บทที่ 5
การขึ้นรูปวัสดุ
Metal Forming

ครั้งที่ 1

รองศาสตราจารย์ธรรม์ณชาติ วันแต่ง
สาขาวิชาวิศวกรรมการผลิตและการจัดการ มหาวิทยาลัยราชภัฏเพชรบูรณ์

Overview

- Process Classification
  - Bulk Deformation Process
  - Sheet Metalworking
- Material Behaviour in Metal Forming
  - Flow Stress
  - Average Flow Stress
- Temperature in Metal Forming
- Effect of Strain Rate
- Friction & Lubrication

กระบวนการขึ้นรูป (Forming Process)

Deformation Process แบ่งได้ดังนี้

- แบ่งตามชนิดของแรงกระทำบนชิ้นงาน
- แบ่งตามการใช้งานของชิ้นงานสำเร็จ
- แบ่งตามขนาดของชิ้นงาน
- แบ่งตามอุณหภูมิในการทำงาน

การรีดขึ้นรูป (Roll Forming)

ใช้แรงสูงกว่าการรีดร้อน อะตอมเกิดจากการบิดเบี้ยว
เกรนเสียรูป เกิดความเค้น (Stress) ขึ้นภายใน

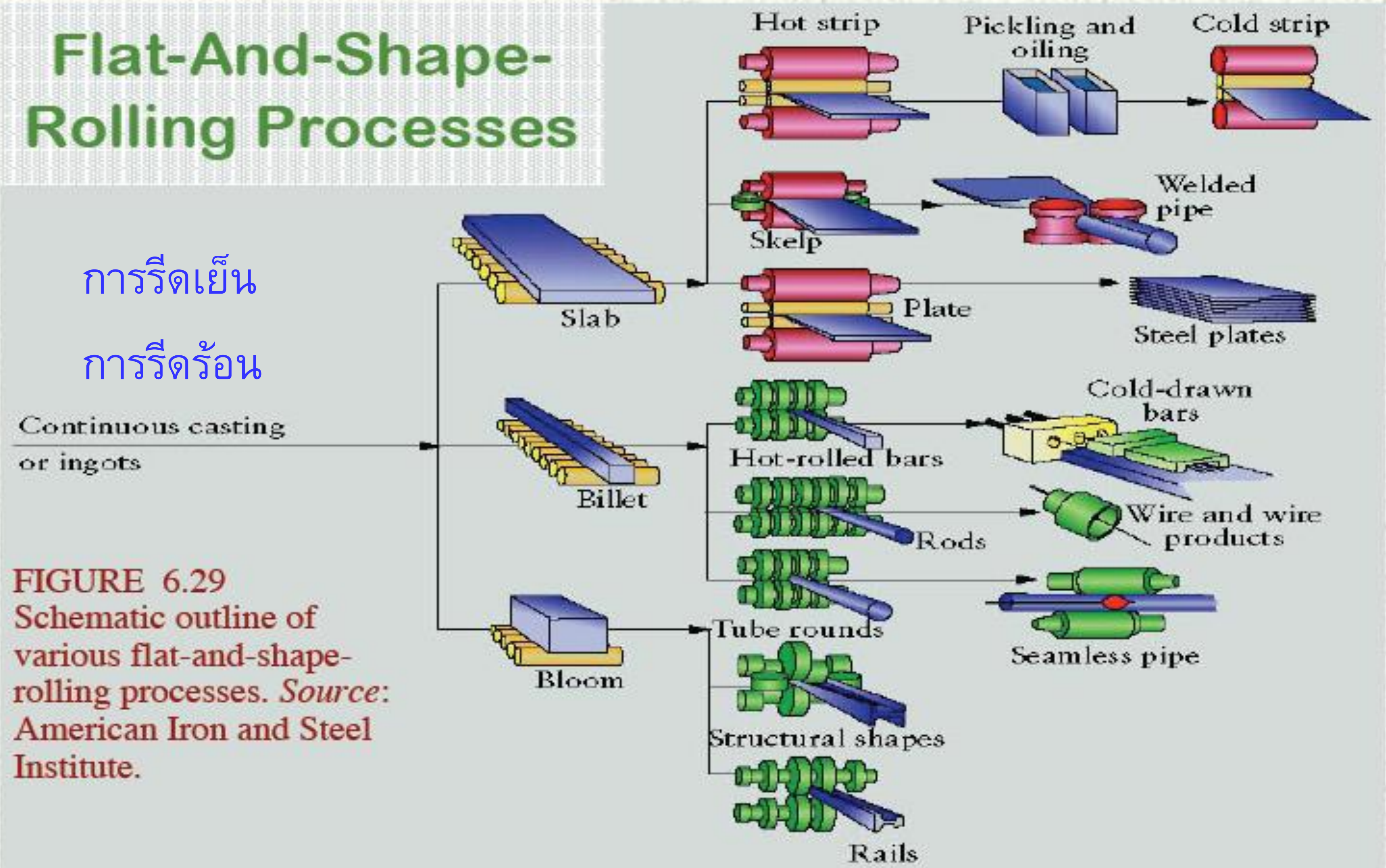
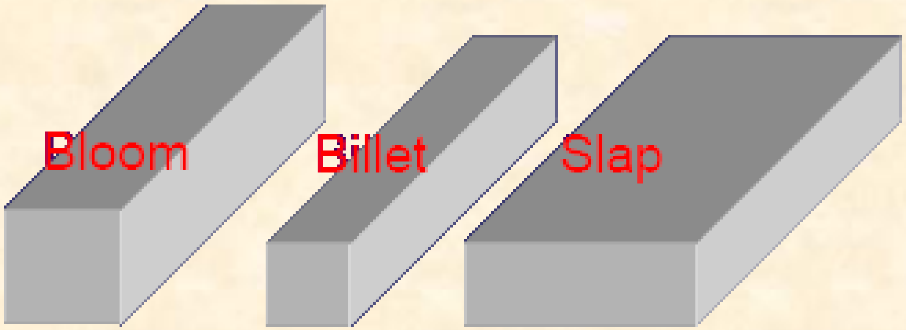
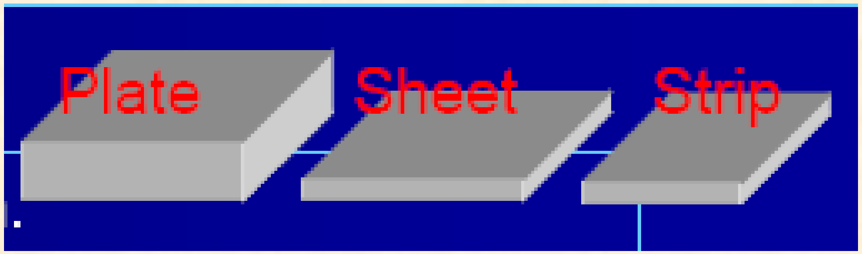


FIGURE 6.29 Schematic outline of various flat-and-shape-rolling processes. *Source*: American Iron and Steel Institute.

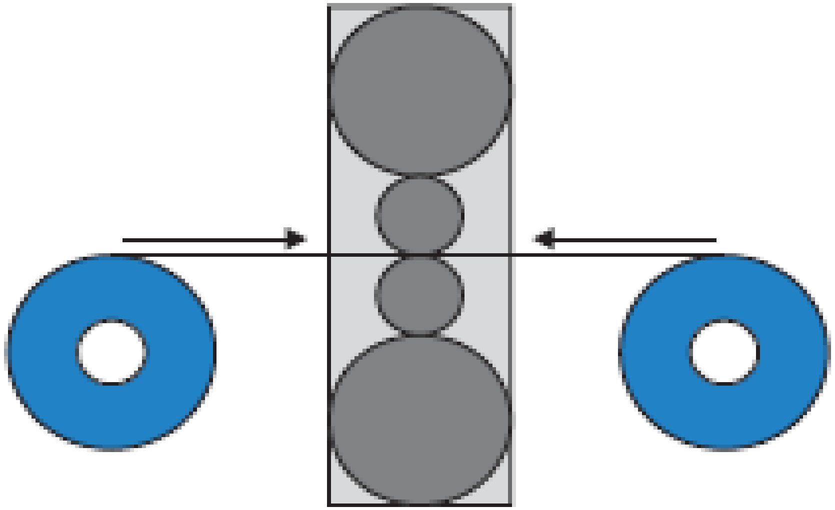


- Bloom เป็นการขึ้นรูปครั้งแรกจาก ingot (Square > 500 mm).
- Billet ผ่านกรรมวิธีรีดร้อนลดขนาด (Square 180 mm).
- Slab ผ่านกรรมวิธีรีดร้อนลดขนาด ingot (Thick > 320 mm and with a wide 3000 mm หรือ ≥ 2 x thickness).

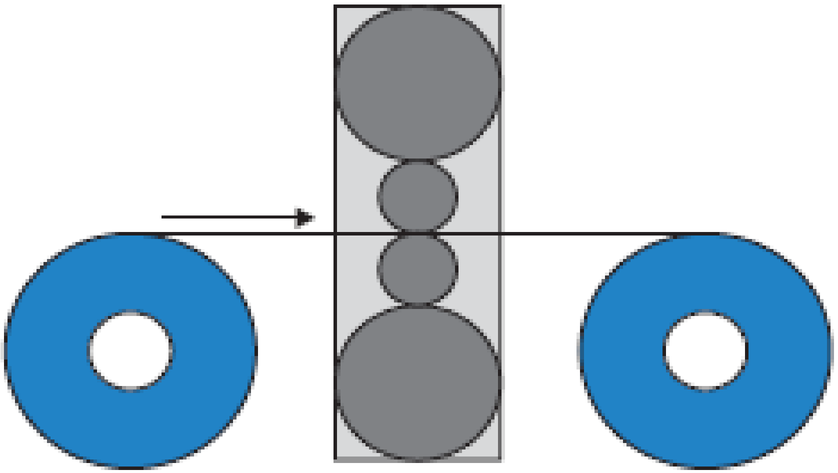
- Plate thickness > 6 mm.
- Sheet thickness < 6 mm and width > 600 mm.
- Strip thickness < 6 mm and width < 600 mm.



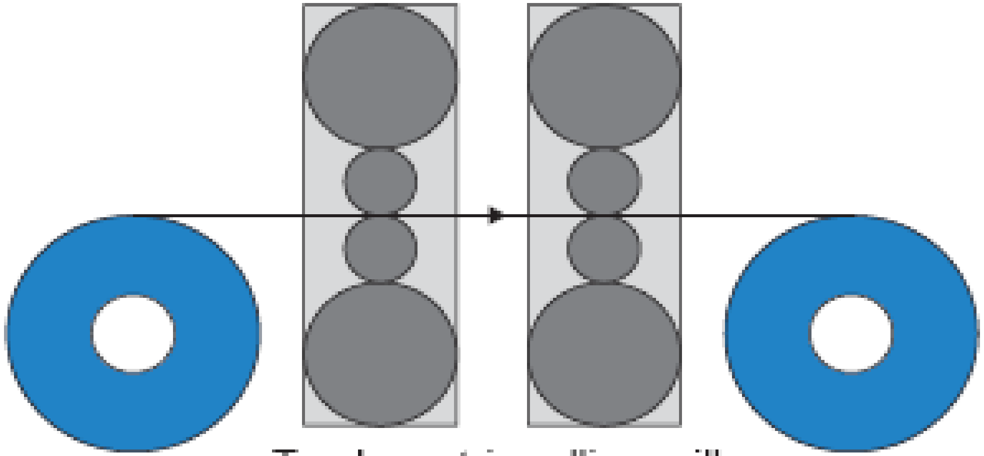
การรีดเป็นแผ่น (Flat Rolling)



Reversing strip rolling mill

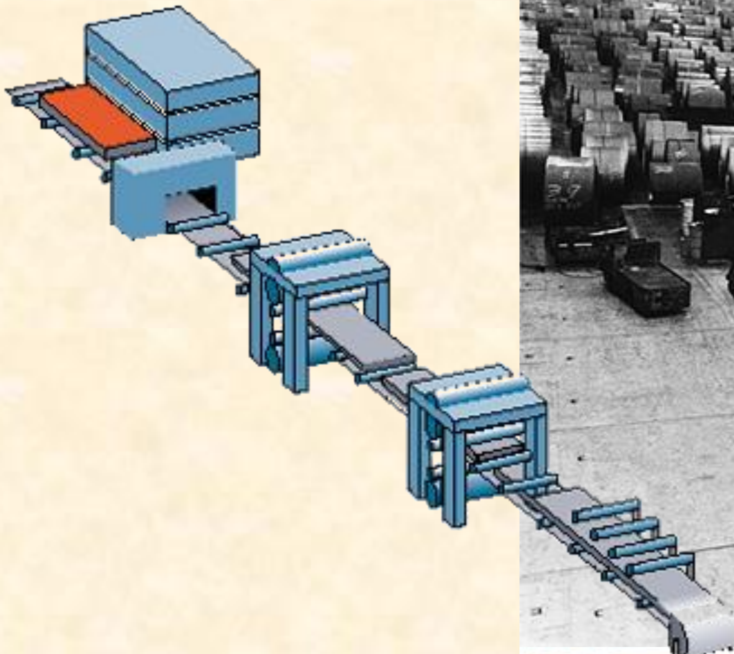


Non-reversing strip rolling mill

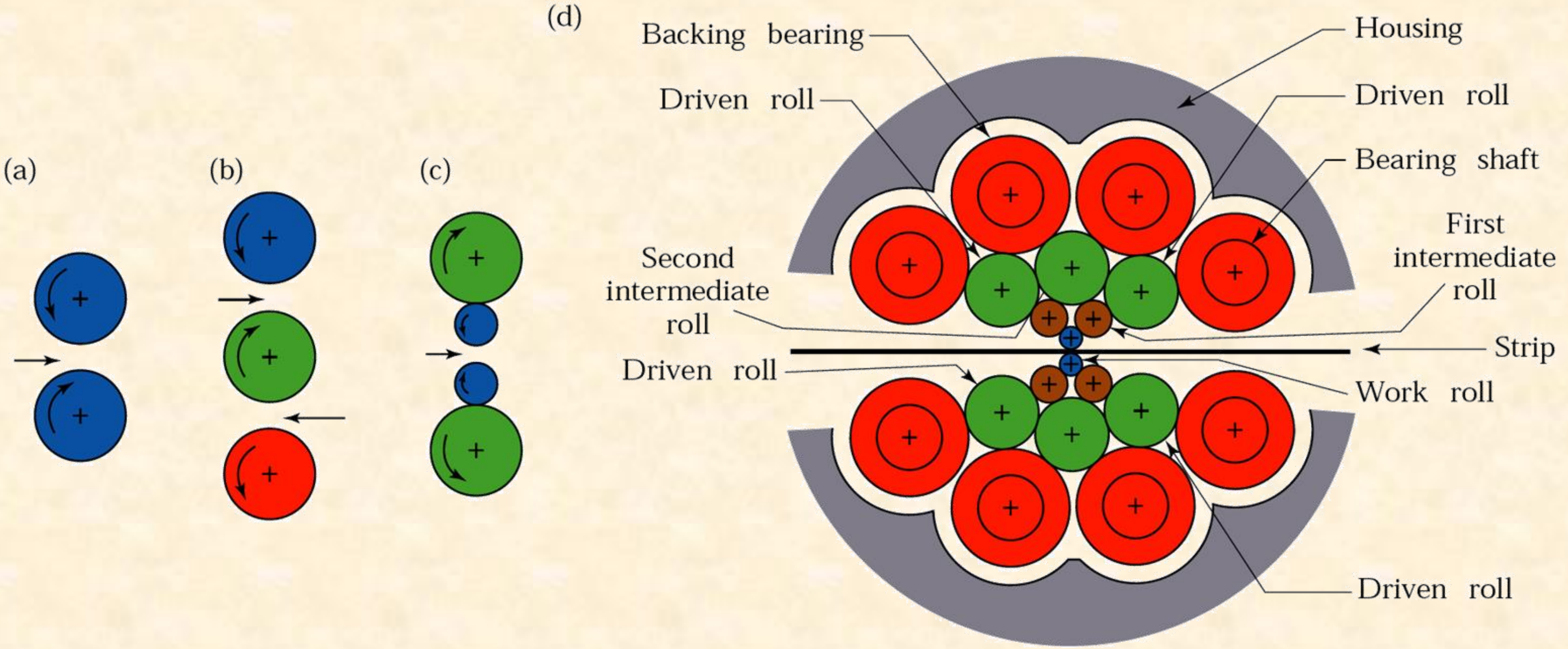


Tandem strip rolling mill

Rolling Mill



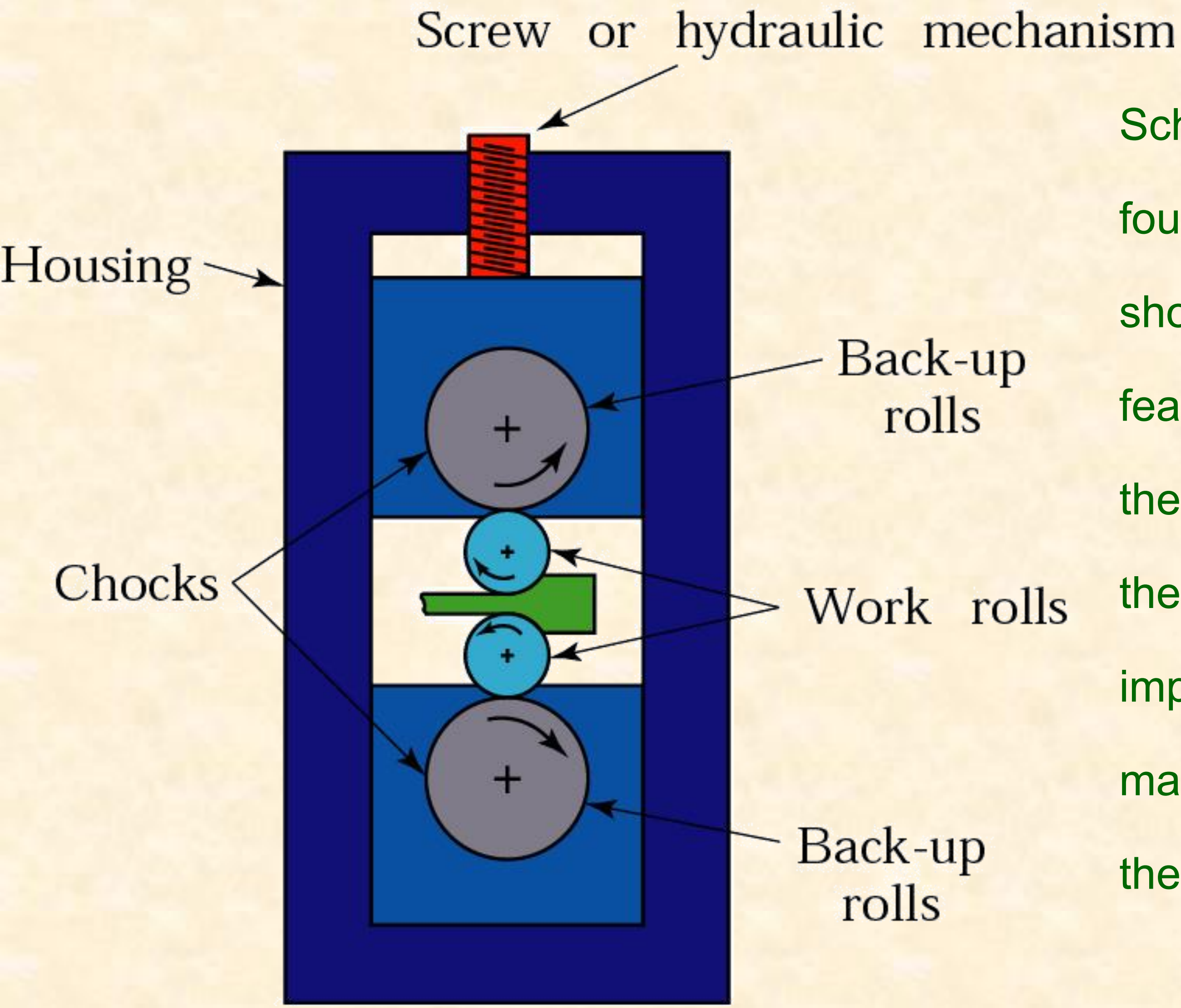
Backing Roll Arrangements



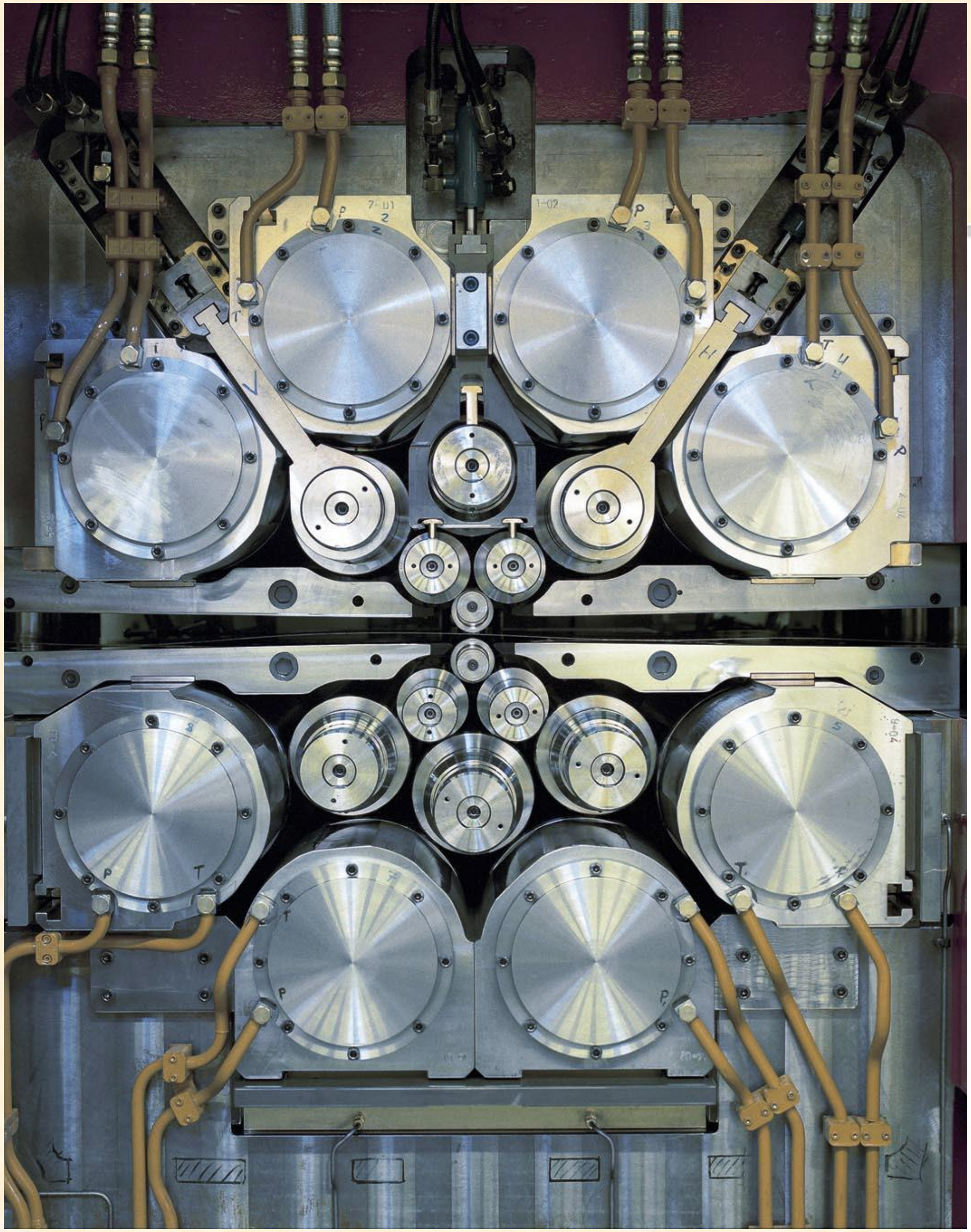
Schematic illustration of various roll arrangements:

(a) Two - high; (b) three - high; (c) four - high; (d) cluster (Sendzimir) mill.

Four-High Rolling Mill



Schematic illustration of a four-high rolling-mill stand, showing its various features. The stiffnesses of the housing, the rolls, and the roll bearings are all important in controlling and maintaining the thickness of the rolled strip.




bkm

การรีดขึ้นรูป (Shape Rolling)

Shape Rolling

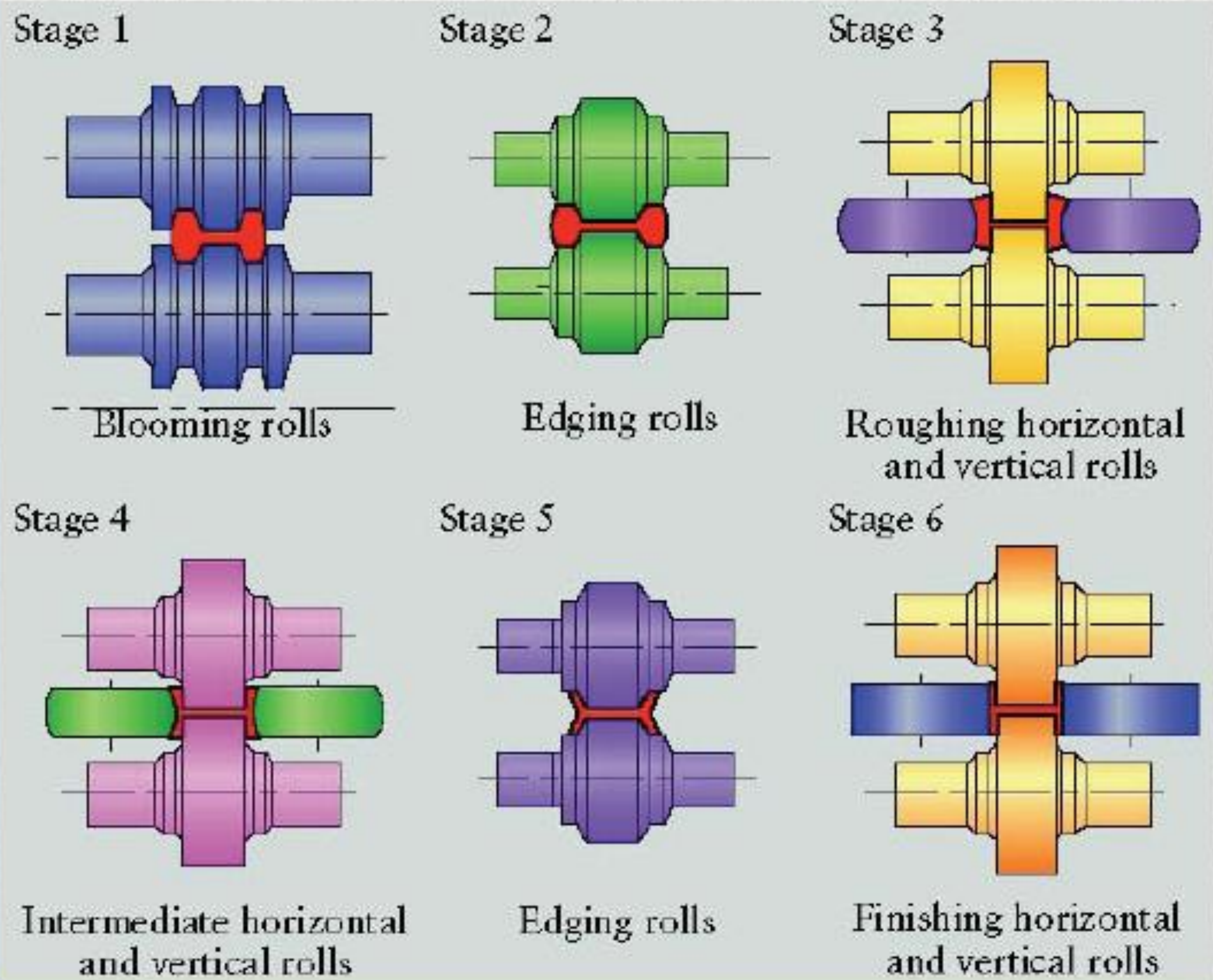
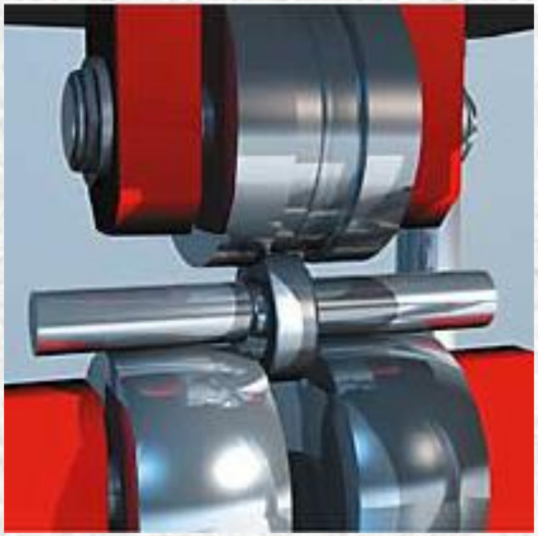
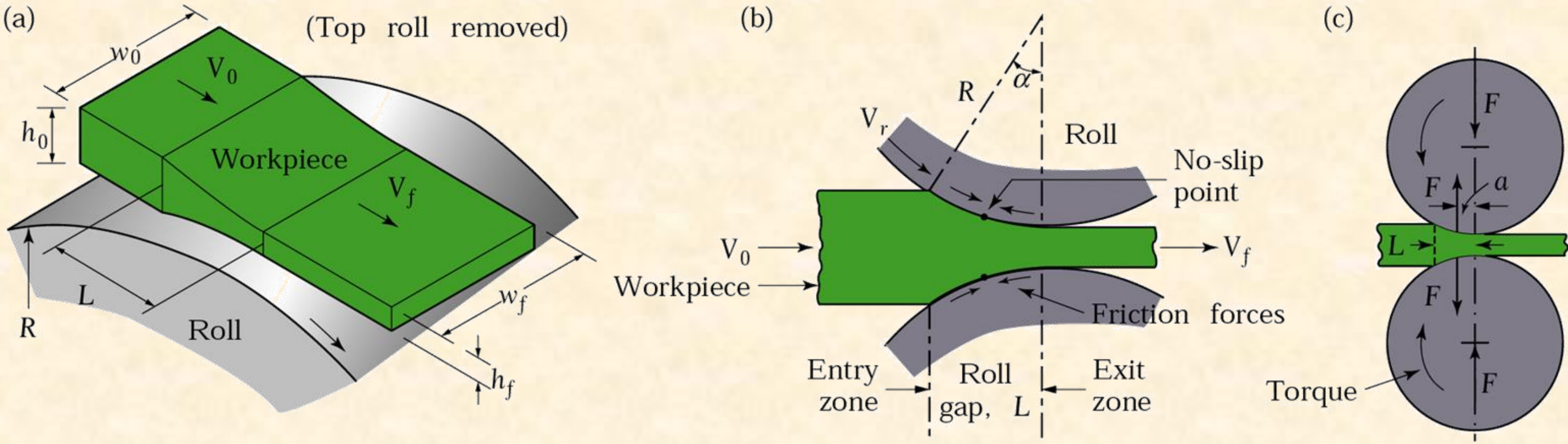


FIGURE 6.44 Stages in shape rolling of an H-section part. Various other structural sections, such as channels and I-beams, are also rolled by this process.



Flat-Rolling

μ

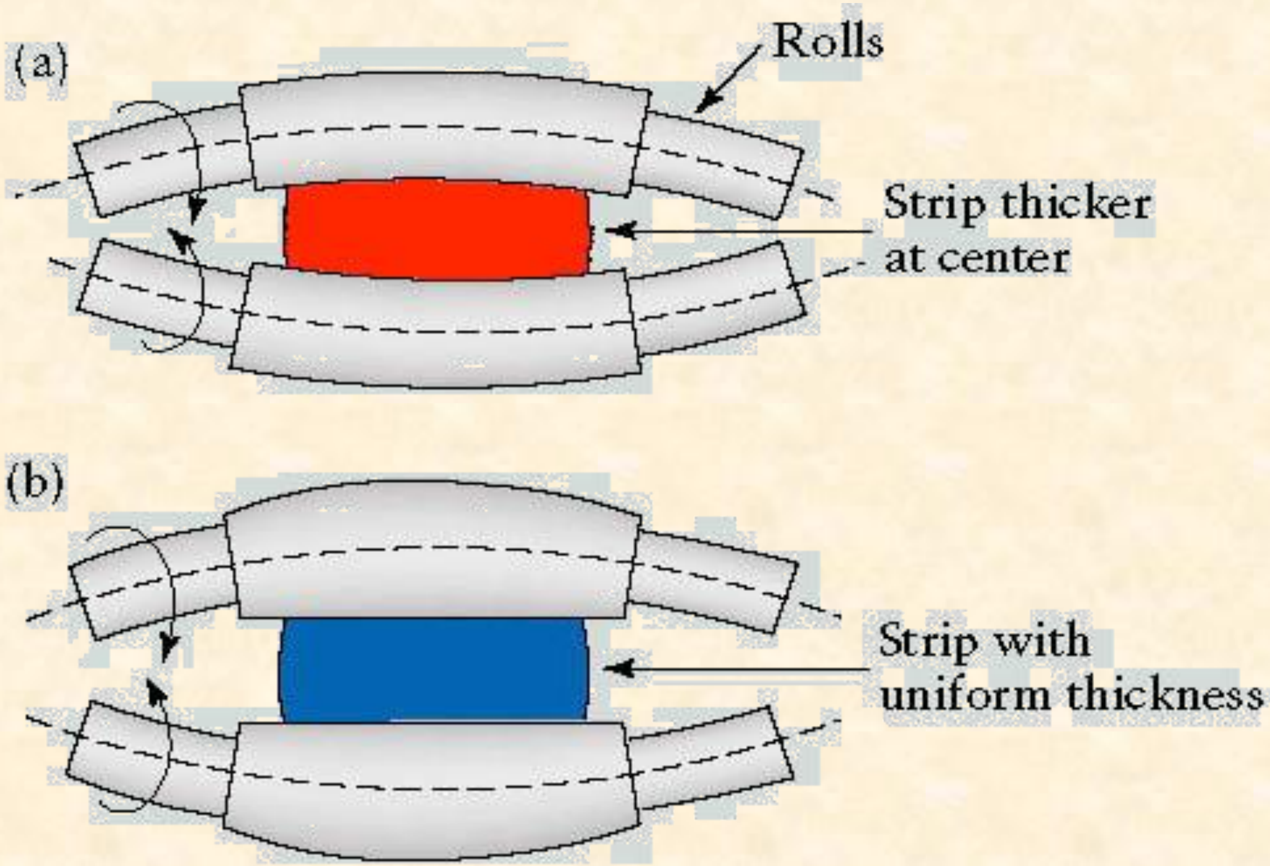


(a) Schematic illustration of the flat-rolling process.

(b) Friction forces acting on strip surfaces.

(c) The roll force, *F*, and the torque acting on the rolls. The width *w* of the strip usually increases during rolling

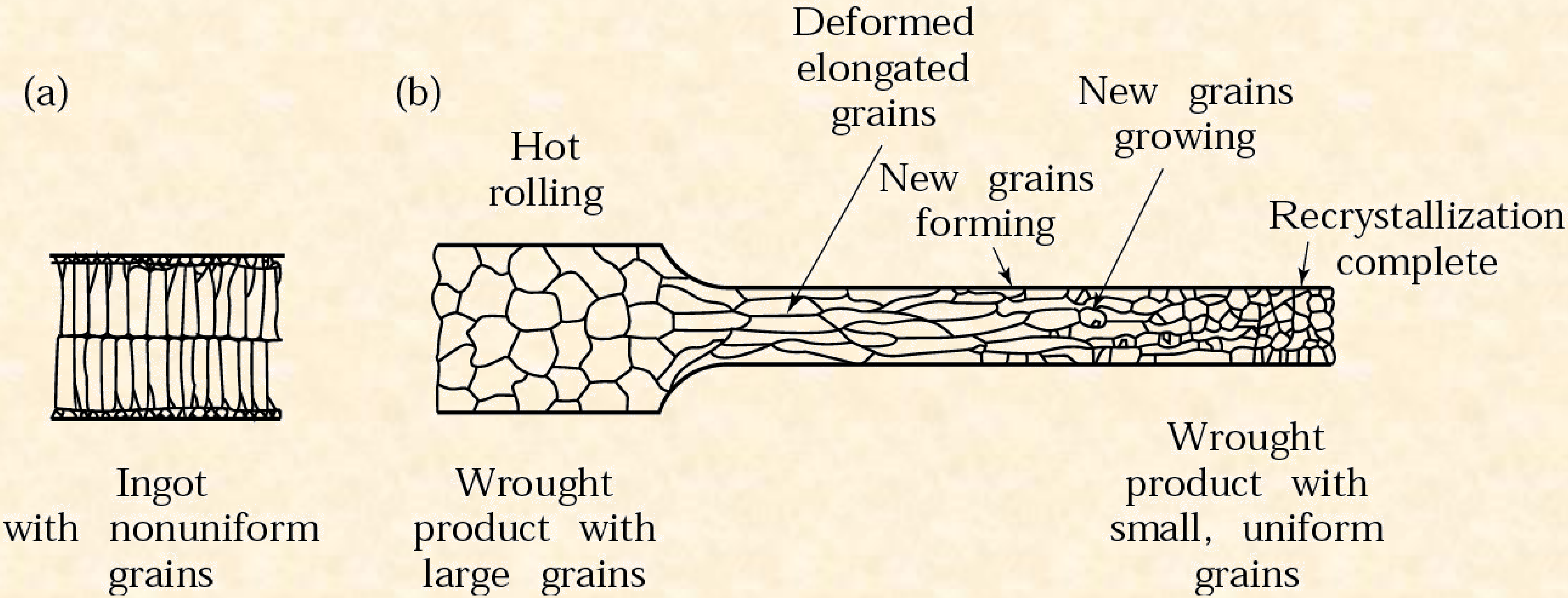
Roll Bending



(a) Bending of straight cylindrical rolls, caused by the roll force.

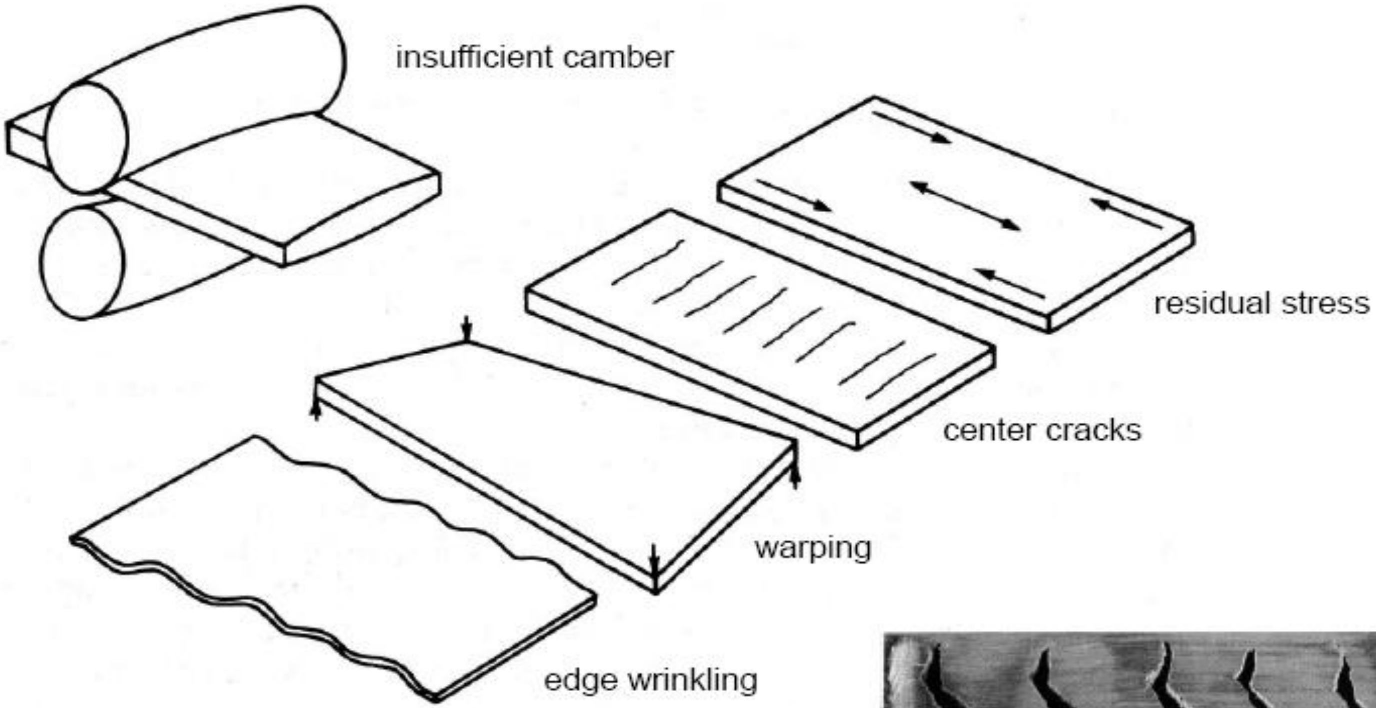
(b) Bending of rolls ground with camber, producing a strip with uniform thickness.

Grain Structure During Hot Rolling



Changes in the grain structure of cast or of large-grain wrought metals during hot rolling. Hot rolling is an effective way to reduce grain size in metals, for improved strength and ductility. Cast structures of ingots or continuous casting are converted to a wrought structure by hot working.

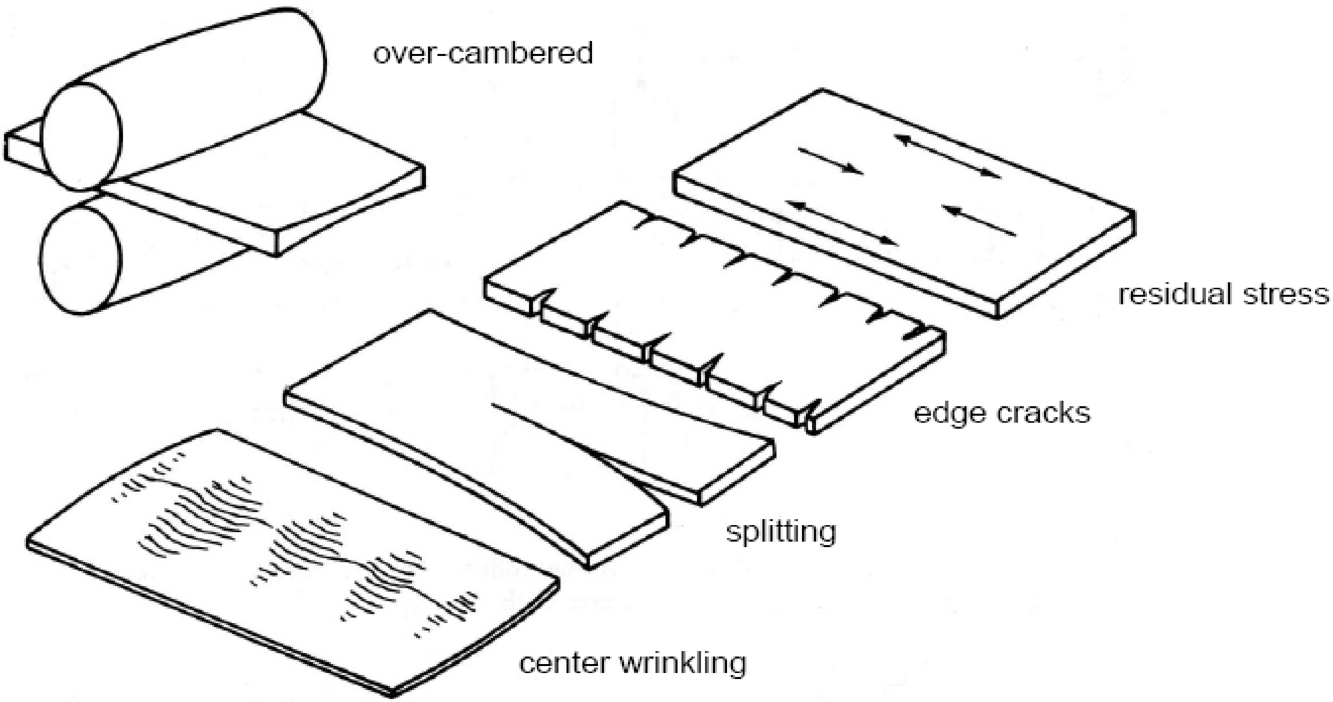
Rolling Defects



Mo bar rolled at high Δ.

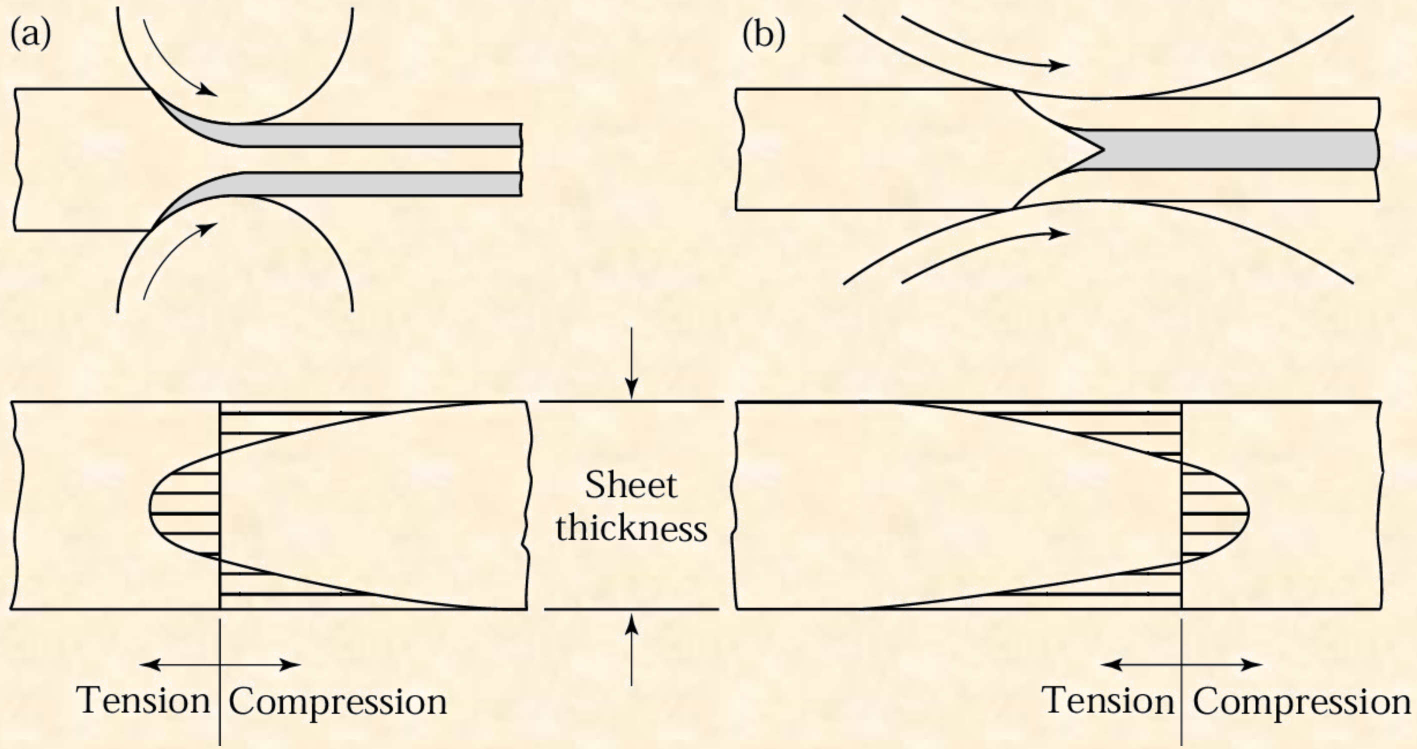
W.F. Hosford and R.M. Caddell, *Metal Forming*, 2nd Ed., Prentice-Hall, Inc., Edgewood Cliffs, NJ, 1993.

Rolling Defects



W.F. Hosford and R.M. Caddell, *Metal Forming*, 2nd Ed., Prentice-Hall, Inc., Edgewood Cliffs, NJ, 1993.

Residual Stresses in Rolling

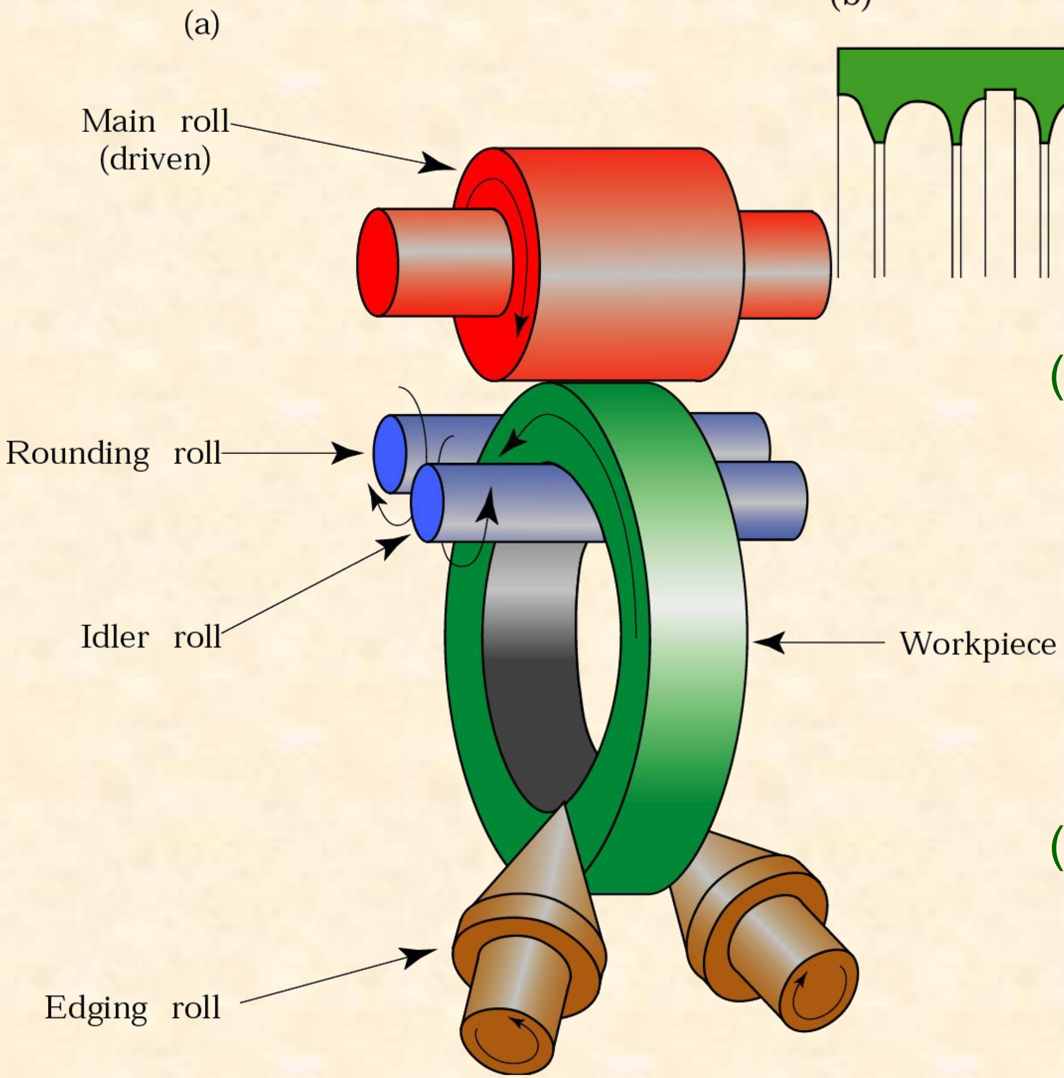


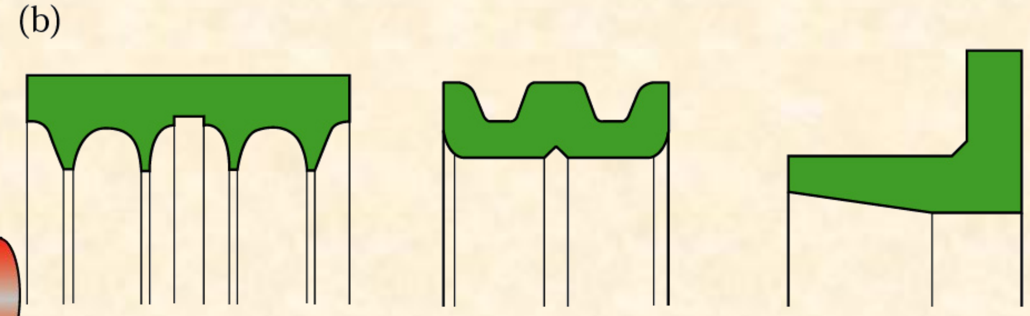
(a) Residual stresses developed in rolling with small rolls or at small reductions in thickness per pass.

(b) Residual stresses developed in rolling with large rolls or at high reductions per pass. Note the reversal of the residual stress patterns.

การรีดในลักษณะอื่น ๆ (Other Rolling)

1) การรีดแหวน หรือห่วง (Ring Rolling)

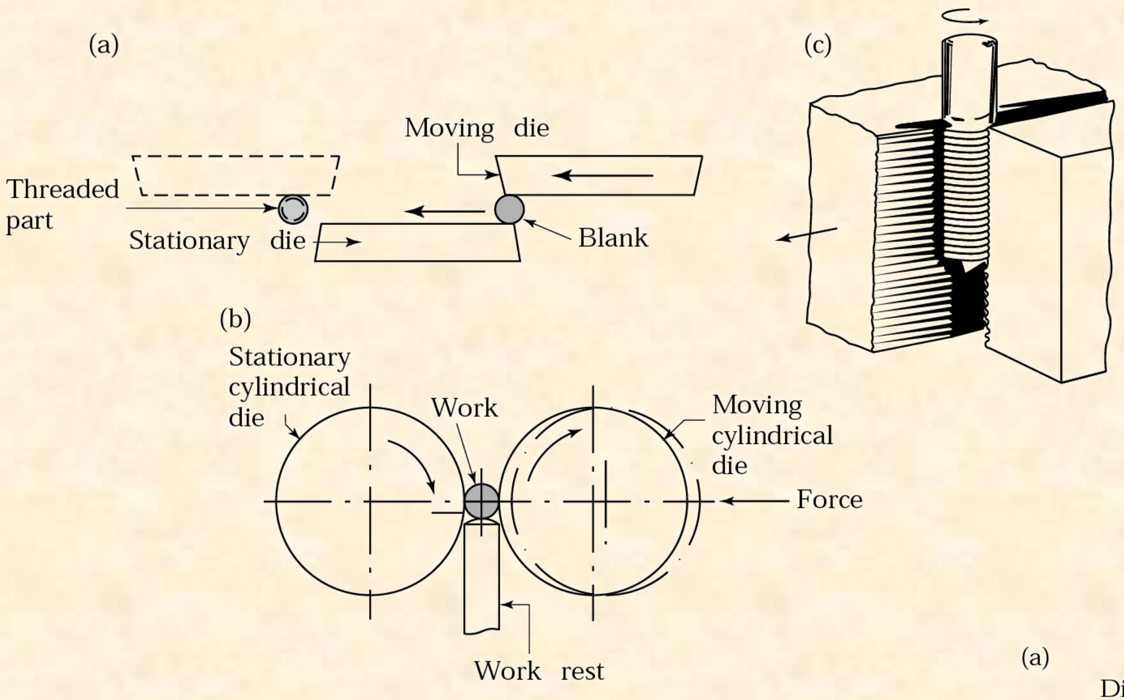




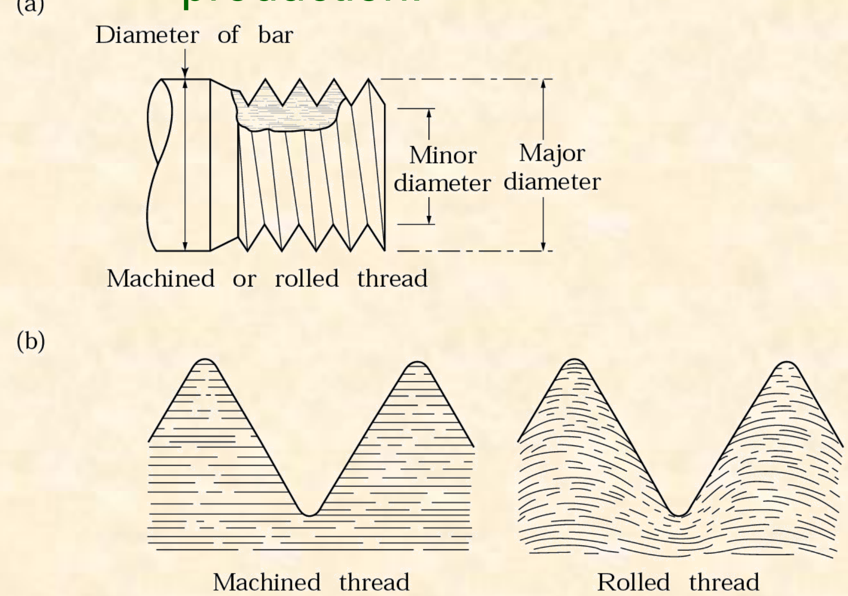
(a) Schematic illustration of a ring-rolling operation. Thickness reduction results in an increase in the part diameter.

(b) Examples of cross-sections that can be formed by ring rolling.

2) การรีดเกลียว (Tread Rolling)



Thread-rolling processes: (a) and (c) reciprocating flat dies; (b) two-roller dies. Threaded fasteners, such as bolts, are made economically by these processes, at high rates of production.

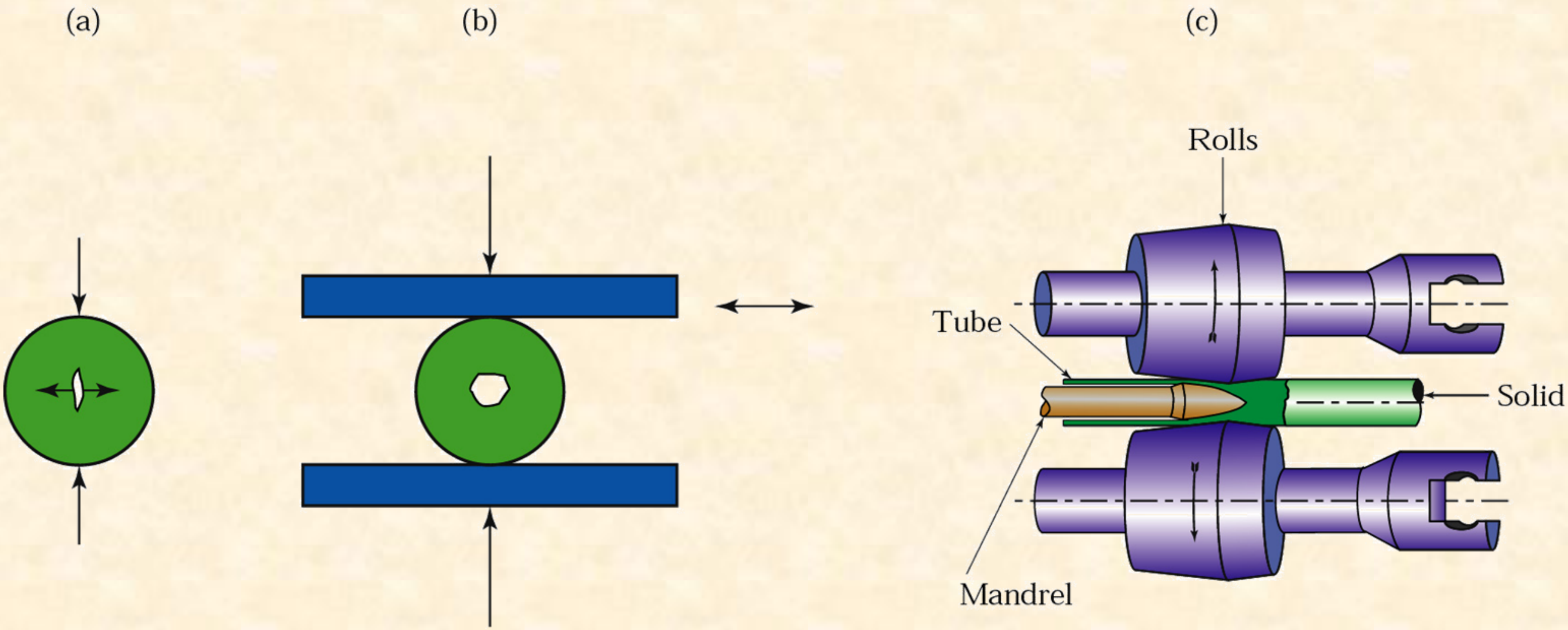


(a) Features of a machined or rolled thread. (b) Grain flow in machined and rolled threads. Unlike machining, which cuts through the grains of the metal, the rolling of threads causes improved strength, because of cold working and favorable grain flow.

3) การรีดท่อไร้ตะเข็บ (Seamless Tubing and Pipe)

Mannesmann Process

Cavity formation in a solid round bar and its utilization in the rotary tube piercing process for making seamless pipe and tubing. (The Mannesmann mill was developed in the 1880s.)



Tube-Rolling

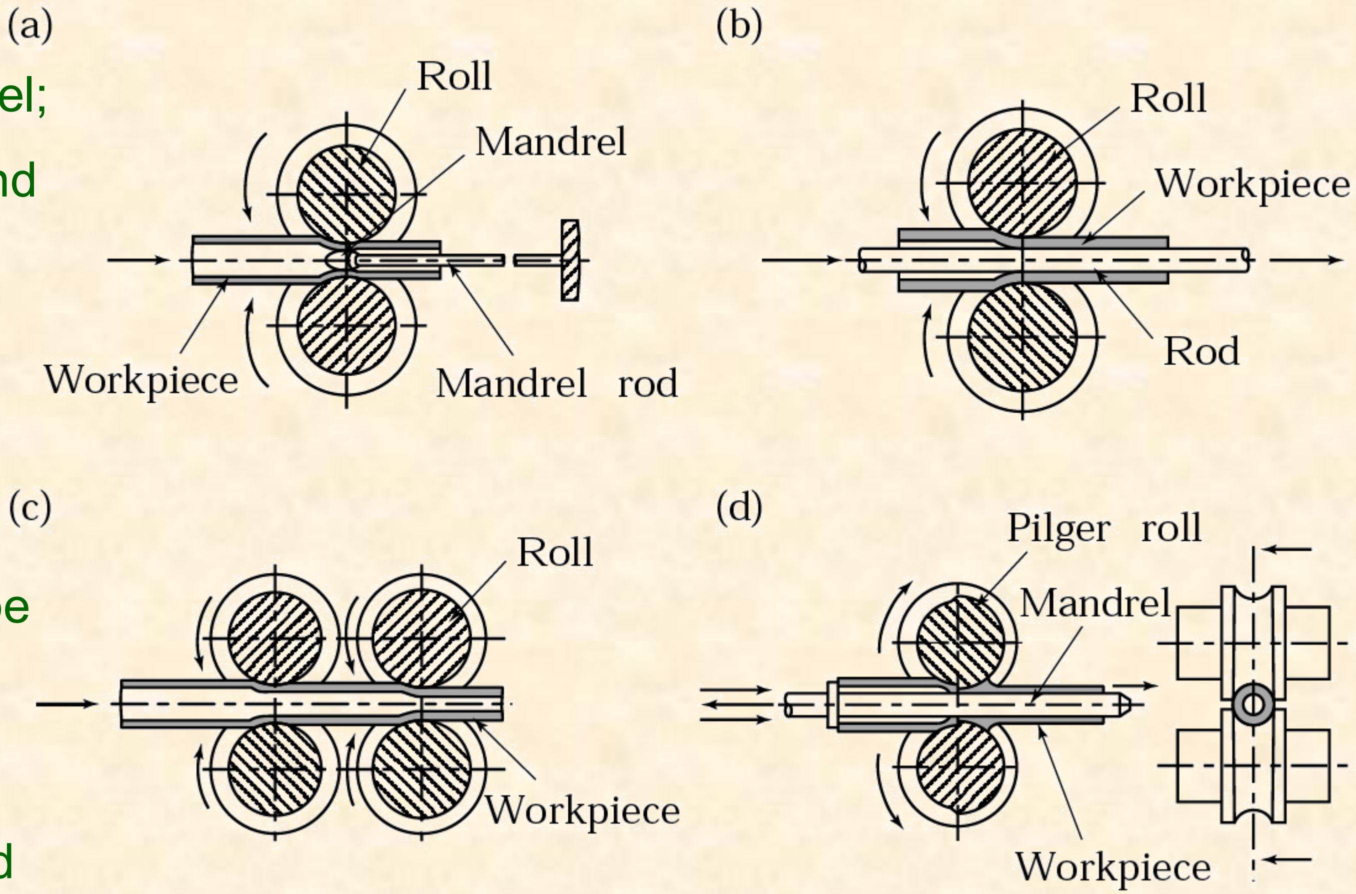
Schematic illustration of various tube-rolling processes:

(a) with fixed mandrel;

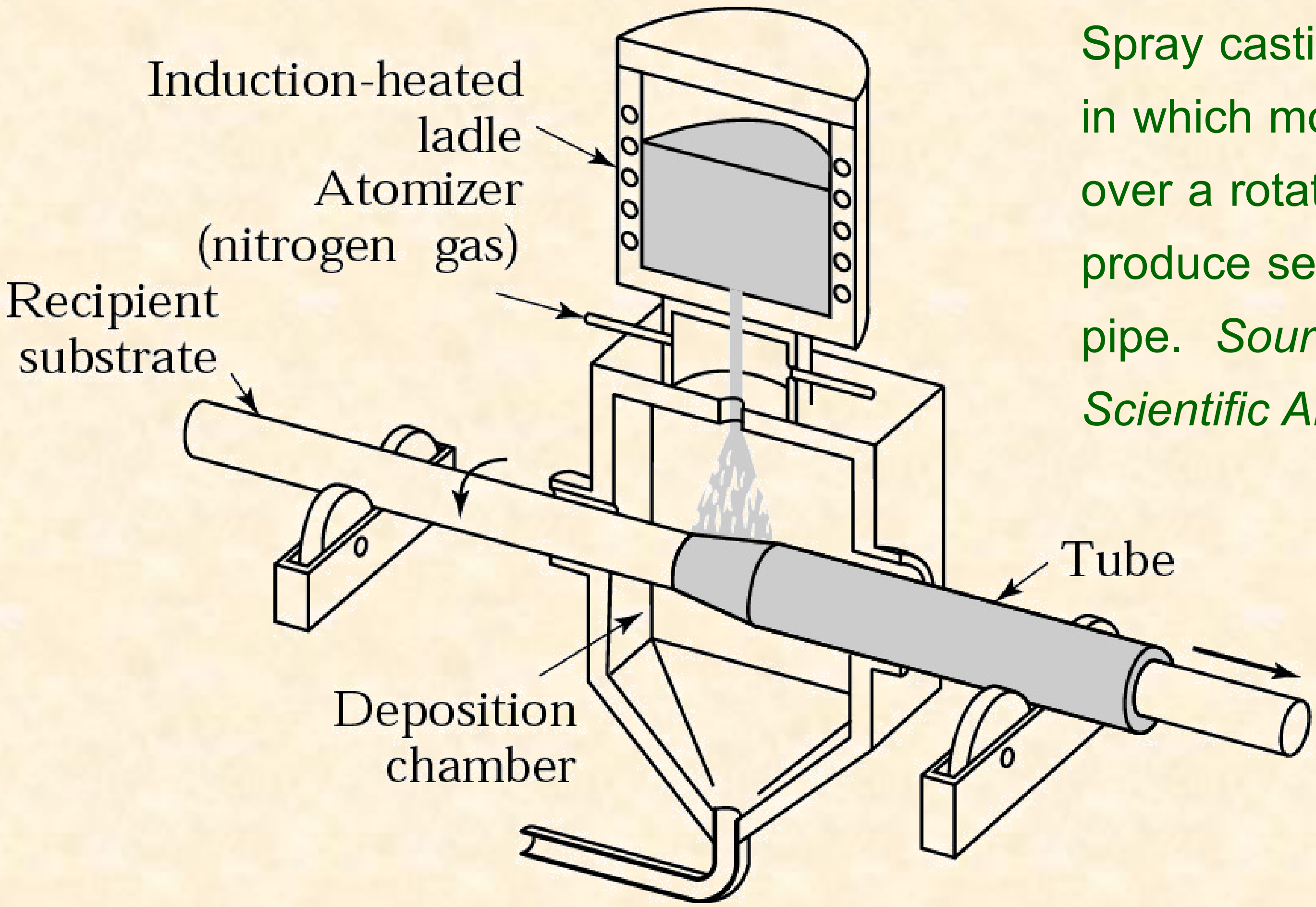
(b) with moving mandrel;

(c) without mandrel; and

(d) pilger rolling over a mandrel and a pair of shaped rolls. Tube diameters and thicknesses can also be changed by other processes, such as drawing, extrusion, and spinning.

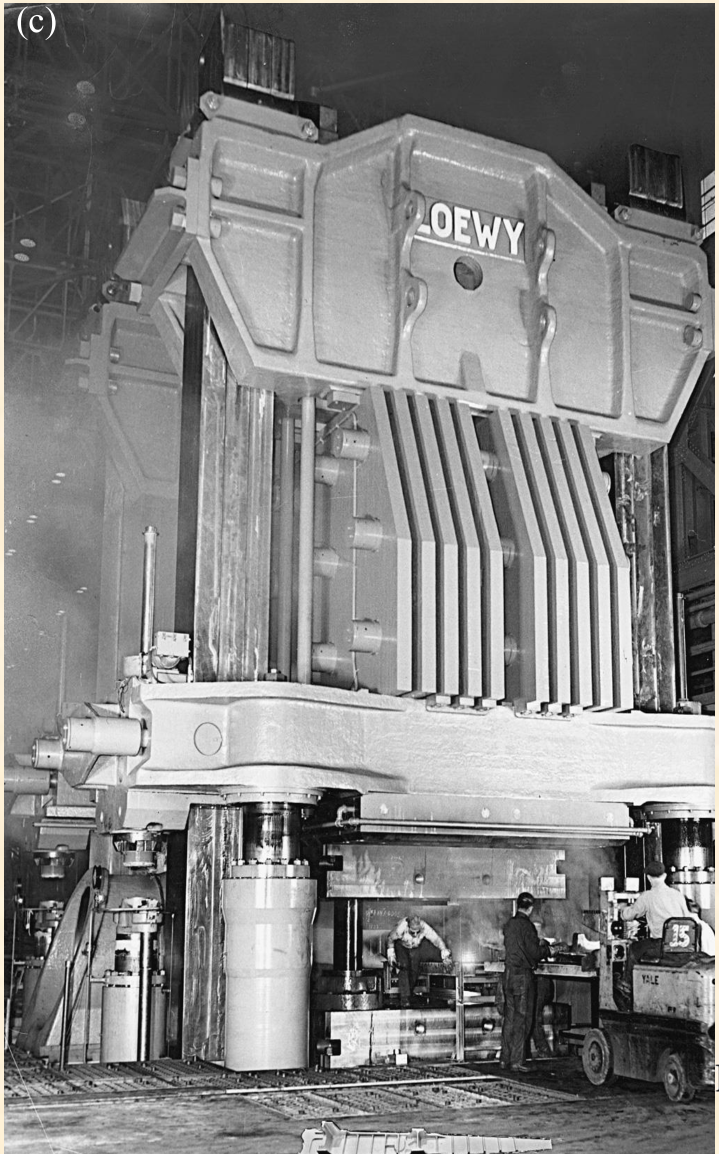


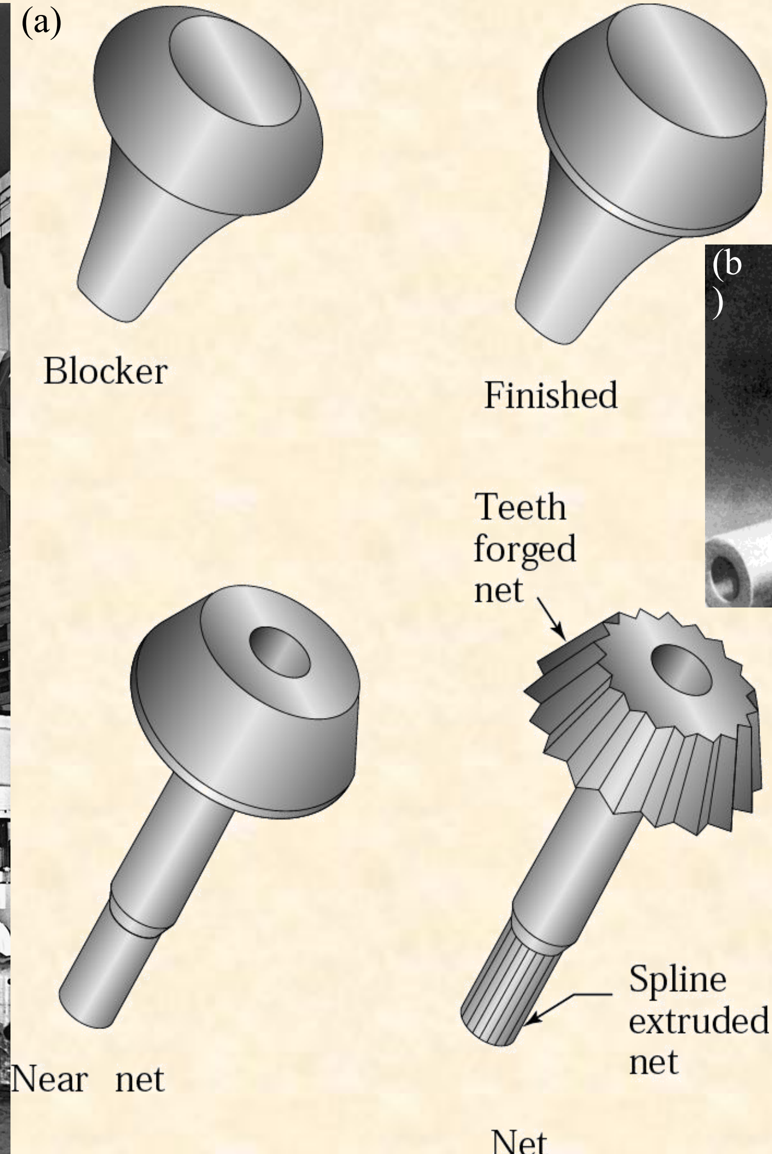
Spray Casting (Osprey Process)

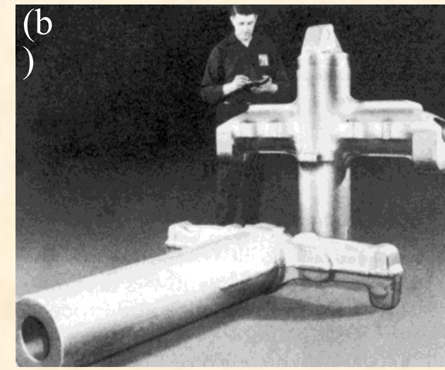


Spray casting (Osprey process), in which molten metal is sprayed over a rotating mandrel to produce seamless tubing and pipe. *Source*: J. Szekely, *Scientific American*, July 1987.

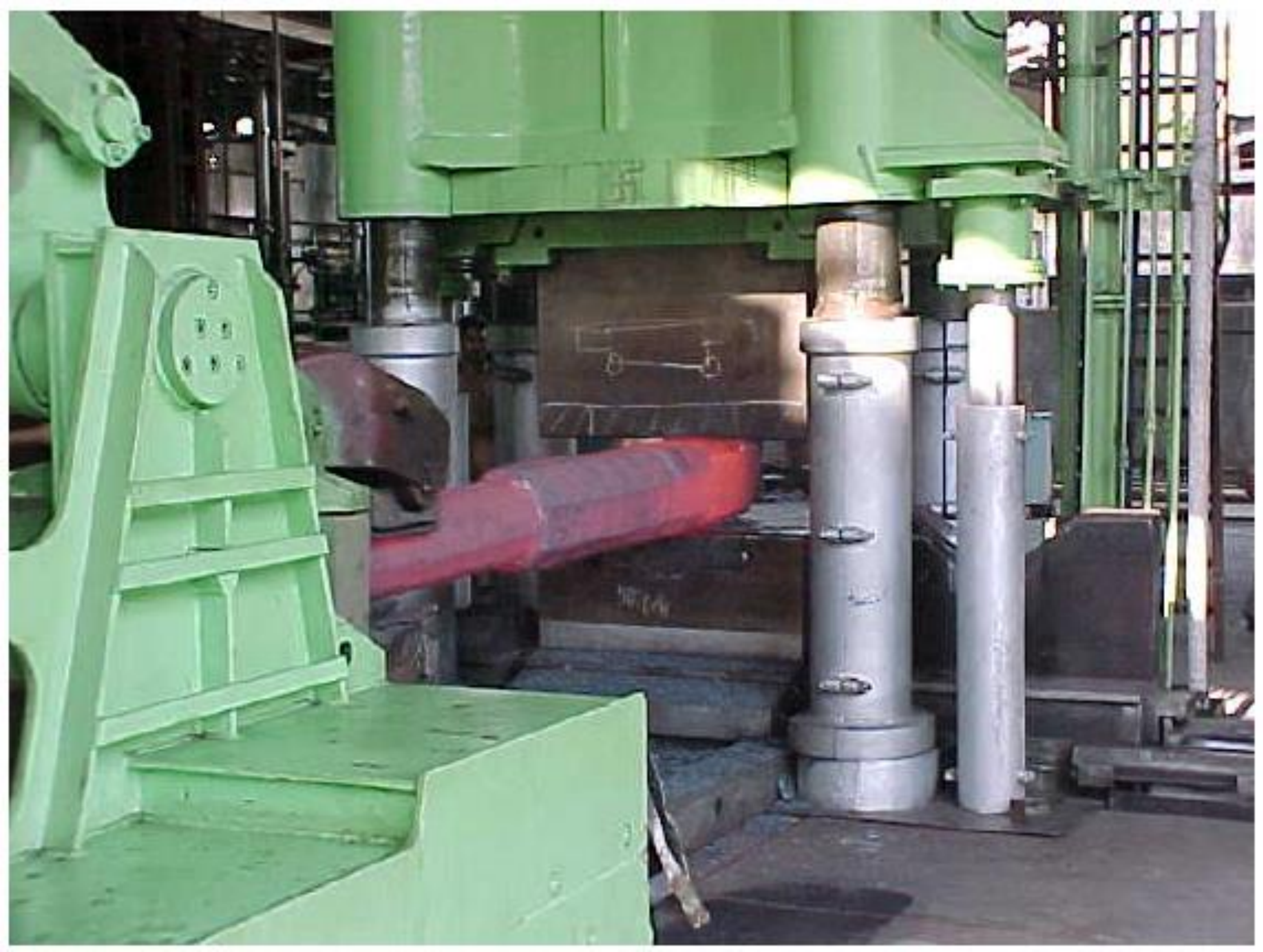
การตีขึ้นรูป (Forging)



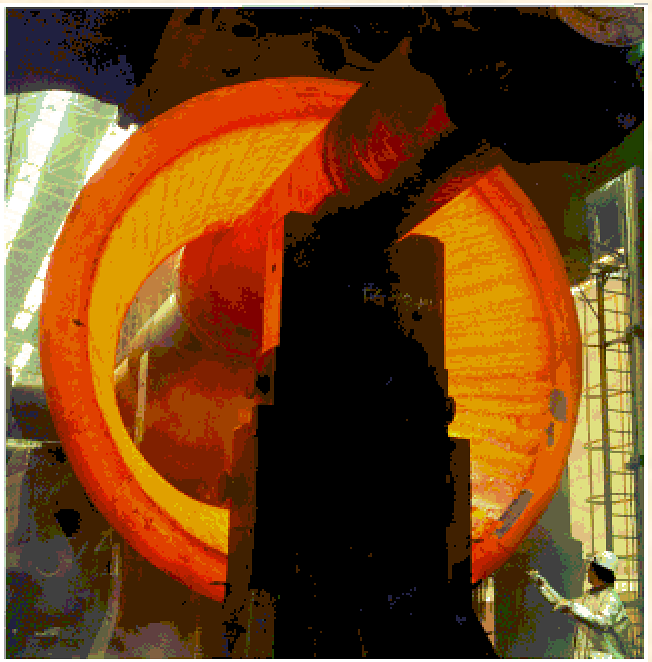


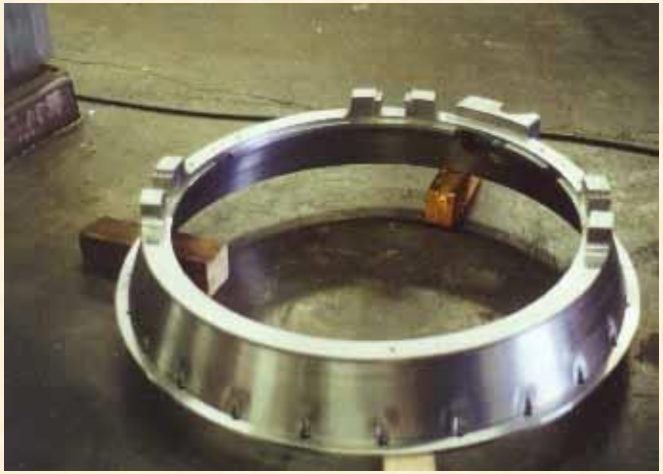


การตีขึ้นรูปด้วยแม่พิมพ์ชนิดเปิด (Open-Die Forging)

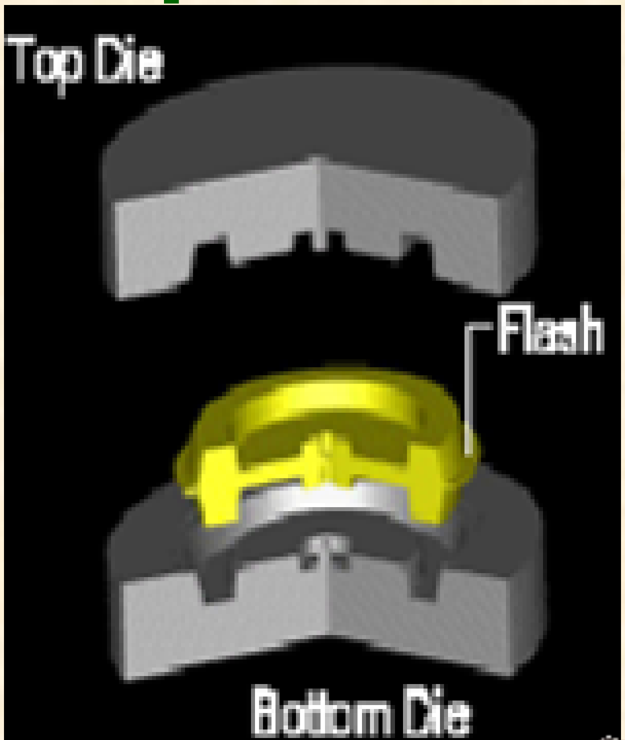


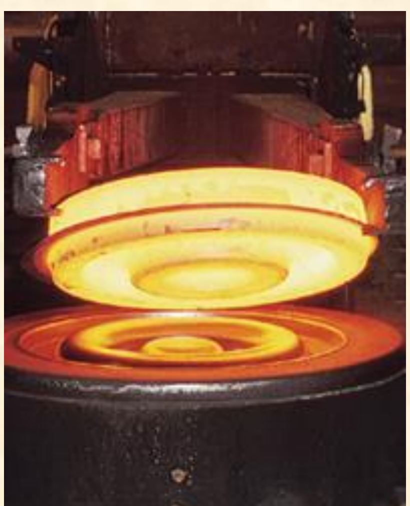
Ring Forging



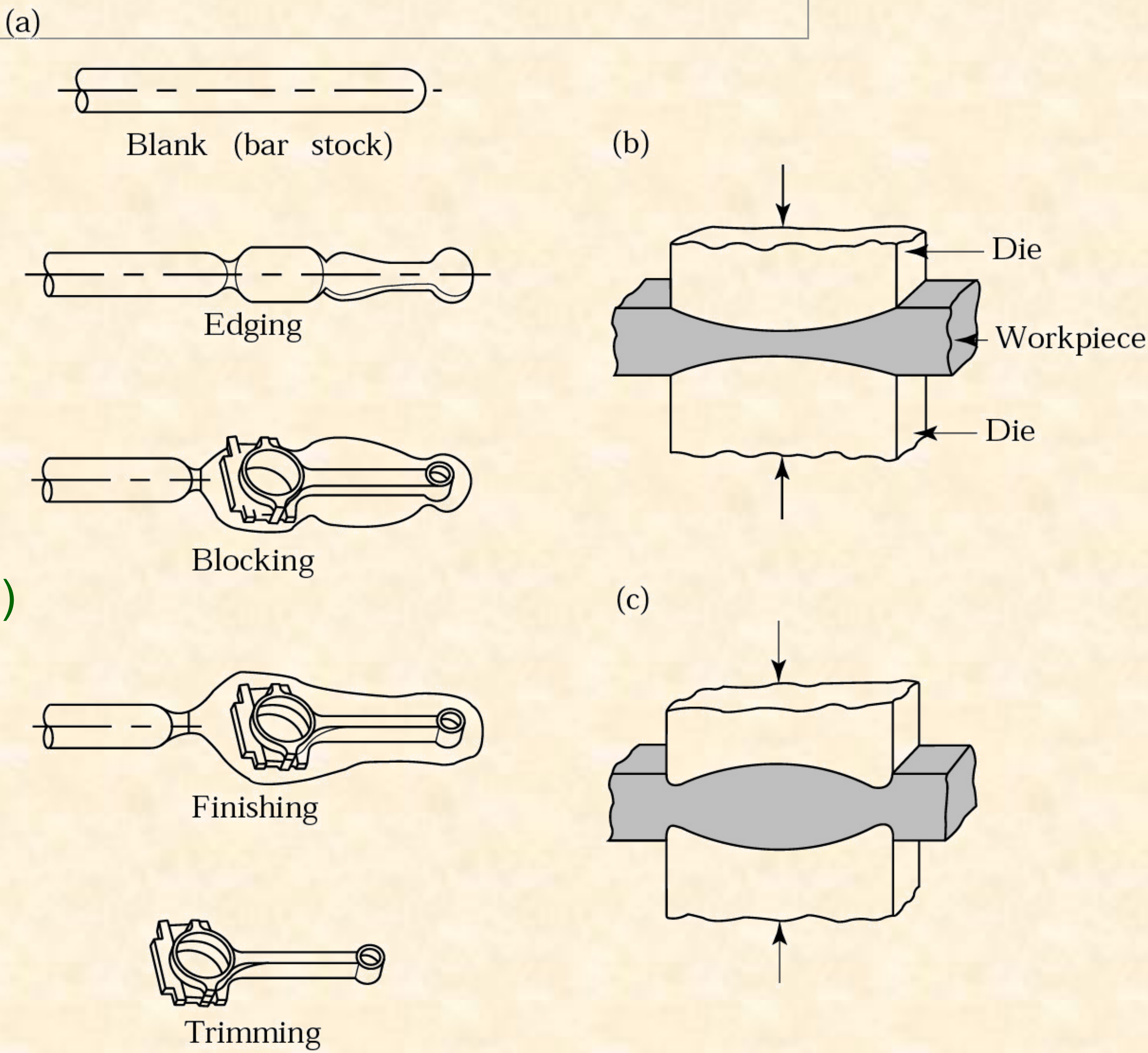


การตีขึ้นรูปด้วยแม่พิมพ์ชนิดปิด (Closed-Die Forging)



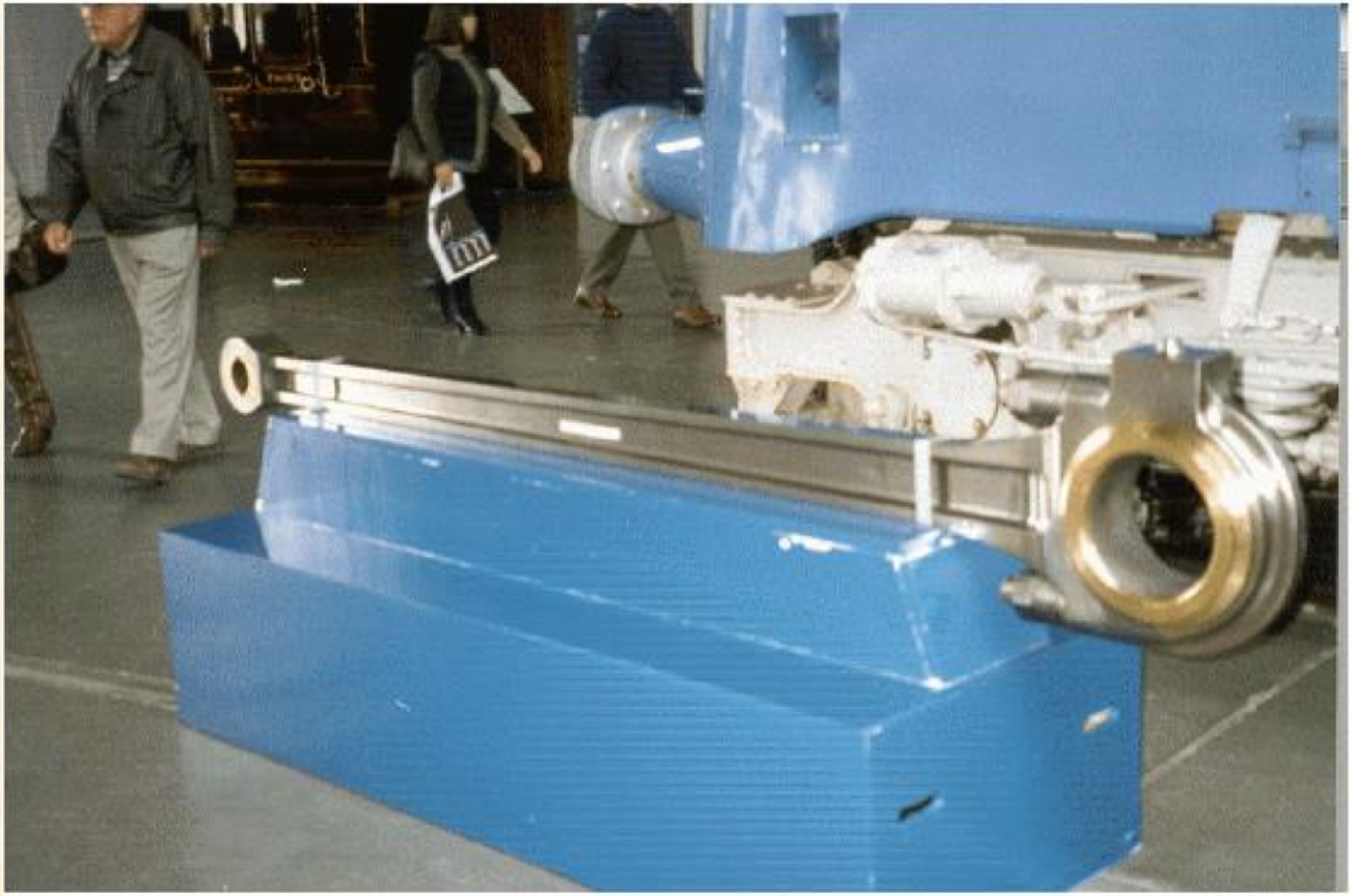


Forging a Connecting Rod



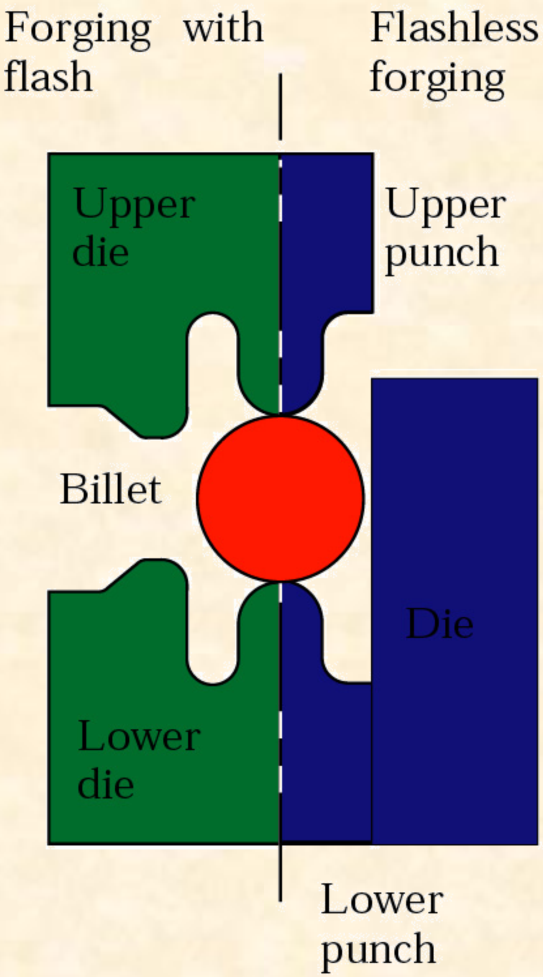
(a) Stages in forging a connecting rod for an internal combustion engine. Note the amount of flash required to ensure proper filling of the die cavities. (b) Fullering, and (c) edging operations to distribute the material when preshaping the blank for forging.

Railroad engine connecting rod

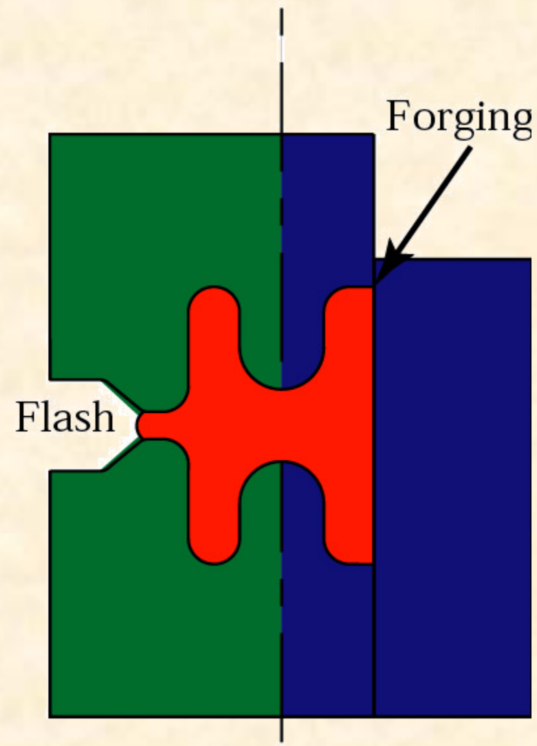


การตีขึ้นรูปแบบไม่มีครีบ (Flashless Forging)

Comparison of Forging With and Without Flash

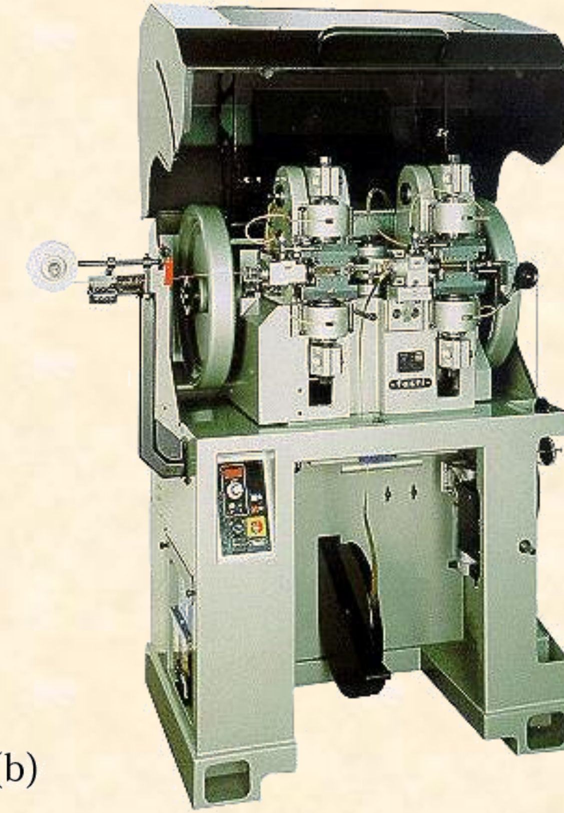


(a) Start of stroke

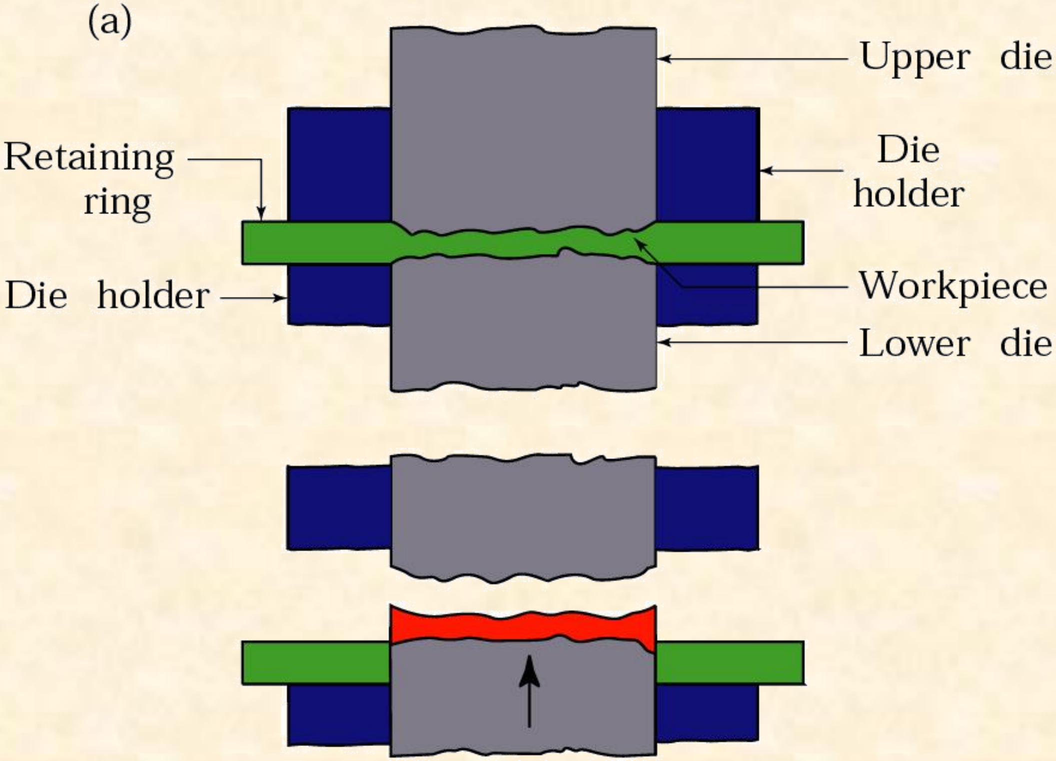


(b) End of stroke

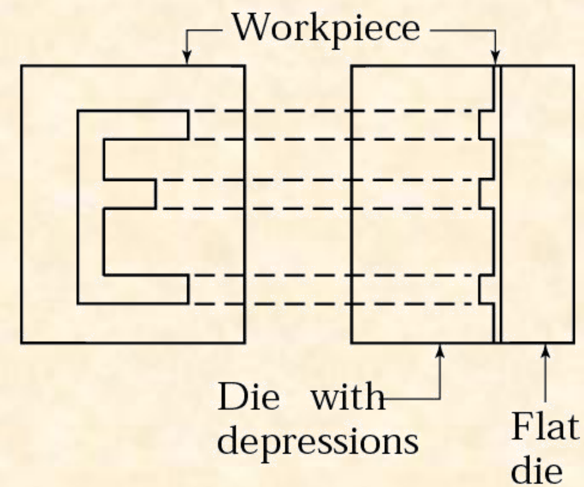
Coining



(a)


Upper die
Die holder
Retaining ring
Workpiece
Die holder
Lower die

(b)


Workpiece
Die with depressions
Flat die

การตีขึ้นรูปในลักษณะอื่น ๆ (Other Forging)

1) การตีขึ้นรูปหัว (Heading)

2) การตอกขึ้นรูป (Swaging)

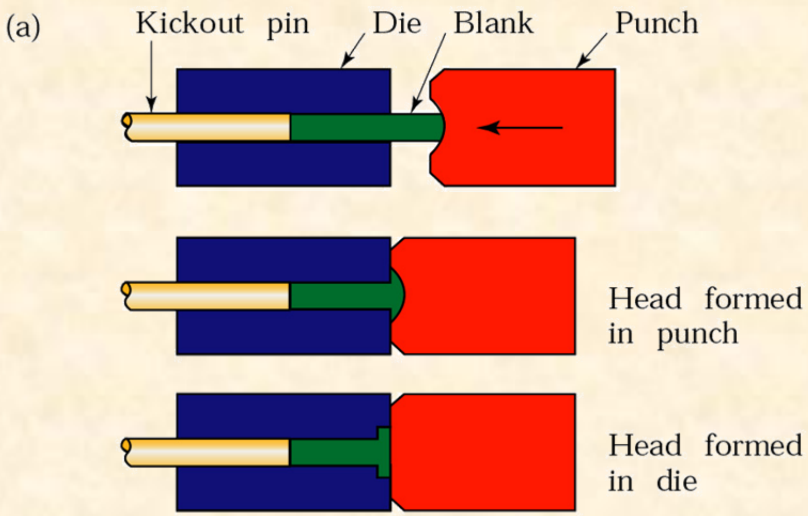
3. การตีขึ้นรูปแบบรีด (Roll Forging)

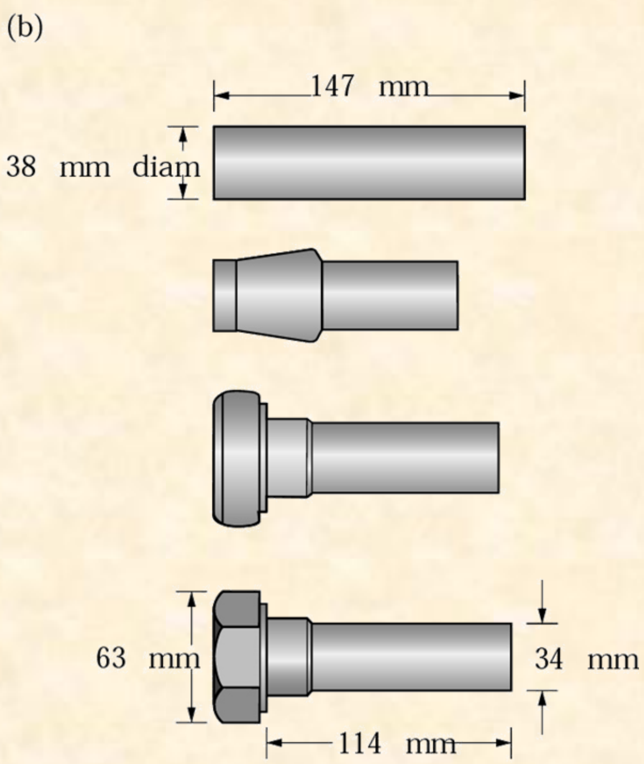
4) การตีขึ้นรูปแบบโคจร (Orbital Forging)

5) Hobbing

การตีขึ้นรูปในลักษณะอื่น ๆ (Other Forging)

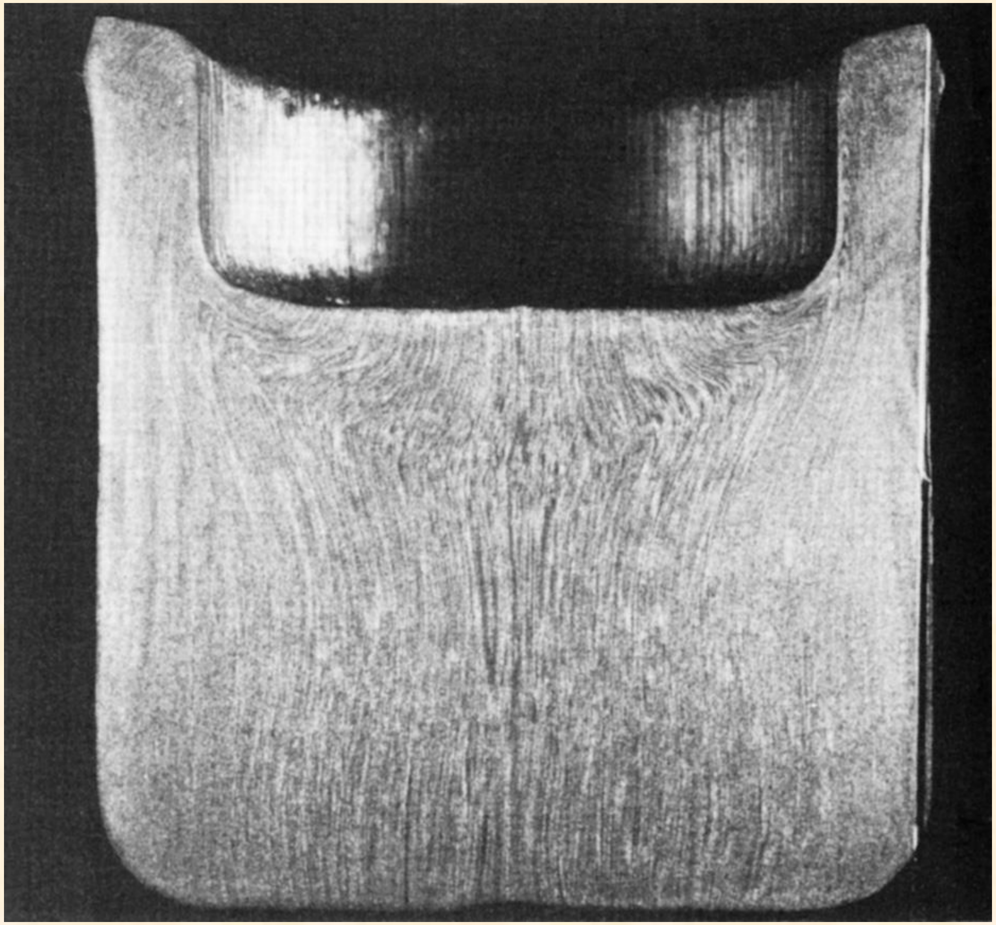
1) การตีขึ้นรูปหัว Heading/Upset Forging





(a) Heading operation, to form heads on fasteners such as nails and rivets. (b) Sequence of operations to produce a bolt head by heading.

Grain Flow Pattern of Pierced Round Billet



A pierced round billet, showing grain flow pattern. *Source*: Courtesy of Ladish Co., Inc.

Grain Flow Lines

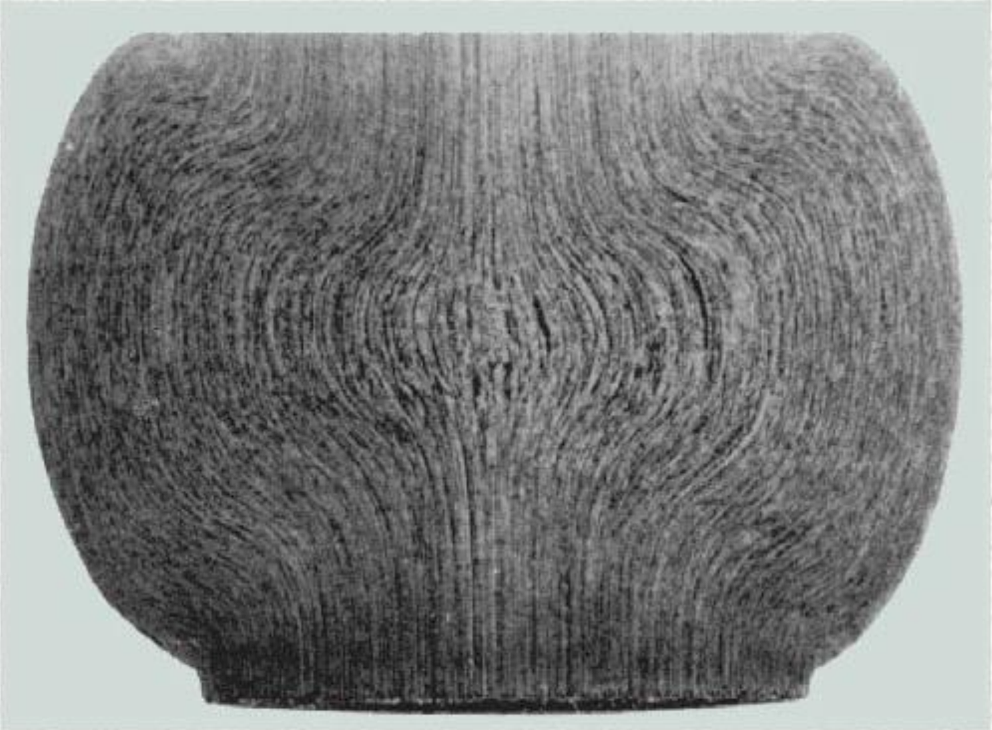
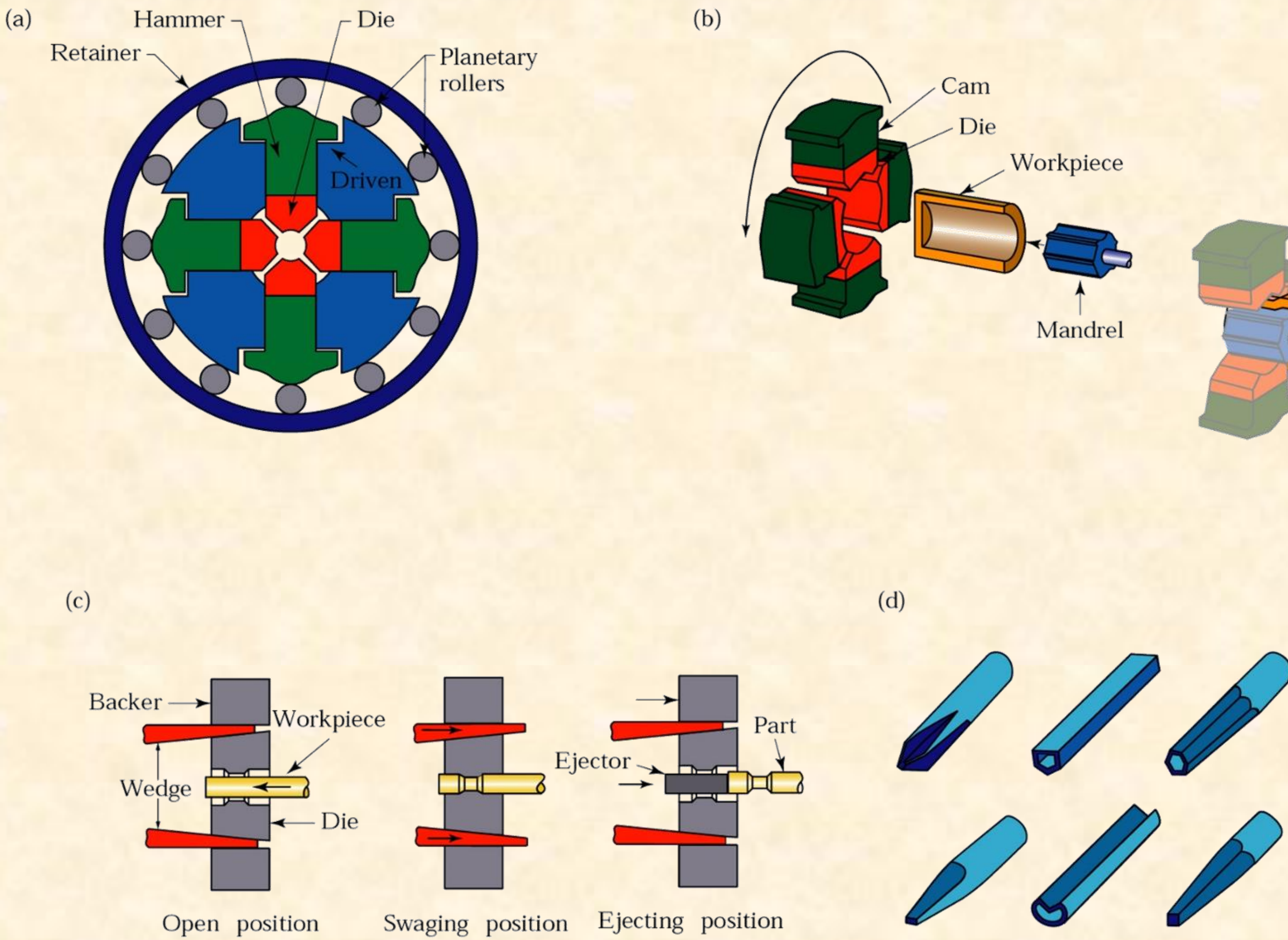


FIGURE 6.2 Grain flow lines in upsetting a solid steel cylinder at elevated temperatures. Note the highly inhomogenous deformation and barreling. The differnet shape of the botte, section of the specemen (as compared with the top) results from the hot specimenresting on the lower, cool die before deformation proceeded. The bottom surface was chilled; thus it exhibits greater strength and hence deforms less than the top surface. *Source*: J. A. Schey et al., IIT Research Institute.

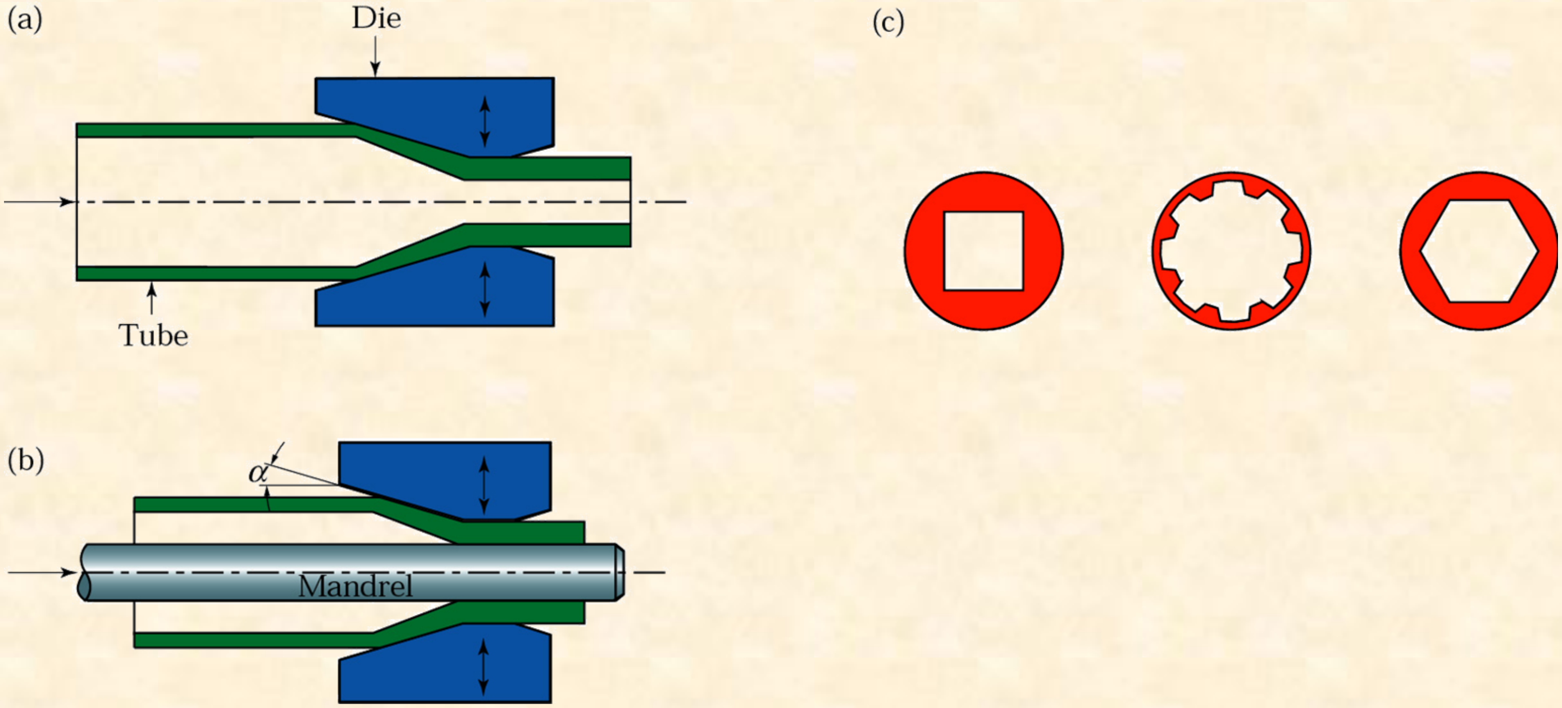
การตอกขึ้นรูป

Swaging



(a) Schematic illustration of the rotary-swaging process. (b) Forming internal profiles on a tubular workpiece by swaging. (c) A die-closing type swaging machine, showing forming of a stepped shaft. (d) Typical parts made by swaging.

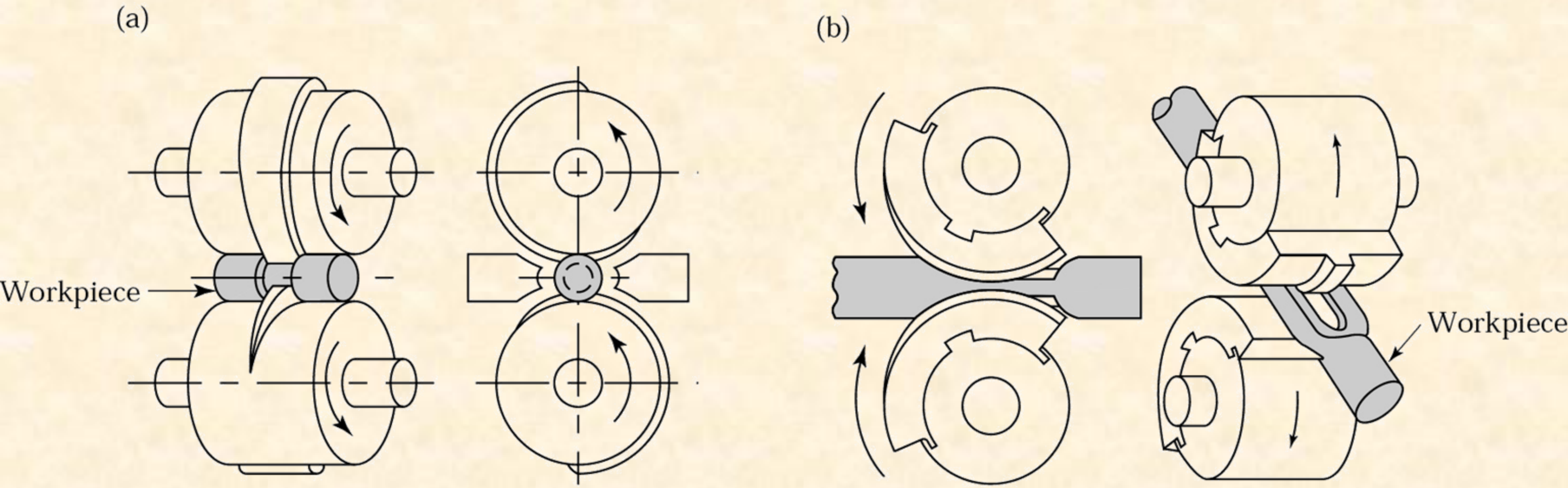
Swaging of Tubes With and Without a Mandrel



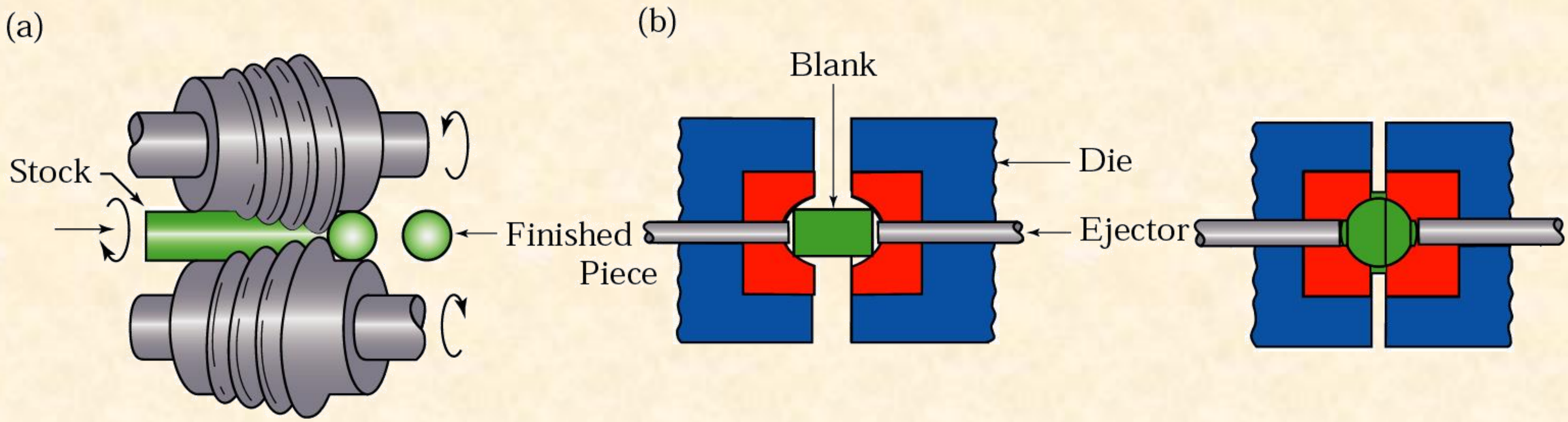
(a) Swaging of tubes without a mandrel; not the increase in wall thickness in the die gap. (b) Swaging with a mandrel; note that the final wall thickness of the tube depends on the mandrel diameter. (c) Examples of cross-sections of tubes produced by swaging on shaped mandrels. Rifling (spiral grooves) in small gun barrels can be made by this process.

Roll-Forging

Two examples of the roll-forging operation, also known as *cross-rolling*. Tapered leaf springs and knives can be made by this process. *Source*: (a) J. Holub; (b) reprinted with permission of General Motors Corporation.

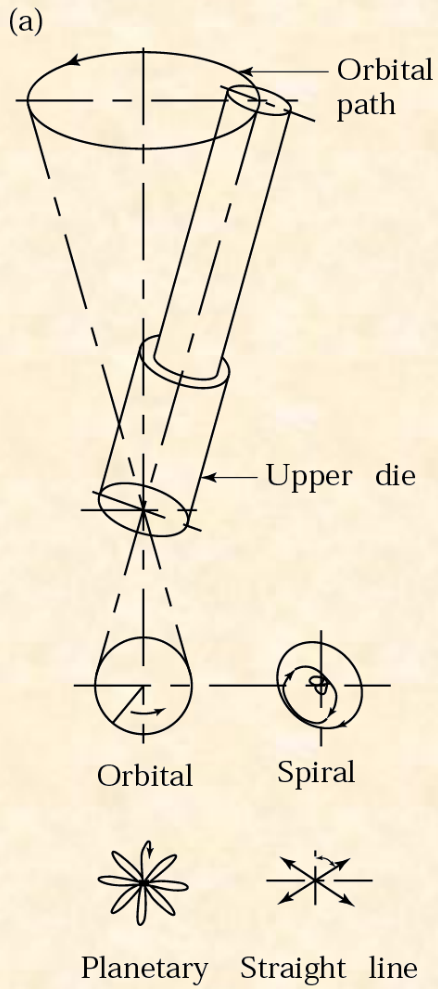


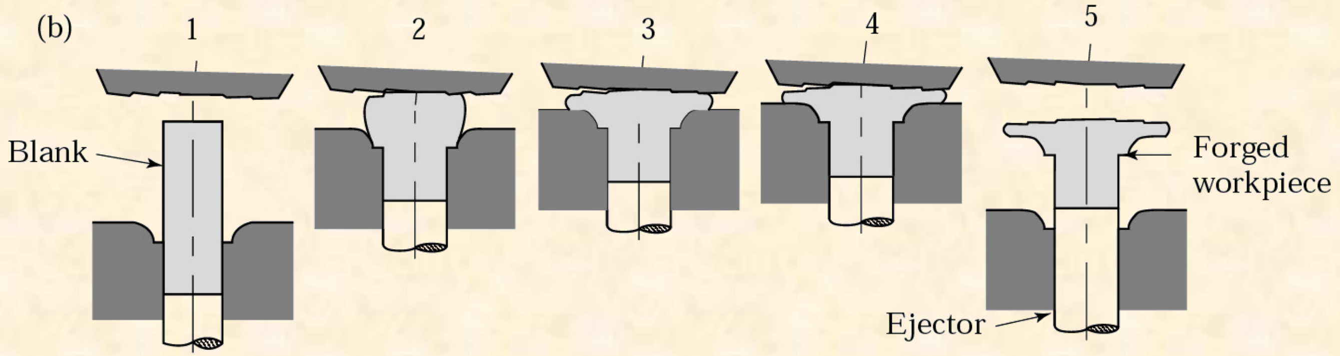
Production of Bearing Blanks



(a) Production of steel balls by the skew-rolling process. (b) Production of steel balls by upsetting a cylindrical blank. Note the formation of flash. The balls made by these processes are subsequently ground and polished for use in ball bearings (see Sections 25.6 and 25.10).

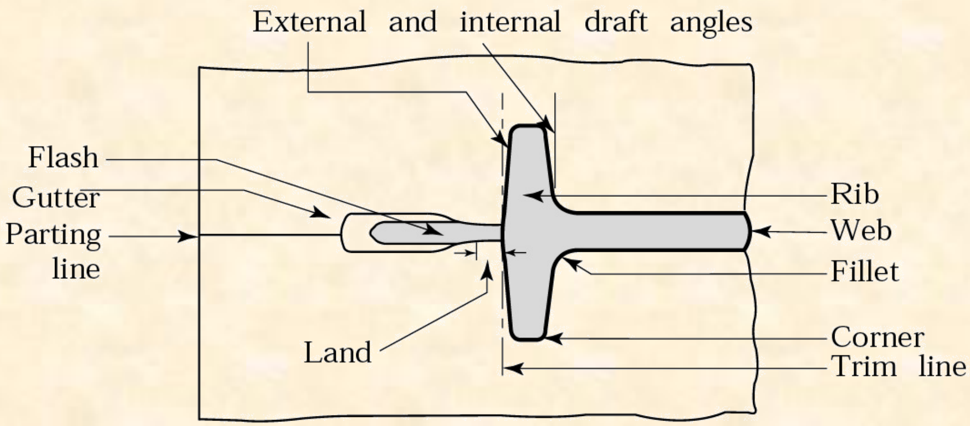
Orbital Forging





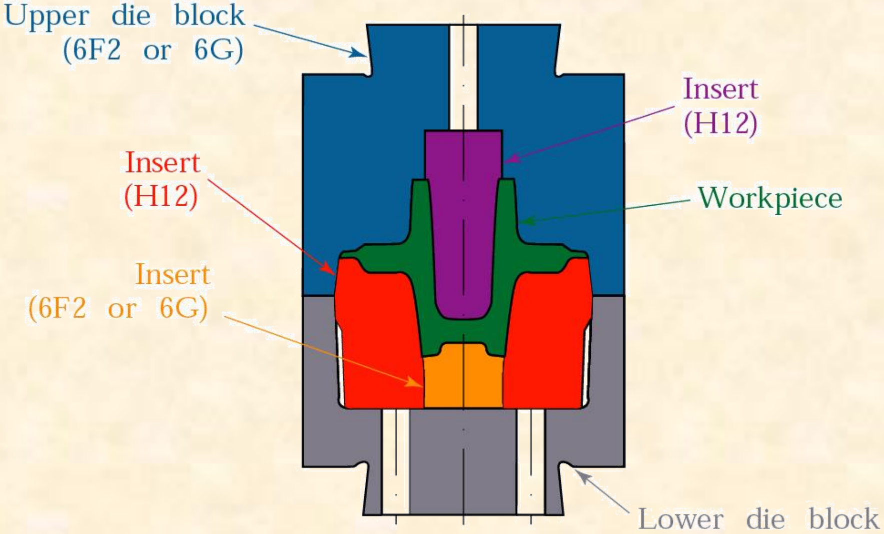
(a) Various movements of the upper die in orbital forging (also called rotary, swing, or rocking-die forging); the process is similar to the action of a mortar and pestle. (b) An example of orbital forging. Bevel gears, wheels, and rings for bearings can be made by this process.

Impression-Forging Die and Die Inserts

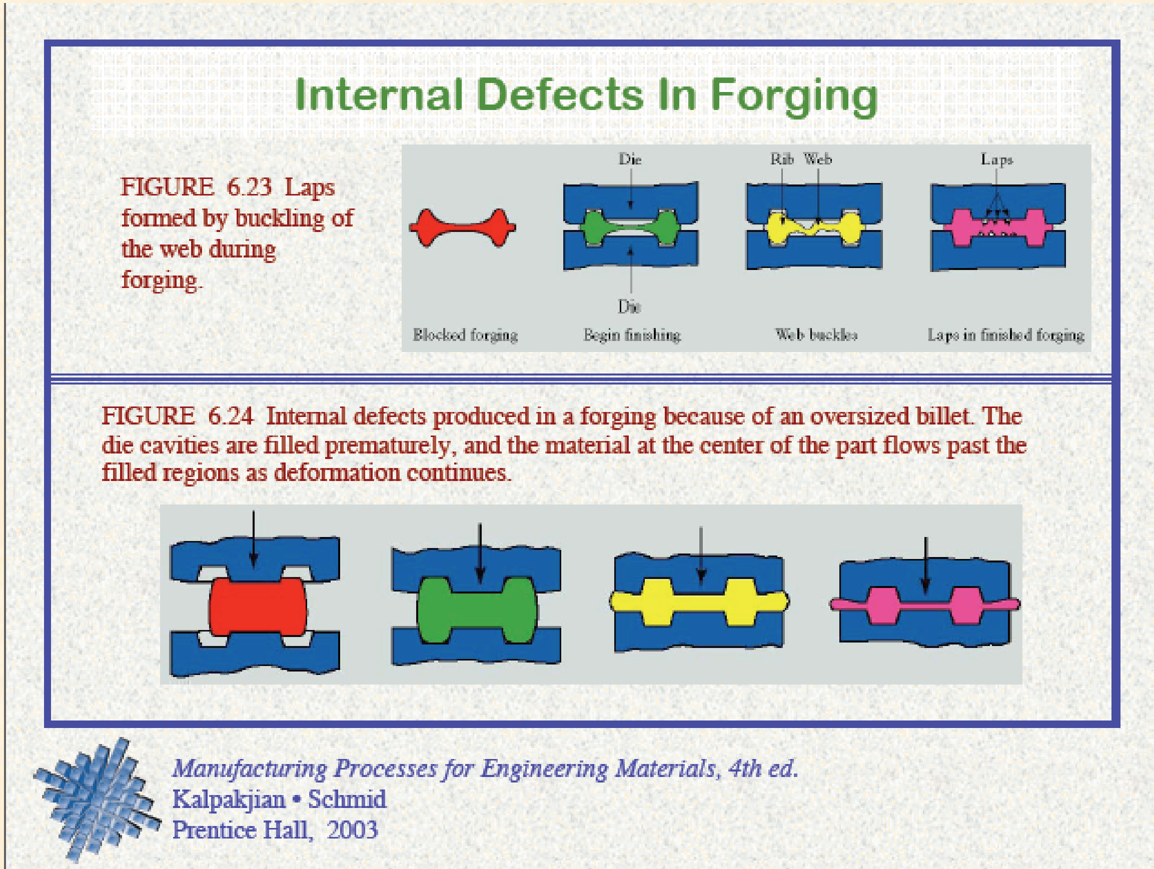


Standard terminology for various features of a typical impression-forging die.

Die inserts used in dies for forging an automotive axle housing. (See Tables 5.5 to 5.7 for die materials.) *Source*: *Metals Handbook, Desk Edition*. ASM International, Metals Park, Ohio, 1985. Used with permission.



Defects in Forged Parts



Examples of defects in forged parts. (a) Labs formed by web buckling during forging; web thickness should be increased to avoid this problem. (b) Internal defects caused by oversized billet; die cavities are filled prematurely, and the material at the center flows past the filled regions as the dies close.

Defect Formation In Forging

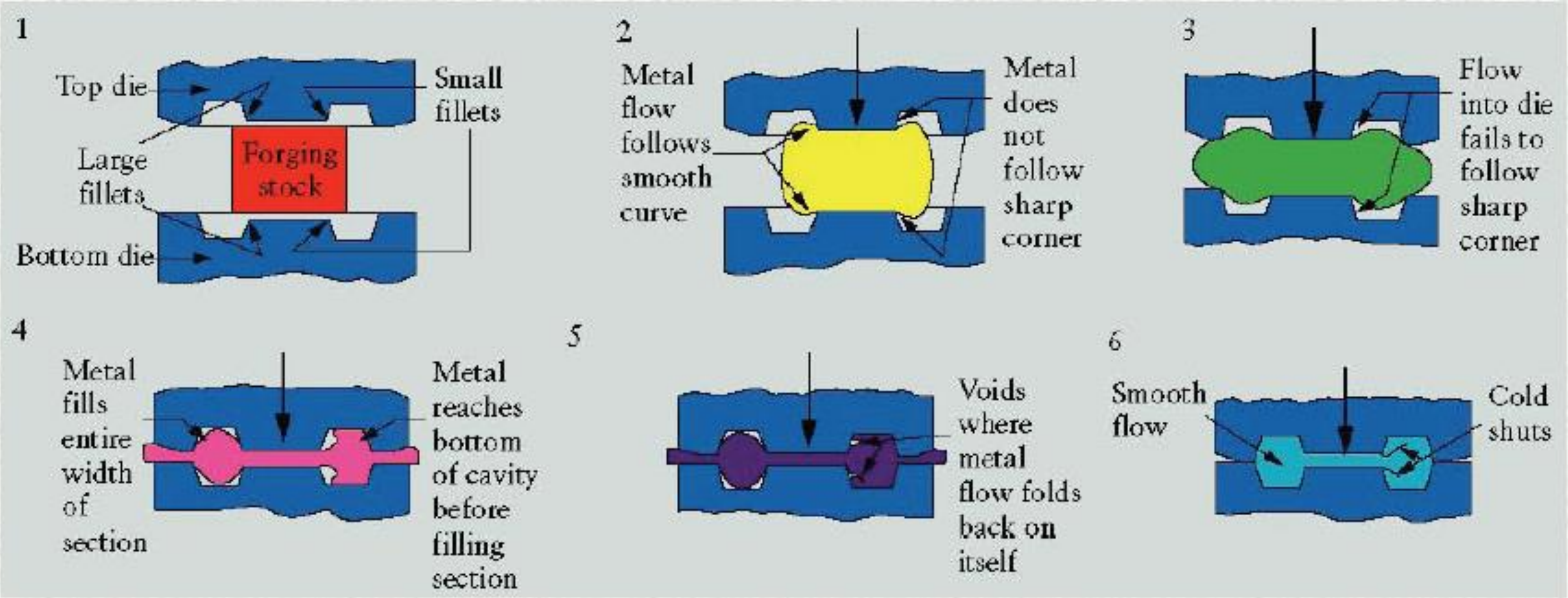


FIGURE 6.25 Effect of fillet radius on defect formation in forging. Small fillets (right side of drawings) cause the defects. *Source*: Aluminum Company of America.

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