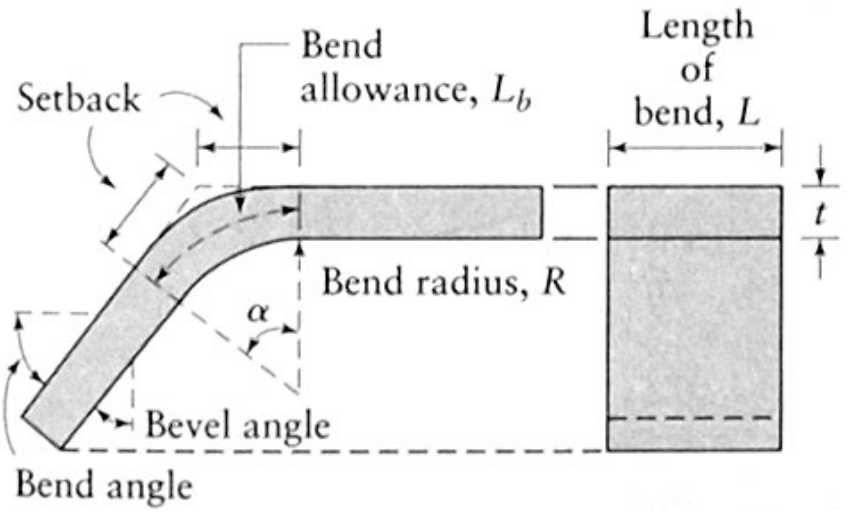
Lavorazione lamiera II

Piegatura della lamiera
Stretch forming
Bulging
Rubber forming e idroformatura
Spinning
Formatura ad alta energia
Formatura superplastica
Altri metodi di formatura

Piegatura della lamiera

- La piegatura viene effettuata per ottenere determinate forme, ma anche per irrigidire alcune strutture
- Bend allowance: lunghezza dell'asse neutro nella zona piegata.



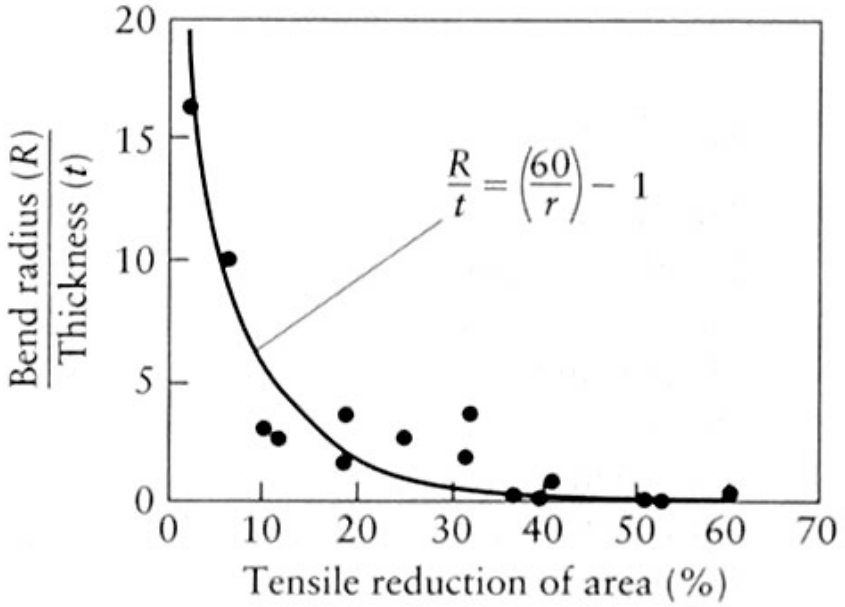
$$L_b = \alpha(R + kt)$$

$$R < 2t \Rightarrow k \rightarrow 0.33$$

$$R > 2t \Rightarrow k \rightarrow 0.5$$

Raggio minimo di piegatura

- Per calcolare il raggio minimo di piegatura si considera che le fibre esterne e interne raggiungono la stessa deformazione assoluta:
- $$e_o = e_i = \frac{1}{\frac{2R}{t} + 1}$$
- La deformazione esterna delle fibre = massimo strain a rottura



$$\varepsilon_f = \ln\left(\frac{A_0}{A_f}\right) = \ln\left(\frac{100}{100 - r}\right)$$

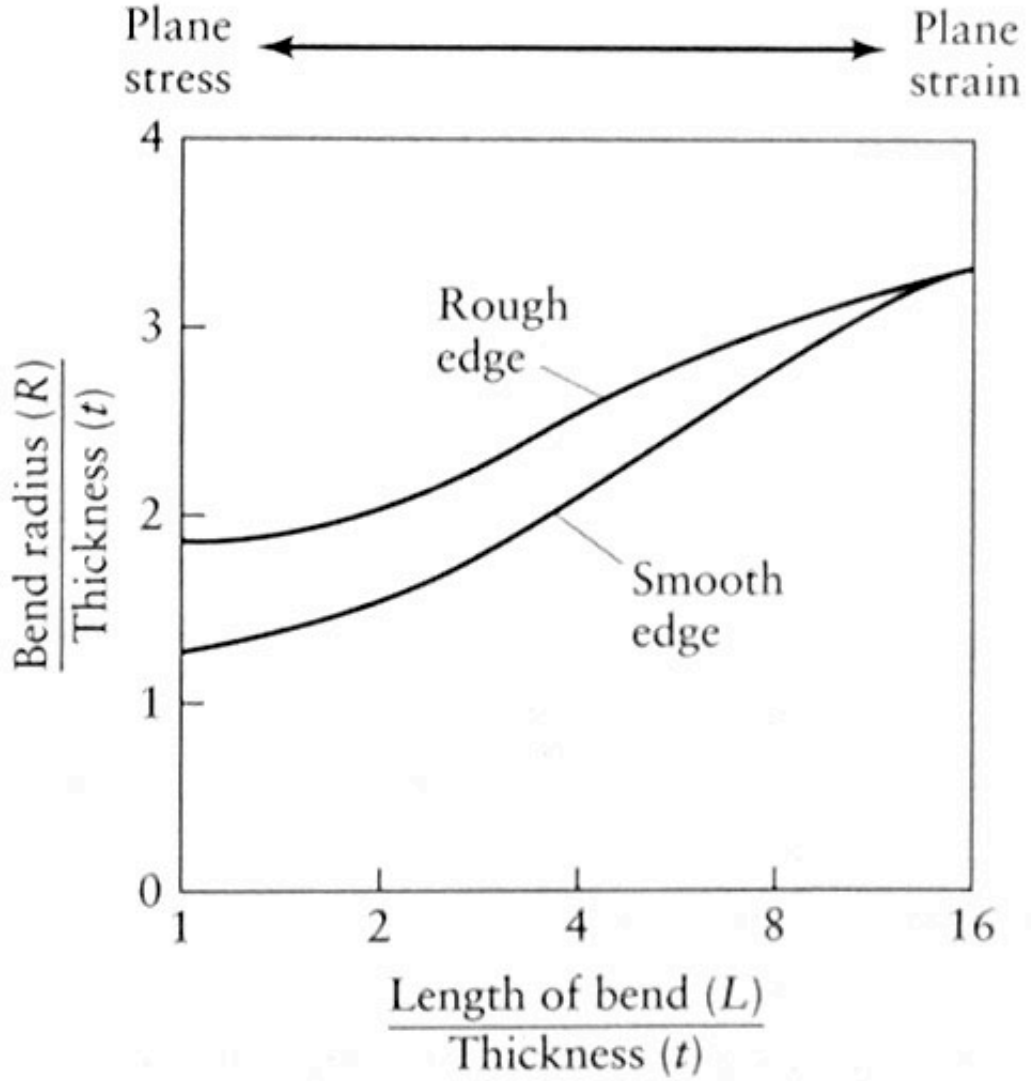
$$\varepsilon_o = \ln(1 + e_o) = \ln\left(1 + \frac{1}{\frac{2R}{t} + 1}\right) = \ln\left(\frac{R + t}{R + \frac{t}{2}}\right)$$

$$\left(\frac{R}{t}\right)_{\min imo} = \frac{50}{r} - 1 \approx \frac{60}{r} - 1$$

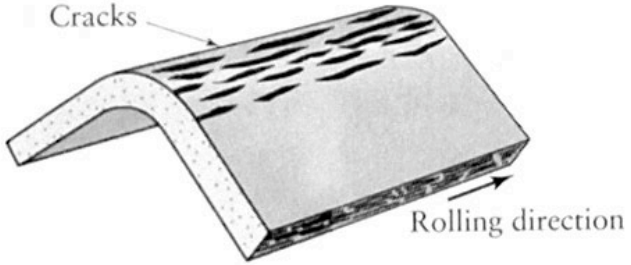
Raggio minimo di piegatura

	Condizione materiale	
Materiale	tenero	duro
Leghe alluminio	0	6t
Berillio, rame	0	4t
Ottone	0	2t
Magnesio	5t	13t
Acciai		
inossidabili austenitici	0.5t	6t
basso carbonio, basso legati, HSLA	0.5t	4t
Titanio	0.7t	3t
Leghe titanio	2.6t	4t

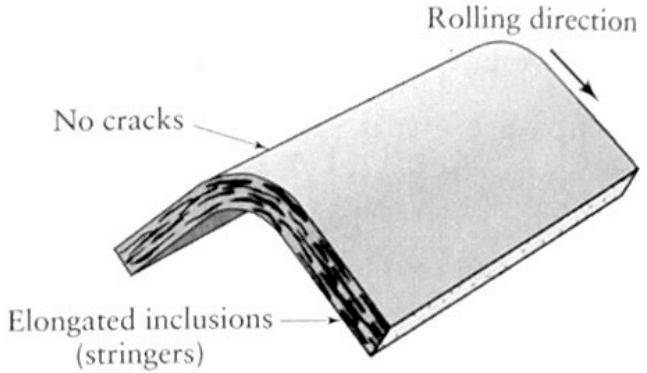
Deformabilità per piegatura



Tessitura e deformabilità per piegatura

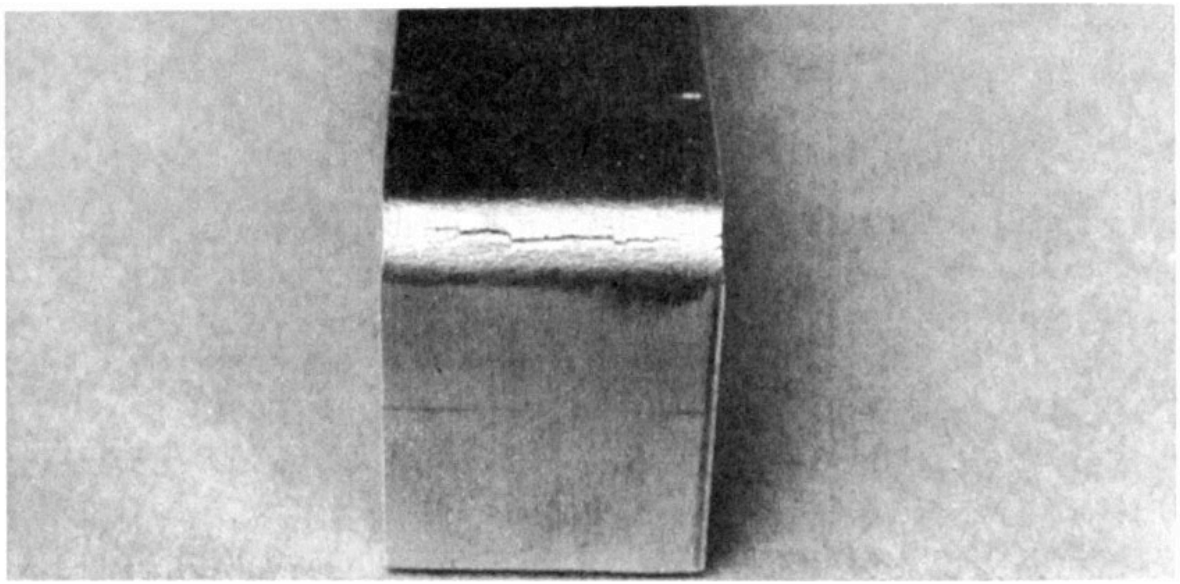


(a)



(b)

Leghe Al

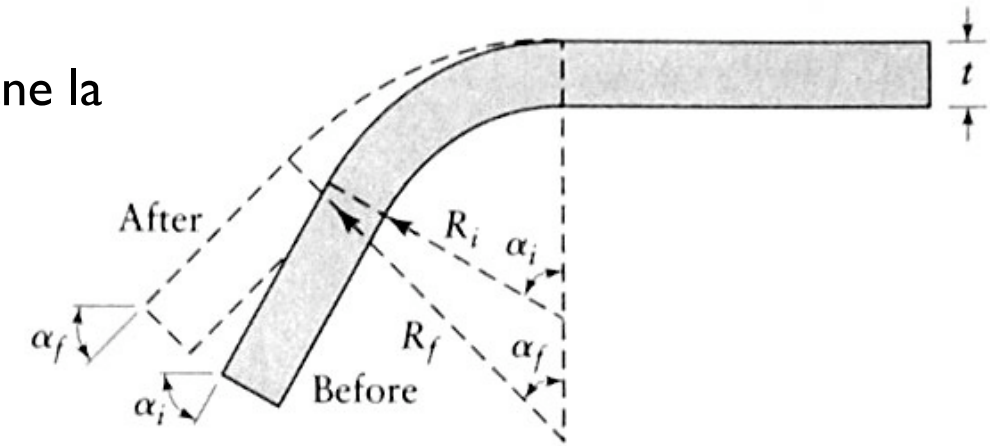


(c)

Ritorno elastico

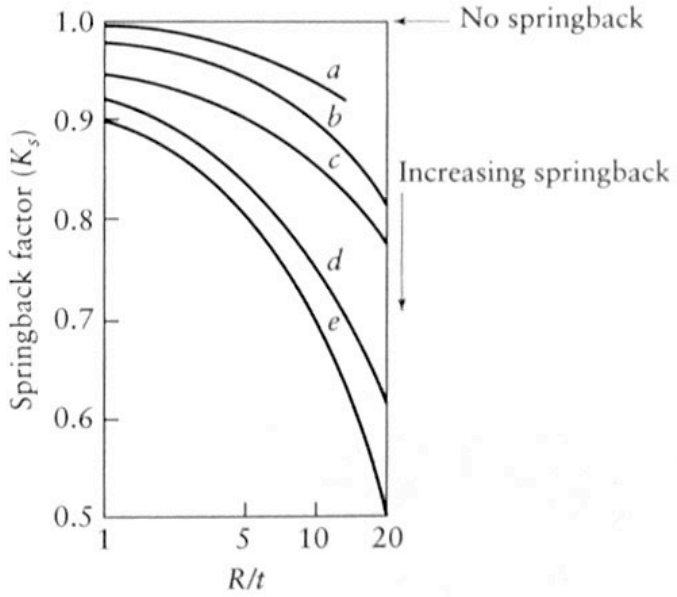
La lunghezza della piegatura rimane la stessa dopo il ritorno elastico:

$$L_b = \left(R_i + \frac{t}{2}\right)\alpha_i = \left(R_f + \frac{t}{2}\right)\alpha_f$$



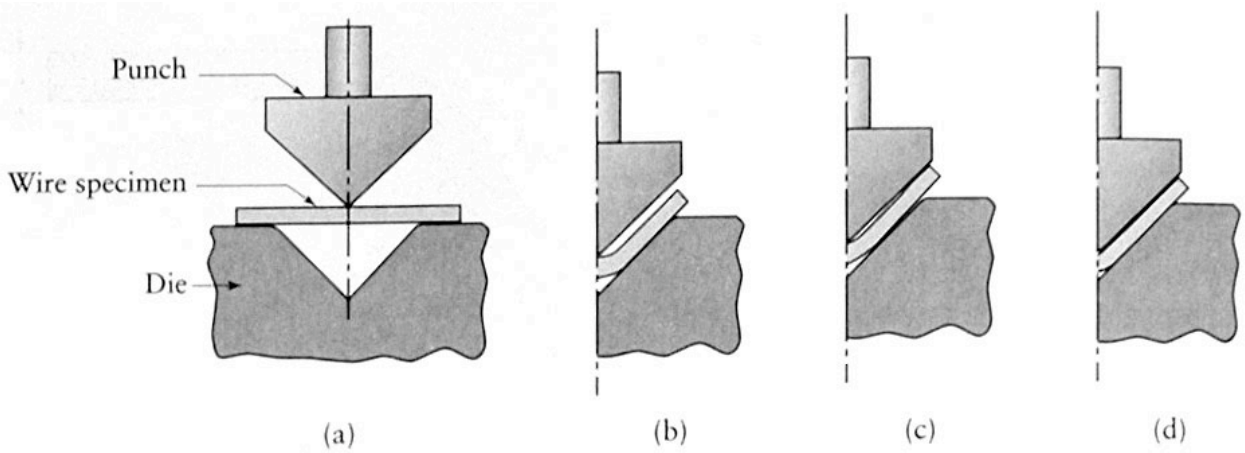
Il fattore di ritorno elastico si definisce quindi come:

$$K_s = \frac{\alpha_f}{\alpha_i} = \frac{\frac{2R_i}{t} + 1}{\frac{2R_f}{t} + 1}$$

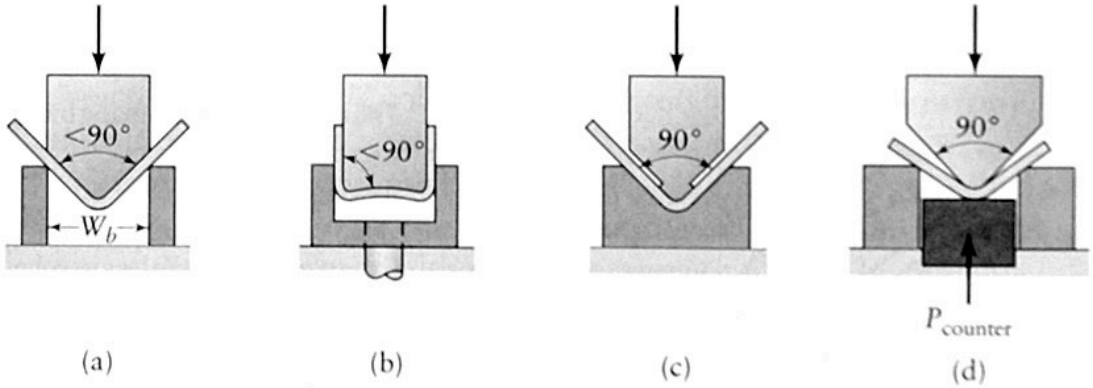


Ritorno elastico negativo e compensazioni

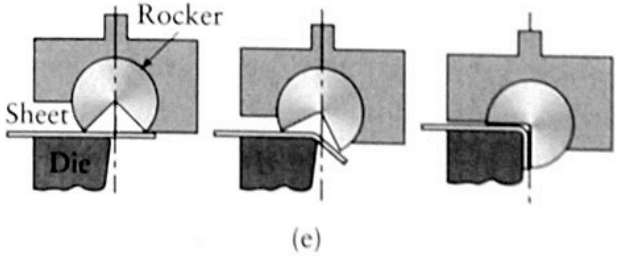
Ritorno elastico negativo



Metodi di compensazione del ritorno elastico



Metodi:
- Overbending (a-b, e)
- Coining (c-d)
- Stretch bending
- Ad alta temperatura

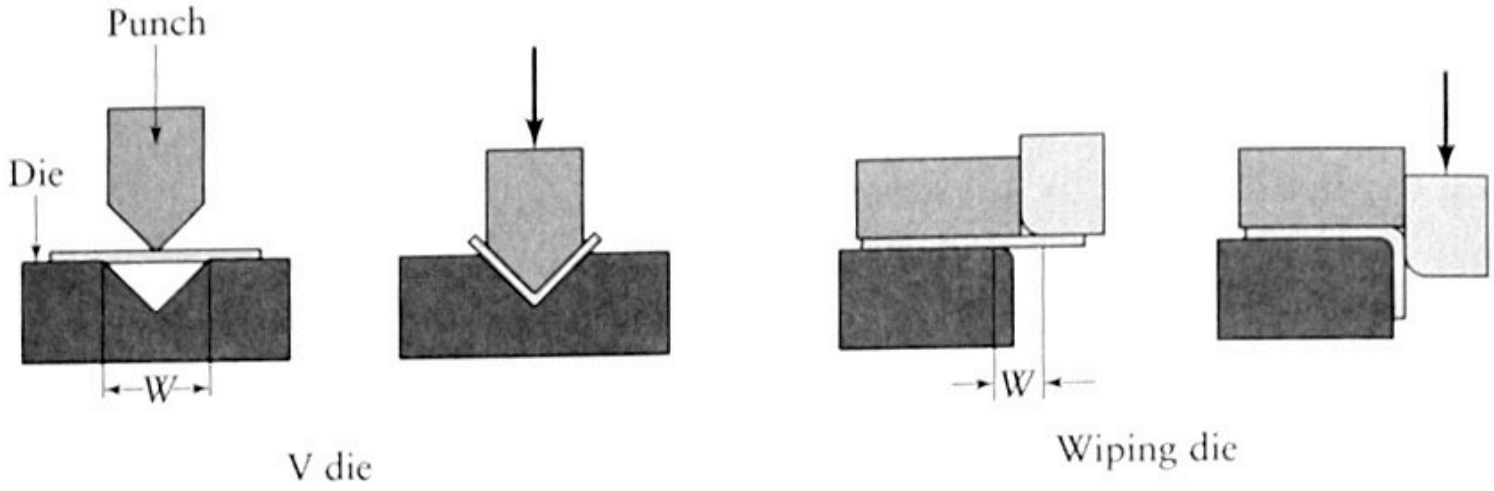


Forza di piegatura

- Se W è l'ampiezza dello stampo e k una variabile che dipende dalla forma dello stampo:

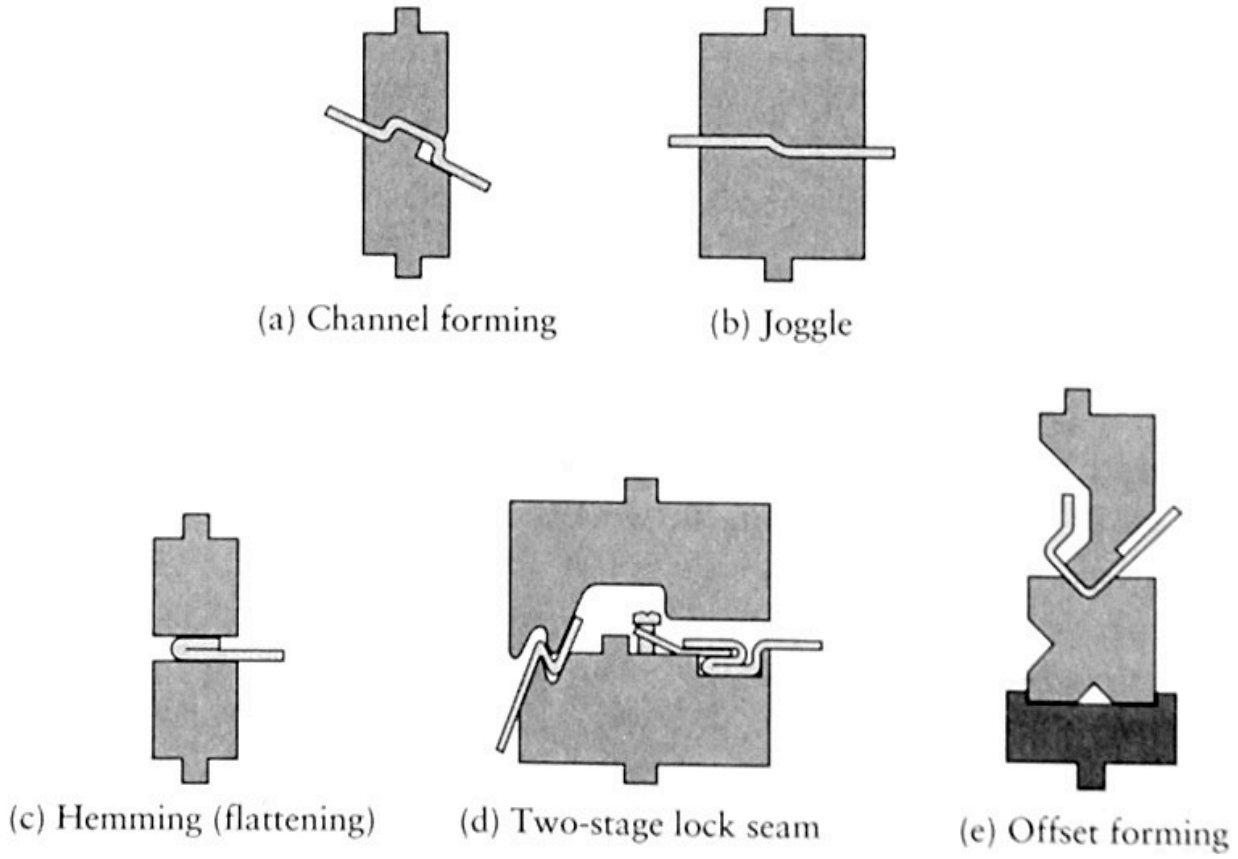
$$F_{\max} = k\frac{(UTS)t^2 L}{W}$$

- k vale 1.2-1.33 per stampo a V oppure 1.4-1.6 per stampo ad U o 0.3-0.4 per "wiping die".

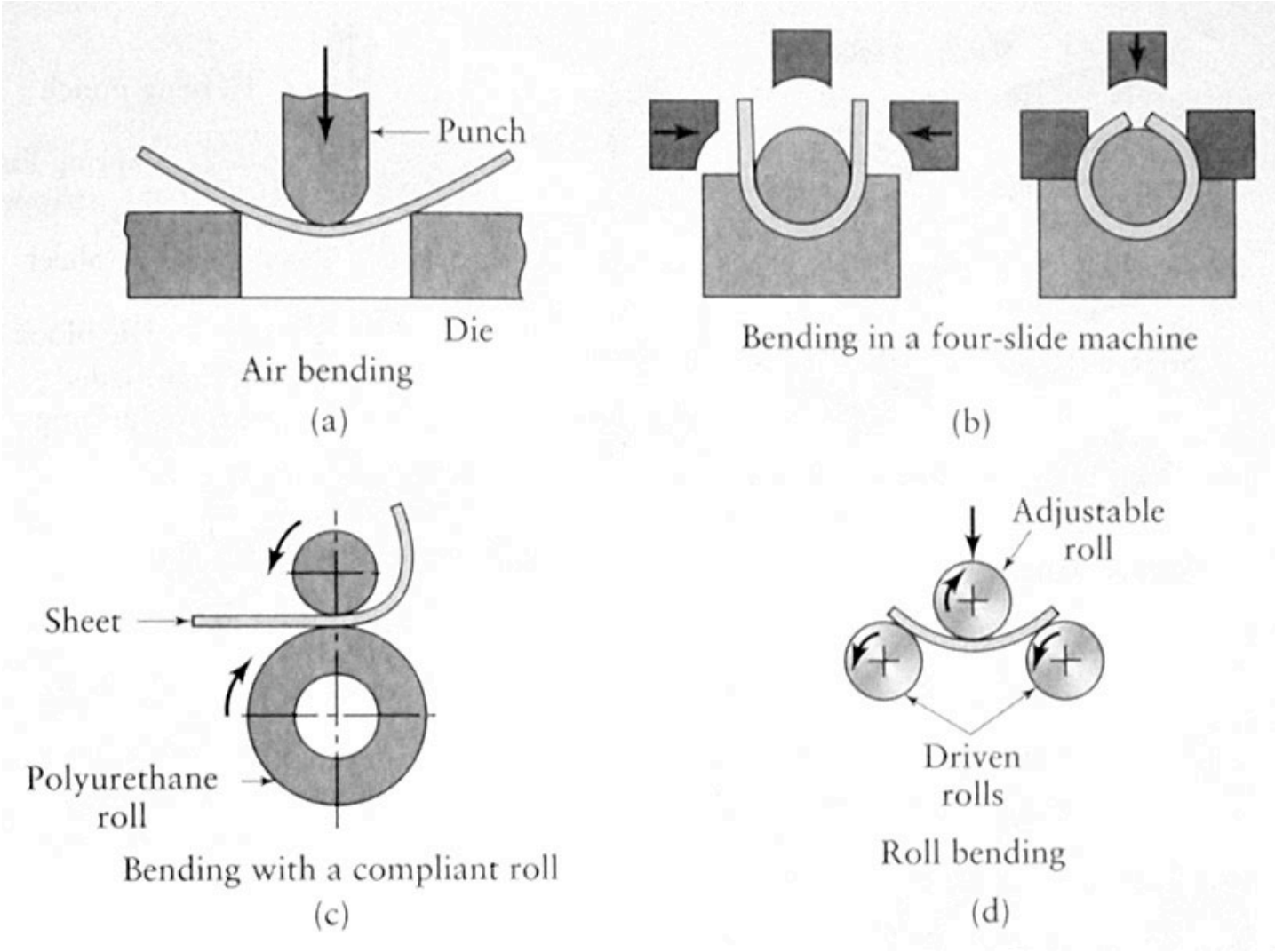


Operazioni di piegatura: tipi

- Formatura in press-brake (pressa frenata):

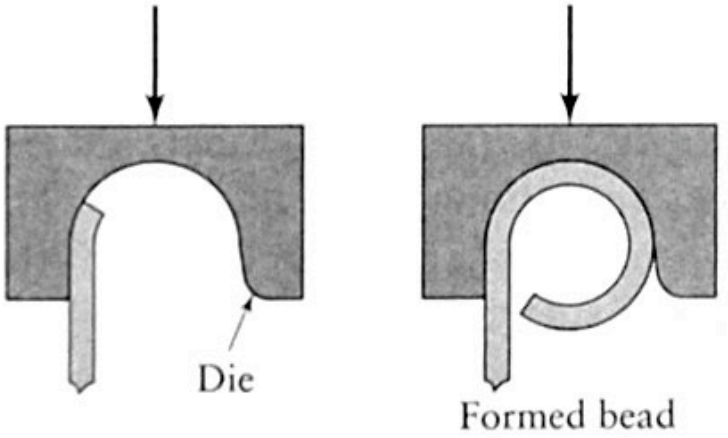


Operazioni di piegatura: tipi

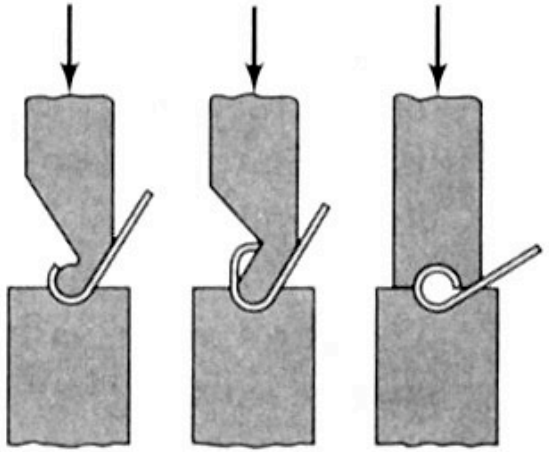


Operazioni di piegatura: tipi

- Beading (modanatura): per incrementare il momento di inerzia degli apici

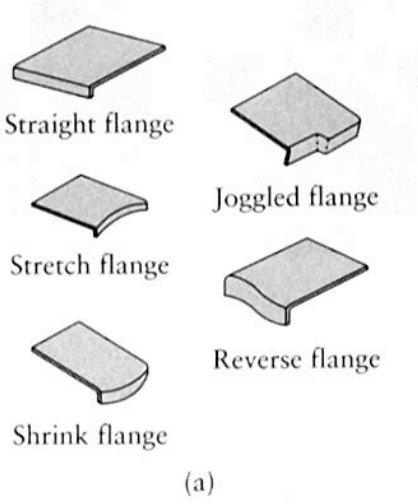


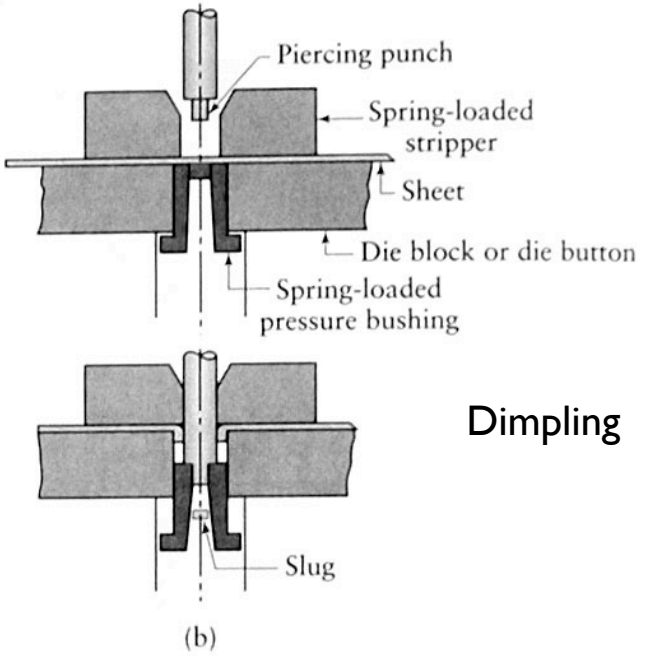
Beading in una press-brake



Operazioni di piegatura: tipi

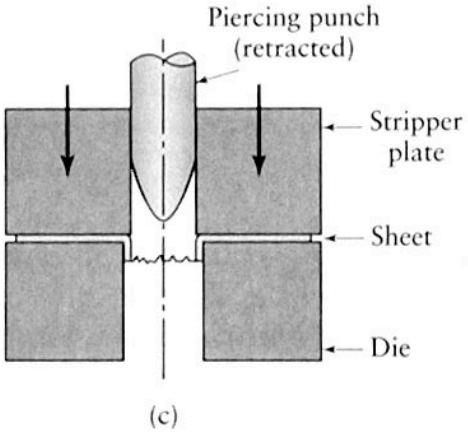
- Flanging (bordatura): per piegare gli spigoli di una piastra

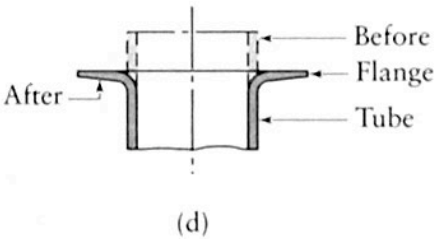




Dimpling

Piercing

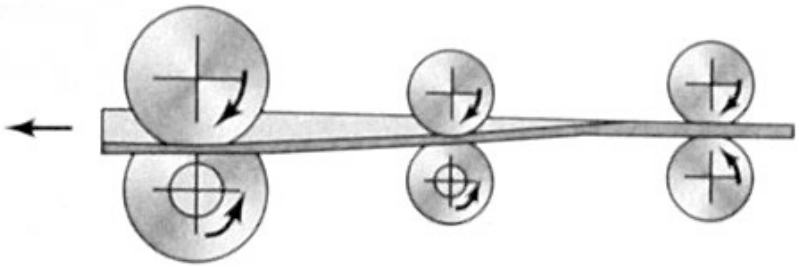


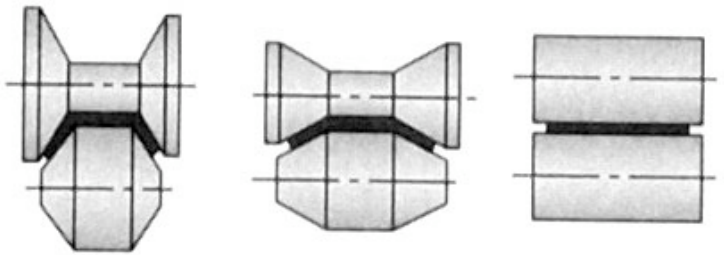


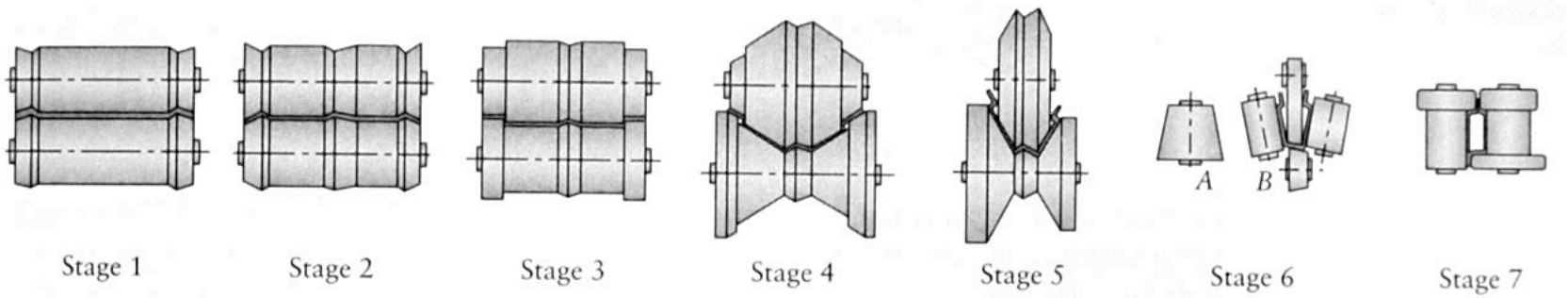
Flangiatura di un tubo

Operazioni di piegatura: tipi

- Roll forming
- I cilindri sono in genere di acciaio e possono essere cromati per migliorare la finitura superficiale nonchè l'usura dei rulli.



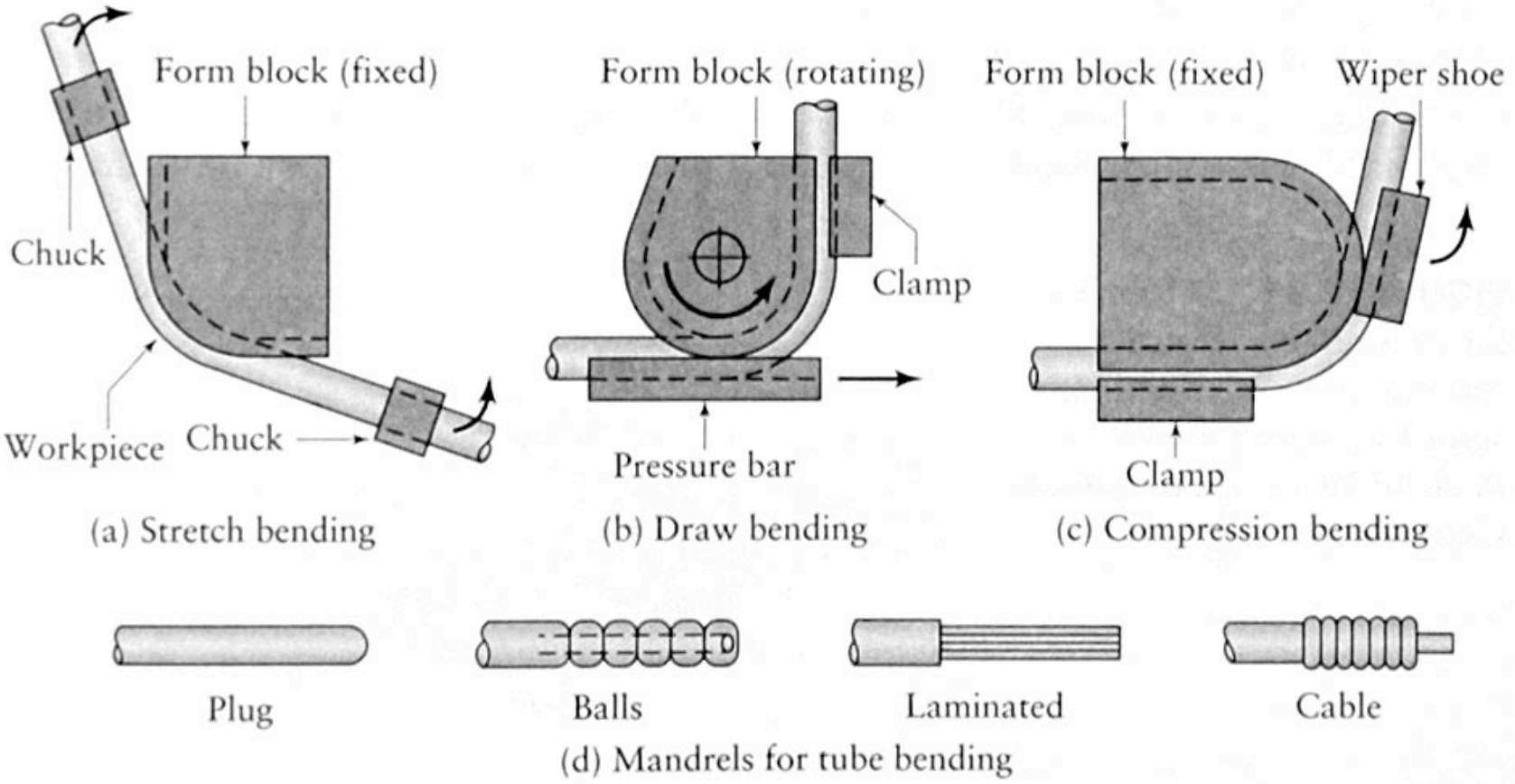




Steps nella formatura di un profilo da serramenti

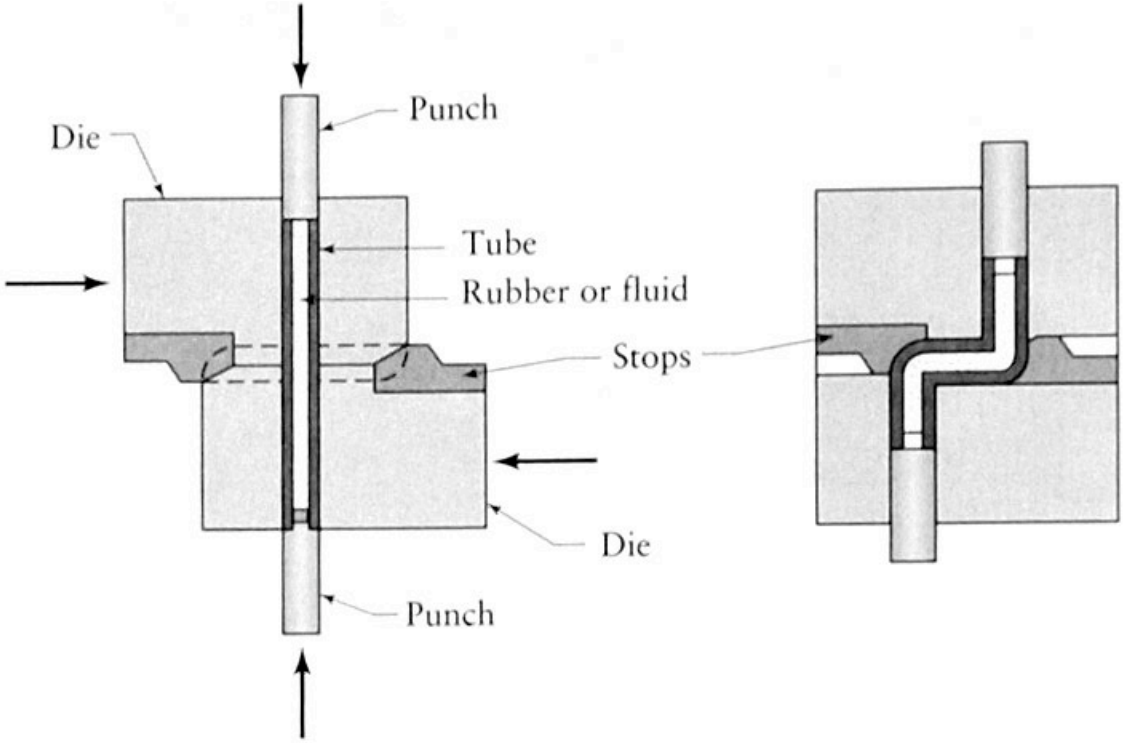
Piegatura di tubi

- Occorrono forme speciali per evitare schiacciamenti e ondulamenti della superficie del tubo a causa del buckling



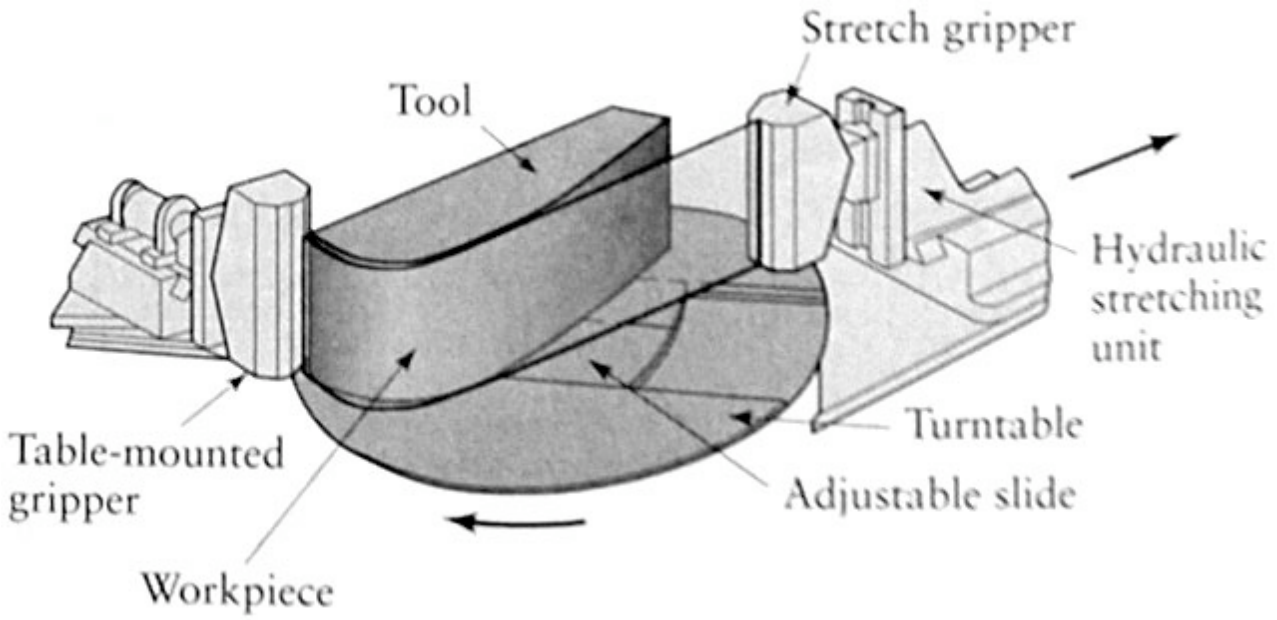
Piegatura di tubi

- Per evitare schiacciamenti o buckling una volta inserivano sabbia, ora si usano mandrini flessibili o liquidi in pressione
- Una compressione longitudinale al tubo permette piegature maggiori



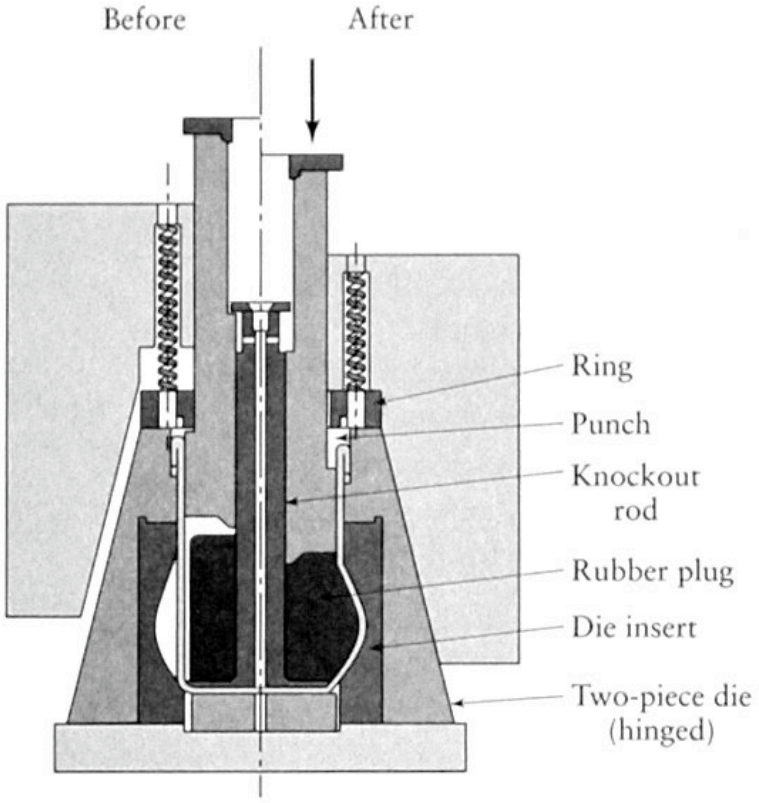
Stretch forming

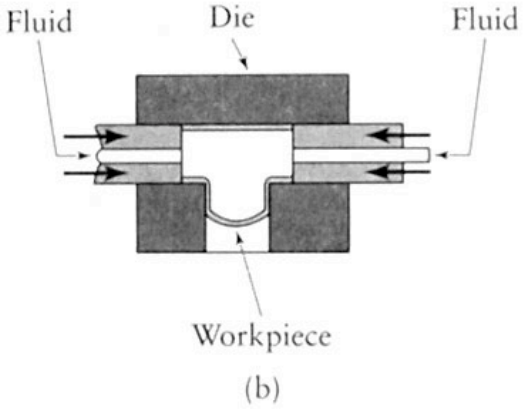
- Si usa per formare pannelli (aerei, automobili etc.), non si producono spigoli vivi, solo forme arrotondate. Le matrici sono di acciaio, zinco, legno o polimeri duri, senza lubrificazione

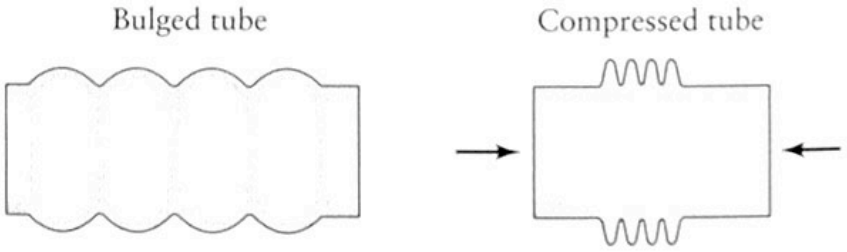


Bulging

- Simile alla soffiatura si usa un liquido viscoso o materiale deformabile come la gomma (poliuretanica) per distribuire il carico.

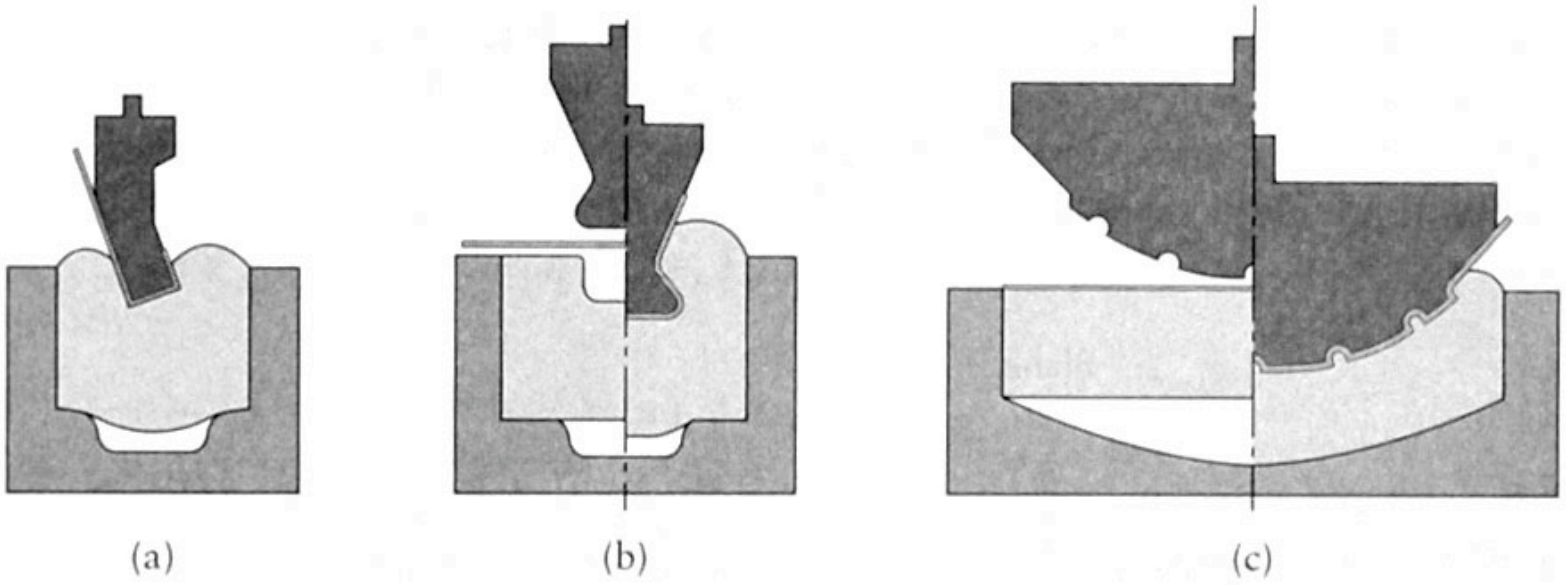






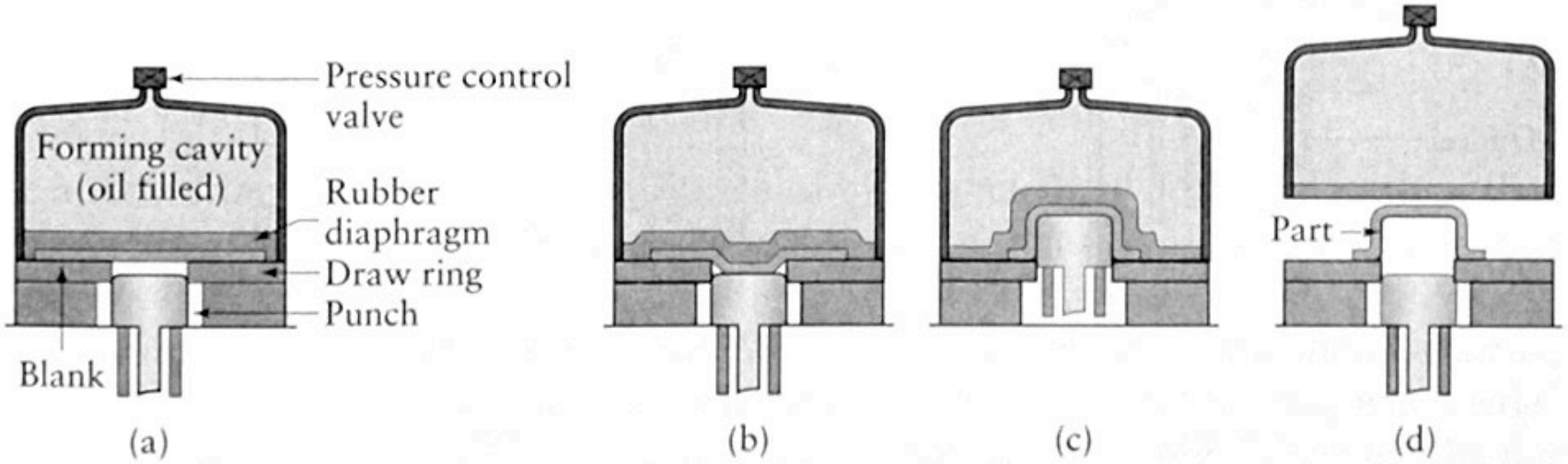
Embossing (bulging-rubber forming)

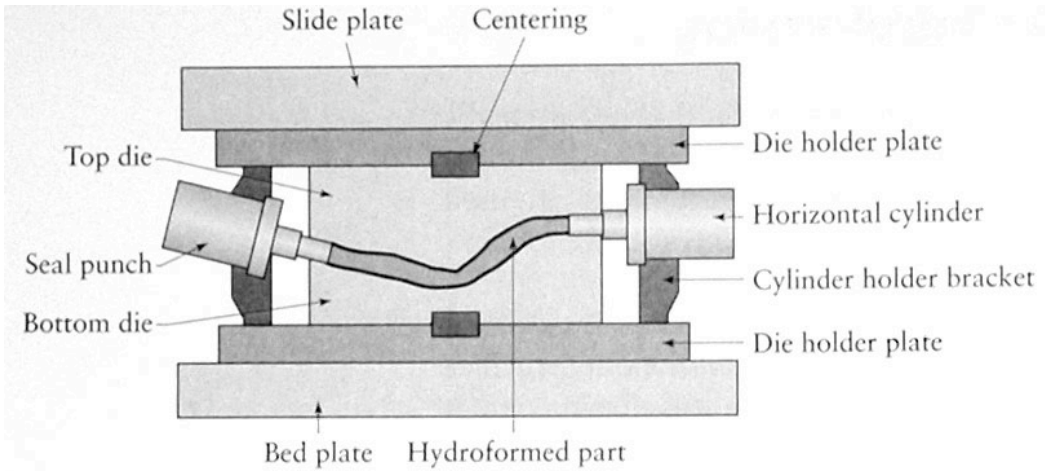
- Si usa anche per rilievi (stampatura di lettere...). Lo stampo femmina è flessibile (poliuretano), mentre il punzone con il maschio viene fatto in acciaio

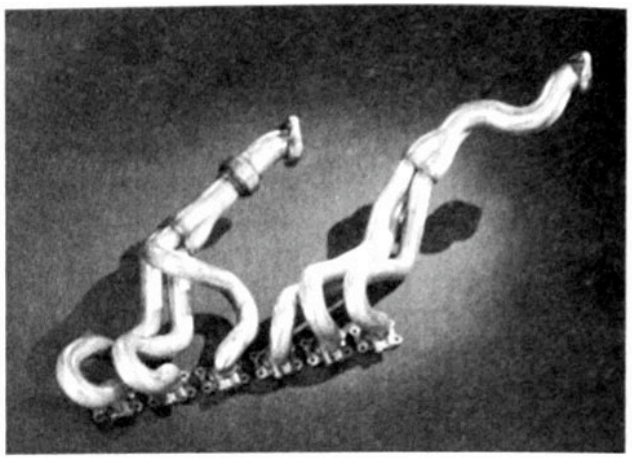


Rubber forming e idroformatura

- Si usano pressioni fino a 100 MPa

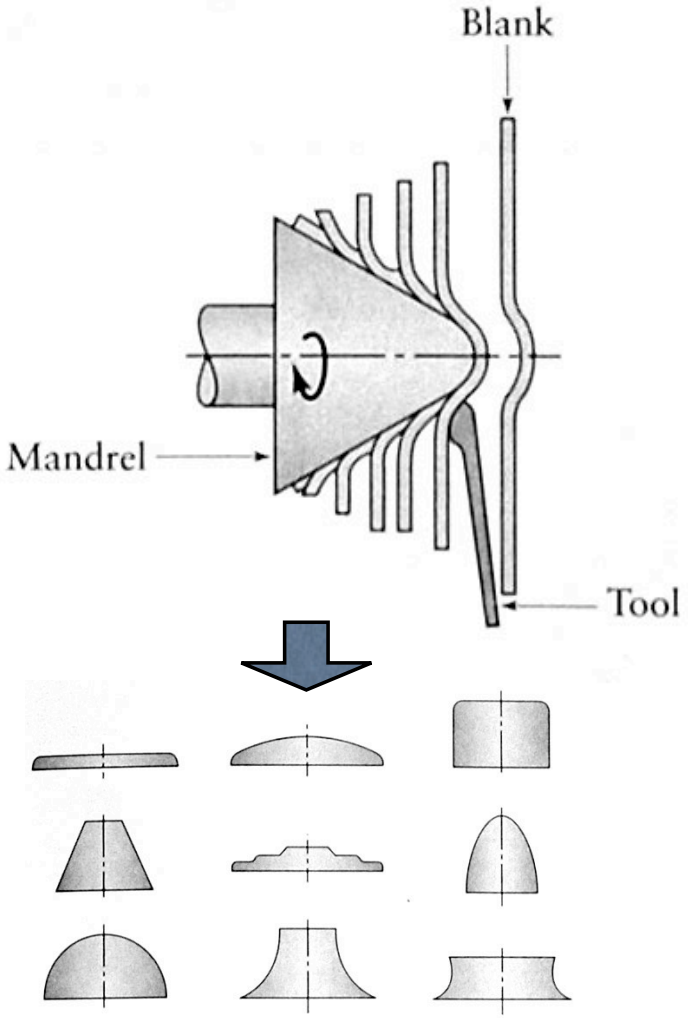


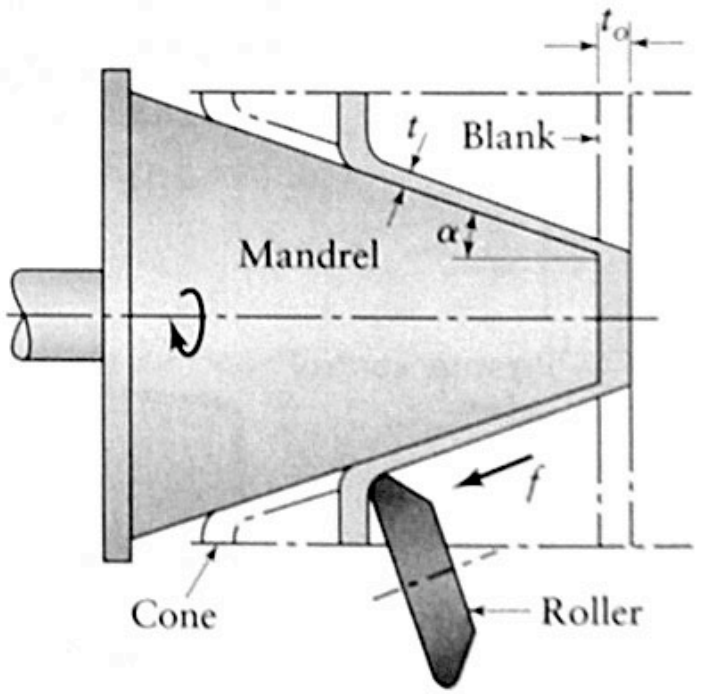




Spinning

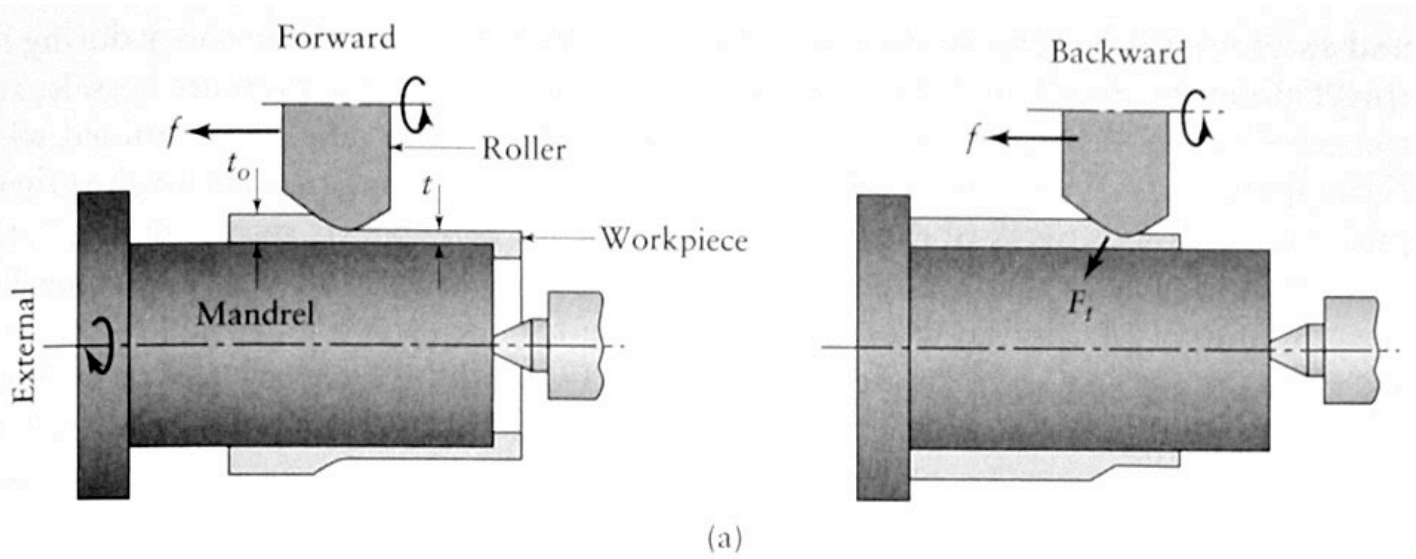
Spinning convenzionale



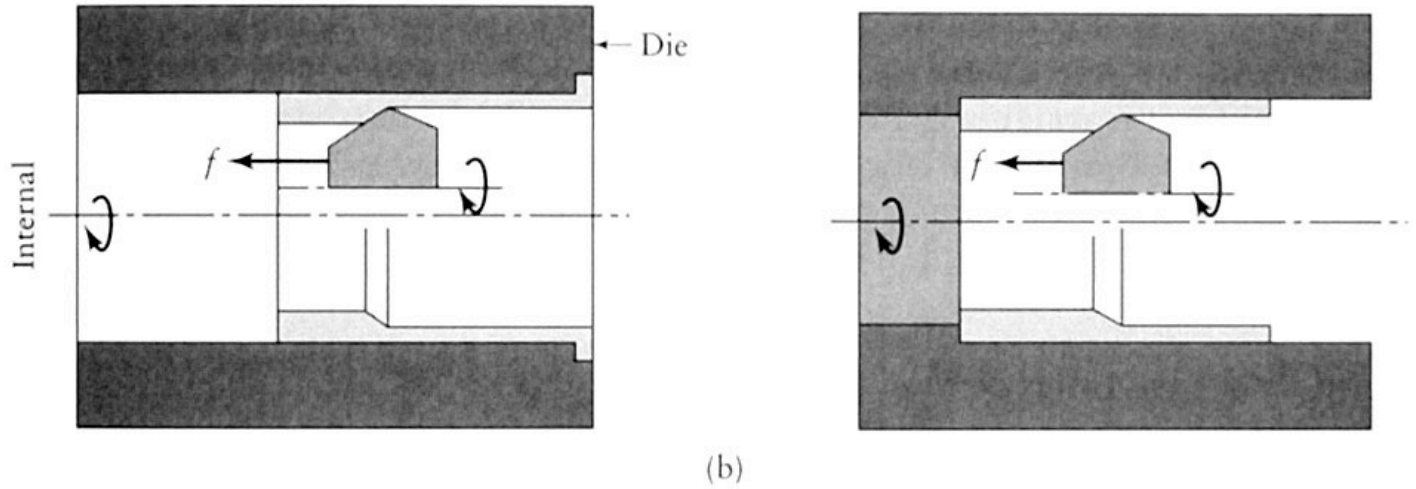


Shear spinning: il diametro del pezzo rimane costante, diminuisce lo spessore

Tube spinning

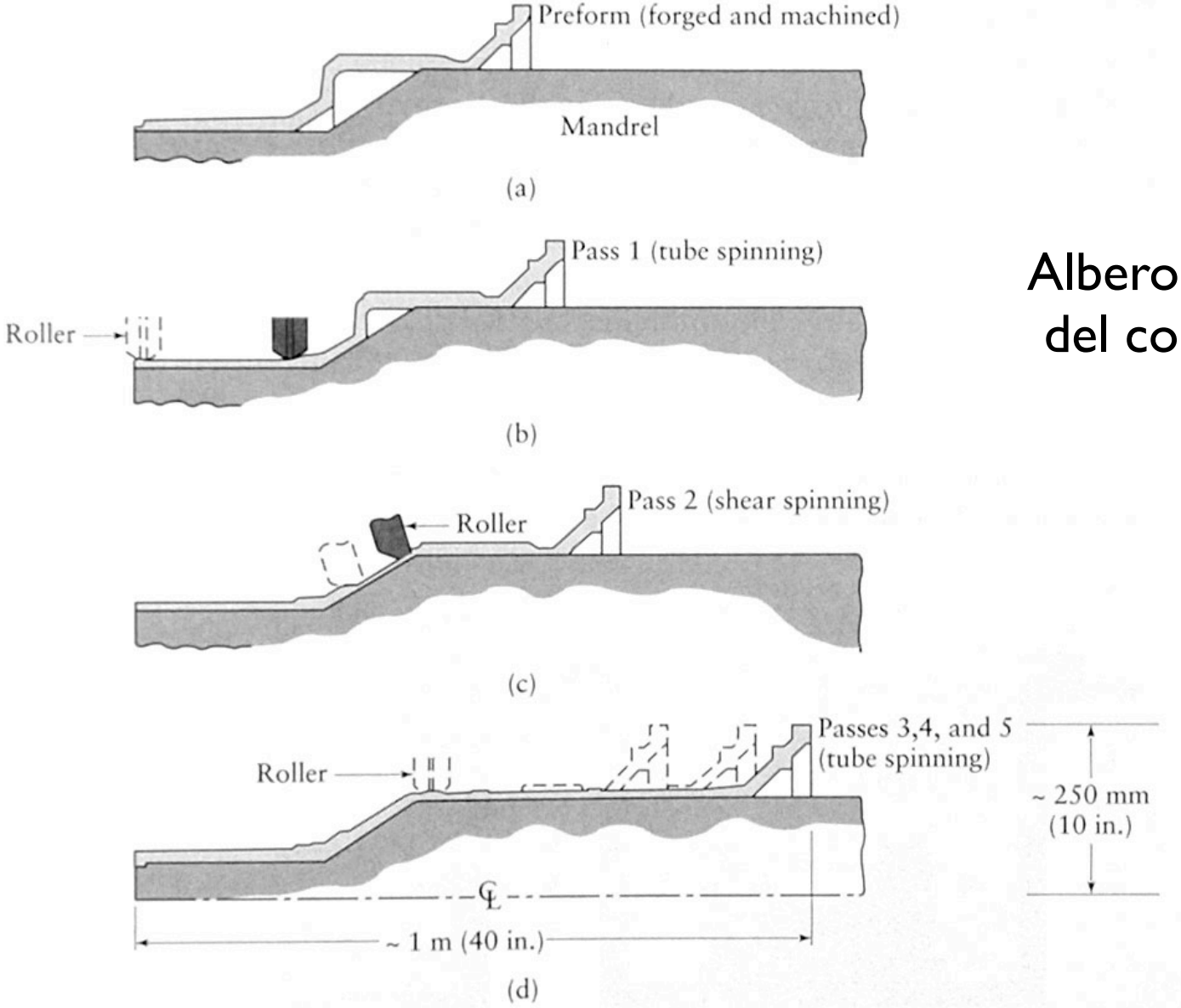


Esterno



Interno

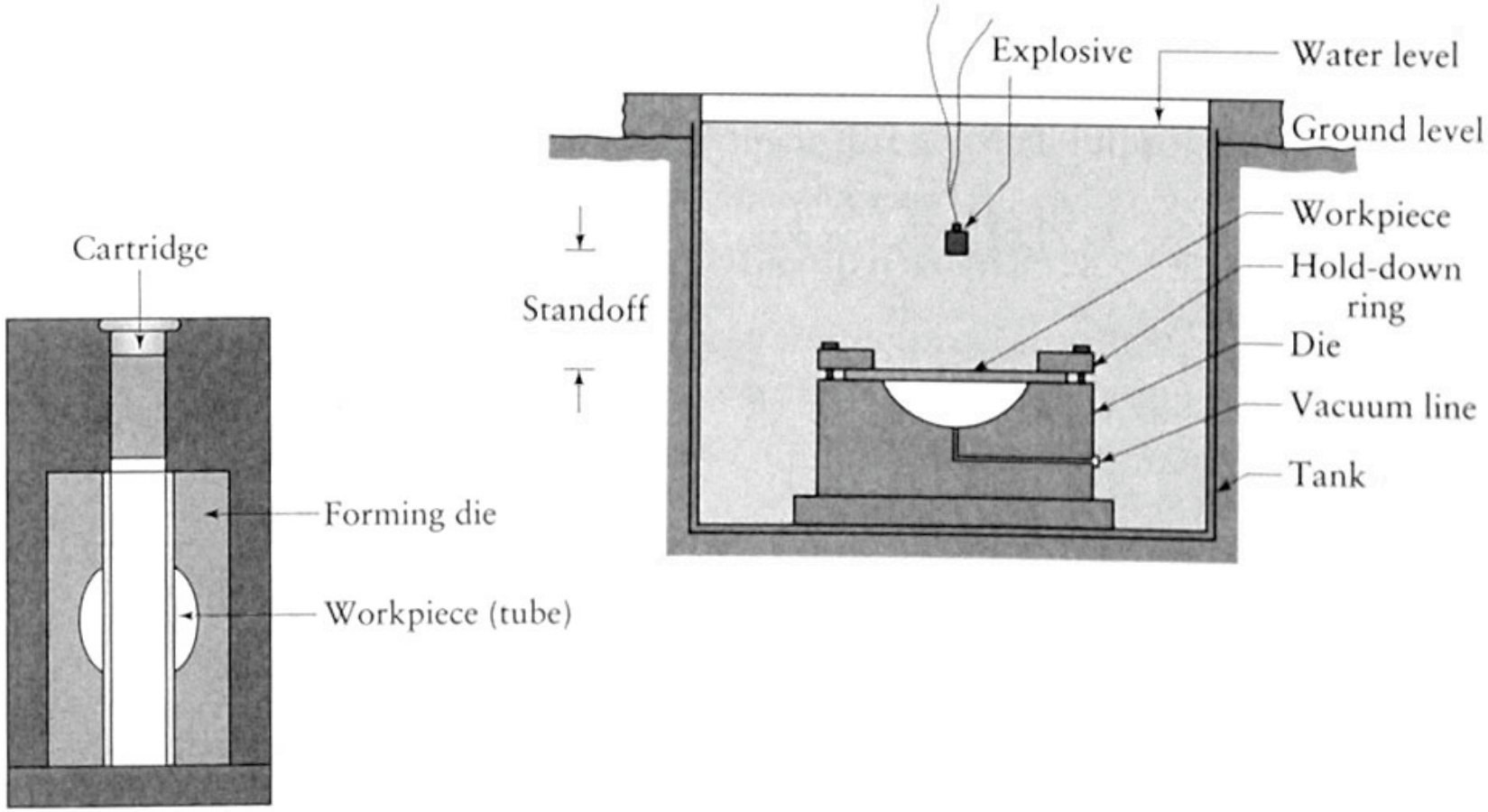
Tube and shear spinning



Albero turbina del concorde

Formatura ad alta energia

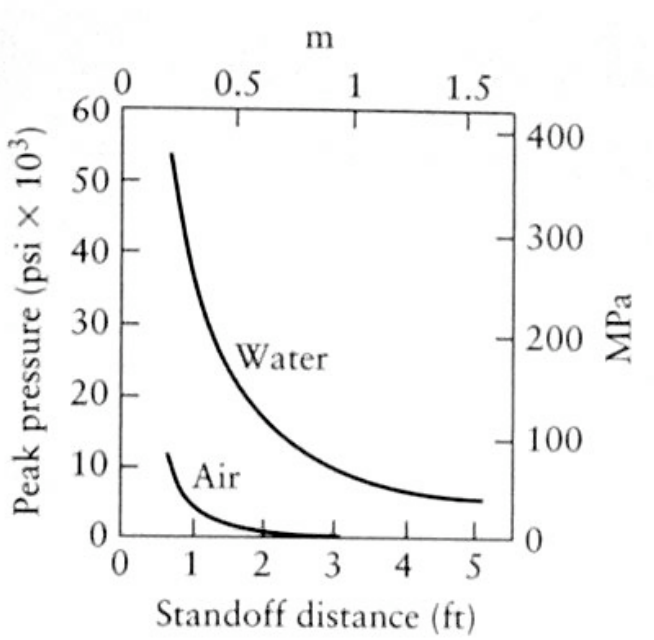
- Per esplosione (explosive forming): spesso si usa acqua



Explosive forming

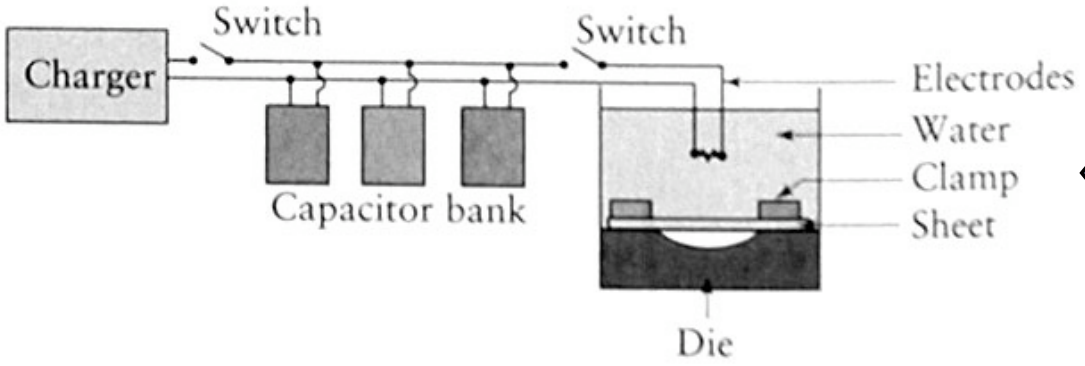
Il picco di pressione generato in acqua si calcola con la formula seguente

$$p = K\left(\frac{\sqrt[3]{W}}{R}\right)^{a}$$

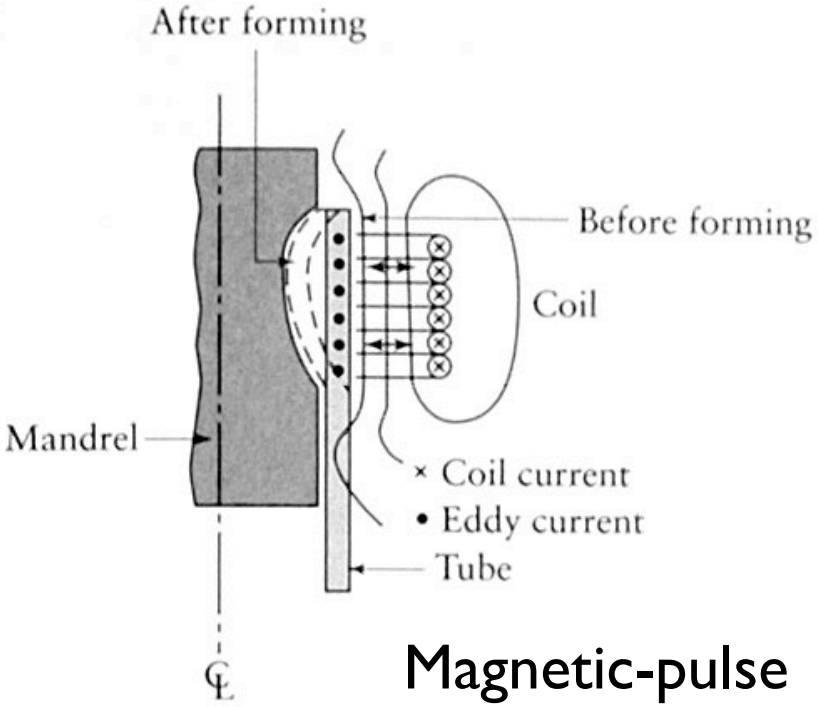


R=distanza esplosivo (in piedi)
K=costante per il tipo di esplosivo (21600 per TNT)
W=peso esplosivo (in pounds)
a=1.15

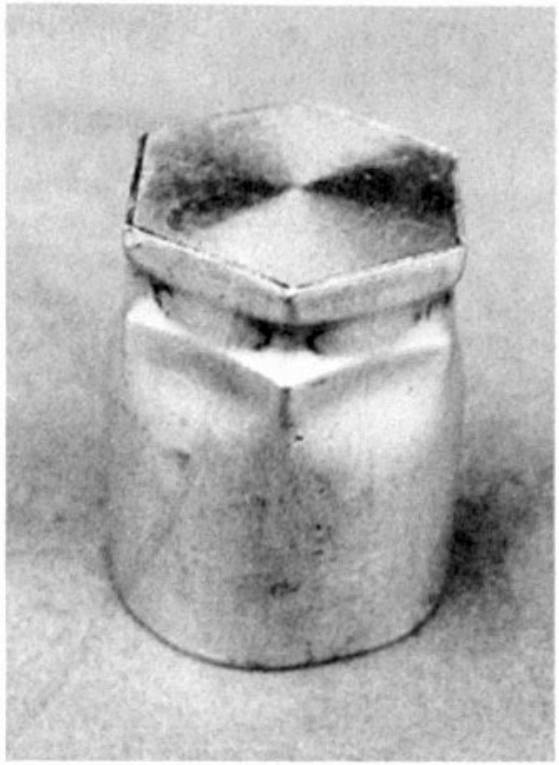
Elettroidraulico e Magnetic-pulse forming



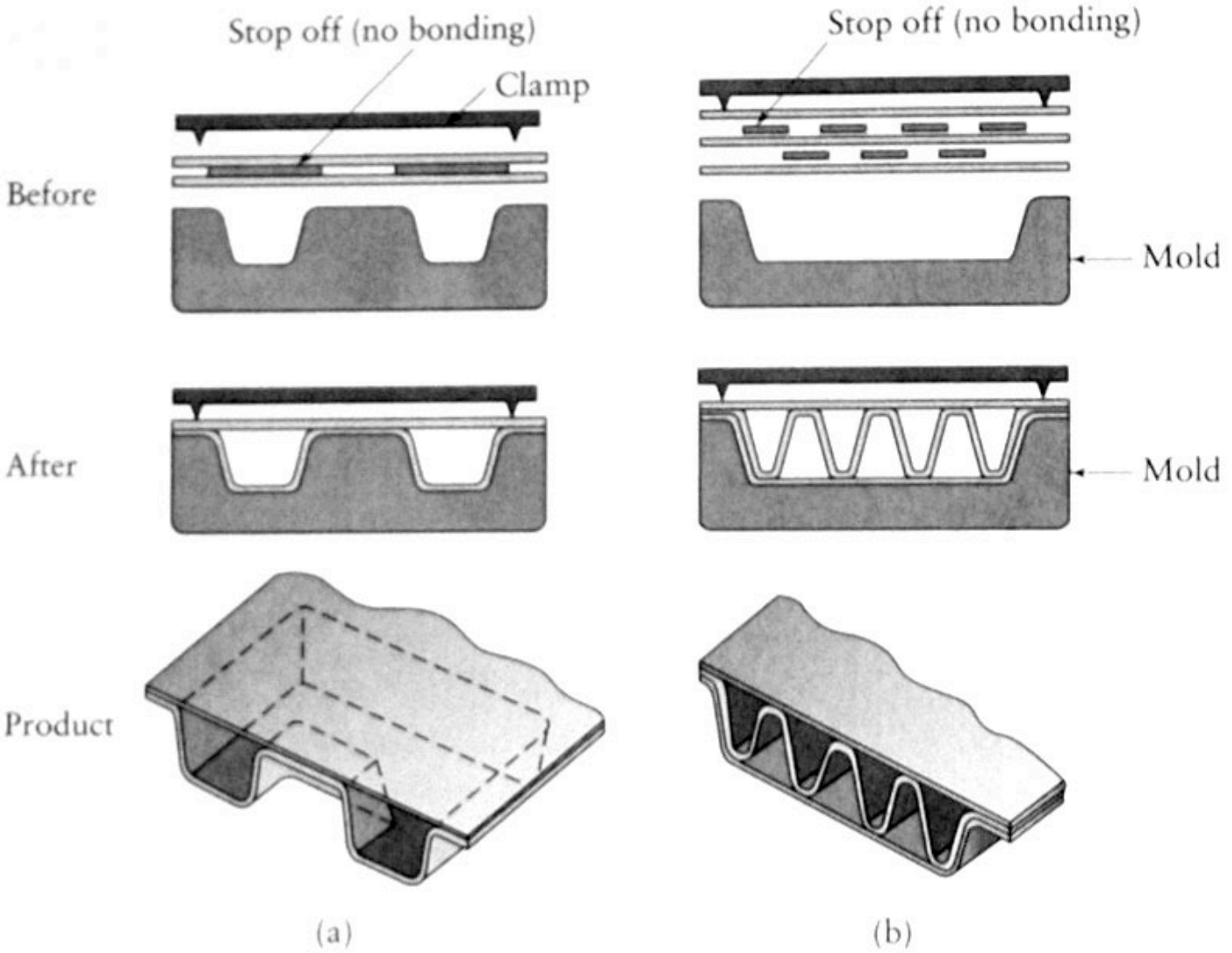
Formatura elettroidraulica



Magnetic-pulse

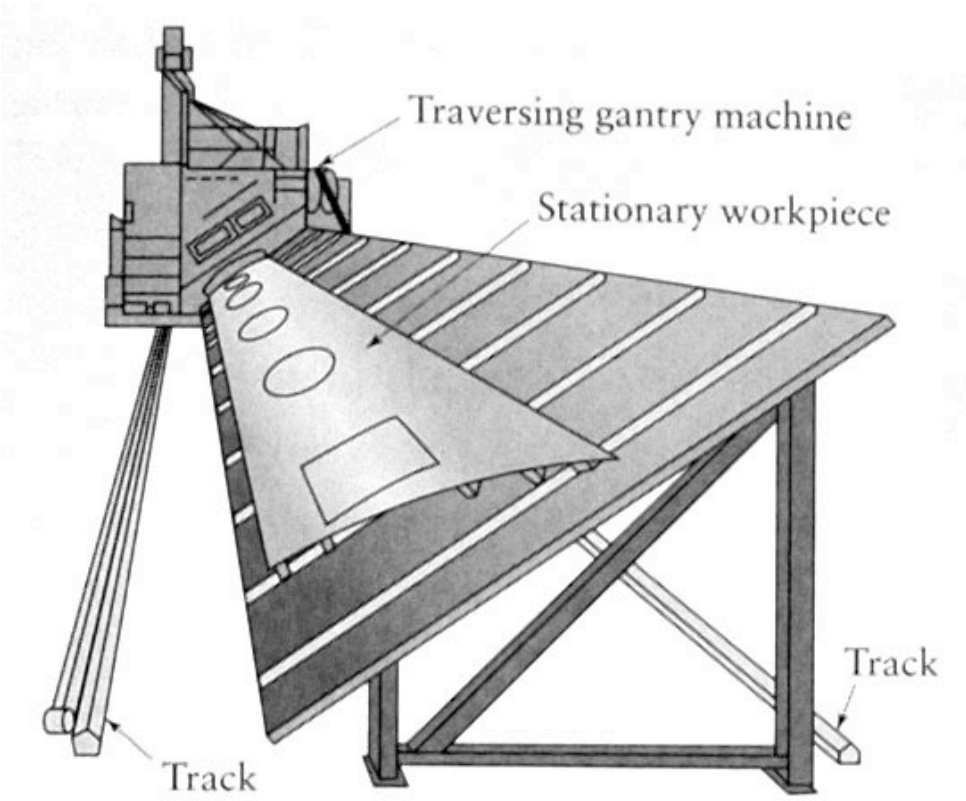


Superplastic forming

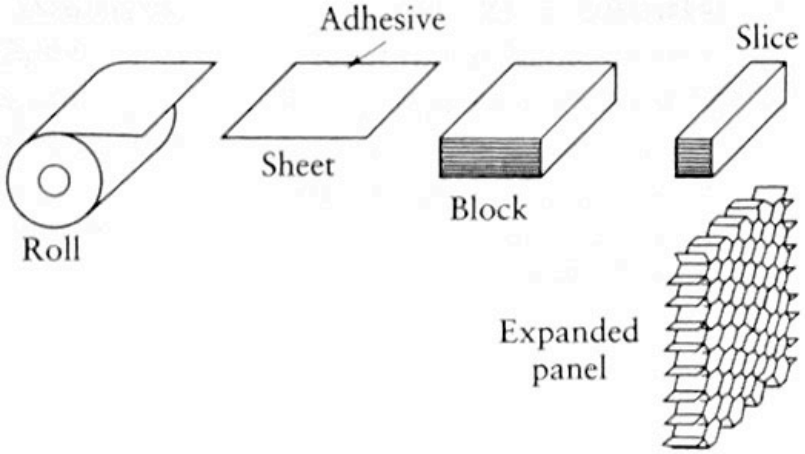


Peen forming

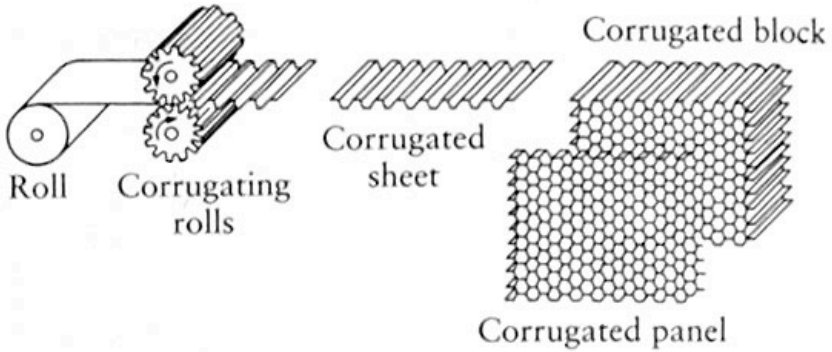
- Si usa un metodo di shot peening (pallinatura con biglie in acciaio) per curvare lamiere sottili. Viene molto usato per la produzione delle lamiere esterne delle ali in aeronautica



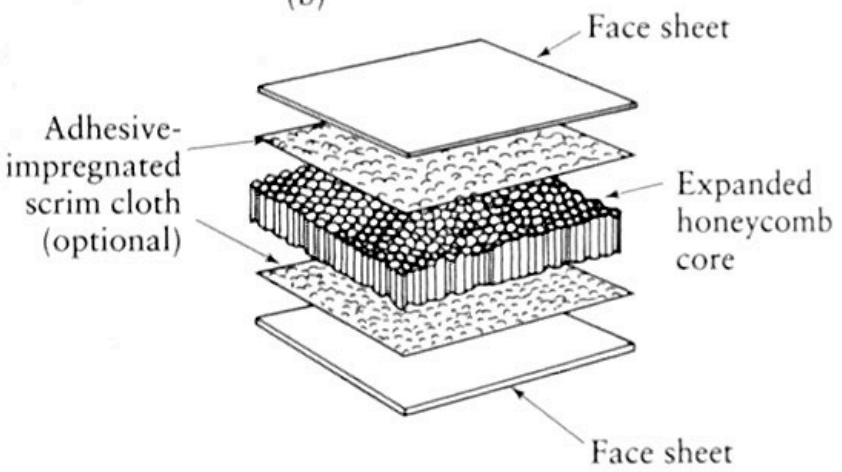
Esempio: produzione honeycomb



(a)



(b)



(c)