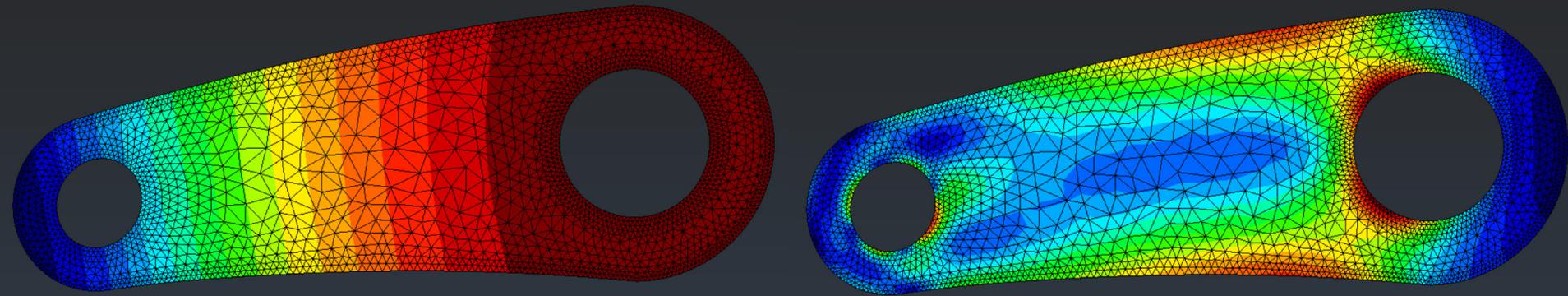


ELEMENTOS DE MÁQUINAS

ME5500



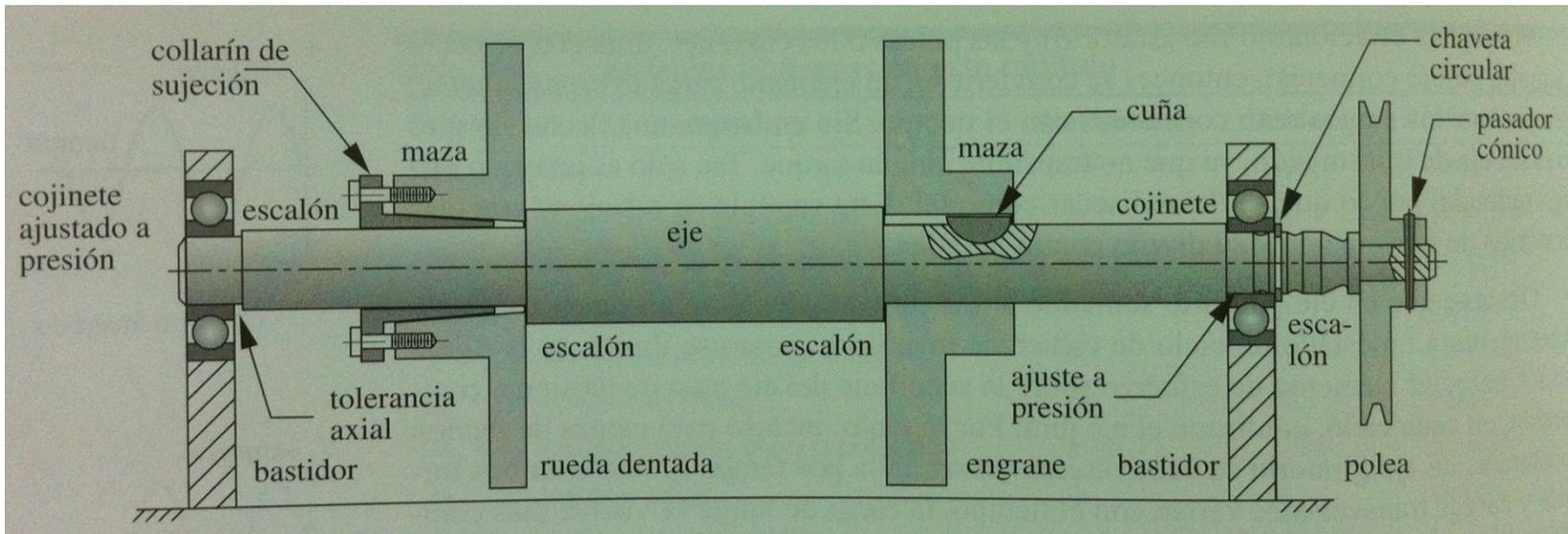
Alejandro Ortiz Bernardin

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www.camlab.cl/alejandro

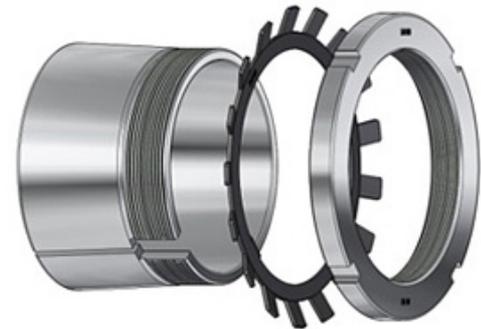
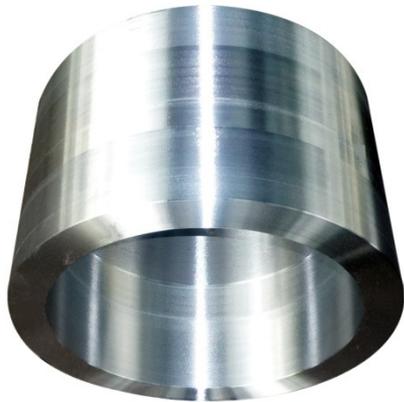
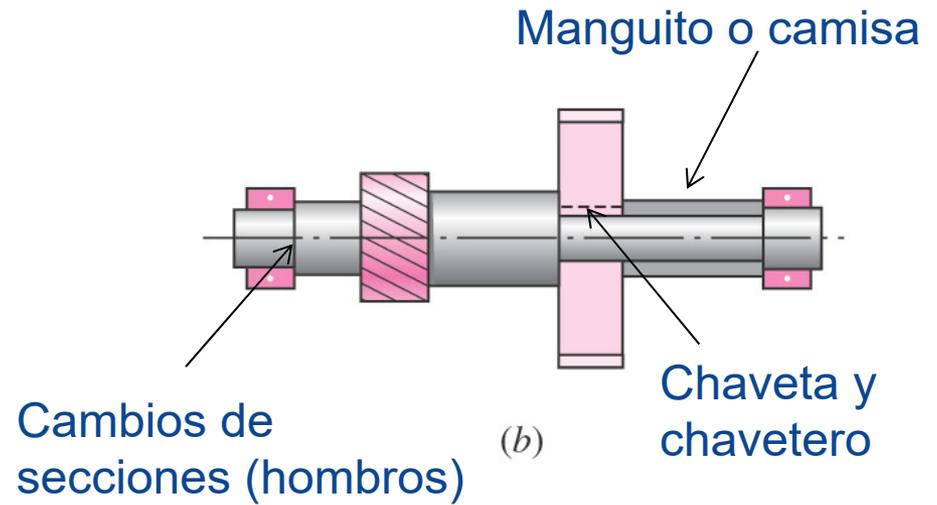
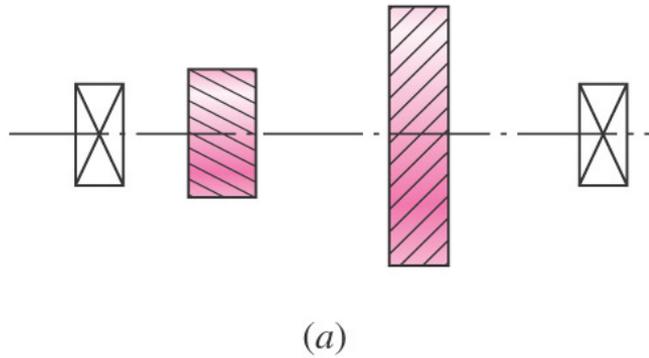
- I. Configuración de Ejes
- II. Fijación Axial de Componentes
- III. Soporte de Cargas Axiales
- IV. Elementos para Transmisión de Torque
- V. Acoplamiento entre Ejes
- VI. Diseño de Ejes por Esfuerzo
- VII. Diseño de Ejes por Deflexión
- VIII. Velocidad Crítica en Ejes

Configuración de Ejes

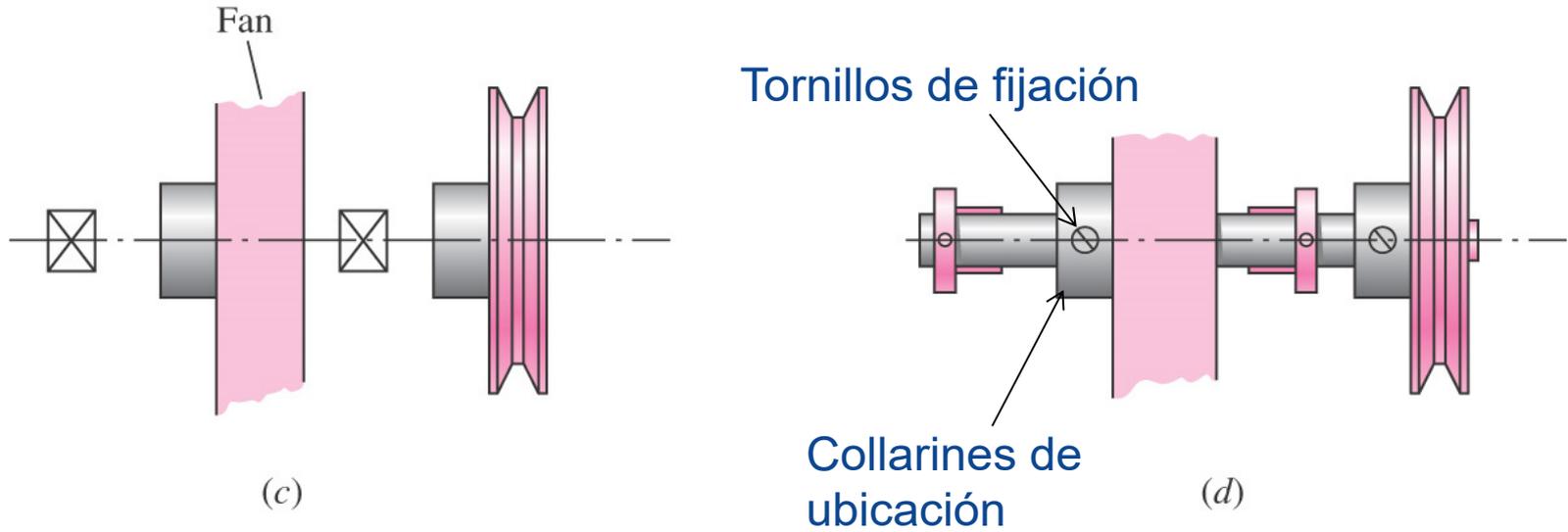


- Posicionamiento axial
- Soporte de cargas axiales
- Transmisión de torque
- Ensamble y desensamble

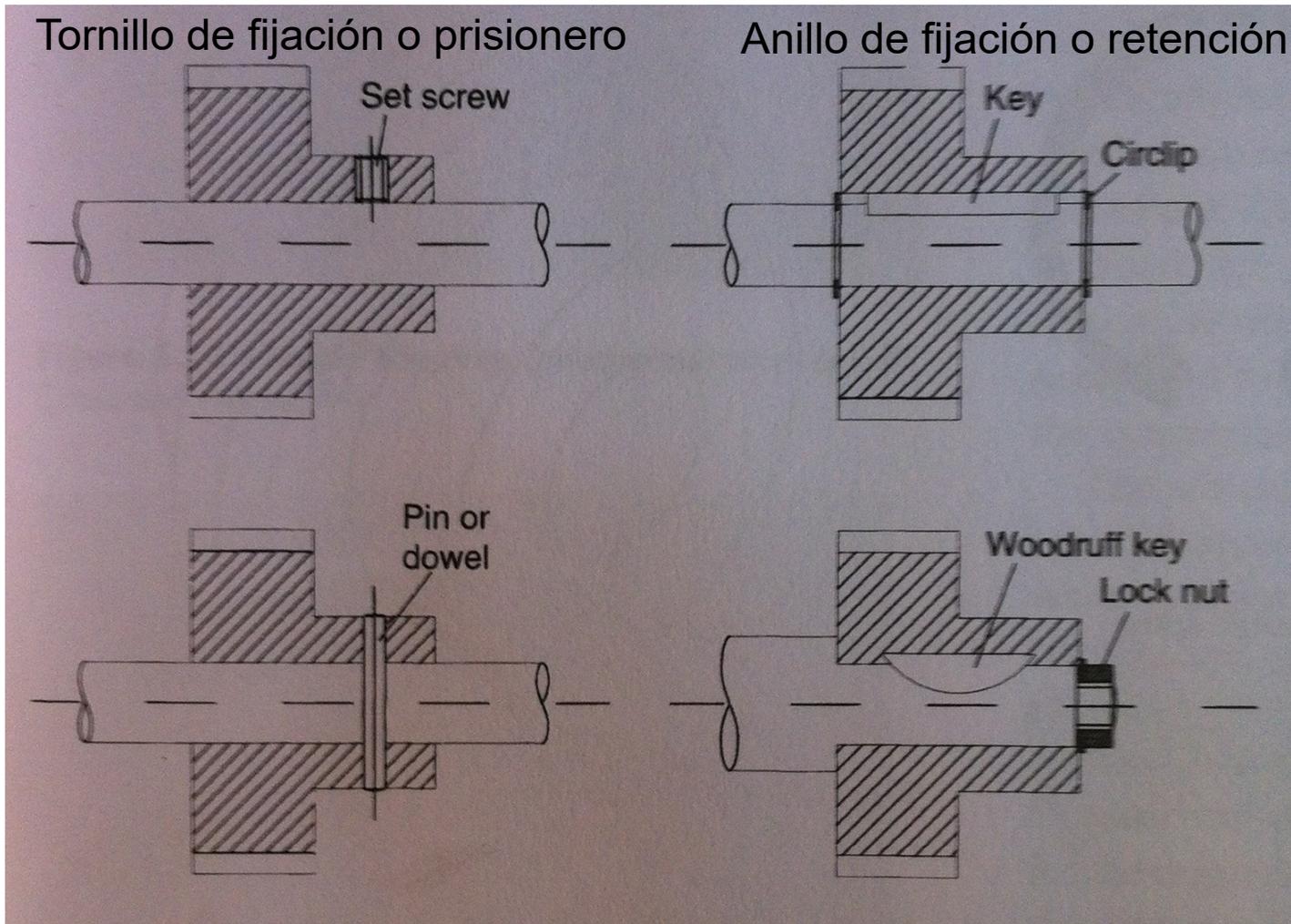
Fijación Axial de Componentes



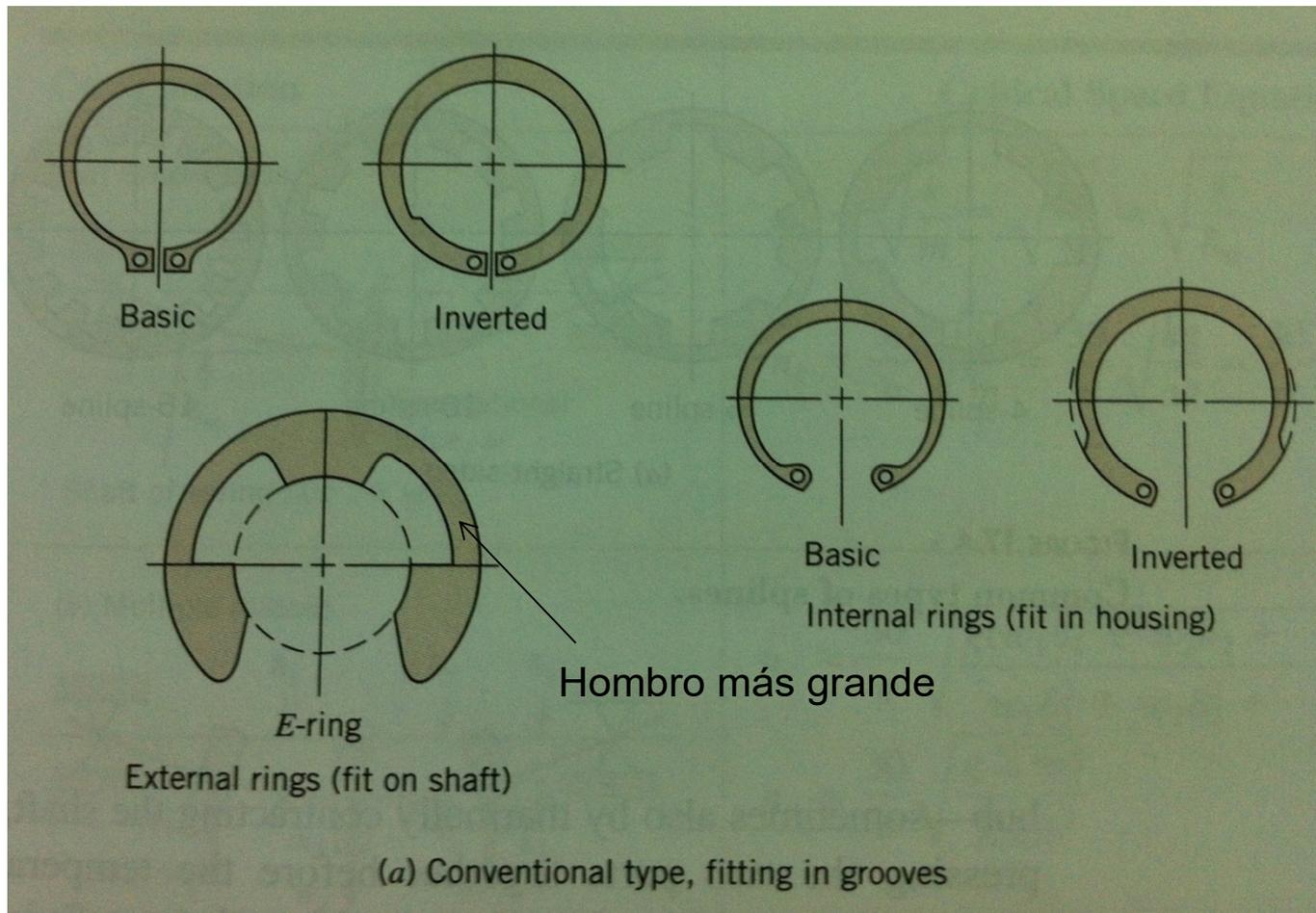
Fijación Axial de Componentes (Cont.)



Otros Elementos de Fijación

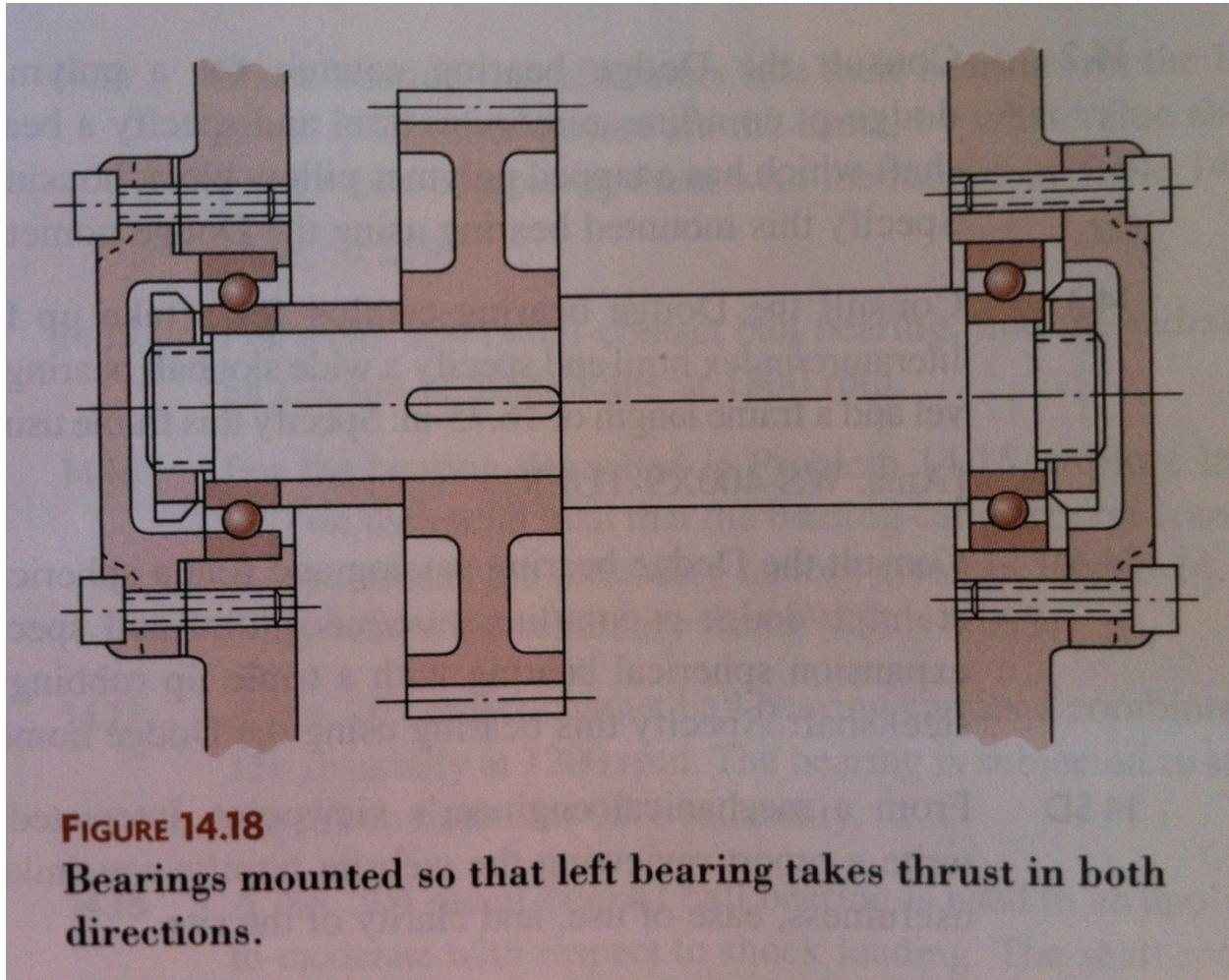


Otros Elementos de Fijación (Cont.)

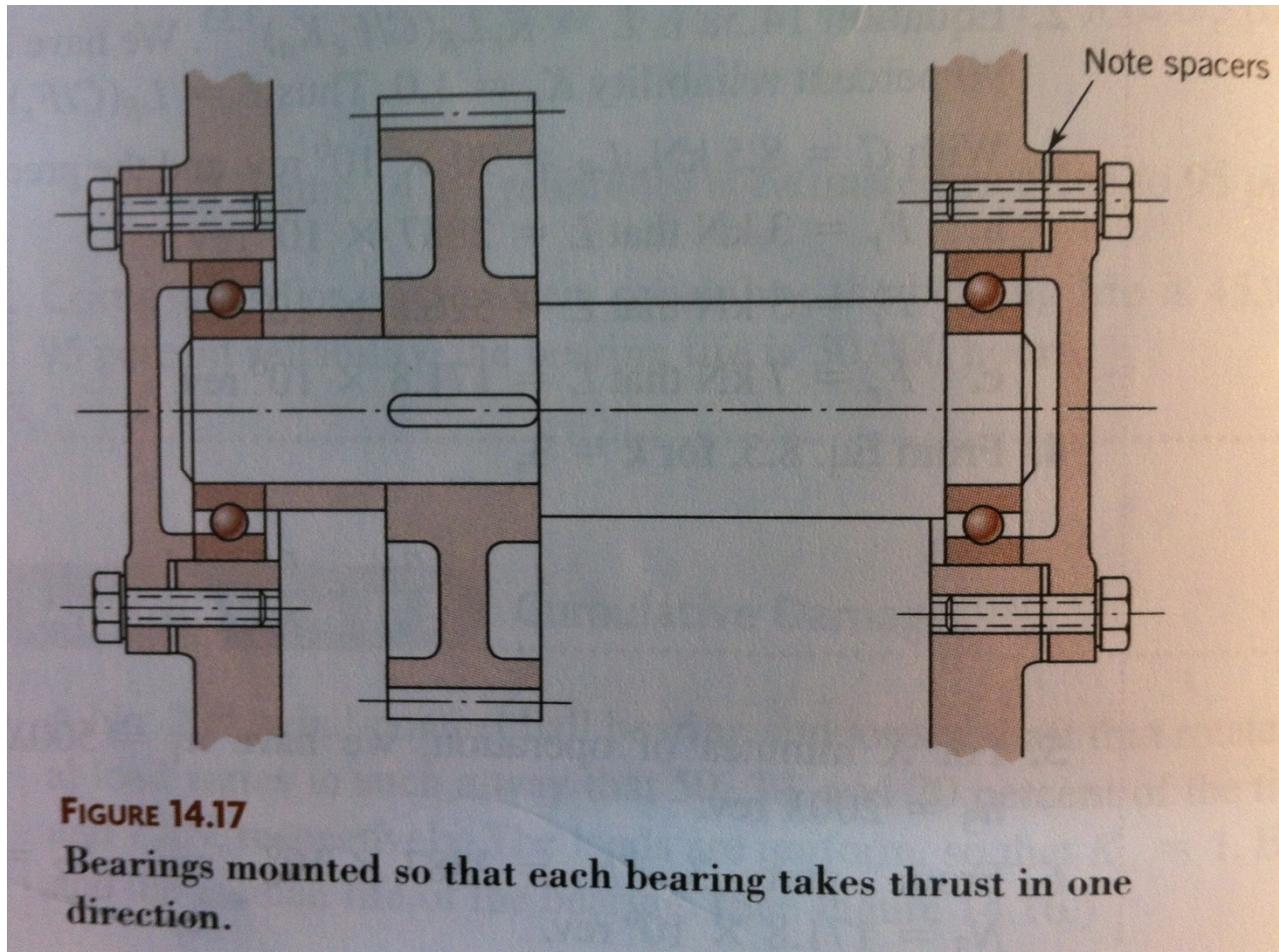


Anillos de retención

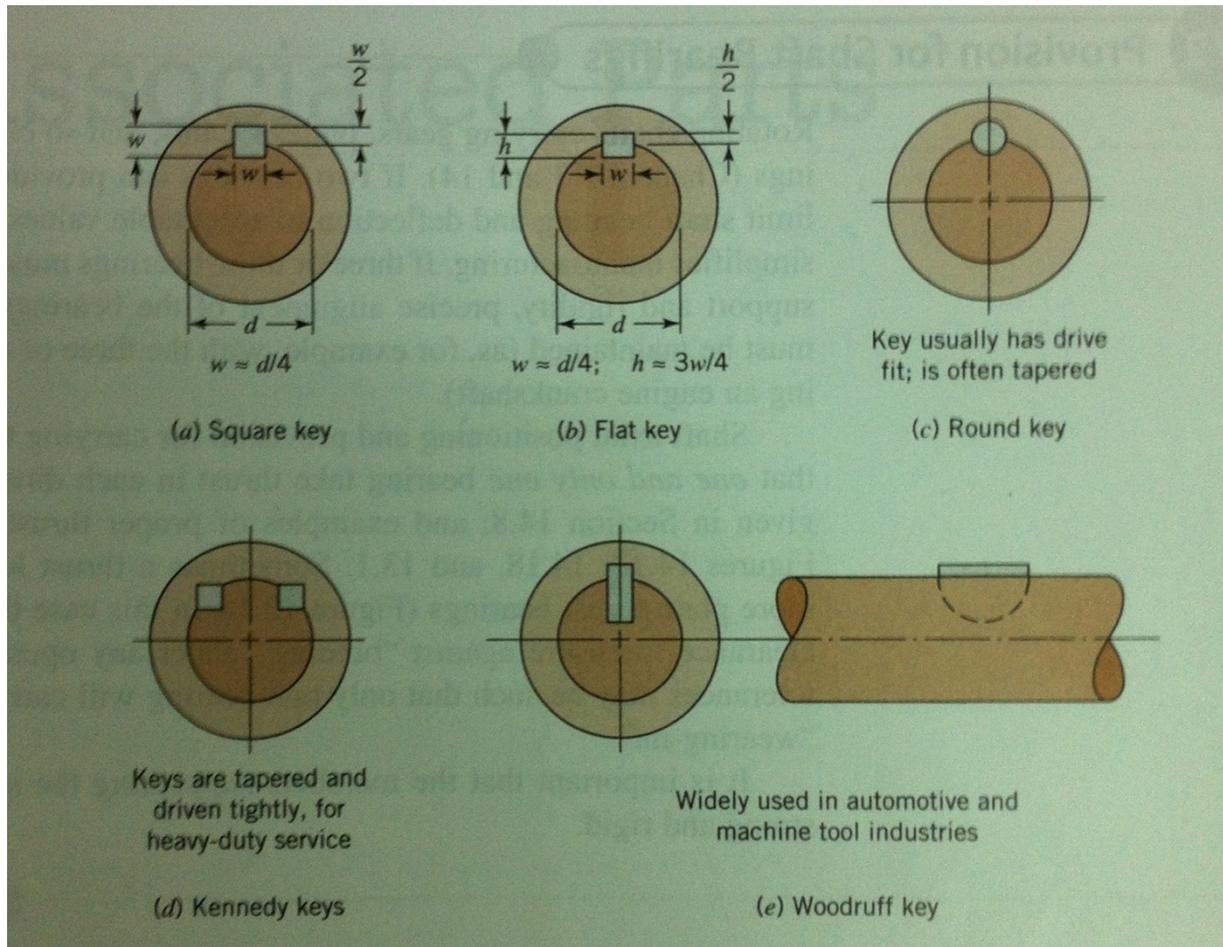
Soporte de Cargas Axiales



Soporte de Cargas Axiales (Cont.)

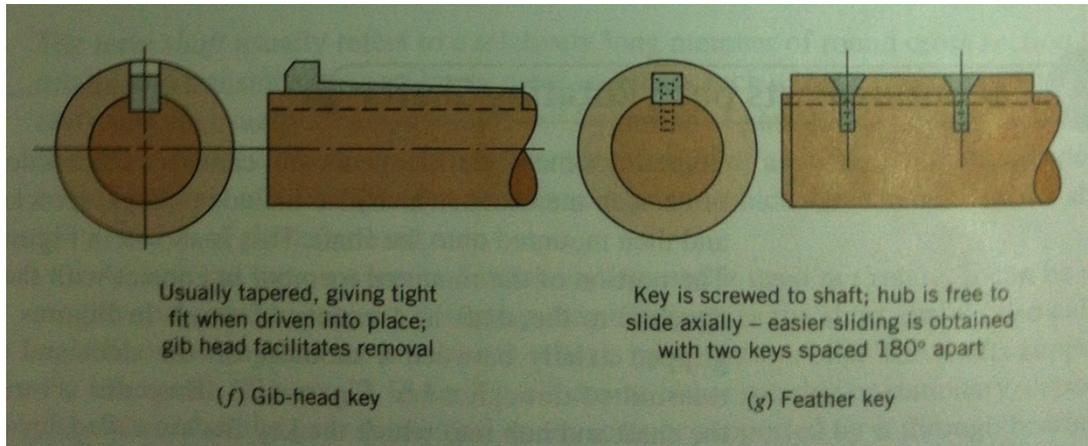


Elementos para Transmisión de Torque

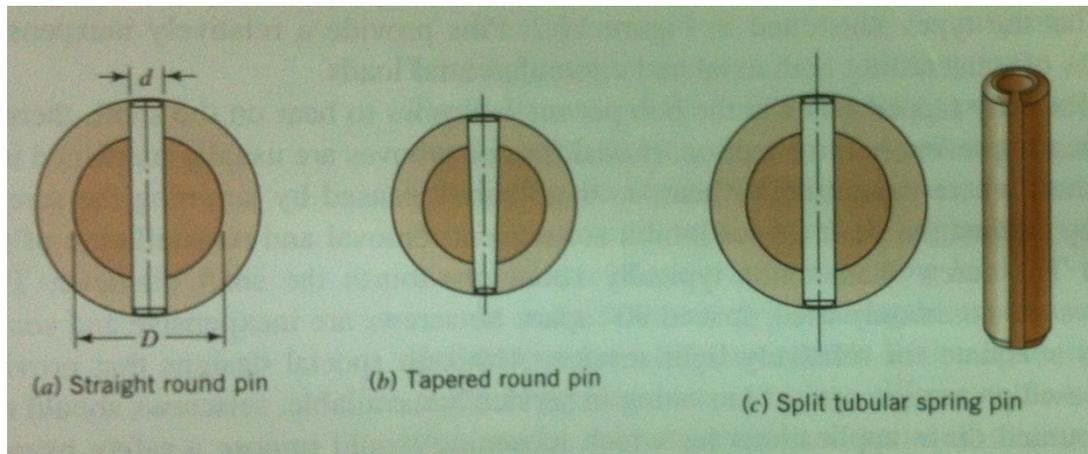


Chavetas

Elementos para Transmisión de Torque (Cont.)

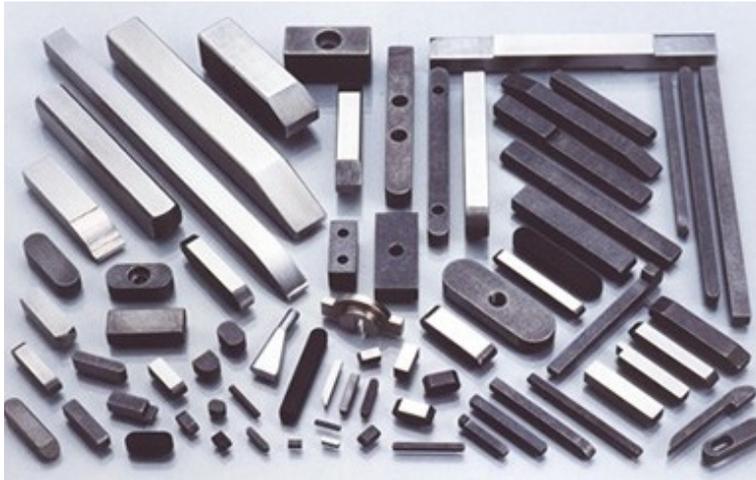


Chavetas

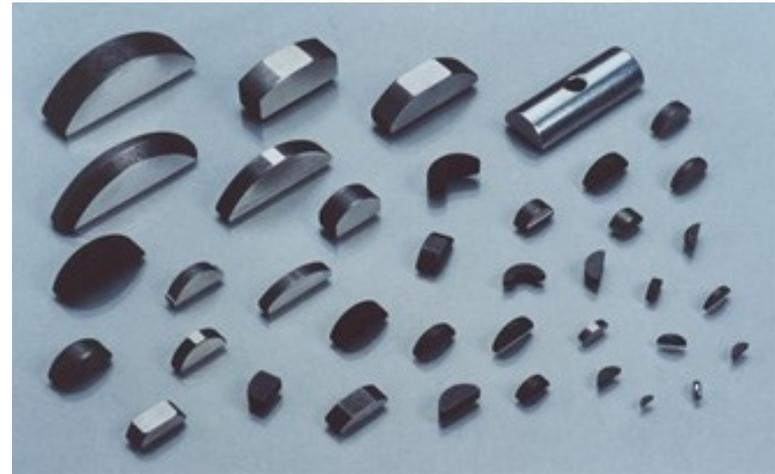


Pasadores

Elementos para Transmisión de Torque (Cont.)



Paralelas



Woodruff

Chavetas Estandarizadas

Shaft Diameter		Key Size		Keyway Depth
Over	To (Incl.)	w	h	
$\frac{5}{16}$	$\frac{7}{16}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{64}$
$\frac{7}{16}$	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{64}$
		$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$
$\frac{9}{16}$	$\frac{7}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$
		$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{32}$
$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{32}$
		$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$
$1\frac{1}{4}$	$1\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{8}$
		$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{32}$
$1\frac{3}{8}$	$1\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
		$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{16}$
$1\frac{3}{4}$	$2\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$
$2\frac{1}{4}$	$2\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{7}{32}$
		$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{16}$
$2\frac{3}{4}$	$3\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$
		$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$

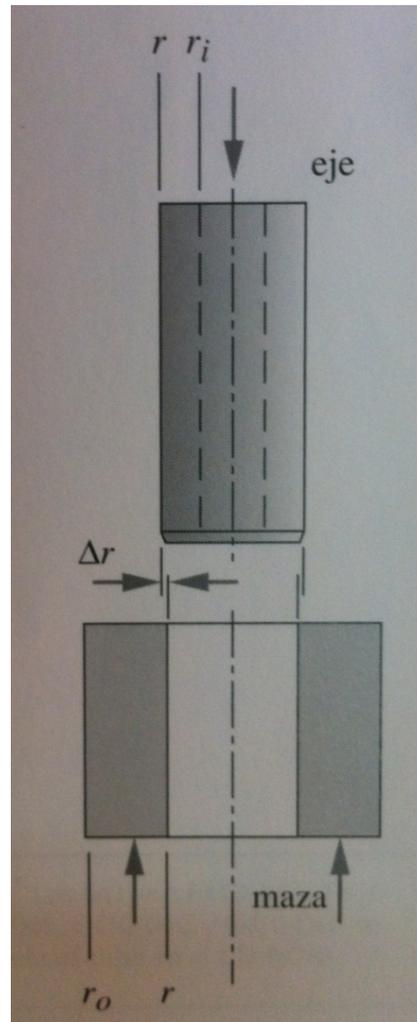
Chavetas cuadradas
y rectangulares

Elementos para Transmisión de Torque (Cont.)



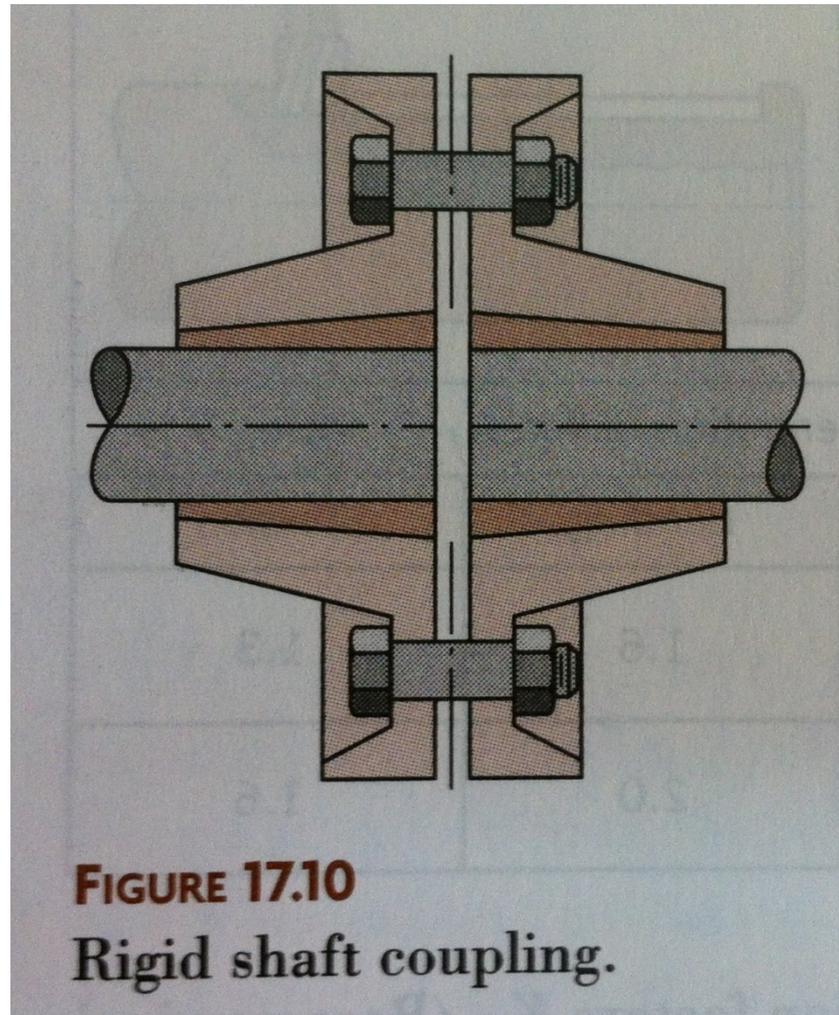
Ejes estriados

Elementos para Transmisión de Torque (Cont.)

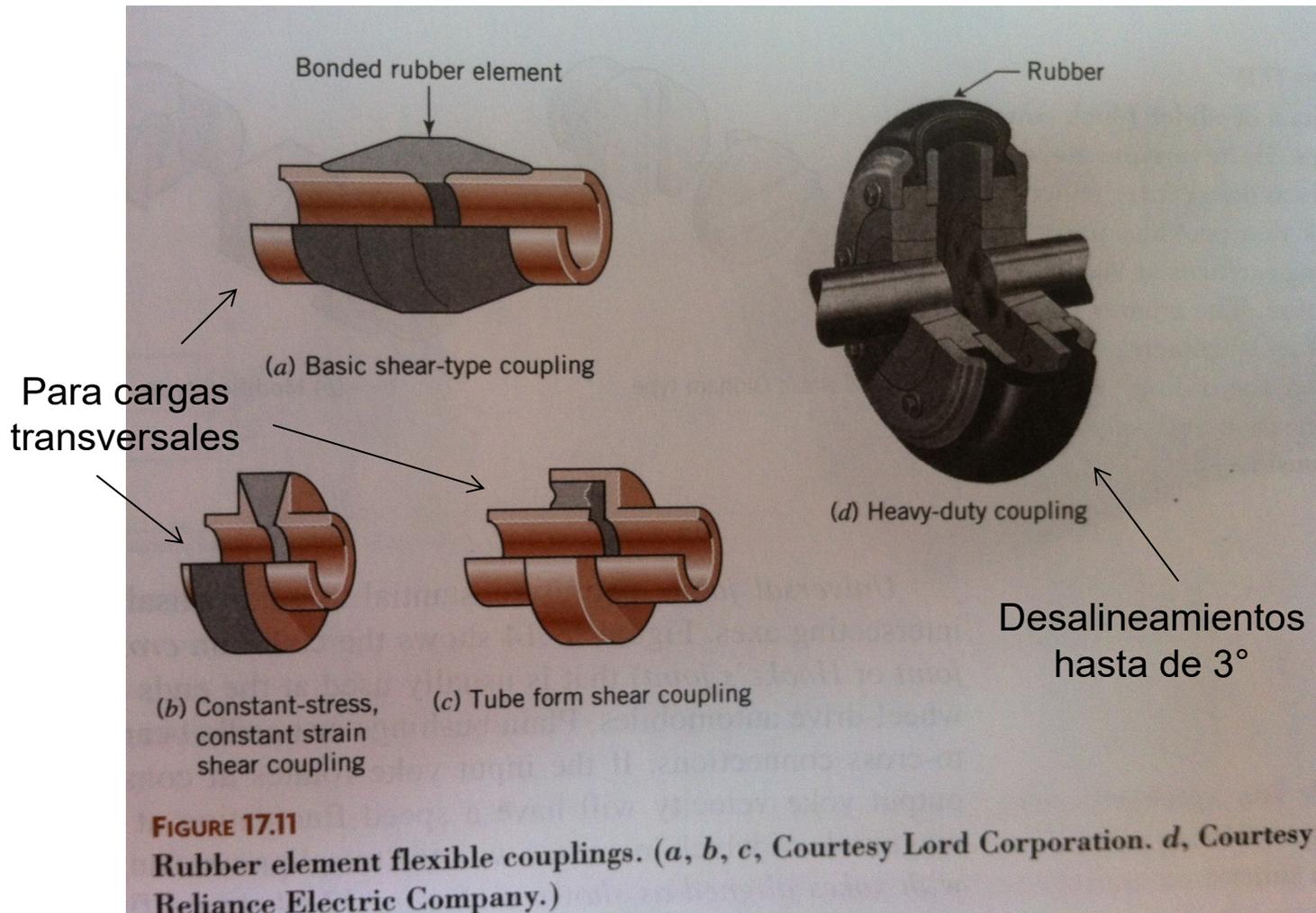


Ajuste por presión

Acoplamiento entre Ejes



Acoplamiento entre Ejes (Cont.)



Acoplamiento entre Ejes (Cont.)

Desalineamientos hasta de 3°. Resistencia torsional a cambios bruscos de torque

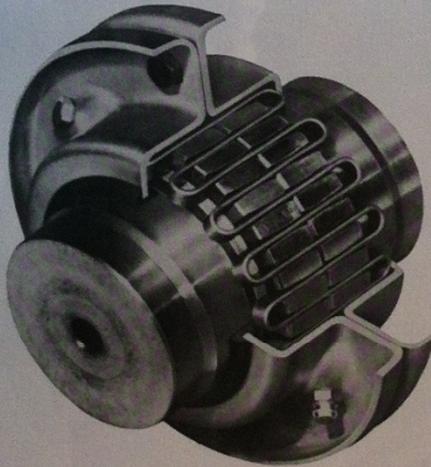


FIGURE 11-18 Grid-Flex coupling. Torque is transmitted through a flexible spring steel grid. Flexing of the grid permits misalignment and makes it torsionally resilient to resist shock loads (Emerson Power Transmission Corporation, Ithaca, NY)

Dientes coronados permiten desalineamientos

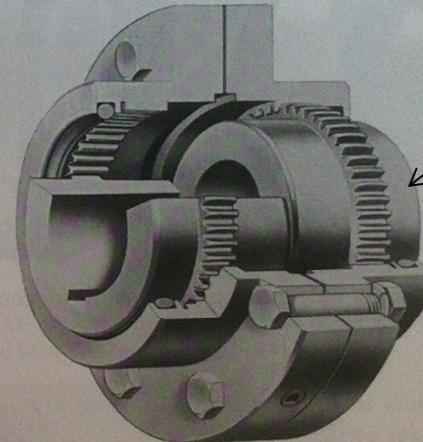


FIGURE 11-19 Gear coupling. Torque is transmitted between crown-hobbed teeth from the coupling half to the sleeve. The crown shape on the gear teeth permits misalignment (Emerson Power Transmission Corporation, Ithaca, NY)

Acoplamiento entre Ejes (Cont.)

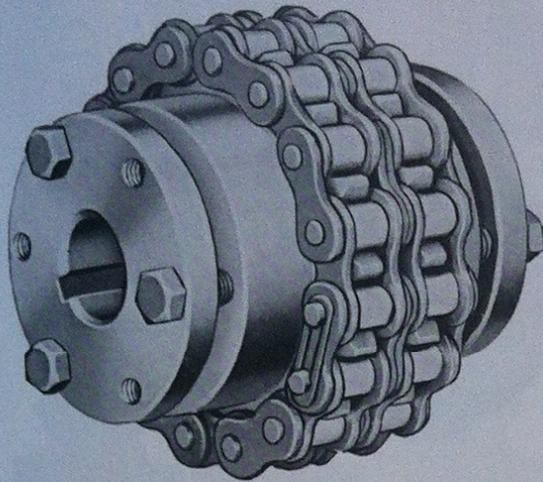


FIGURE 11-16 Chain coupling. Torque is transmitted through a double roller chain. Clearances between the chain and the sprocket teeth on the two coupling halves accommodate misalignment (Emerson Power Transmission Corporation, Ithaca, NY)

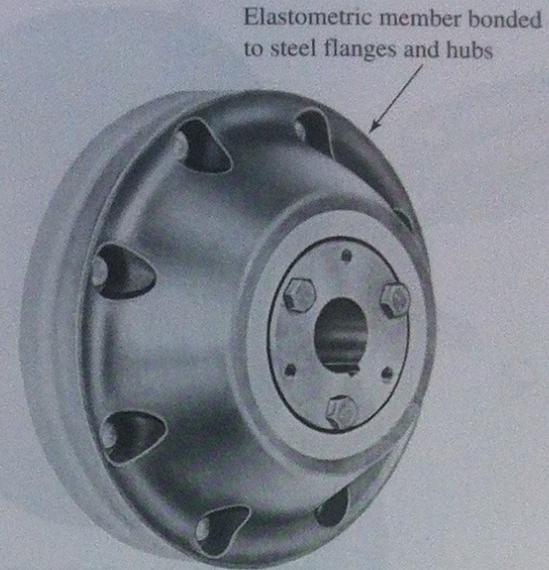
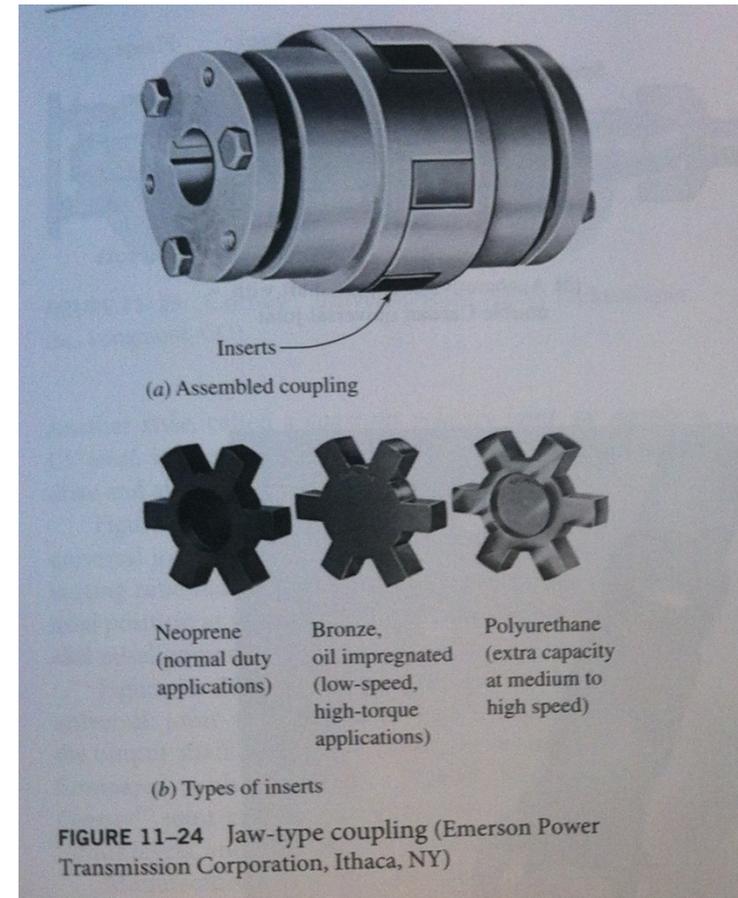
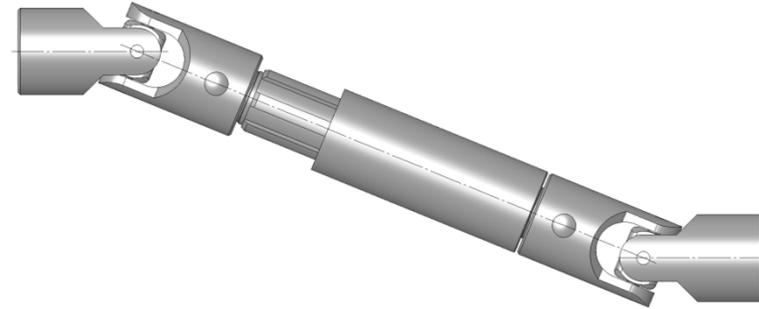
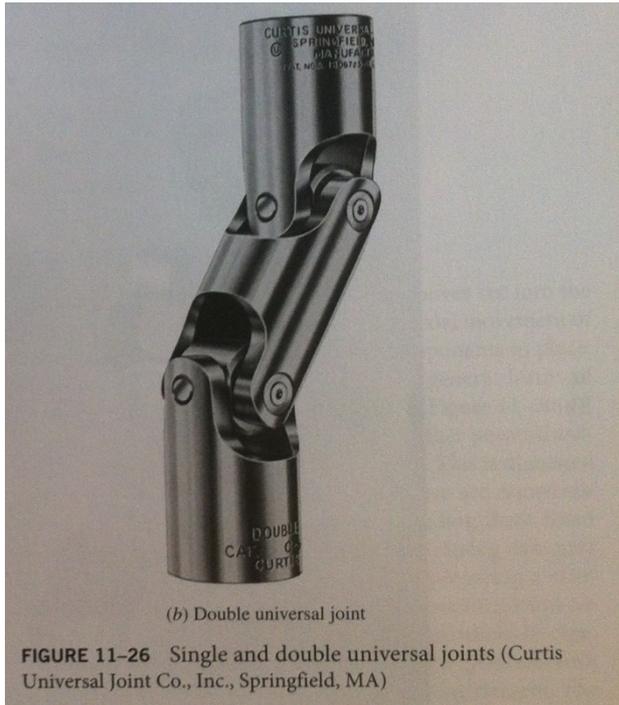


FIGURE 11-17 Ever-Flex coupling. The features of this coupling are that it (1) generally minimizes torsional vibration; (2) cushions shock loads; (3) compensates for parallel misalignment up to $1/32$ in; (4) accommodates angular misalignment of $\pm 3^\circ$; and (5) provides adequate end float, $\pm 1/32$ in (Emerson Power Transmission Corporation, Ithaca, NY)

Acoplamiento entre Ejes (Cont.)



Acoplamiento entre Ejes (Cont.)



Juntas universales
permiten grandes
desalineaciones ($\gg 3^\circ$)



Acoplamiento entre Ejes (Cont.)



Juntas universales

- Esfuerzos alternante y medio

$$\sigma_a = K_f \frac{M_a c}{I} \quad \sigma_m = K_f \frac{M_m c}{I}$$
$$\tau_a = K_{fs} \frac{T_a c}{J} \quad \tau_m = K_{fs} \frac{T_m c}{J}$$

- Para ejes redondos

$$\sigma_a = K_f \frac{32M_a}{\pi d^3} \quad \sigma_m = K_f \frac{32M_m}{\pi d^3}$$
$$\tau_a = K_{fs} \frac{16T_a}{\pi d^3} \quad \tau_m = K_{fs} \frac{16T_m}{\pi d^3}$$

Diseño de Ejes por Esfuerzo (Cont.)

- Esfuerzos combinados

$$\sigma'_a = (\sigma_a^2 + 3\tau_a^2)^{1/2} = \left[\left(\frac{32K_f M_a}{\pi d^3} \right)^2 + 3 \left(\frac{16K_{fs} T_a}{\pi d^3} \right)^2 \right]^{1/2}$$

$$\sigma'_m = (\sigma_m^2 + 3\tau_m^2)^{1/2} = \left[\left(\frac{32K_f M_m}{\pi d^3} \right)^2 + 3 \left(\frac{16K_{fs} T_m}{\pi d^3} \right)^2 \right]^{1/2}$$

Diseño de Ejes por Esfuerzo (Cont.)

- Ecuación de diseño (Goodman)

$$\frac{1}{n} = \frac{\sigma'_a}{S_e} + \frac{\sigma'_m}{S_{ut}}$$



$$\frac{1}{n} = \frac{16}{\pi d^3} \left\{ \frac{1}{S_e} [4(K_f M_a)^2 + 3(K_{fs} T_a)^2]^{1/2} + \frac{1}{S_{ut}} [4(K_f M_m)^2 + 3(K_{fs} T_m)^2]^{1/2} \right\}$$



$$d = \left(\frac{16n}{\pi} \left\{ \frac{1}{S_e} [4(K_f M_a)^2 + 3(K_{fs} T_a)^2]^{1/2} + \frac{1}{S_{ut}} [4(K_f M_m)^2 + 3(K_{fs} T_m)^2]^{1/2} \right\} \right)^{1/3}$$

- Esfuerzo máximo

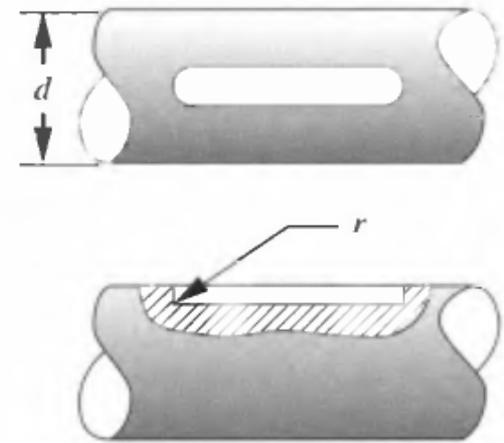
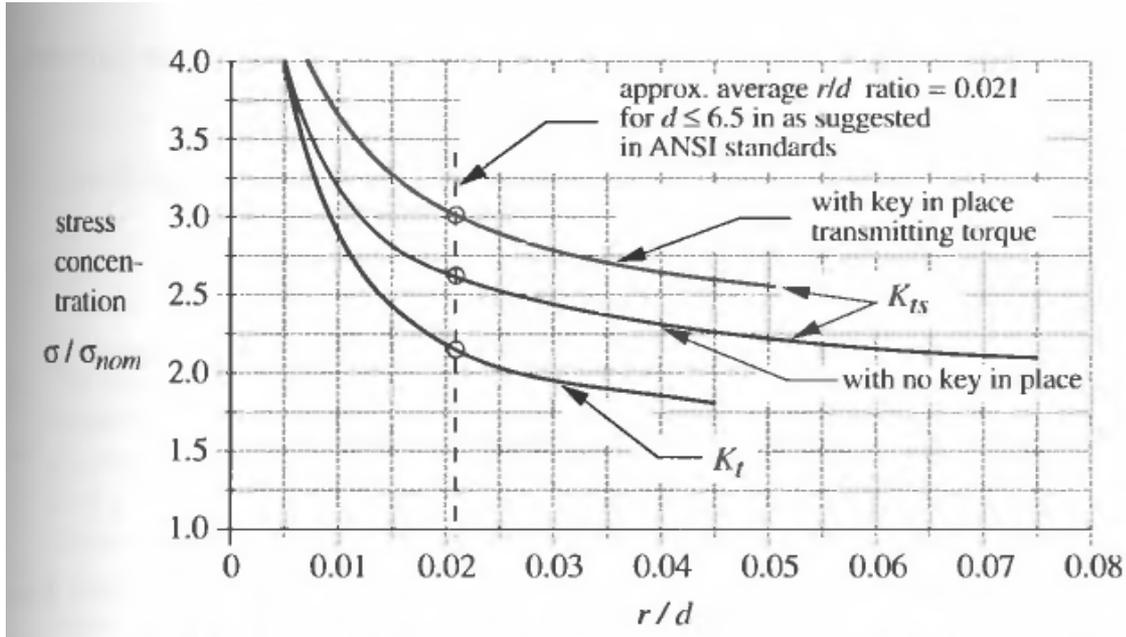
$$\begin{aligned}\sigma'_{\max} &= [(\sigma_m + \sigma_a)^2 + 3(\tau_m + \tau_a)^2]^{1/2} \\ &= \left[\left(\frac{32K_f (M_m + M_a)}{\pi d^3} \right)^2 + 3 \left(\frac{16K_{fs} (T_m + T_a)}{\pi d^3} \right)^2 \right]^{1/2}\end{aligned}$$

$$n_y = \frac{S_y}{\sigma'_{\max}}$$

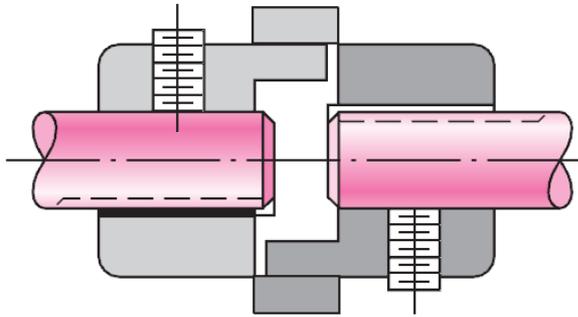
- Alternativamente (más conservador)

$$\sigma'_{\max} = \sigma'_a + \sigma'_m$$

Concentraciones de Esfuerzos en Ejes

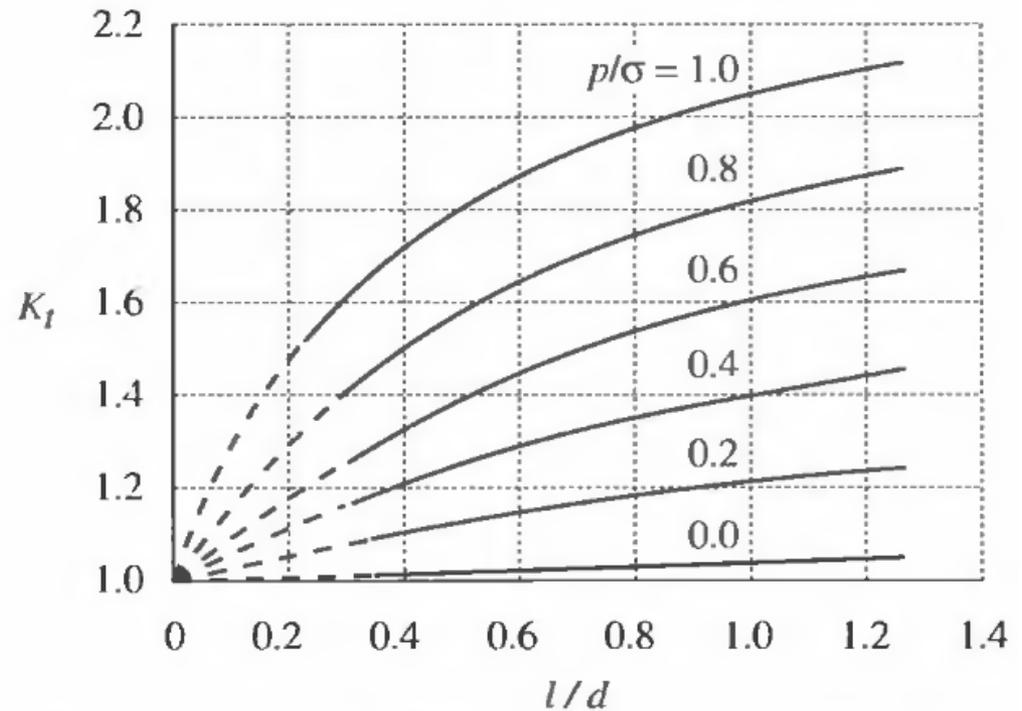


Concentración de Esfuerzos en el Ajuste

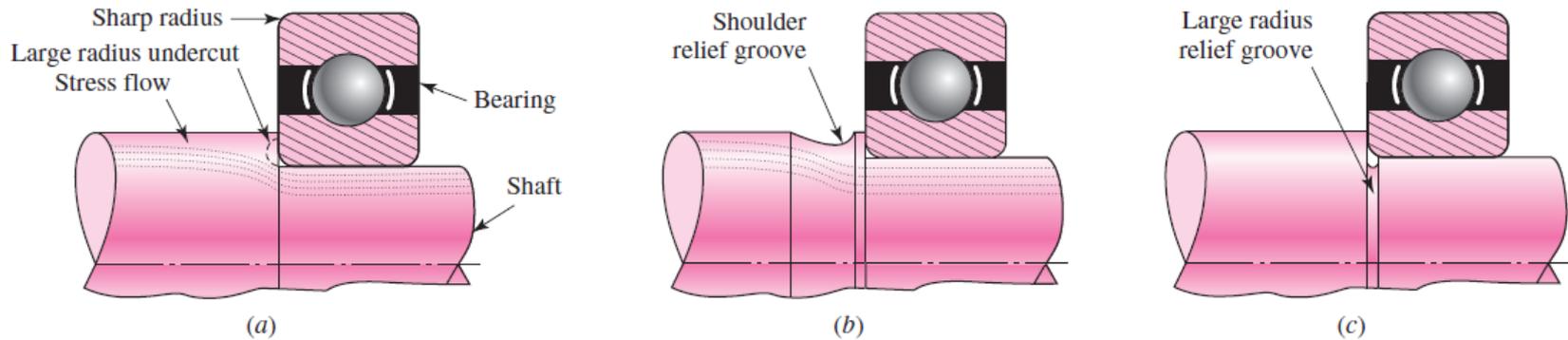


$$p/\sigma = \frac{\text{nominal press-fit pressure}}{\text{nominal bending stress}}$$

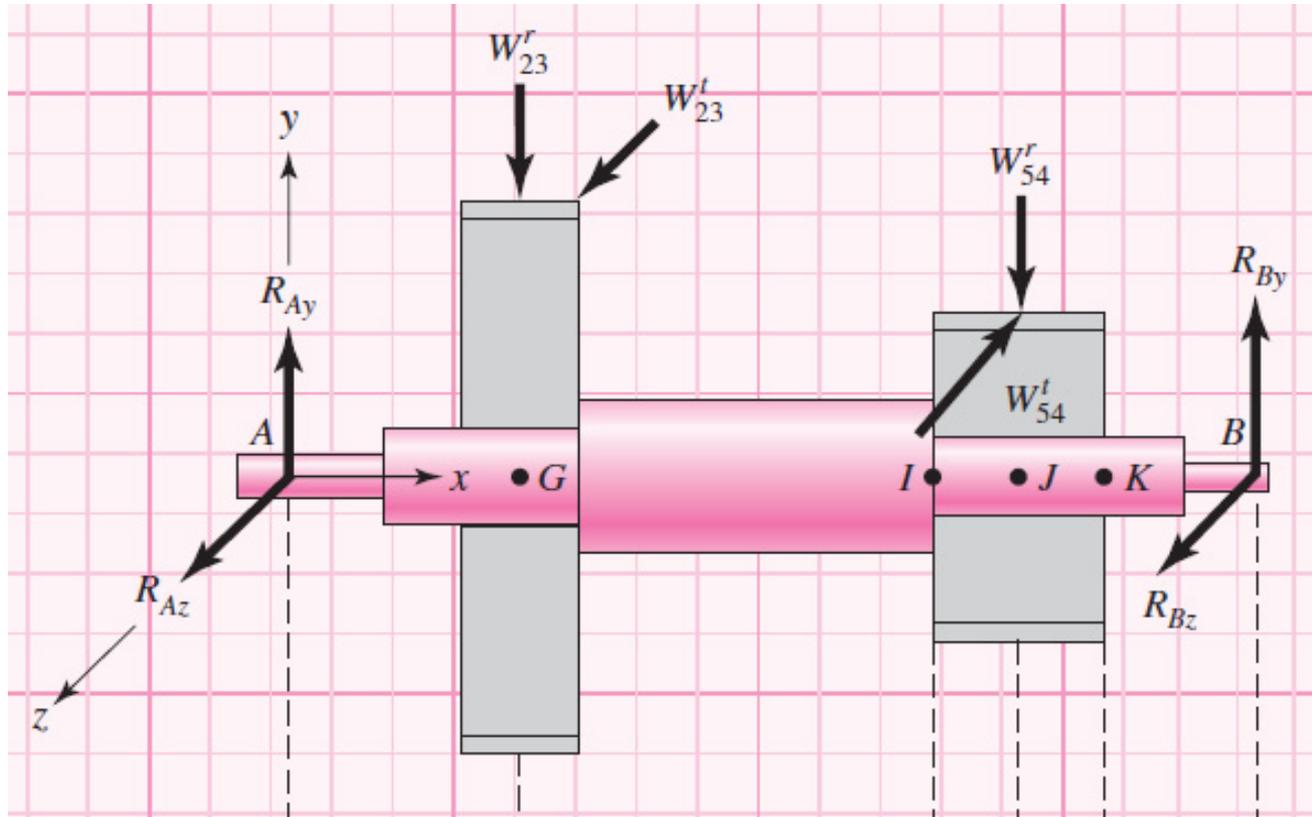
$$l/d = \frac{\text{length of hub}}{\text{diameter of shaft}}$$



Reduciendo Concentraciones de Esfuerzo



Diseño de Ejes por Deflexión



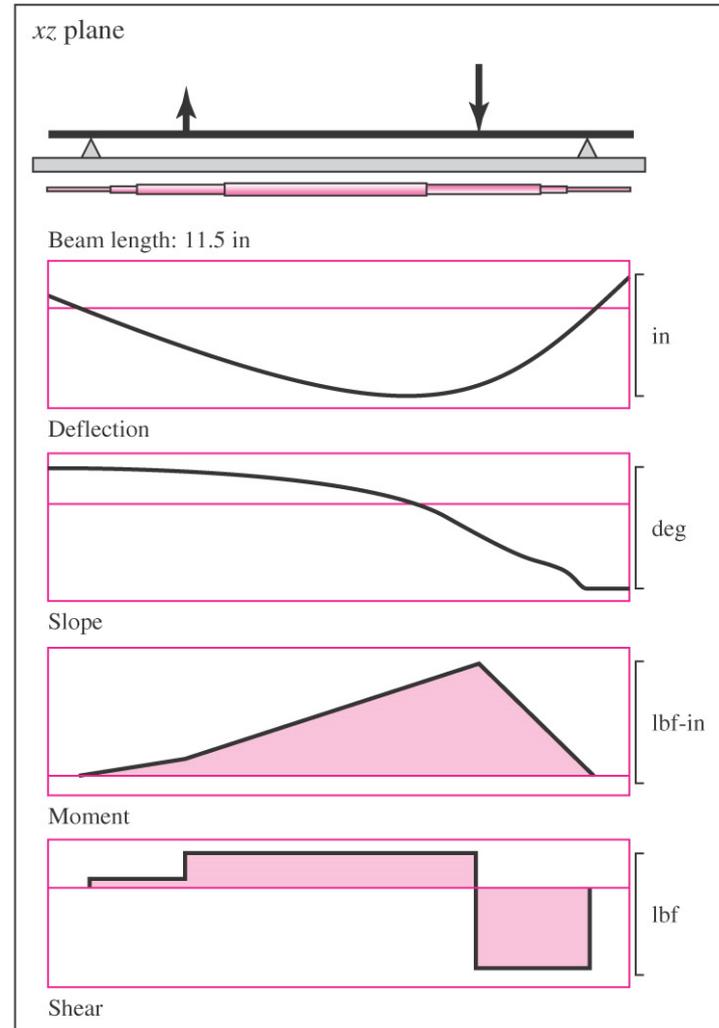
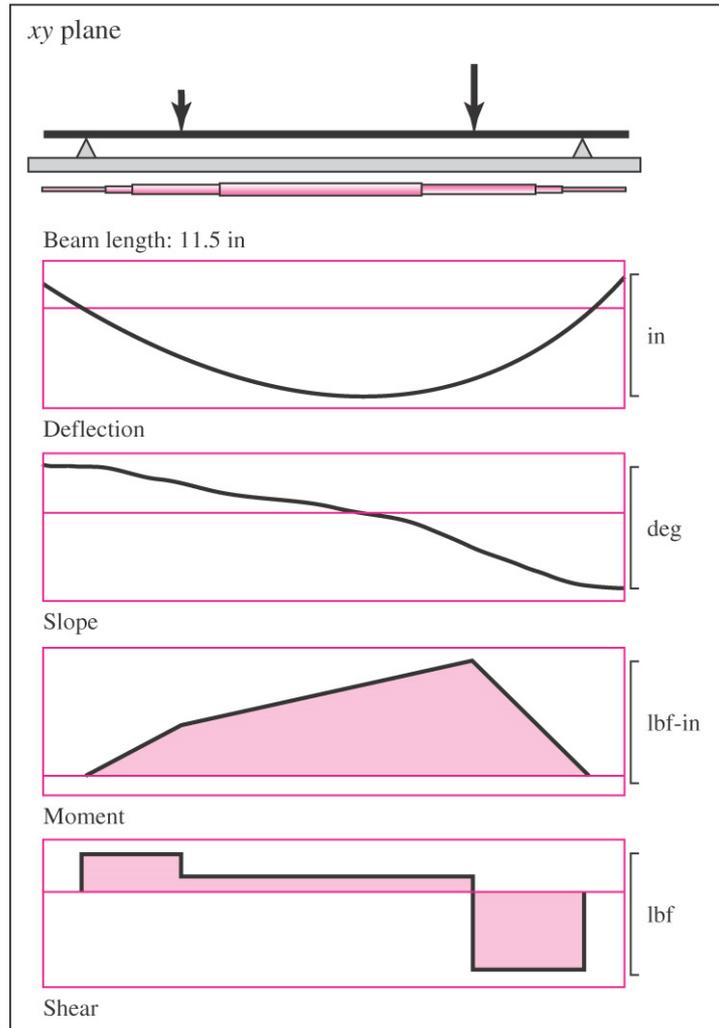
$$W_{23}^t = 540 \text{ lbf}$$

$$W_{23}^r = 197 \text{ lbf}$$

$$W_{54}^t = 2431 \text{ lbf}$$

$$W_{54}^r = 885 \text{ lbf}$$

Diseño de Ejes por Deflexión (Cont.)



Diseño de Ejes por Deflexión (Cont.)

Point of Interest	xz Plane	xy Plane	Total
Left bearing slope	0.02263 deg	0.01770 deg	0.02872 deg 0.000501 rad
Right bearing slope	0.05711 deg	0.02599 deg	0.06274 deg 0.001095 rad
Left gear slope	0.02067 deg	0.01162 deg	0.02371 deg 0.000414 rad
Right gear slope	0.02155 deg	0.01149 deg	0.02442 deg 0.000426 rad
Left gear deflection	0.0007568 in	0.0005153 in	0.0009155 in
Right gear deflection	0.0015870 in	0.0007535 in	0.0017567 in

Verificar límites en Tabla 7-2

Diseño de Ejes por Deflexión (Cont.)

Table 7-2

Typical Maximum
Ranges for Slopes and
Transverse Deflections

Slopes	
Tapered roller	0.0005–0.0012 rad
Cylindrical roller	0.0008–0.0012 rad
Deep-groove ball	0.001–0.003 rad
Spherical ball	0.026–0.052 rad
Self-align ball	0.026–0.052 rad
Uncrowned spur gear	< 0.0005 rad

Transverse Deflections	
Spur gears with $P < 10$ teeth/in	0.010 in
Spur gears with $11 < P < 19$	0.005 in
Spur gears with $20 < P < 50$	0.003 in

Ajustando Diámetros para Deflexión Admisible

- Escalamiento de diámetro

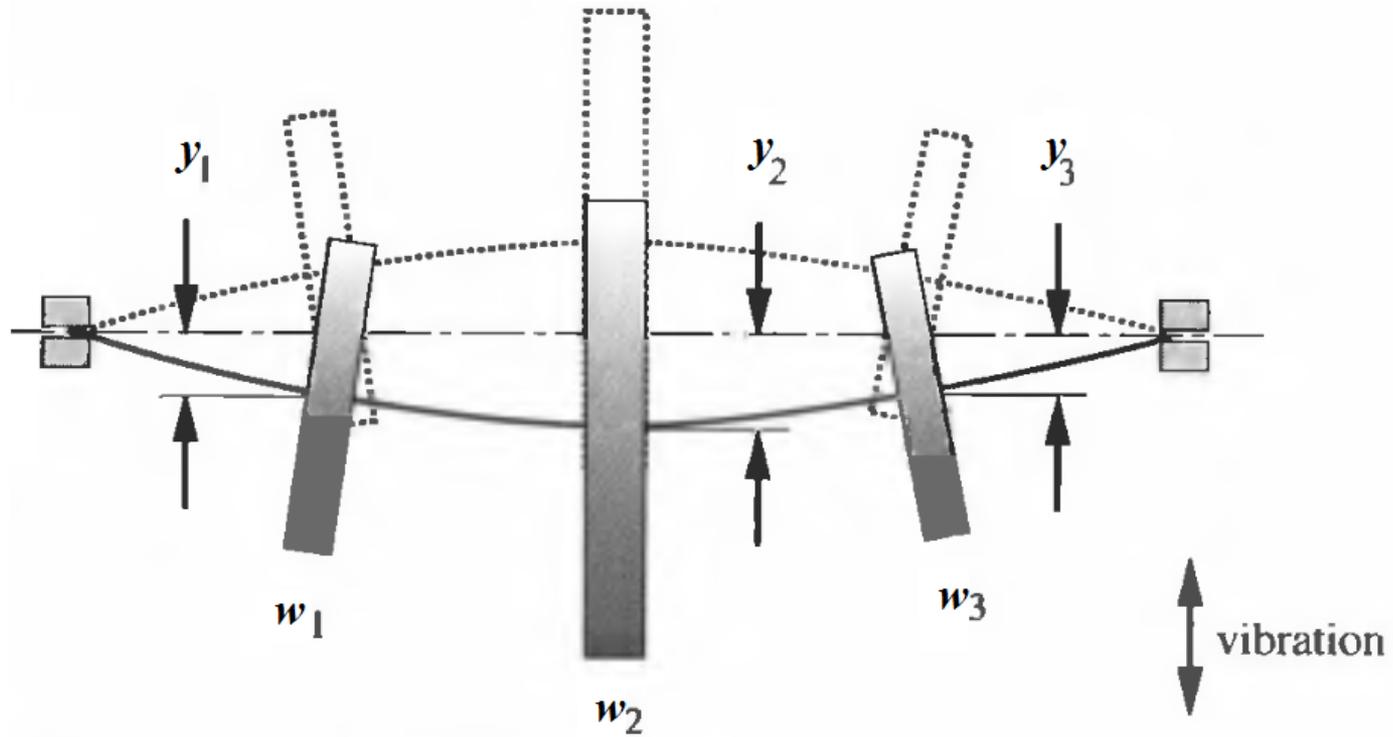
$$d_{\text{new}} = d_{\text{old}} \left| \frac{n_d y_{\text{old}}}{y_{\text{all}}} \right|^{1/4}$$

- Escalamiento de pendientes

$$d_{\text{new}} = d_{\text{old}} \left| \frac{n_d (dy/dx)_{\text{old}}}{(\text{slope})_{\text{all}}} \right|^{1/4}$$

Permite
mantener los
factores de
concentración
de esfuerzos

Velocidad Crítica en Ejes

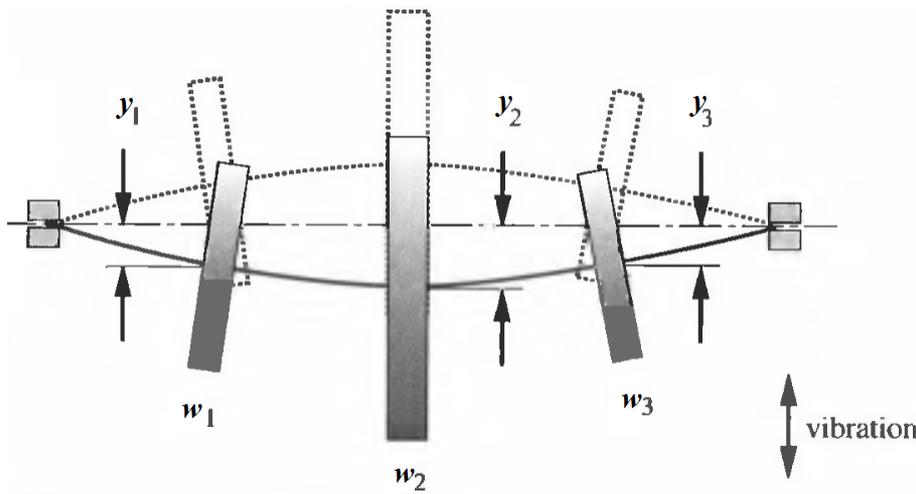


Velocidad Crítica en Ejes (Cont.)

- Eje de diámetro uniforme y simplemente apoyado

$$\omega_1 = \left(\frac{\pi}{l}\right)^2 \sqrt{\frac{EI}{m}} = \left(\frac{\pi}{l}\right)^2 \sqrt{\frac{gEI}{A\gamma}}$$

- Método de Rayleigh para masas concentradas



$$\omega_1 = \sqrt{\frac{g \sum w_i y_i}{\sum w_i y_i^2}}$$

g campo gravitatorio
 W_i peso en la i -ésima ubicación
 y_i deflexión en la i -ésima ubicación