

Clase 9

- Procesos de Laminación



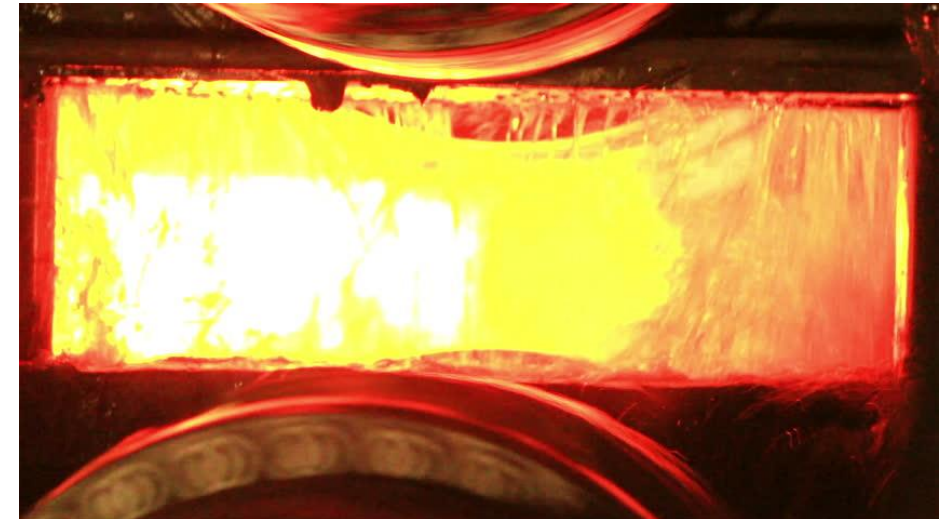
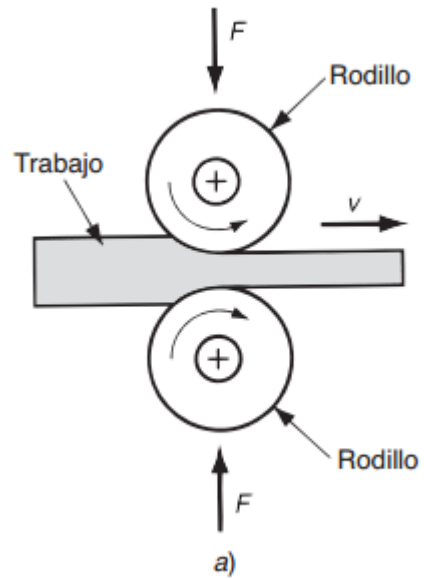
DIMEC
INGENIERÍA MECÁNICA
UNIVERSIDAD DE CHILE

14 October
2020

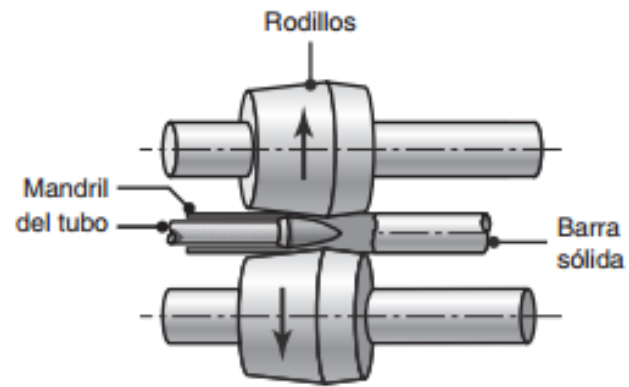


Laminación

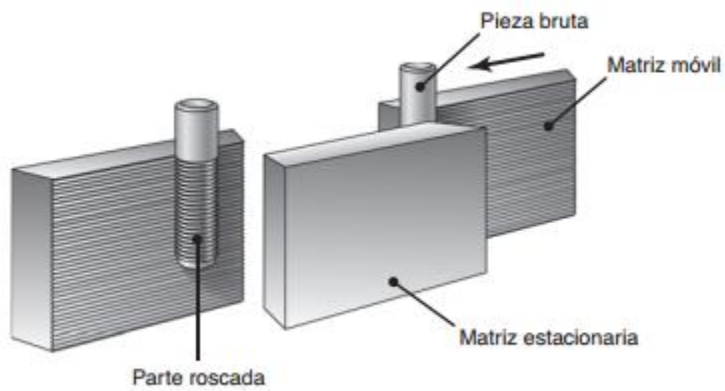
Laminación



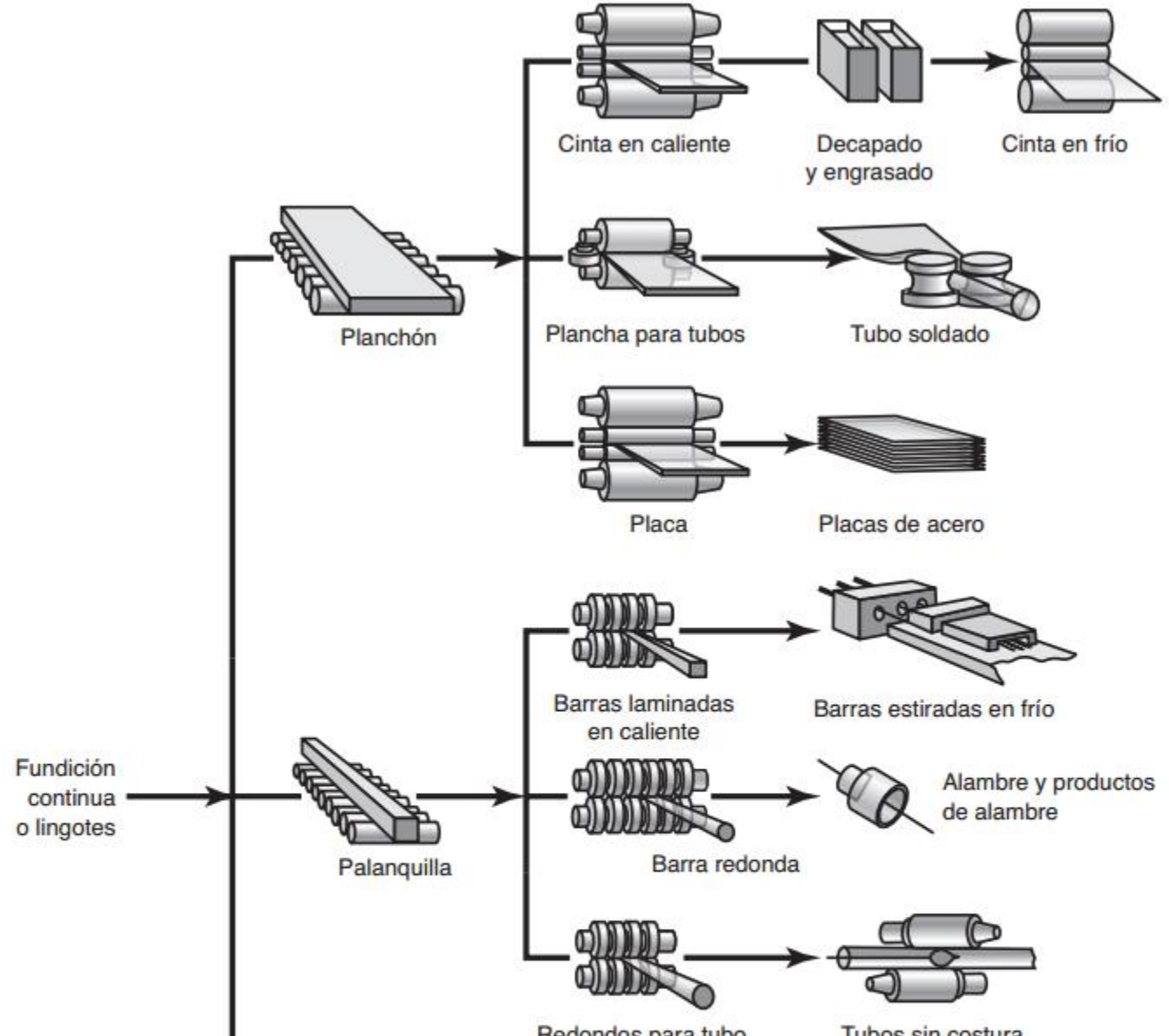
Laminación



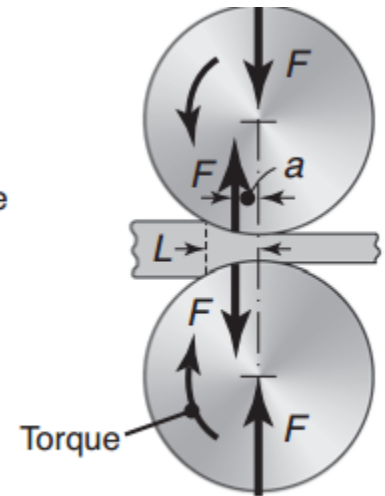
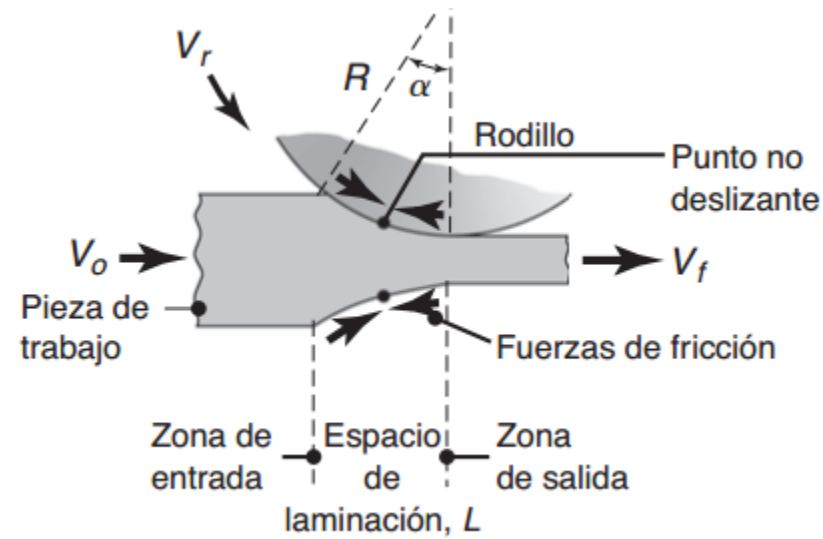
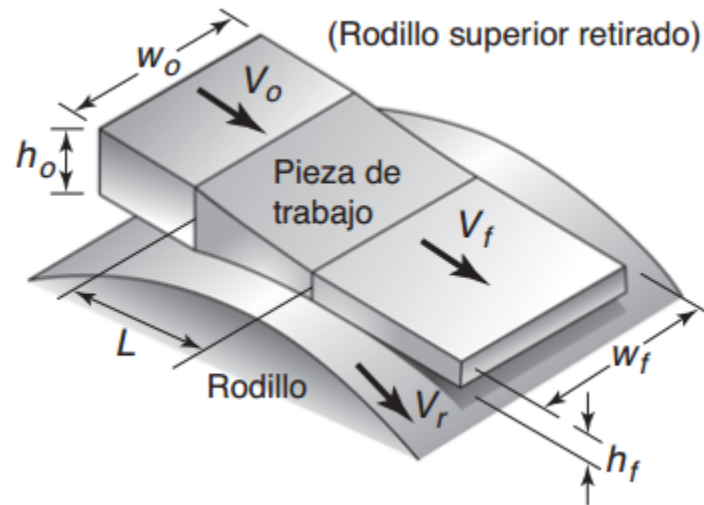
1.3.3



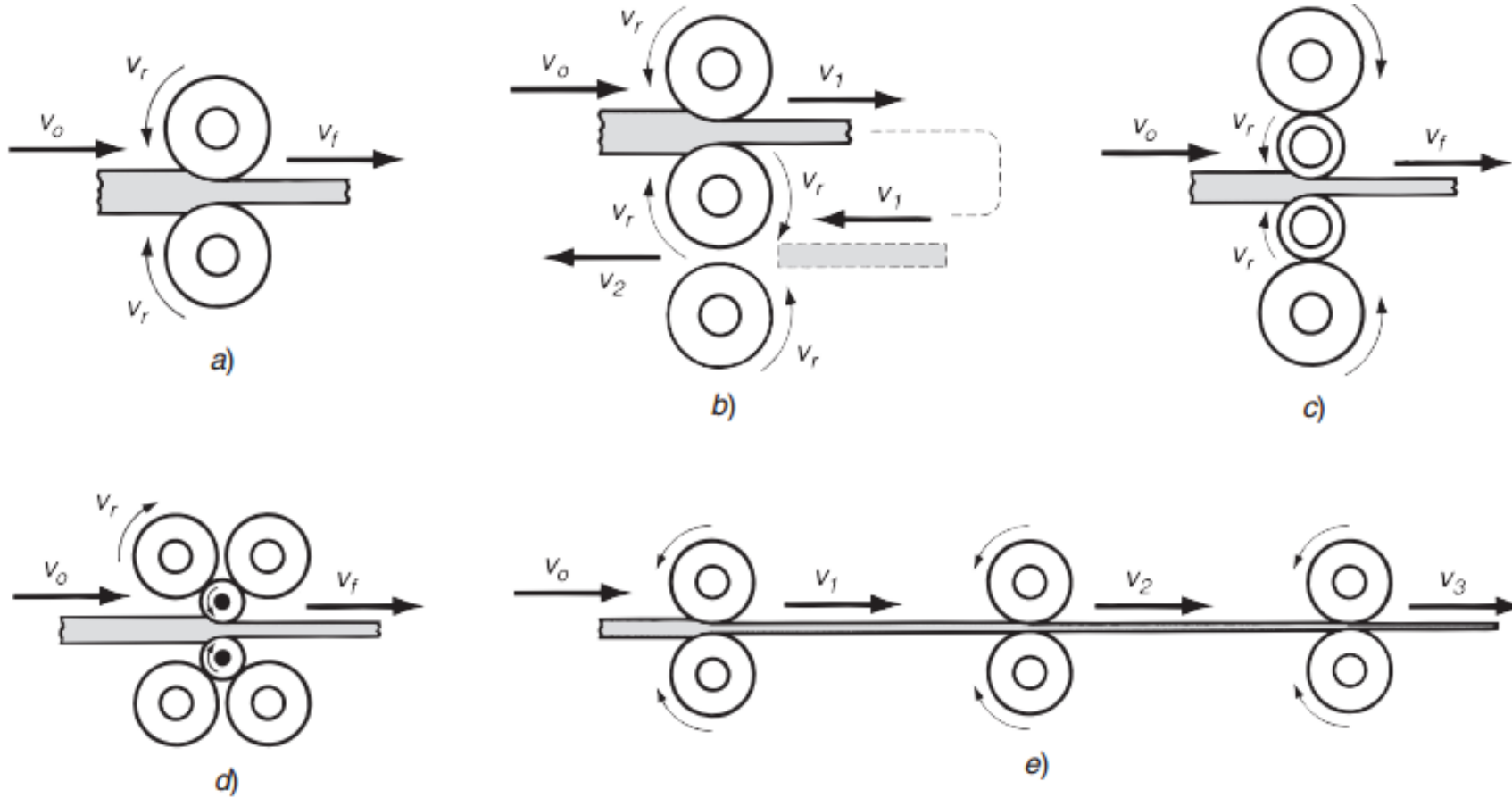
(a)



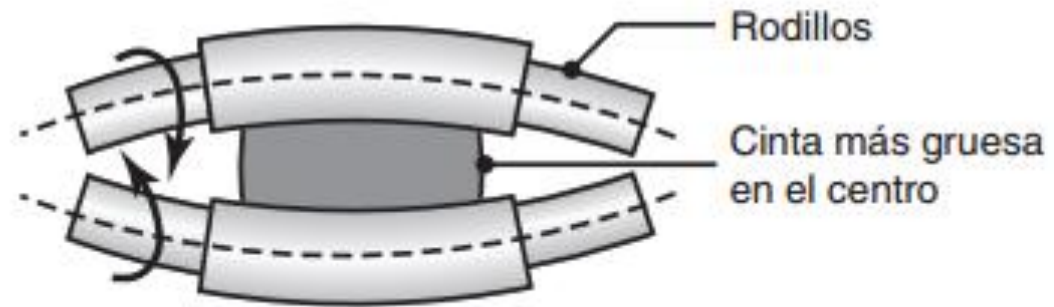
Laminación



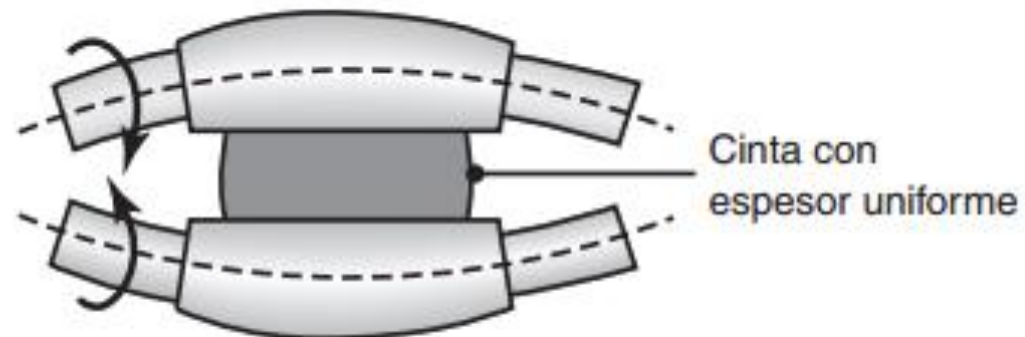
Arreglo de Rodillos



Doblado de Rodillos

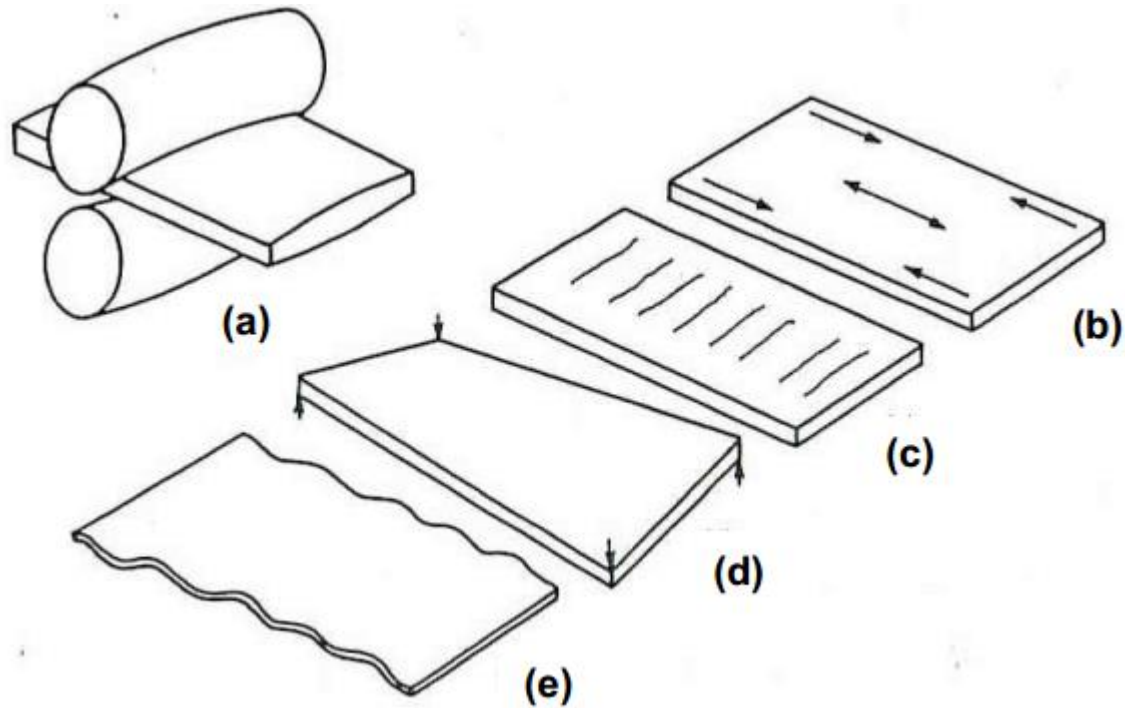


(a)

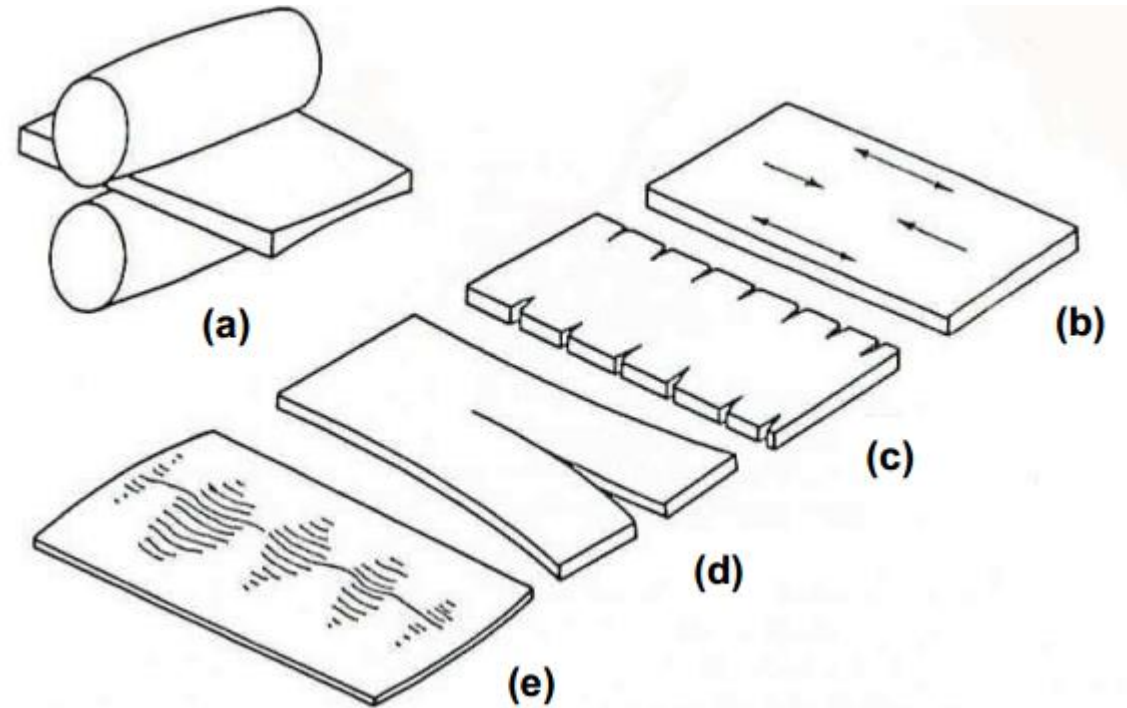


Defectos en laminación

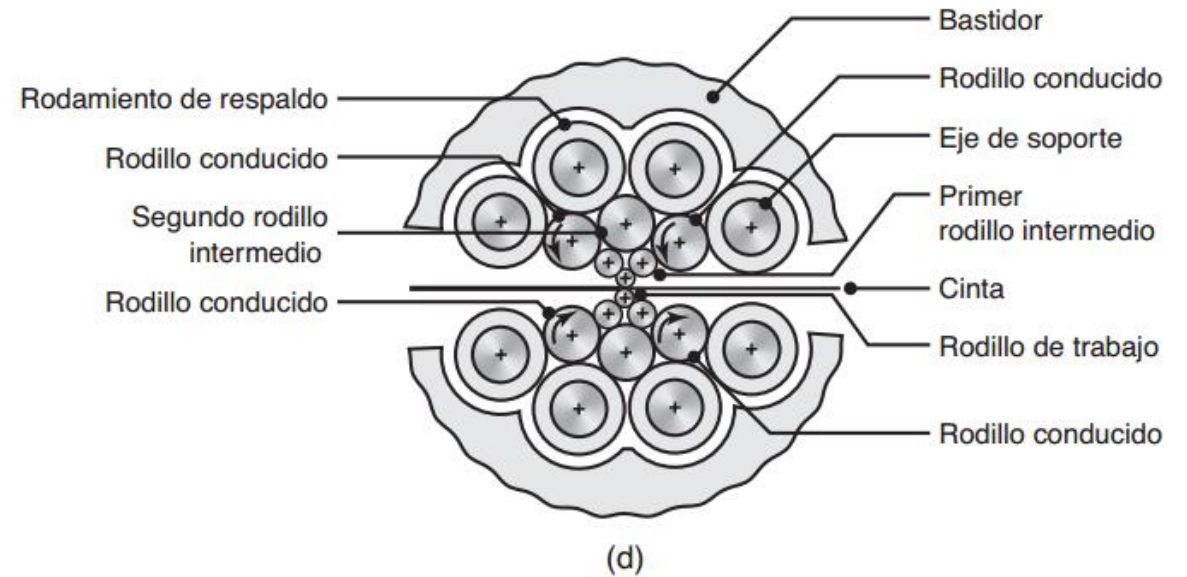
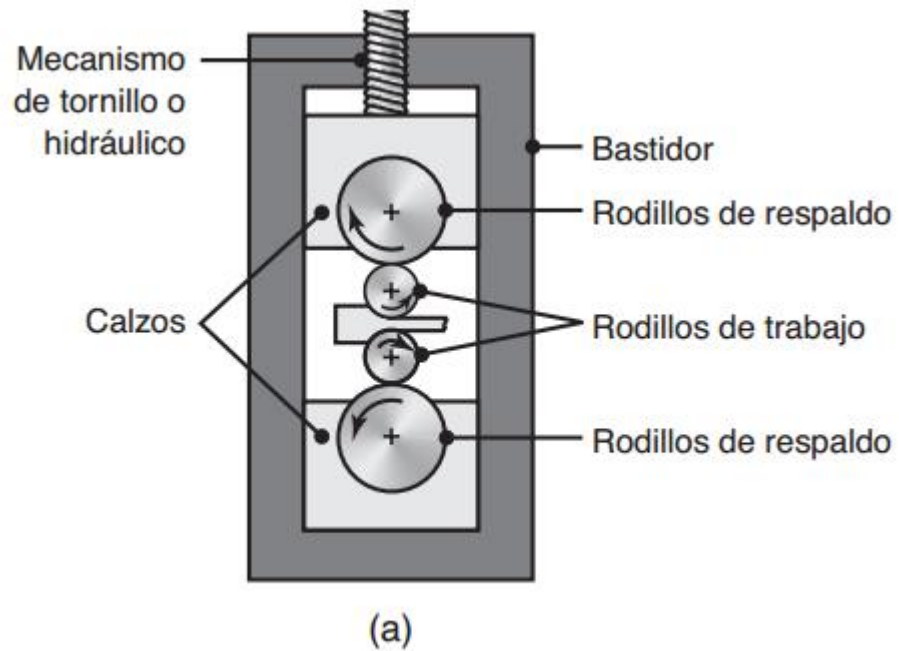
Mucha Flexión



Mucha Rectificación



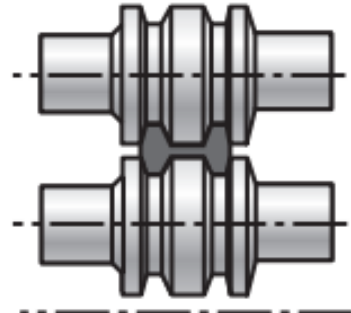
Múltiples rodillos



Otros tipos de Laminado

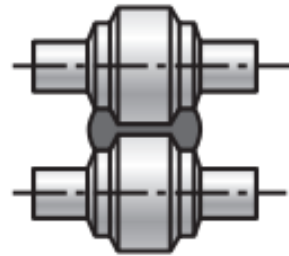
Laminado de Formas

Etapa 1



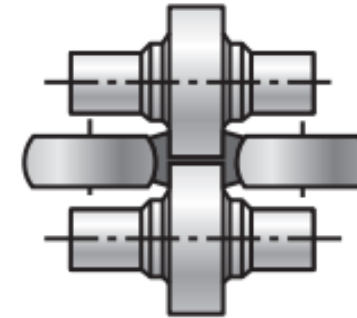
Rodillos de desbaste

Etapa 2



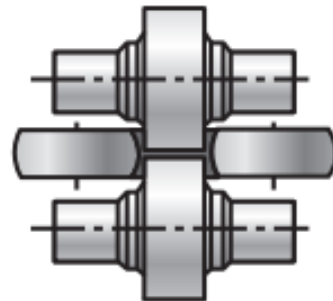
Rodillos de recalcado

Etapa 3



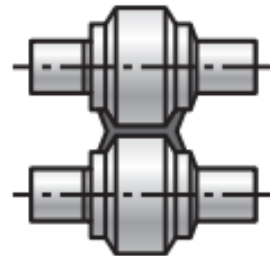
Rodillos horizontal
y vertical de desbaste

Etapa 4



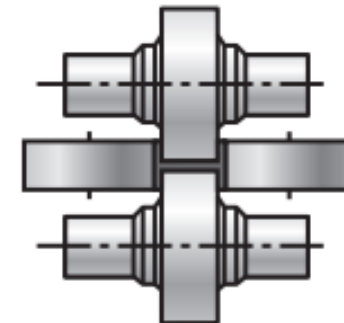
Rodillos intermedios
horizontal y vertical

Etapa 5



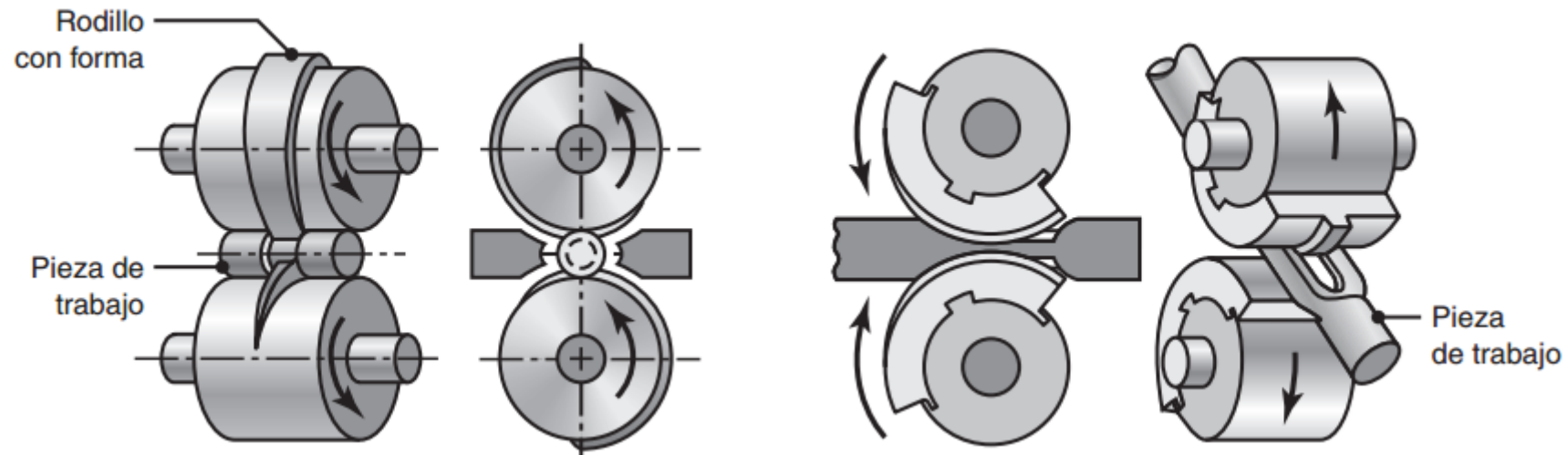
Rodillos de recalcado

Etapa 6



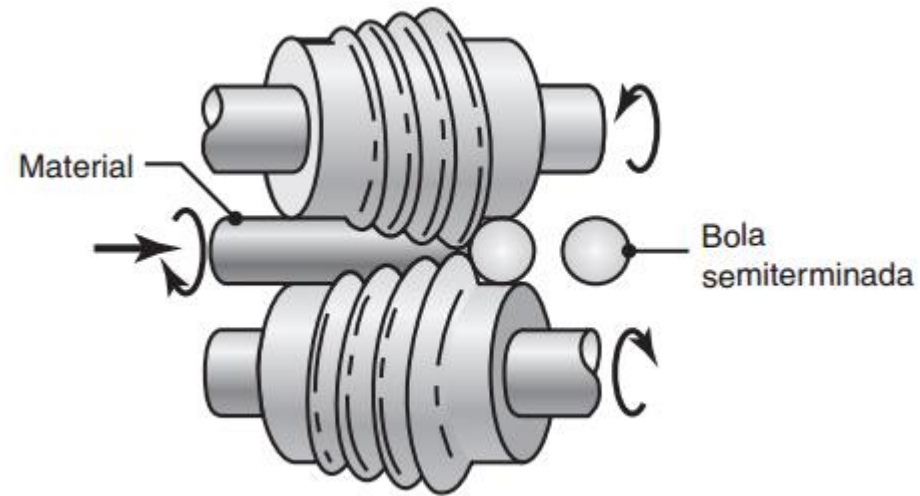
Rodillos horizontal
y vertical de acabado

Laminado Cruzado



<https://www.youtube.com/watch?v=q6mBrzzsRpo>

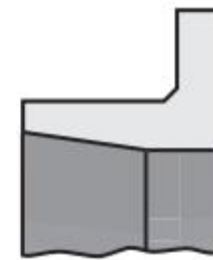
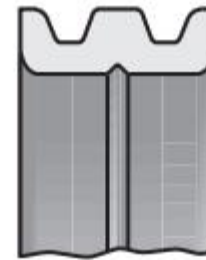
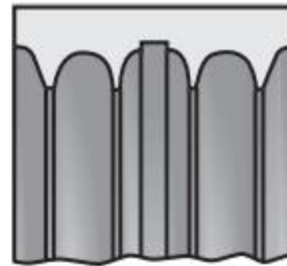
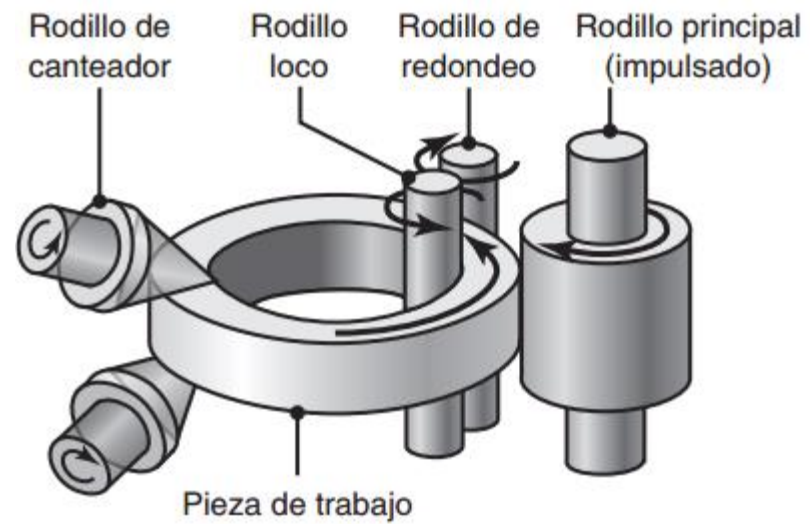
Laminado Oblicuo



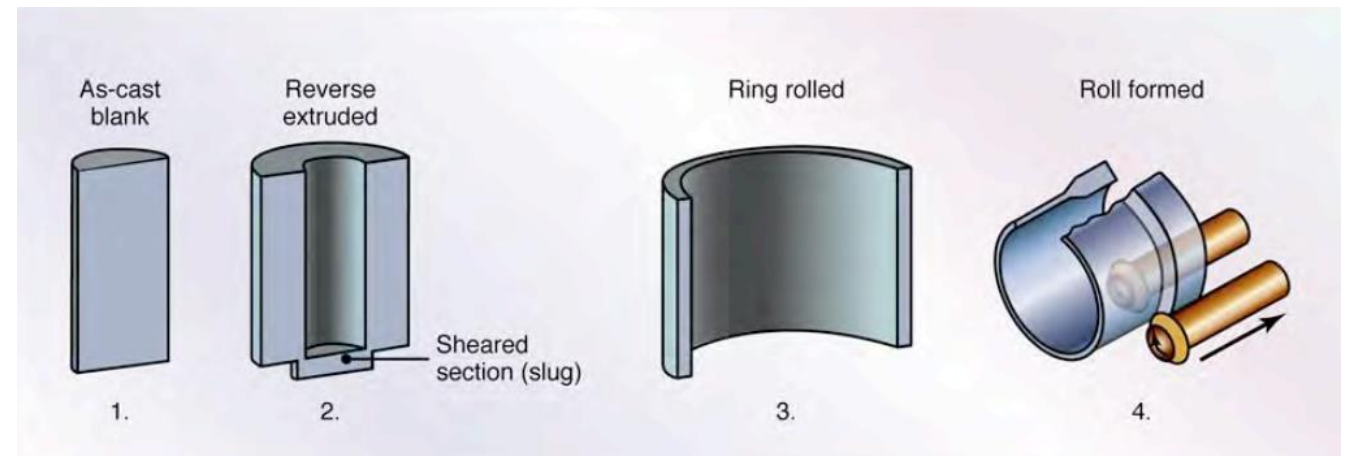
<https://www.youtube.com/watch?v=BazQnUg0k2Q>

<https://www.youtube.com/watch?v=DOqHW8JL0hw>

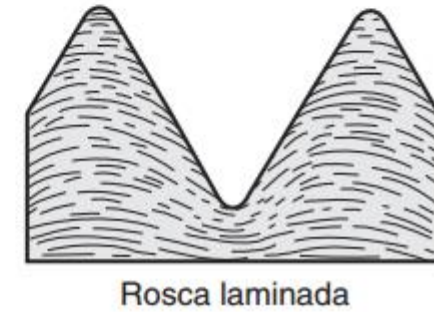
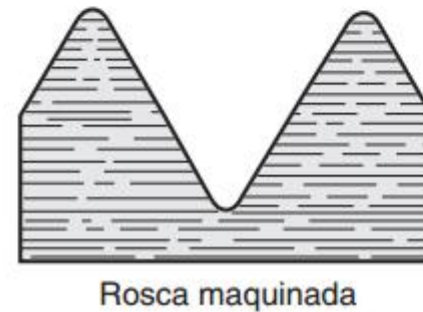
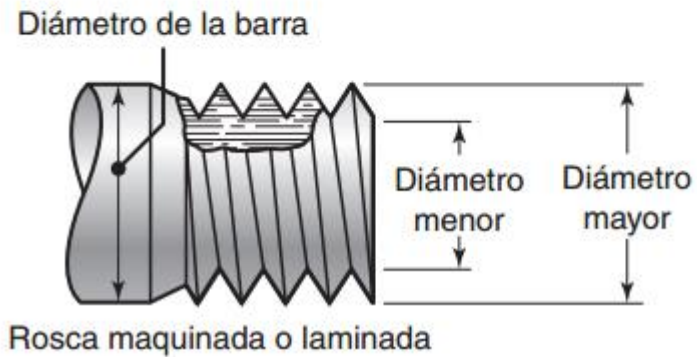
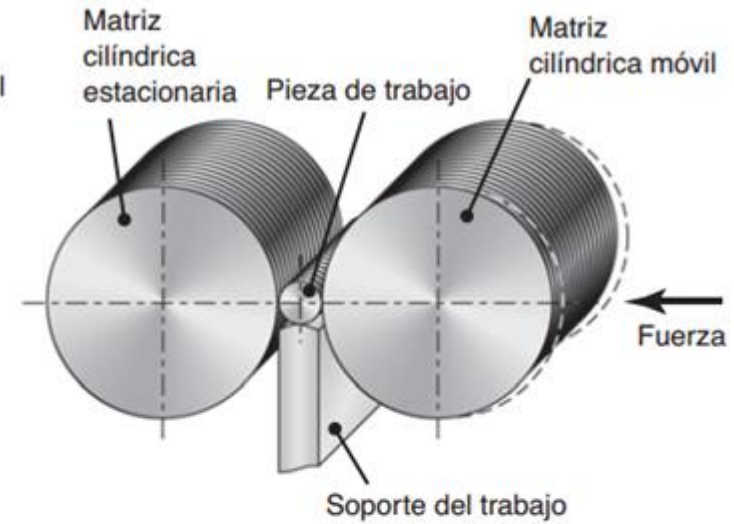
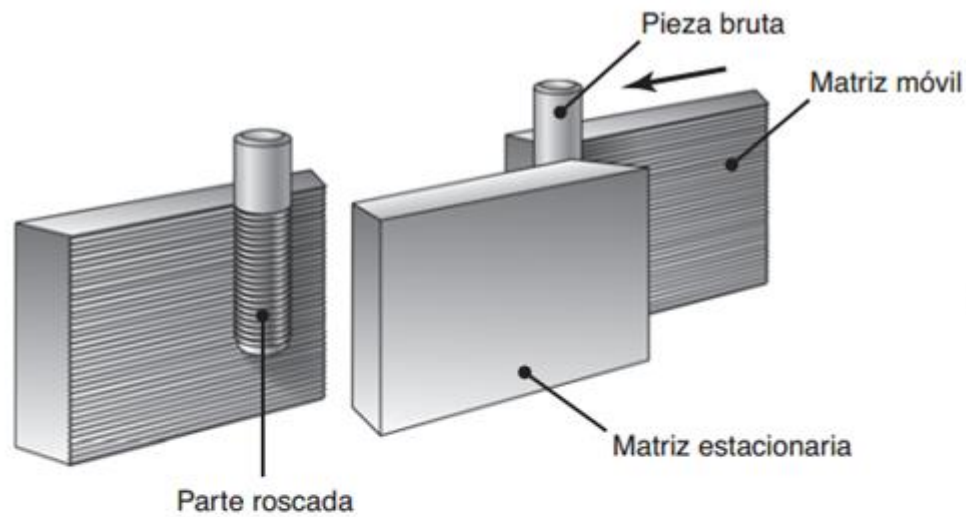
Laminado de Anillo



Laminado de Anillo

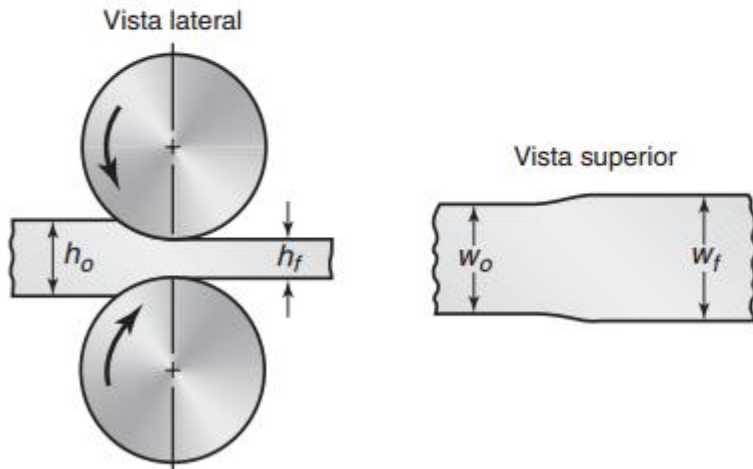


Laminado de Hilos

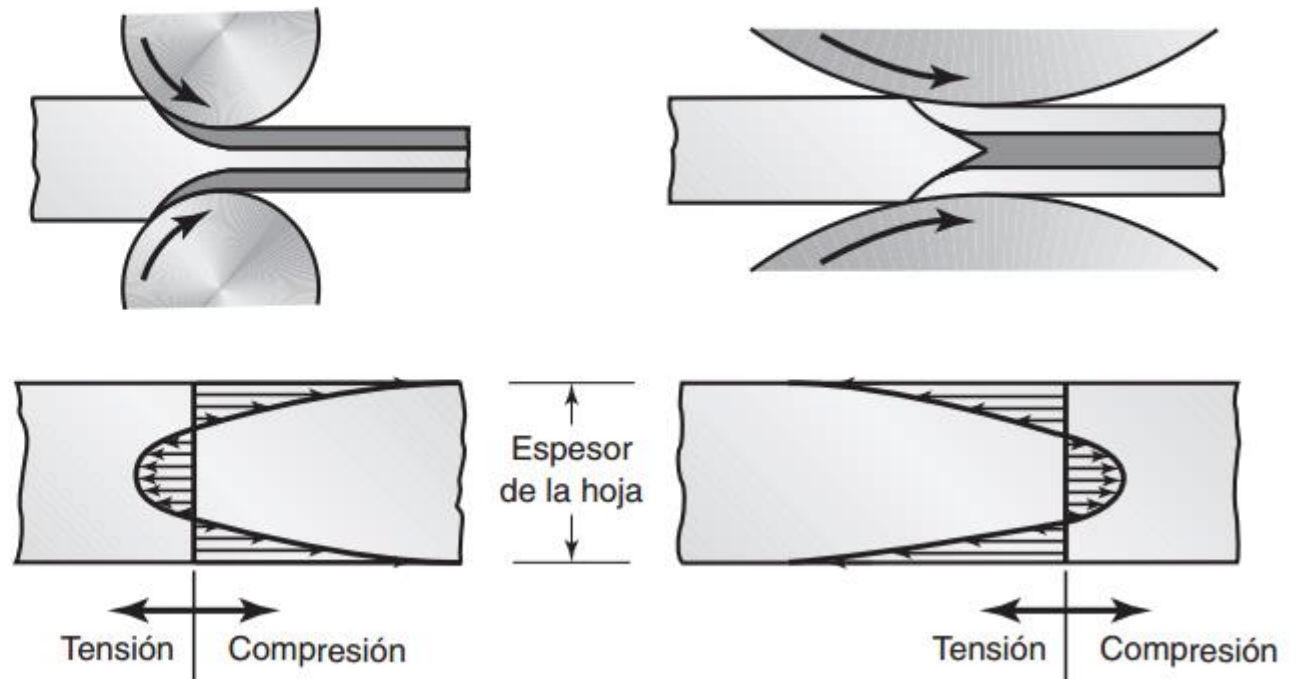


Consideraciones

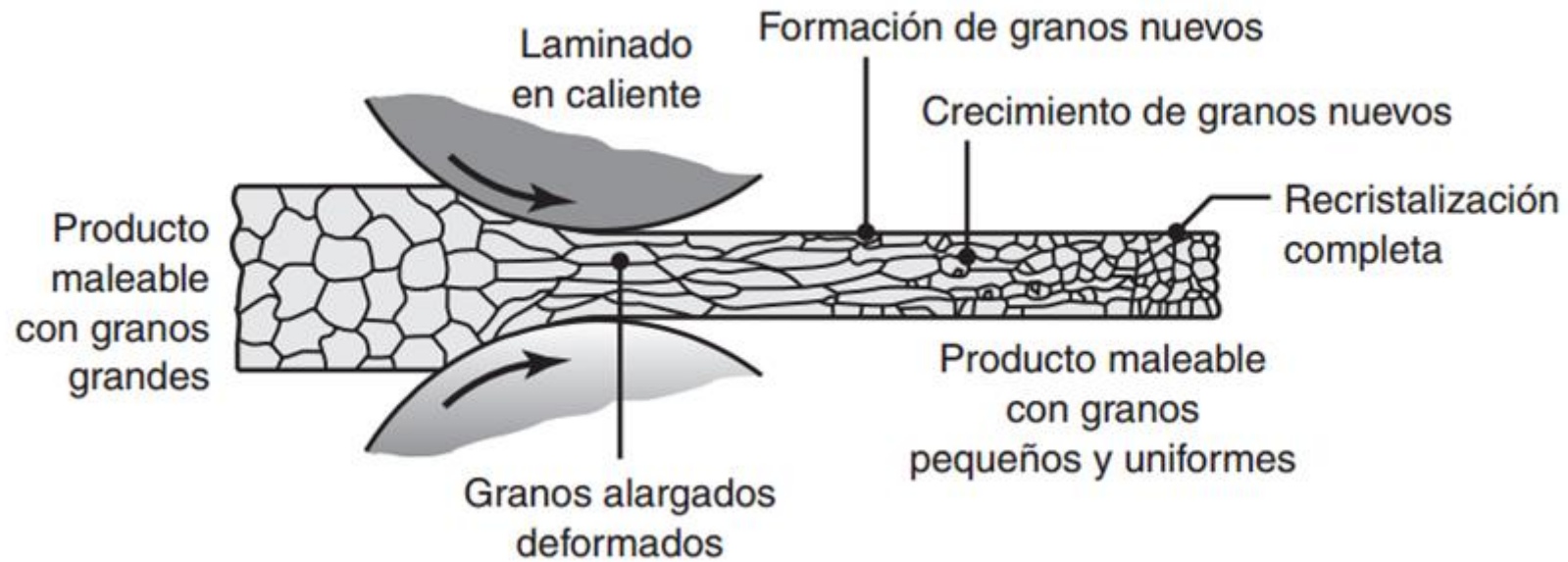
Ensanchamiento



Esfuerzos residuales



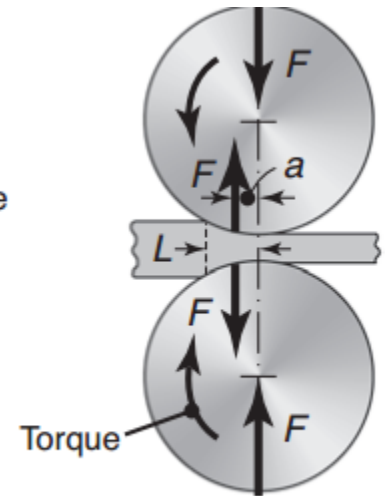
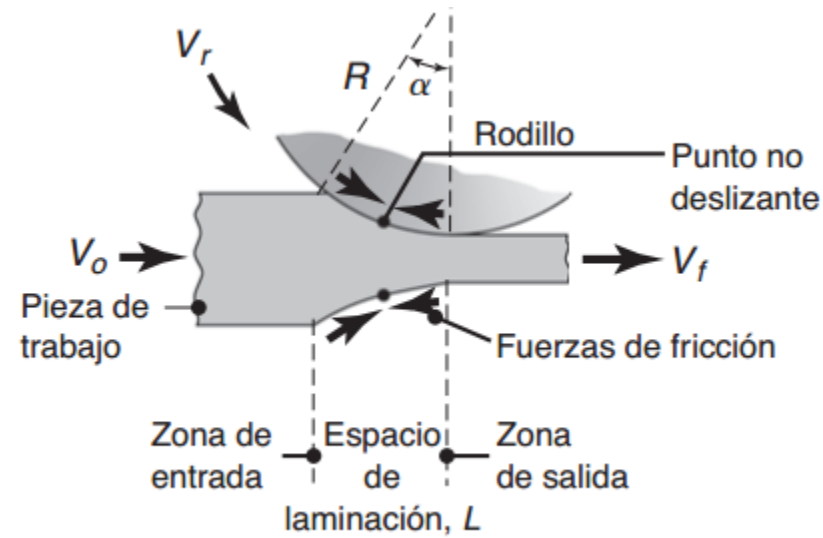
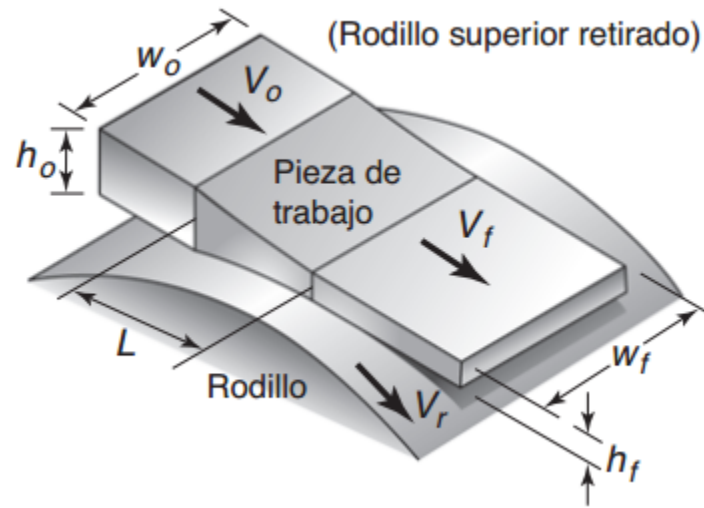
Microestructura de laminado caliente



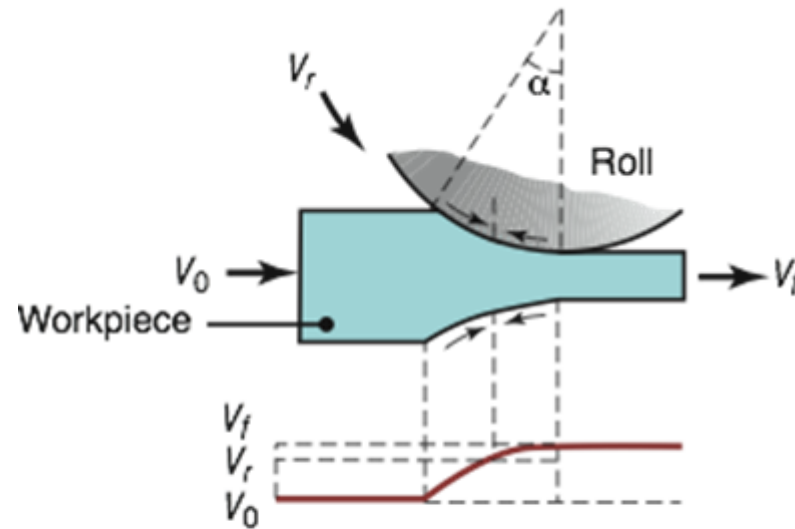


<https://www.youtube.com/watch?v=BazQnUg0k2Q>

Laminación



Análisis de laminación plana



$$h_0 w_0 V_0 = h_f w_f V_f$$

Donde:

h : espesor de la lámina

w : Ancho de la lámina

V : Velocidad de la lámina

f : final del rodillo

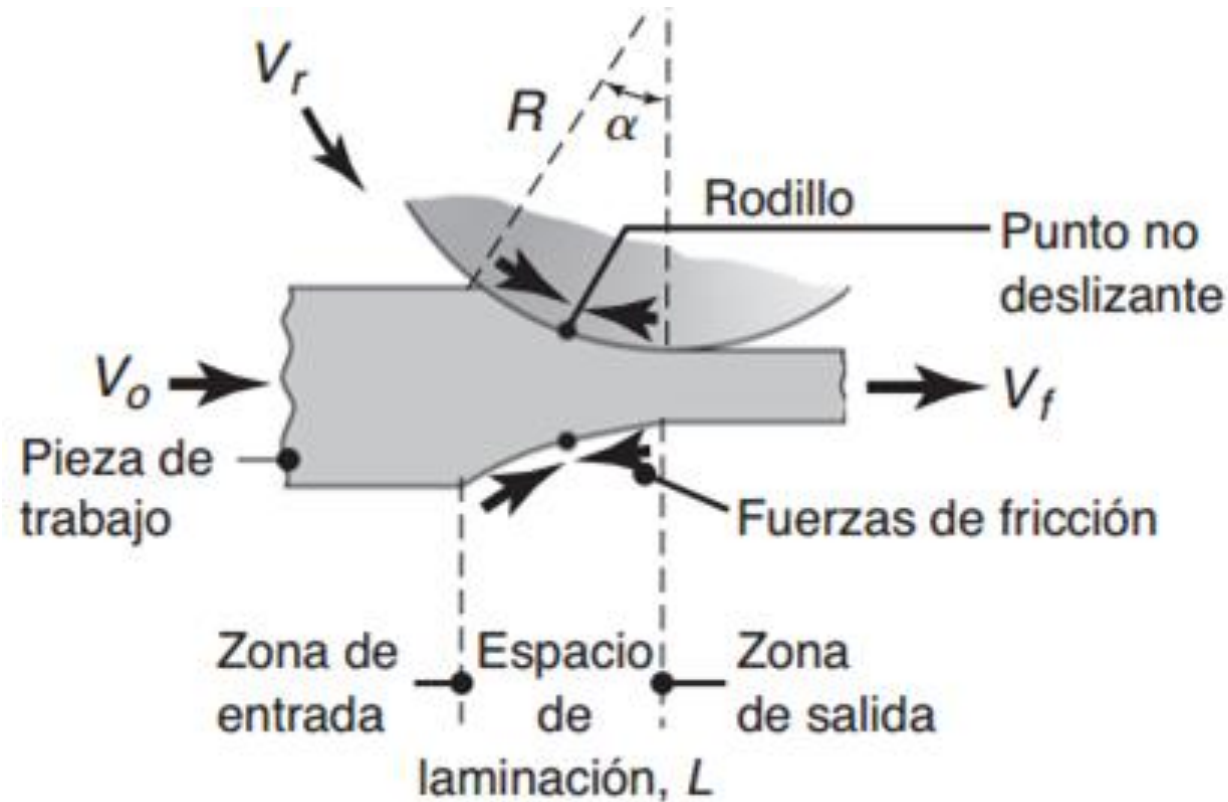
0 : inicio del rodillo

Si:

$$w_0 = w_f$$

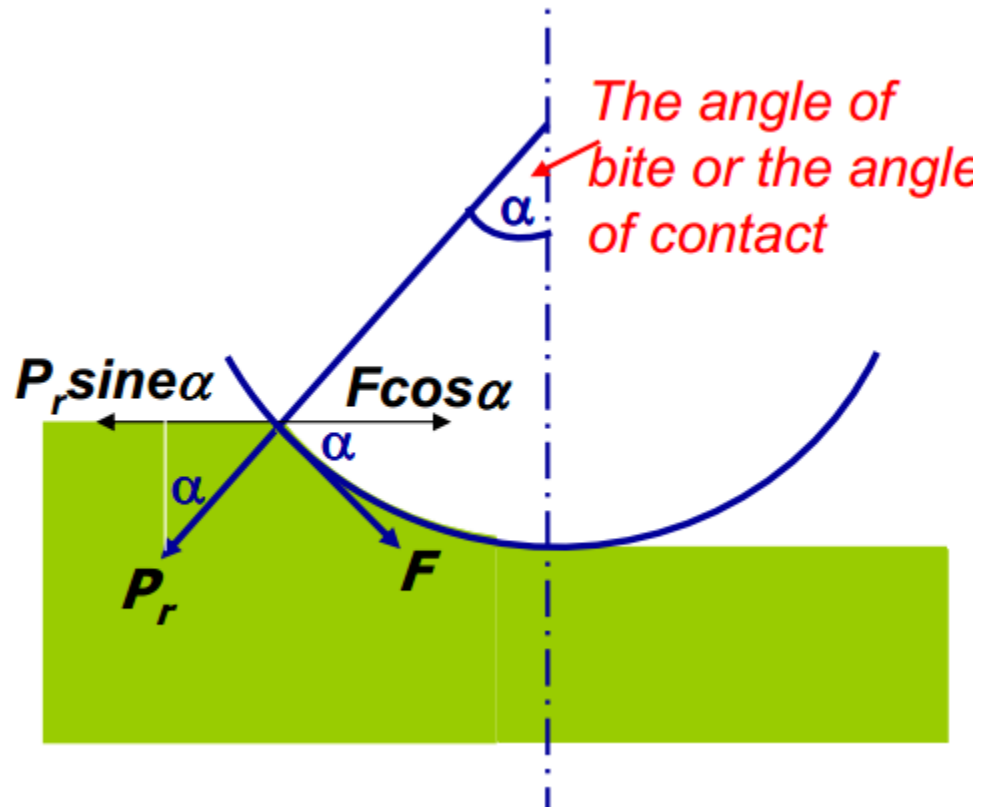
$$\frac{V_0}{V_f} = \frac{h_f}{h_0}$$

Largo de Contacto



$$L \approx \sqrt{R\Delta h}$$

Análisis de laminación plana



- Para que ocurra laminación

$$\tan \alpha \leq \mu$$

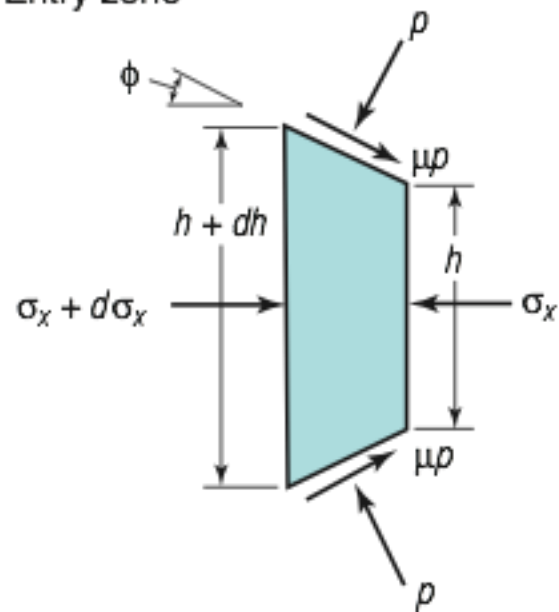
- Para habilitar laminación

- Incrementar μ
- Reducir α (Aumentar R)

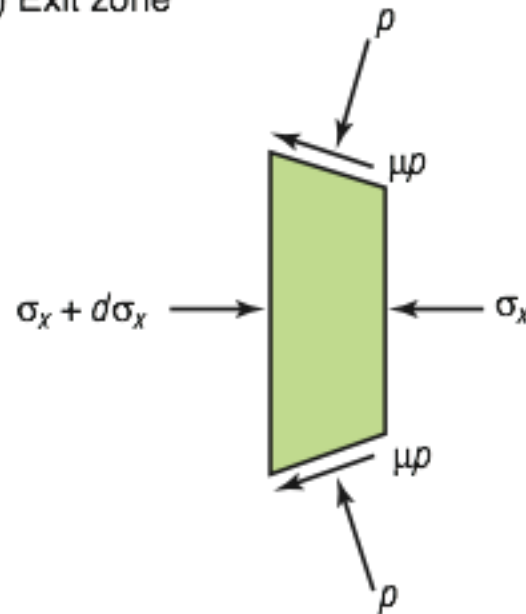
- Por otro lado, en el caso límite $\Delta h_{max} \leq \mu^2 R$

Análisis de laminación plana

(a) Entry zone



(b) Exit zone

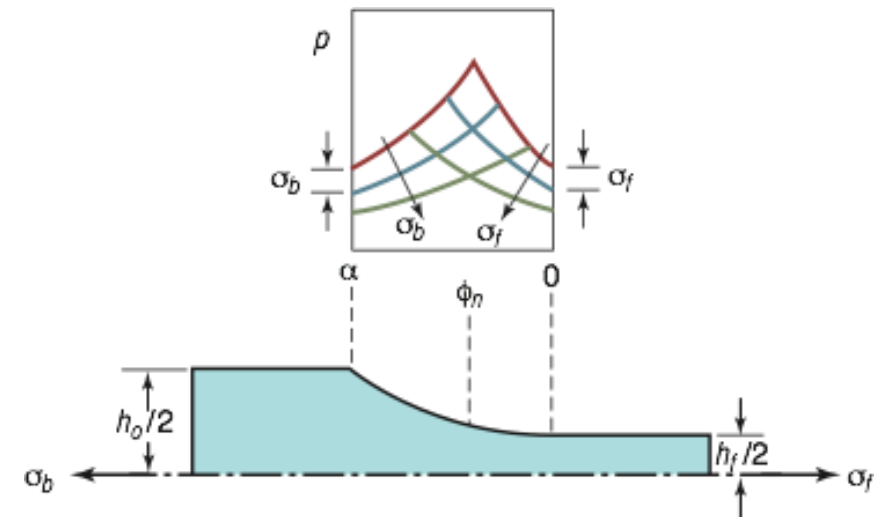
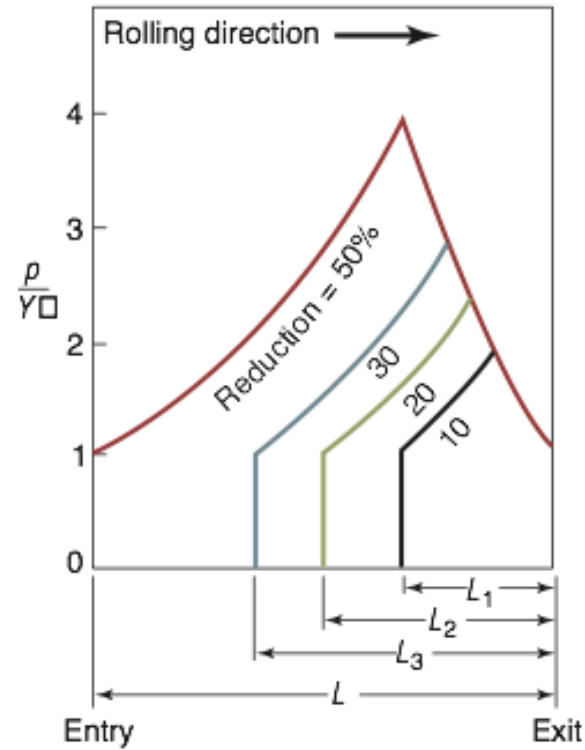
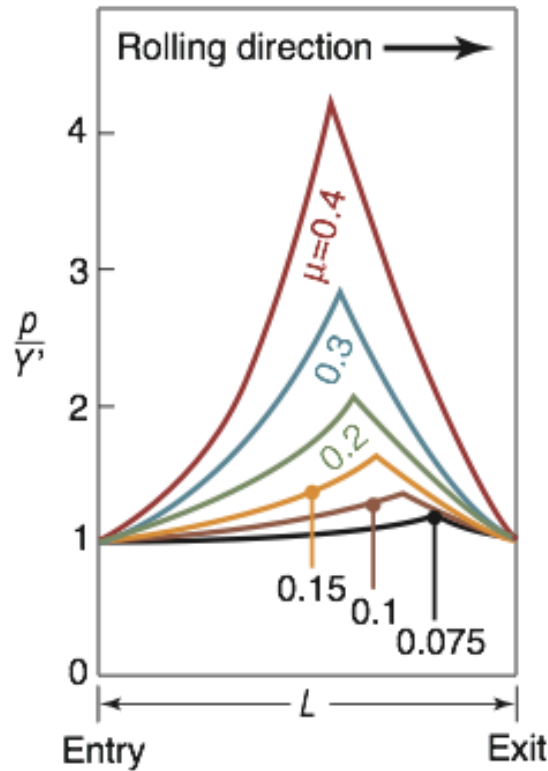


$$p = Y'_f \frac{h}{h_0} e^{\mu(H_0 - H)}$$

$$p = Y'_f \frac{h}{h_f} e^{\mu H}$$

$$H = 2\sqrt{\frac{R}{h_f}} \tan^{-1} \left(\sqrt{\frac{R}{h_f}} \phi \right)$$

Análisis de laminación plana



Análisis de laminación plana

Caso sin Fricción

$$F \approx \bar{p}wL \approx \bar{\sigma}_y wL$$

Caso Con Fricción

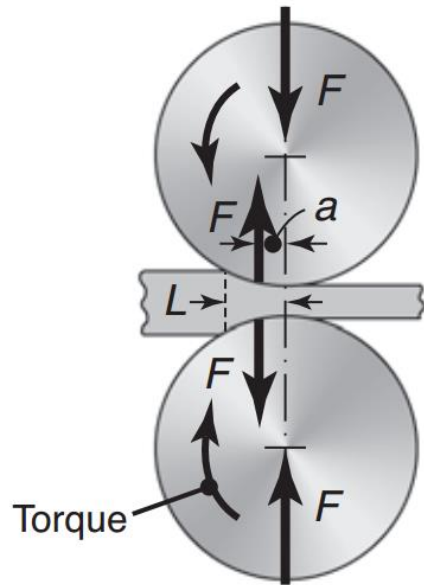
$$F \approx \bar{p}wL \approx \bar{\sigma}_y \left(\frac{e^Q - 1}{Q} \right) wL$$

$$Q = \frac{\mu L}{\bar{h}}$$

$$L \approx \sqrt{R\Delta h}$$

Análisis de laminación plana

- Torque y Potencias



$$T \approx \frac{FL}{2}$$

$$P \approx 2 \times \frac{2\pi N}{60} T$$

Ejemplo

- Lamiando en frio

- $w=300\text{mm}$
- $h_o= 25\text{mm}$
- $h_f= 22\text{mm}$
- $R=250\text{mm}$
- $N=50 \text{ RPM}$
- $\mu = 0.12 \text{ (frio)}$ 0.5 caliente

$$\sigma_y = 270\text{MPa} \varepsilon^{0.15}$$

- frio

- ¿Es posible?

- Fuerza
- Torque
- Potencia

Resumen de la Clase

- Introducción a Laminación
- Análisis de Laminación
- Siguiendo clase
 - Introducción y Análisis de Forja