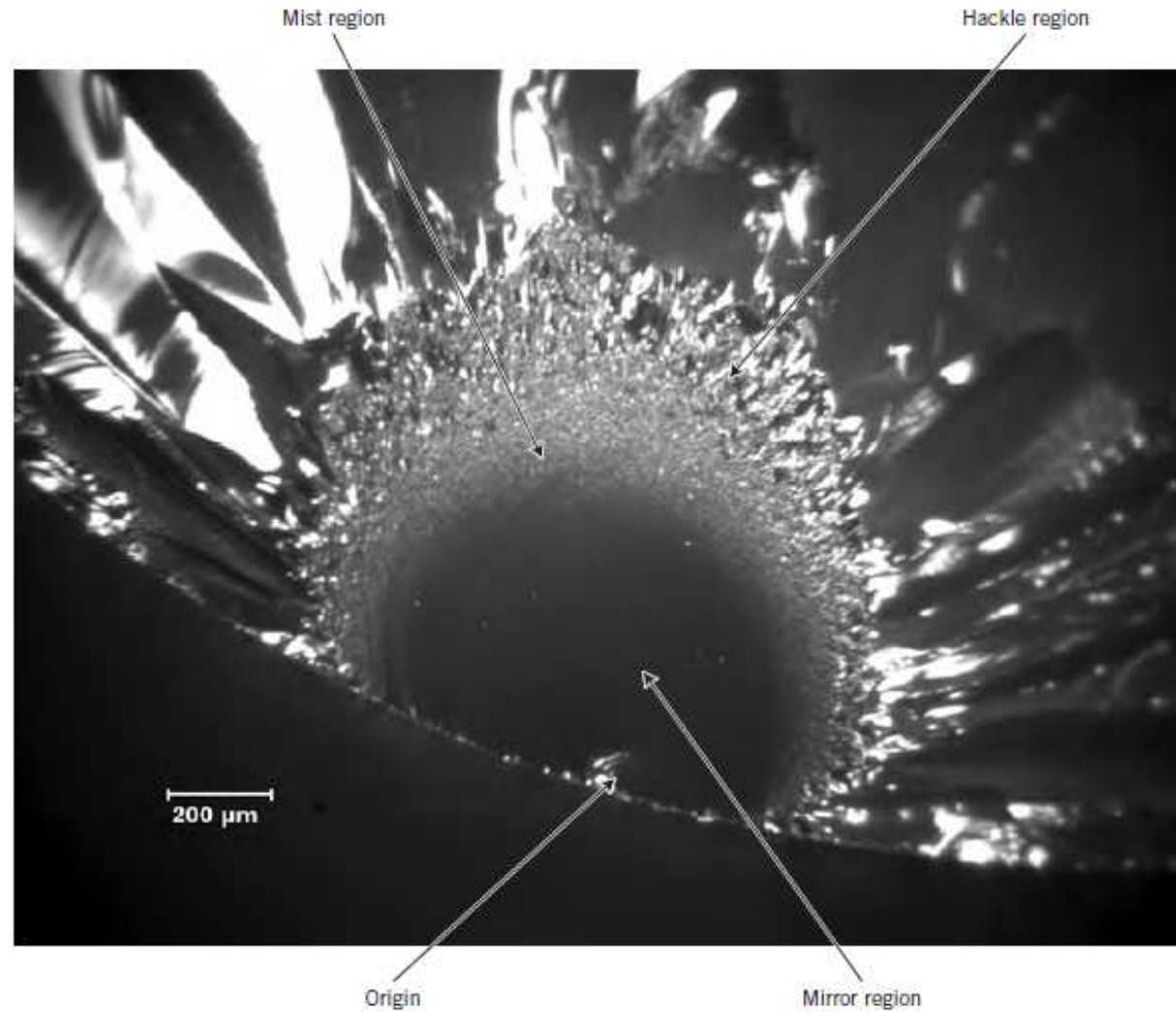


# [ Fratura frágil de cerâmicas ]

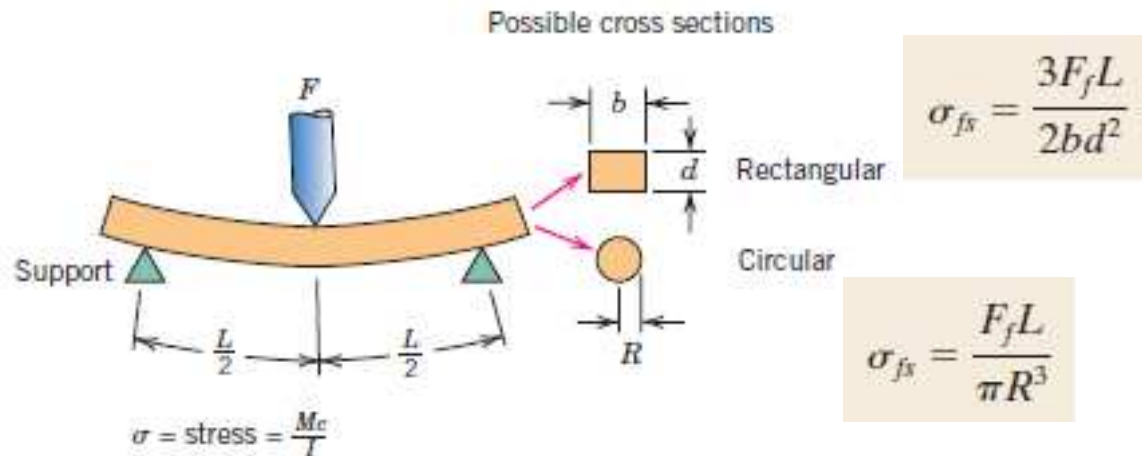




# [ Fratura frágil de cerâmicas ]



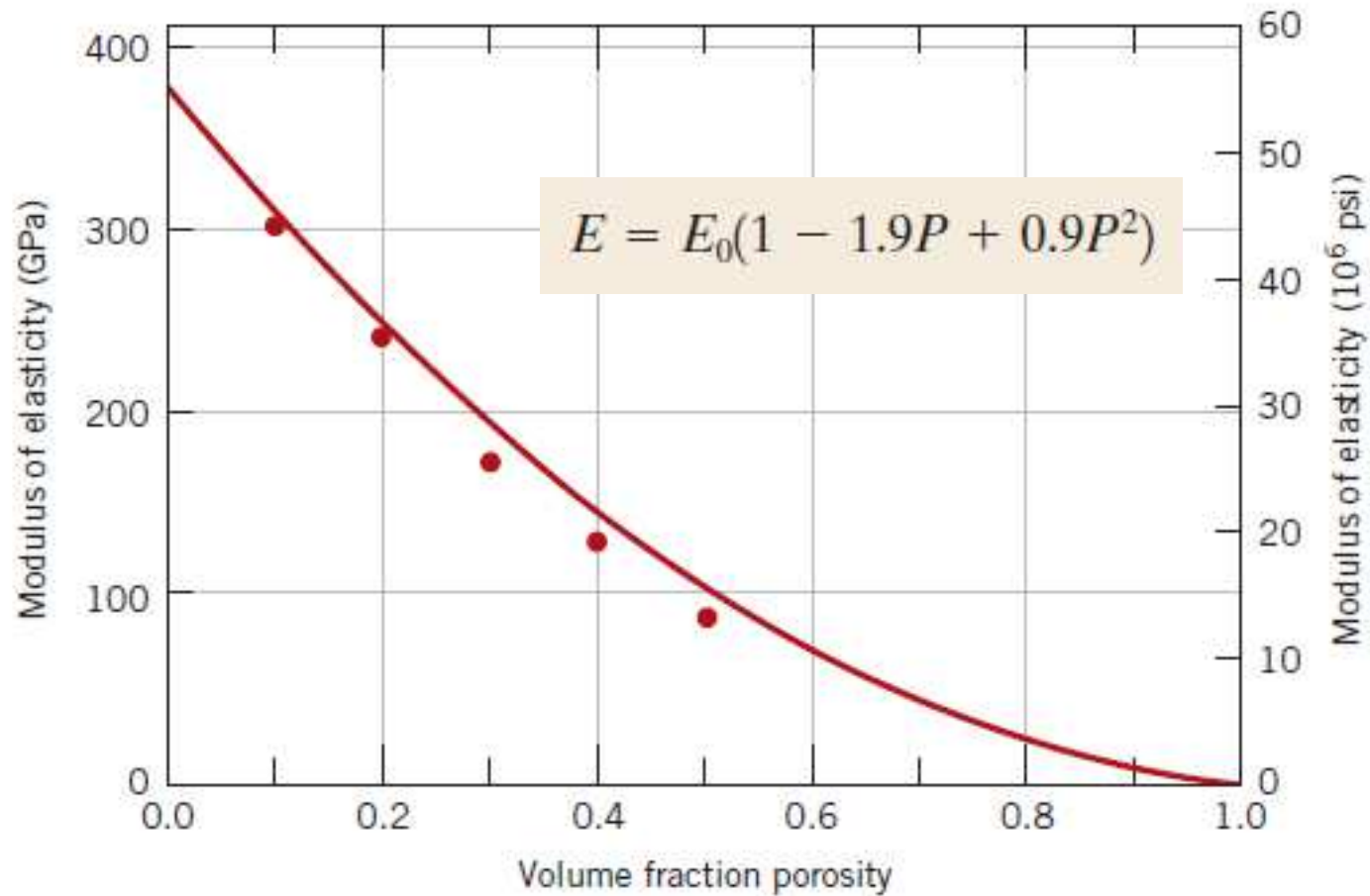
# [ Ensaio de Flexão ]



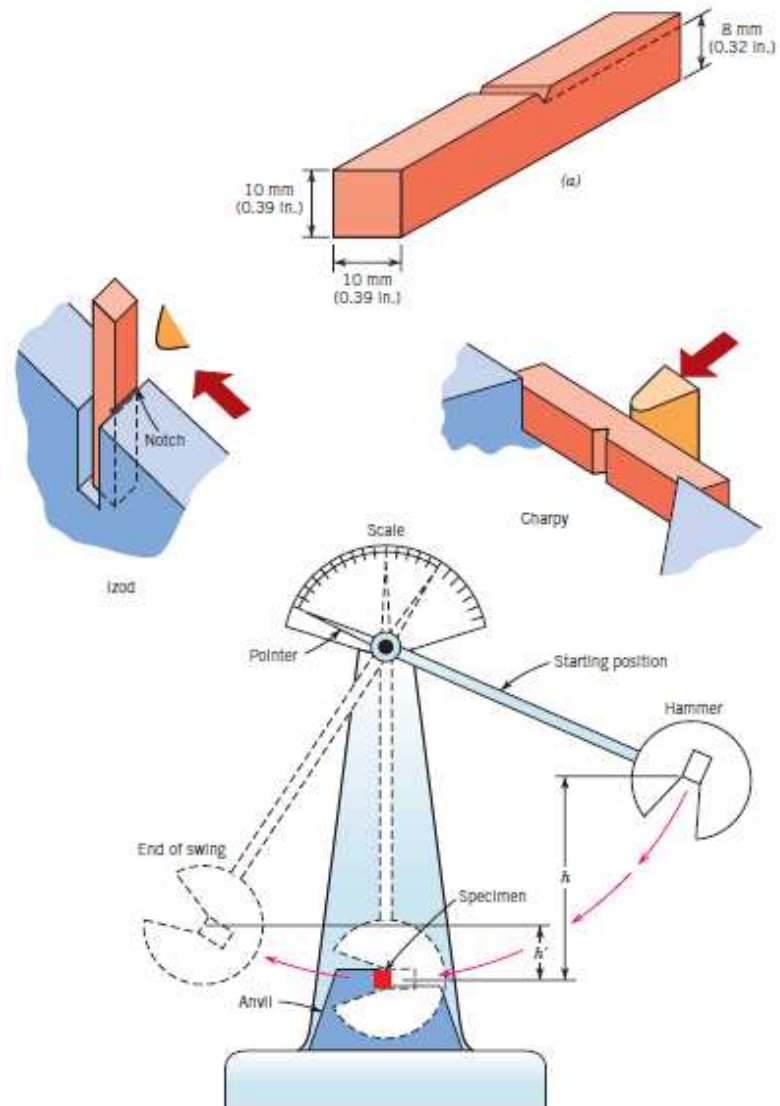
where  $M$  = maximum bending moment  
 $c$  = distance from center of specimen to outer fibers  
 $I$  = moment of inertia of cross section  
 $F$  = applied load

	$\frac{M}{4}$	$\frac{c}{2}$	$\frac{I}{12}$	$\frac{\sigma}{2bd^2}$
Rectangular	$\frac{FL}{4}$	$\frac{d}{2}$	$\frac{bd^3}{12}$	$\frac{3FL}{2bd^2}$
Circular	$\frac{FL}{4}$	$R$	$\frac{\pi R^4}{4}$	$\frac{FL}{\pi R^3}$

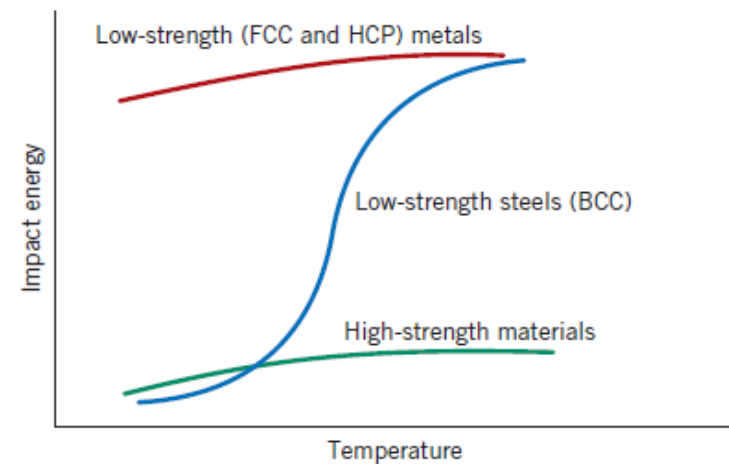
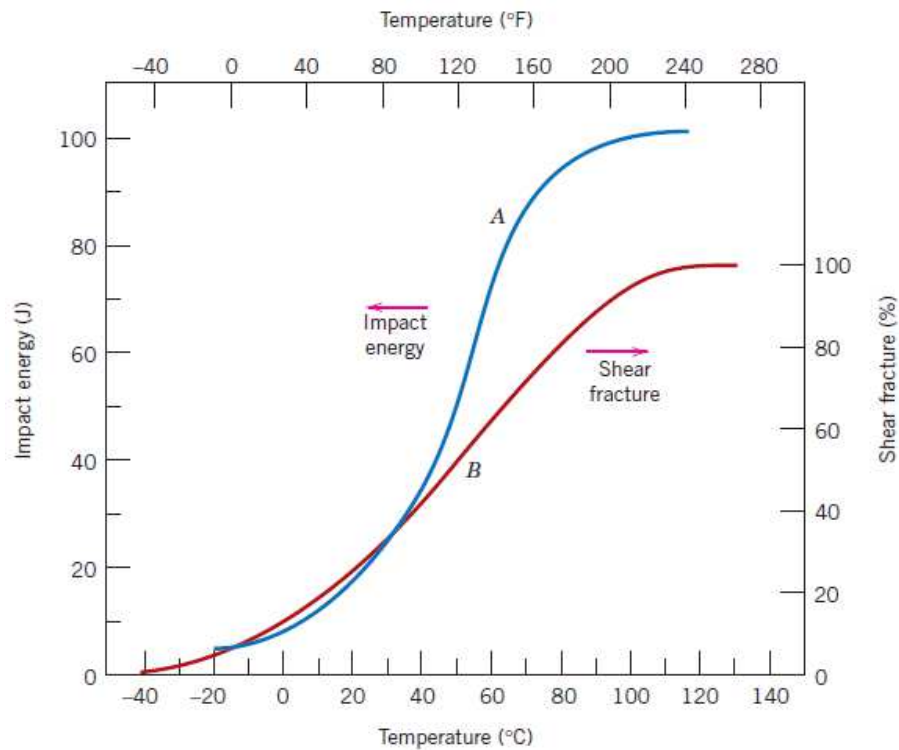
# Influência de Porosidade em Cerâmicas



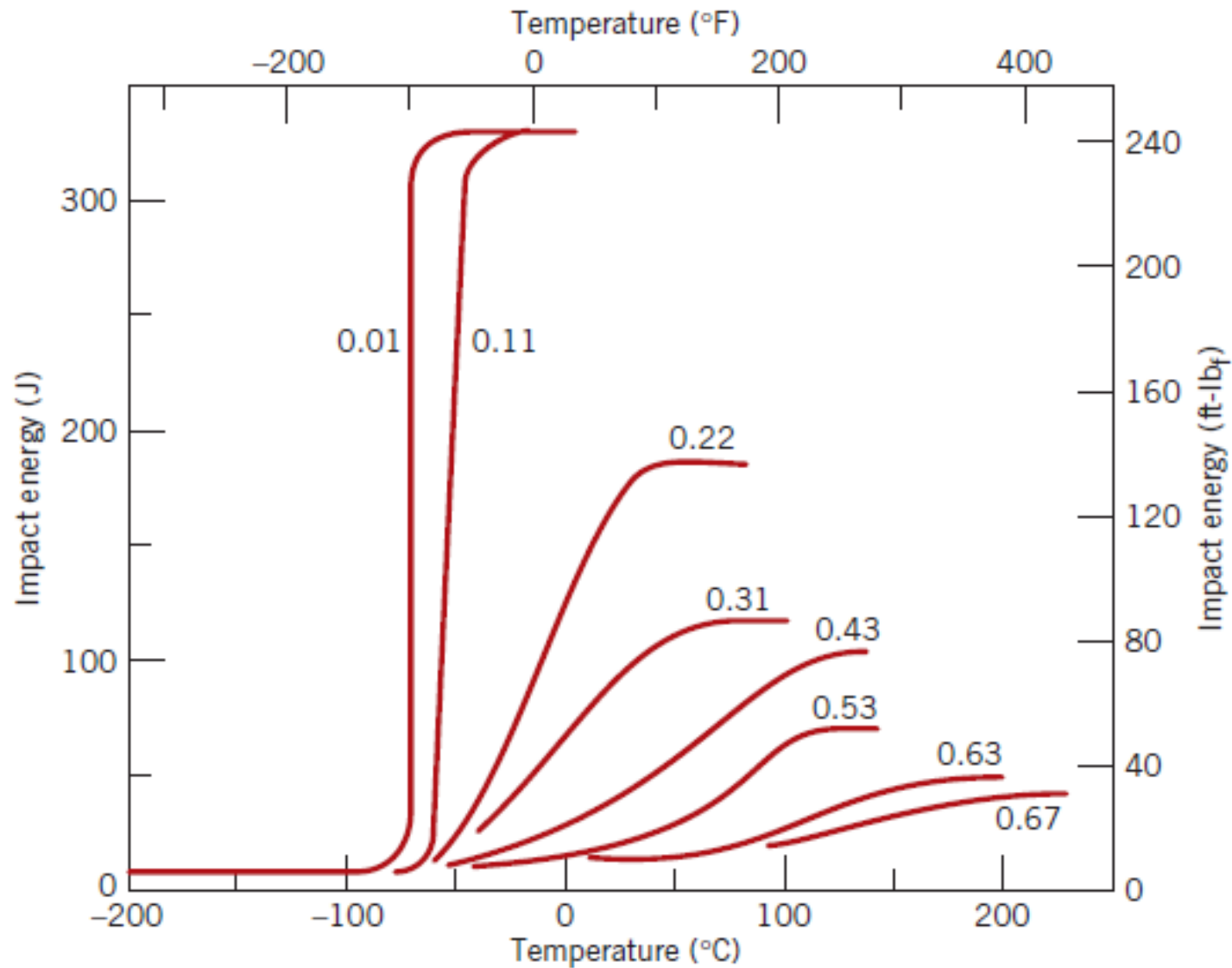
# [ Ensaaios de impacto ]



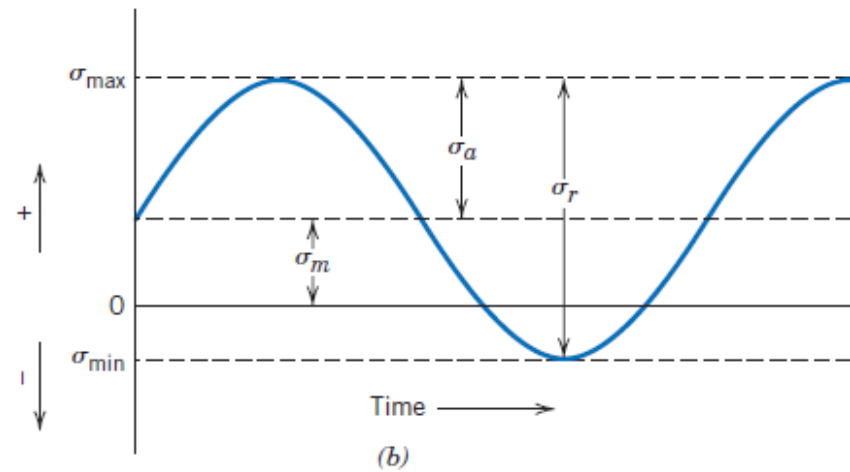
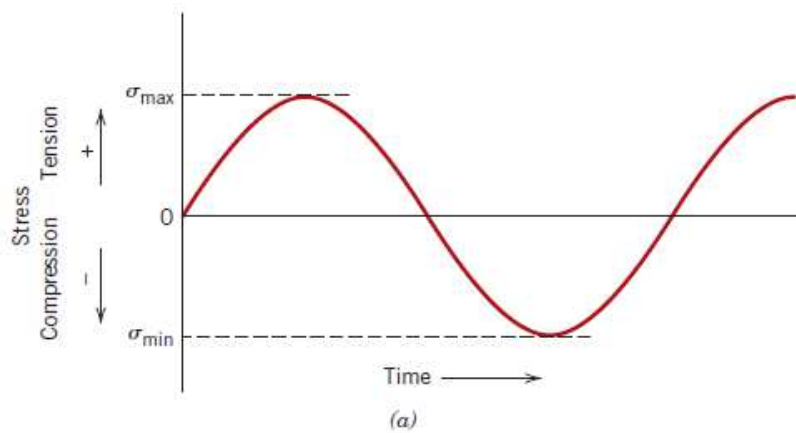
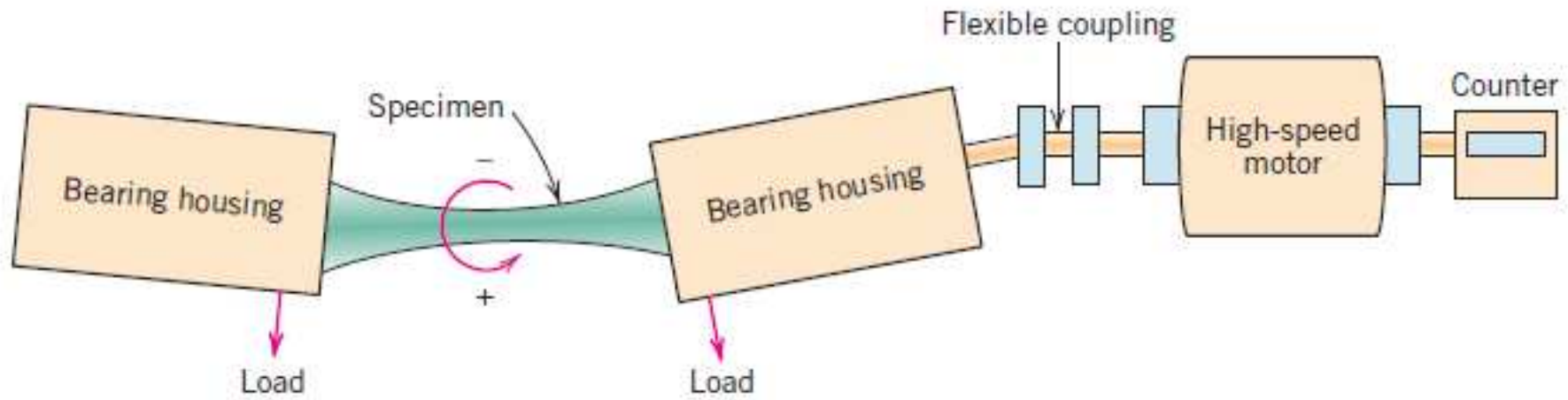
# [ Transição frágil x dúctil ]



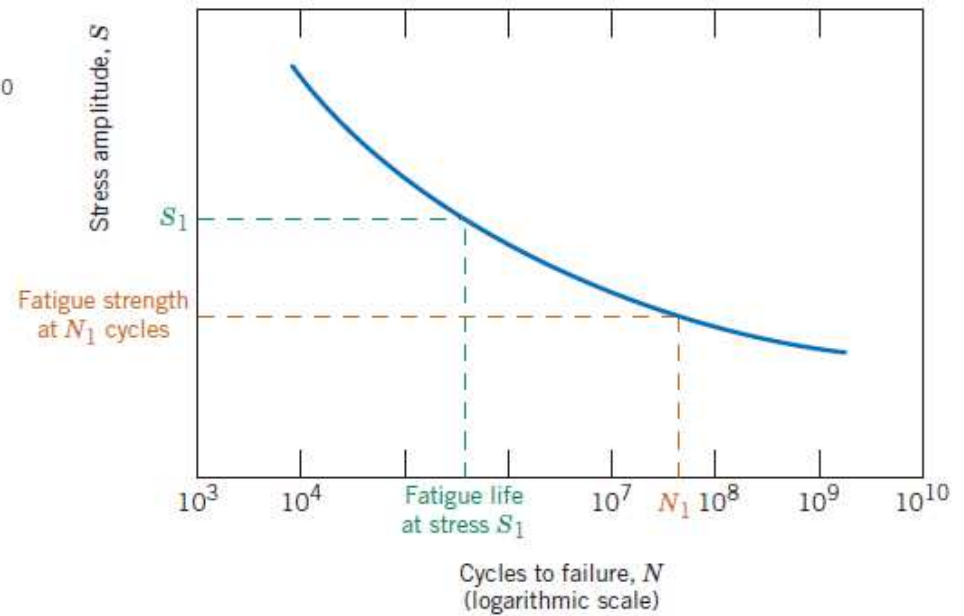
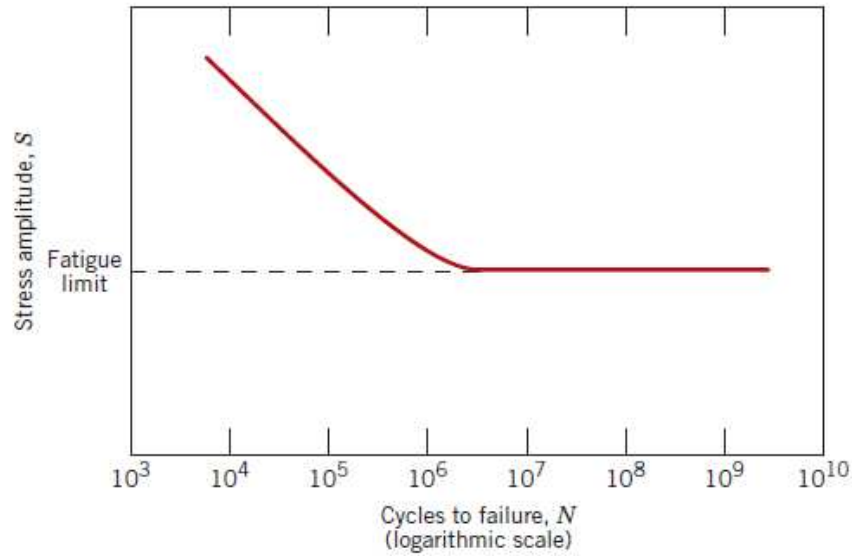
# [ Transição frágil x dúctil ]



# [ Fadiga ]

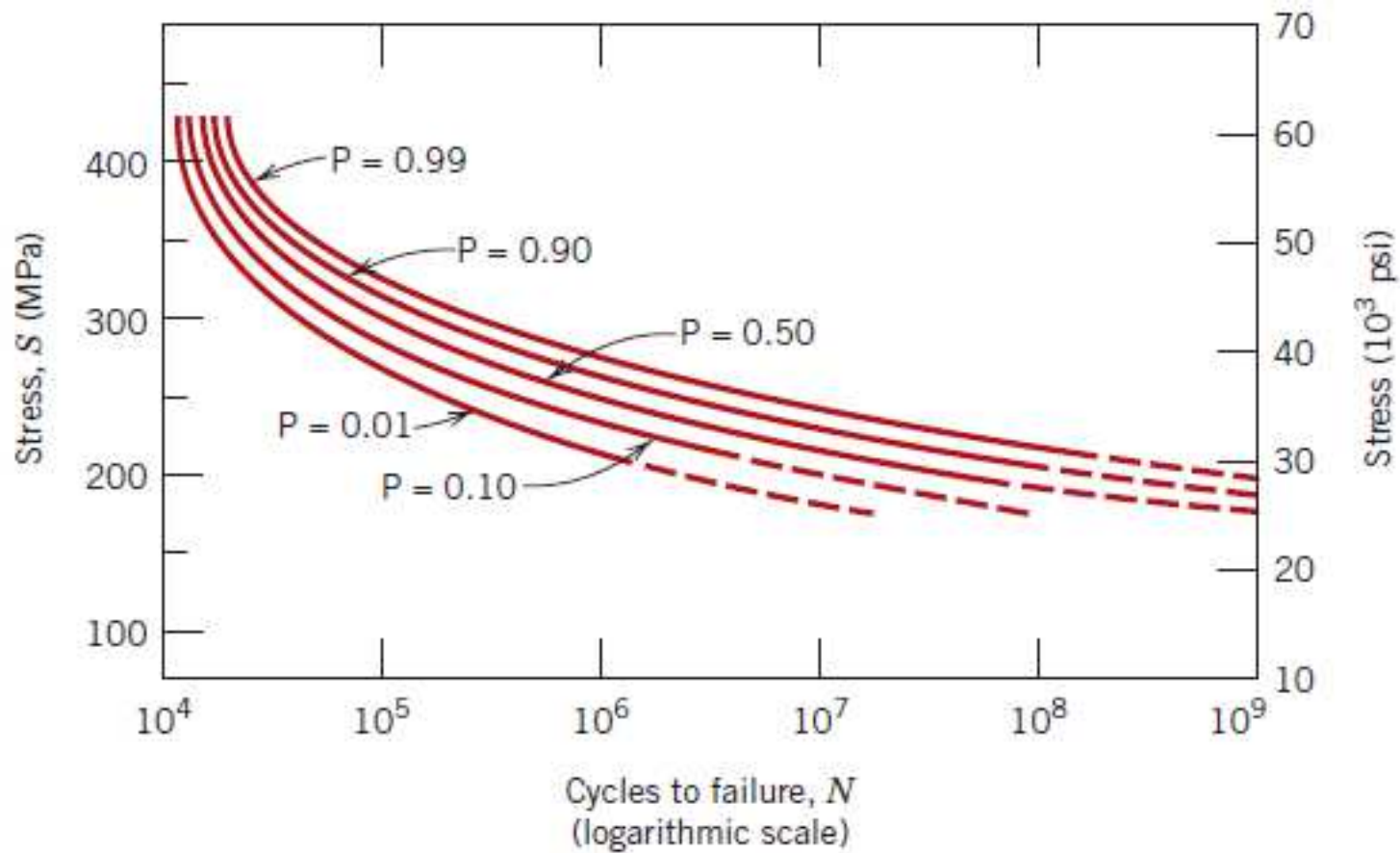


# [ Fadiga ]

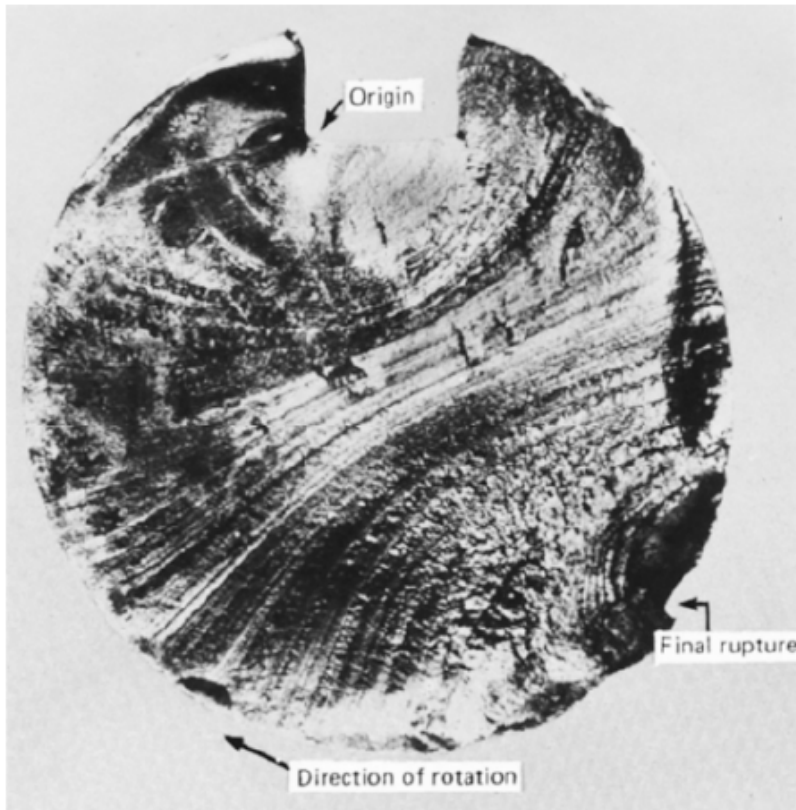




# [ Fadiga ]



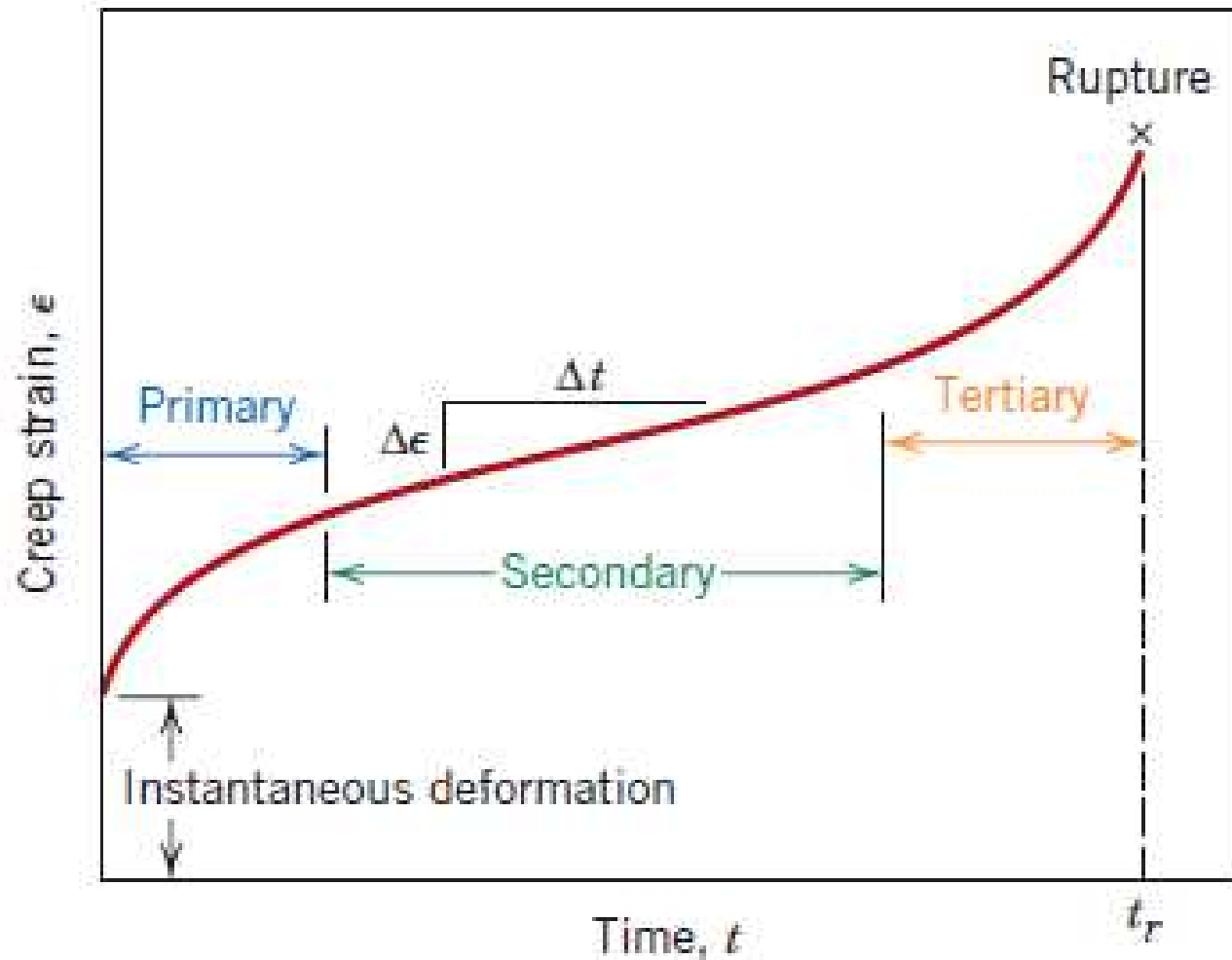
# Nucleação e Propagação da Trinca



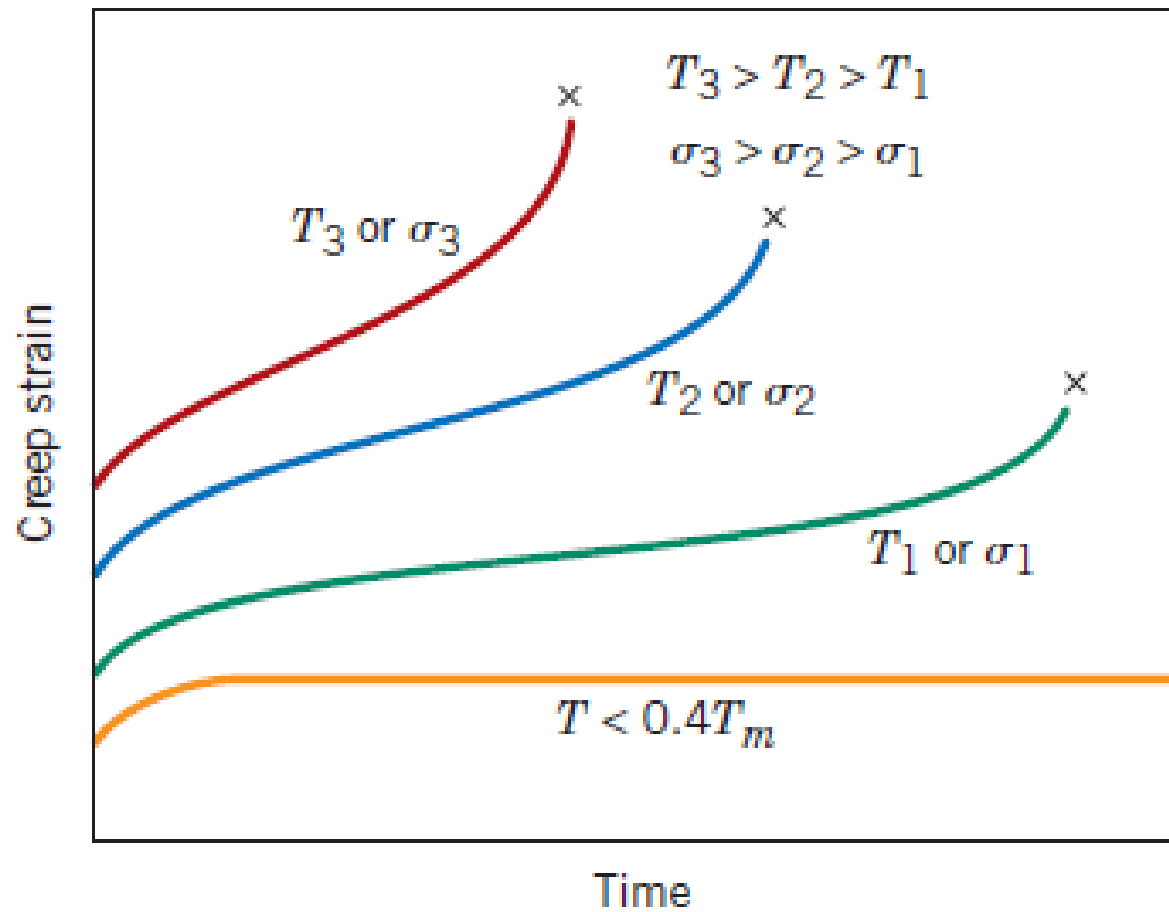
MEV



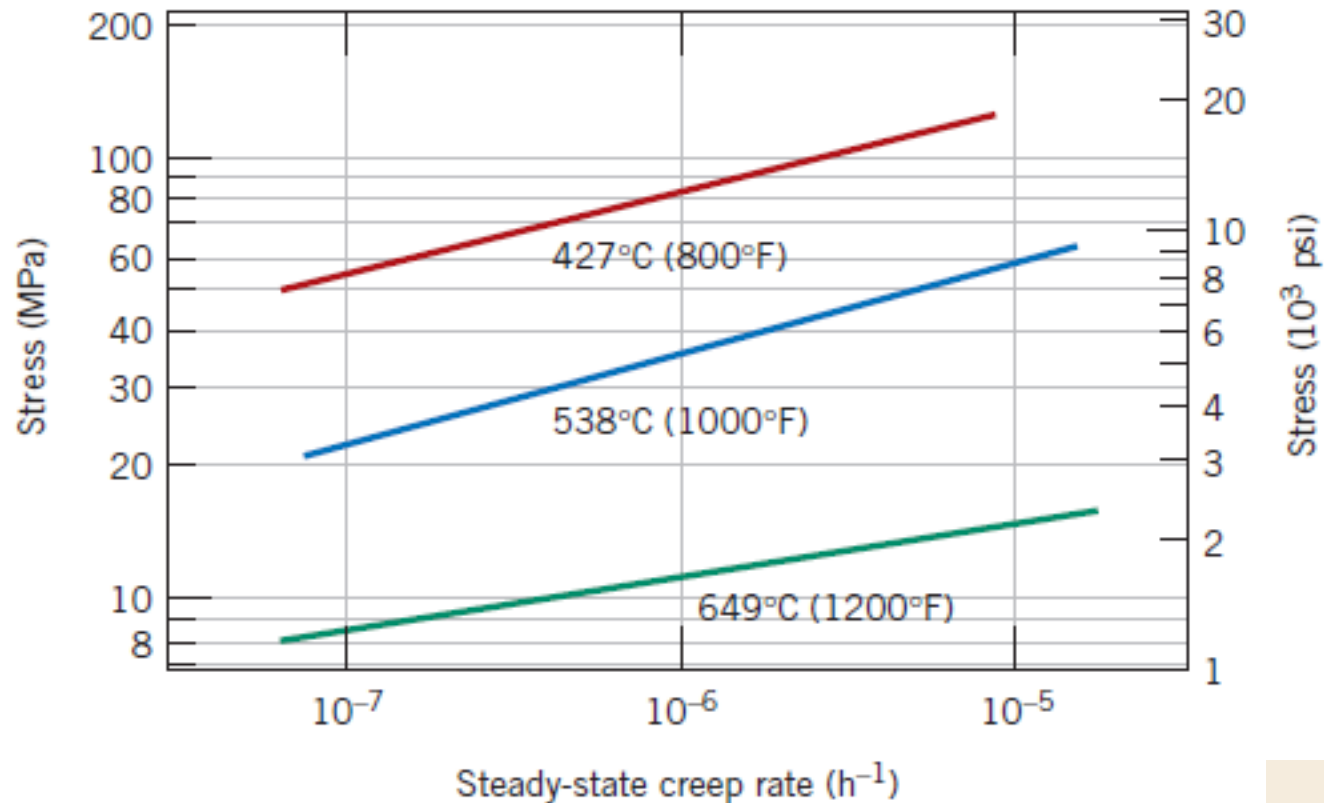
# [ Fluência ]



# [ Fluência ]



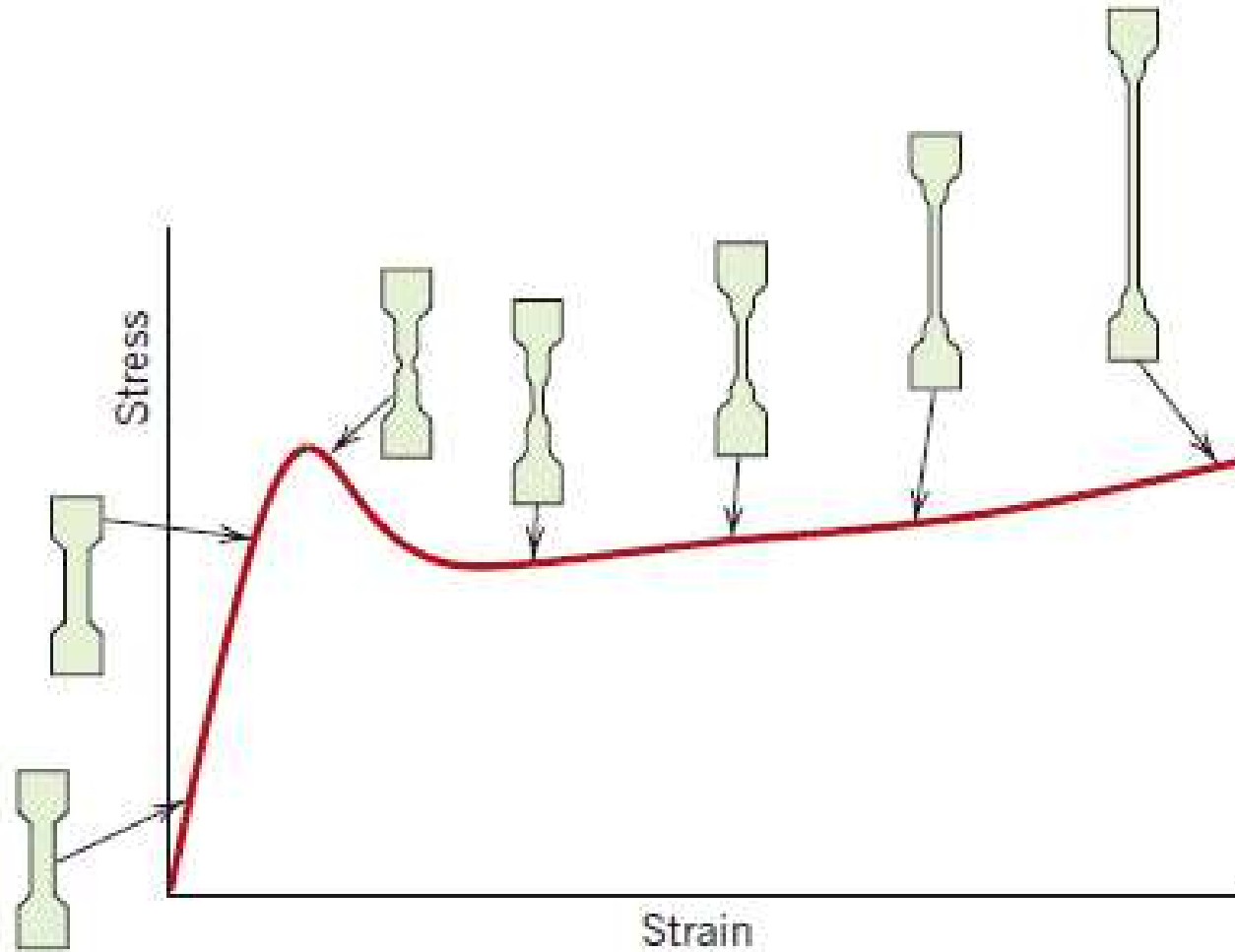
# [ Fluência ]



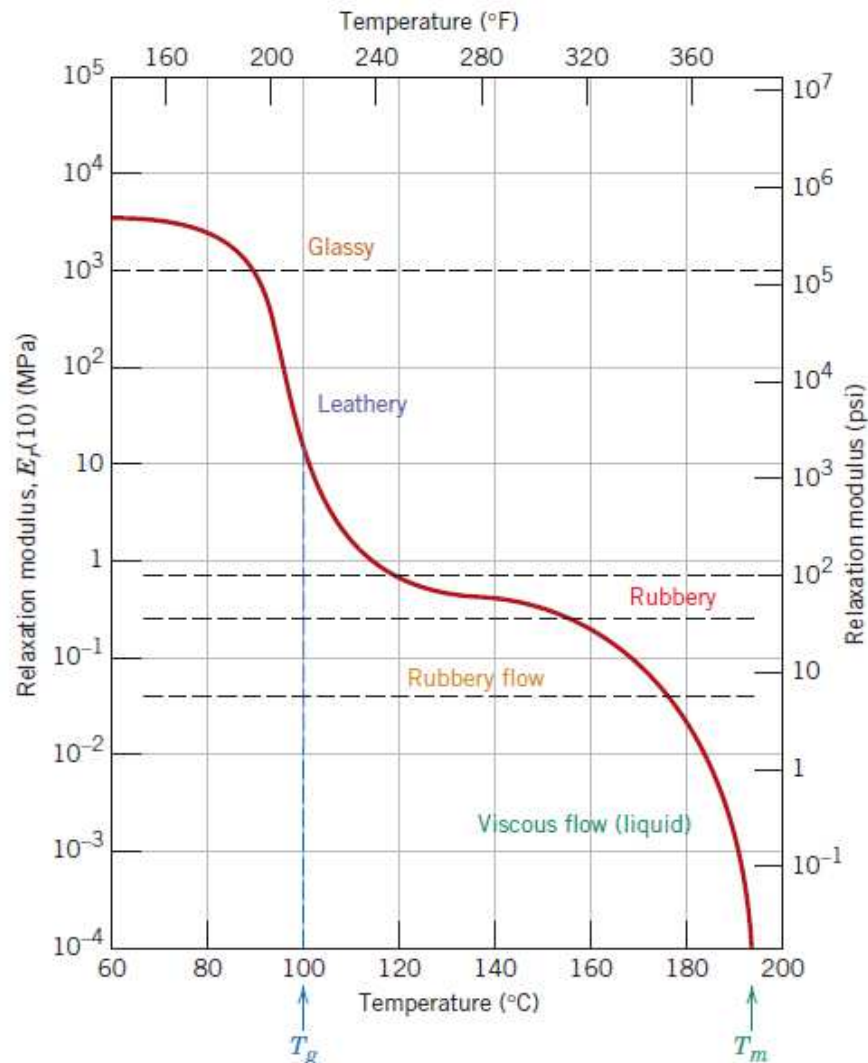
$$\dot{\epsilon}_s = K_1 \sigma^n$$

$$\dot{\epsilon}_s = K_2 \sigma^n \exp\left(-\frac{Q_c}{RT}\right)$$

# Viscoelasticidade em Polímeros

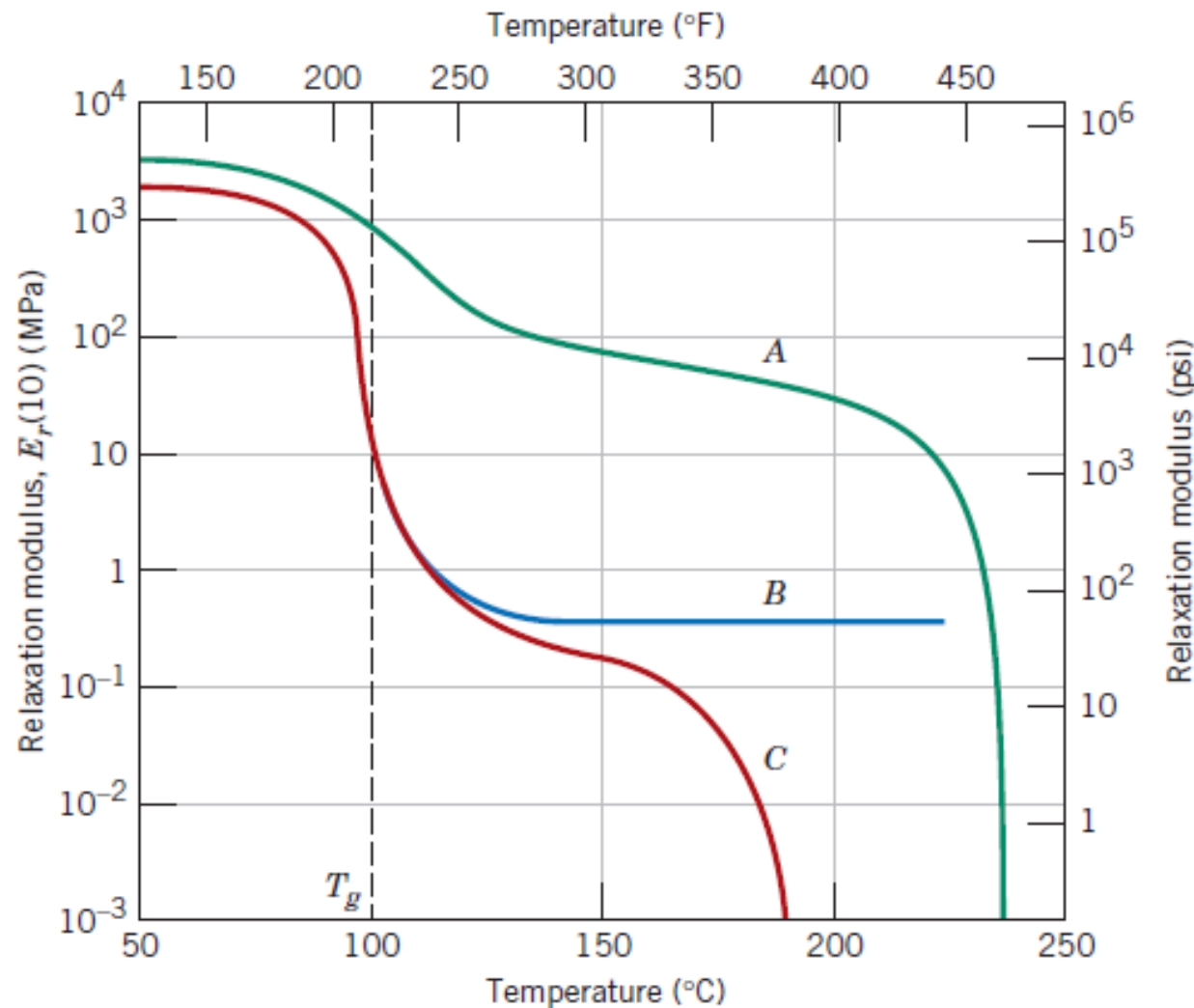


# [ Relaxação em Polímeros ]



$$E_r(t) = \frac{\sigma(t)}{\epsilon_0}$$

# Módulo de Relaxação x Estrutura



**Figure 15.8**

Logarithm of the relaxation modulus versus temperature for crystalline isotactic (curve A), lightly crosslinked atactic (curve B), and amorphous (curve C) polystyrene. (From A. V. Tobolsky, *Properties and Structures of Polymers*. Copyright © 1960 by John Wiley & Sons, New York. Reprinted by permission of John Wiley & Sons, Inc.)