EDPT 601

MATERIALS MANUFACTURING TECHNOLOGY

Metal Forming Processes:

Hot working processes

Refs: Ch 17 and 18 DeGarmo

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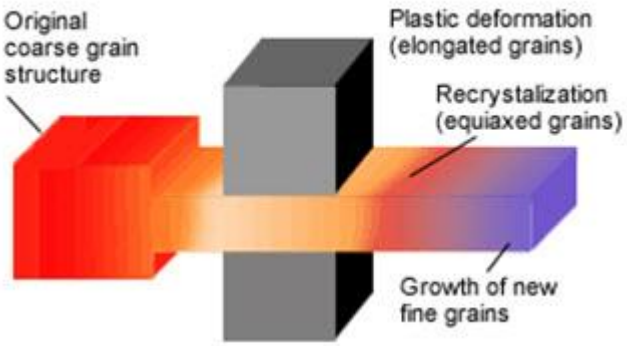
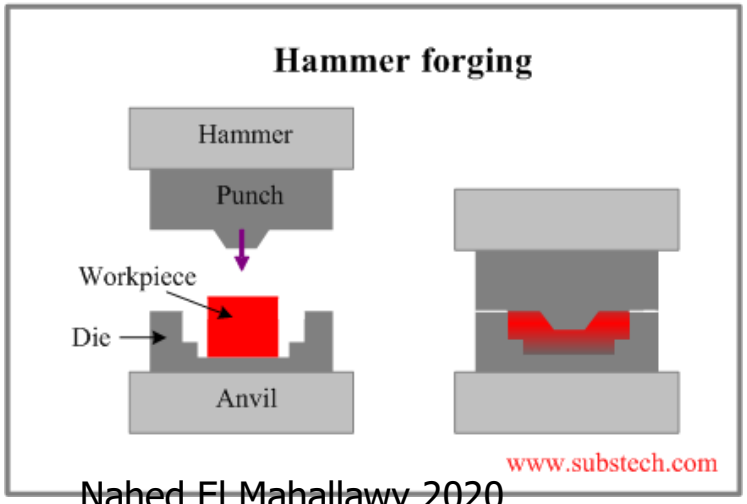
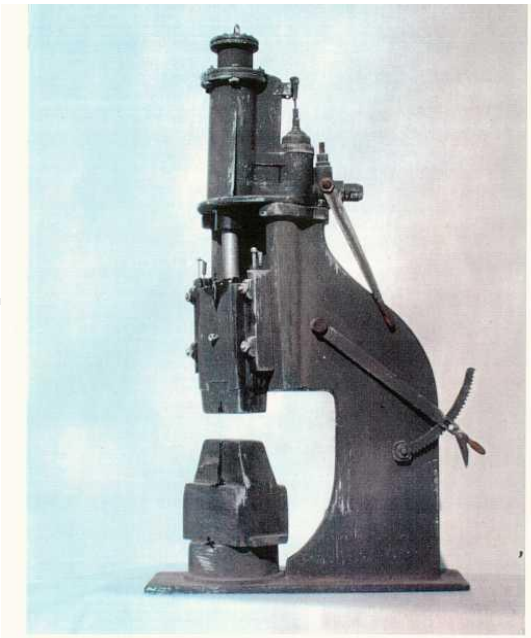
Forging

- Is the controlled plastic deformation or working of metal into a predetermined shape by pressure or blows or a combination of both







1/12 Scale Small Steam Hammer
National RR Museum

WAYNE WESOLOWSKI, Ph.D.
Model Maker

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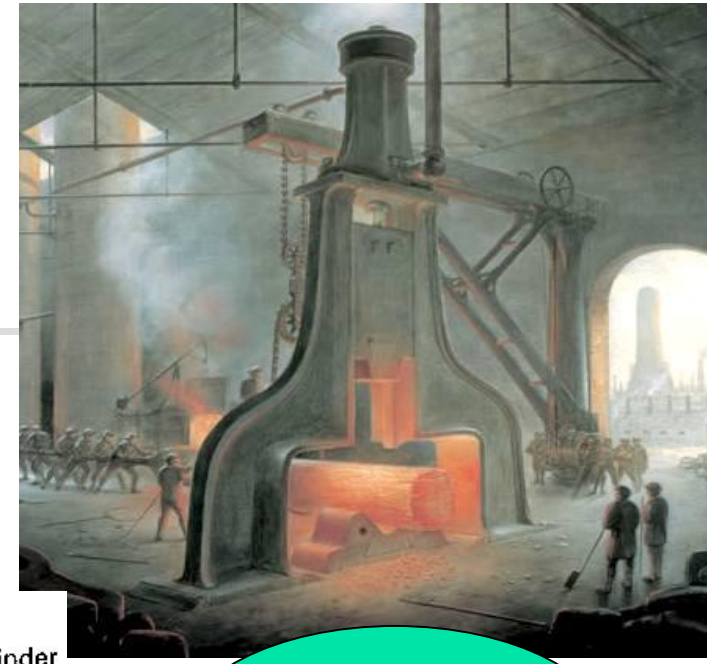
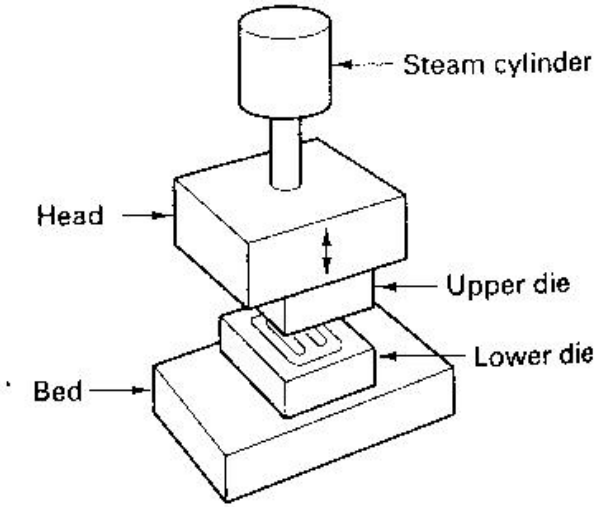
Open die Forging:
1. machines

pneumatic hammer

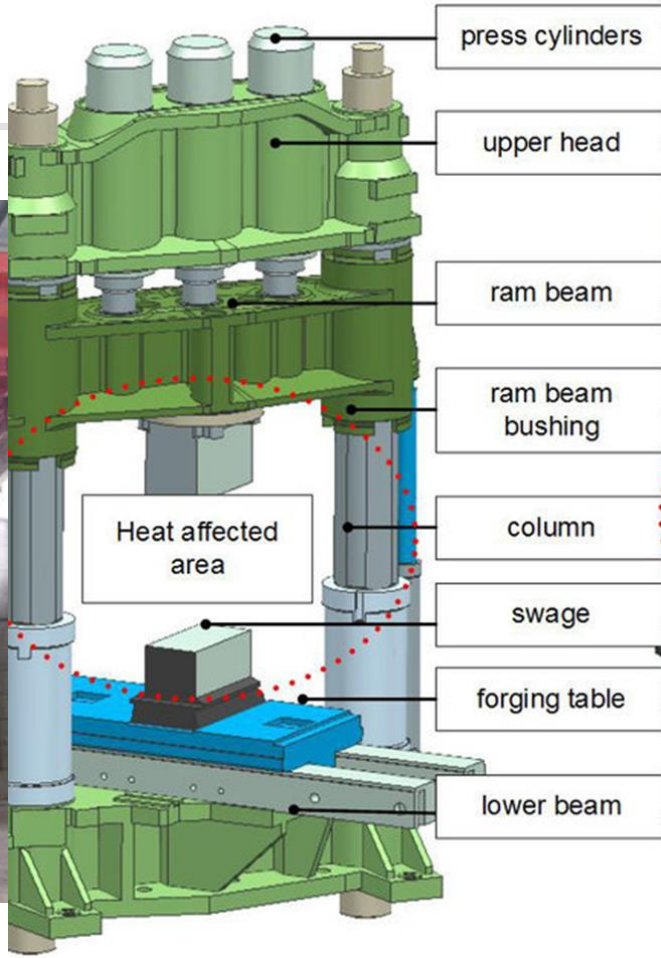


Steam hammer



Tools used: Upper and lower dies

Open die forging Machines:
2.Presses



Open die forging operations: -upsetting

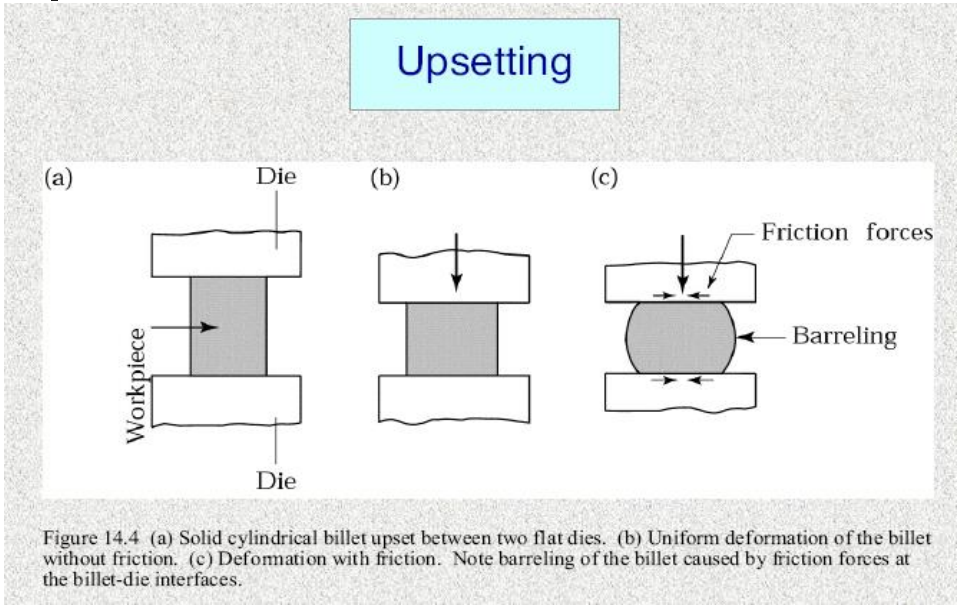
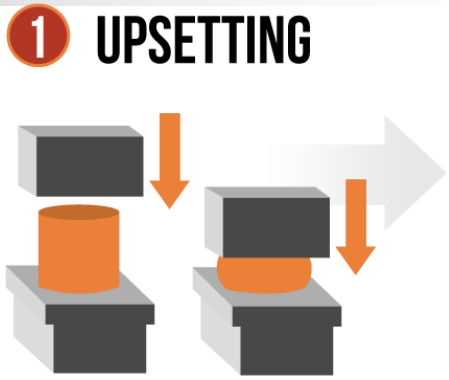
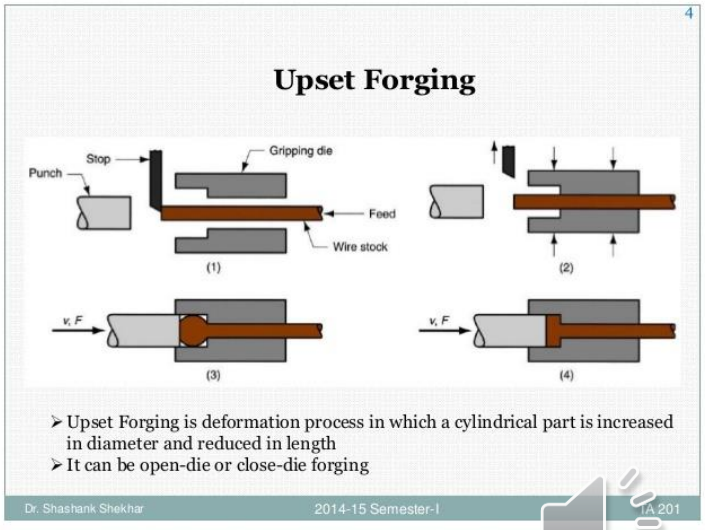


Figure 14.4 (a) Solid cylindrical billet upset between two flat dies. (b) Uniform deformation of the billet without friction. (c) Deformation with friction. Note barreling of the billet caused by friction forces at the billet-die interfaces.





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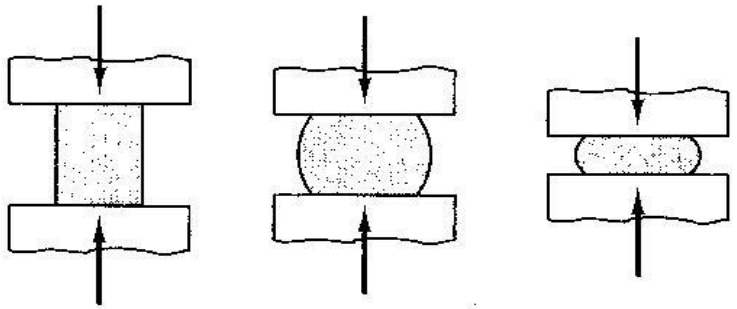
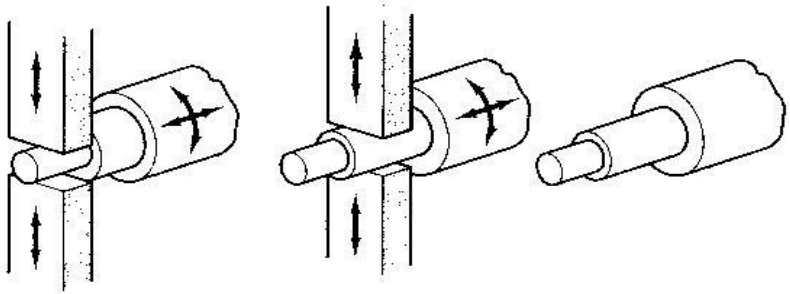
- Forging of multi diameter shaft, seamless ring

Unrestrained flow Of material in open die

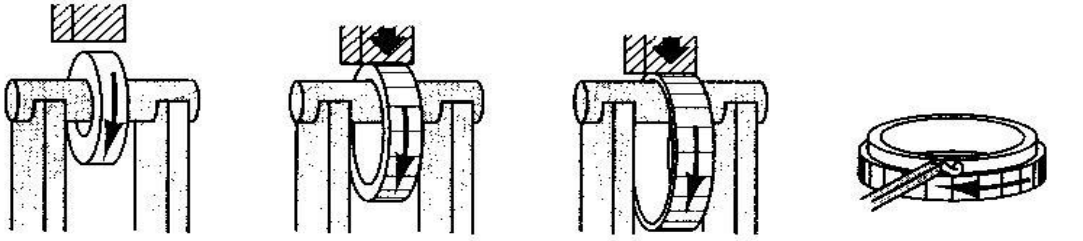


Note the Barrel shape due to friction

Open die for Multi diam shaft



Forging of seamless Ring



1 Preform mounted on saddle/mandrel.

2 Metal displacement– reduce preform wall thickness to increase diameter.

3 Progressive reduction of wall thickness to produce ring dimensions.

4 Machining to near net shape.

- Cogging or drawing out

Cogging

To reduce the thickness of bars by hammering the part on an anvil

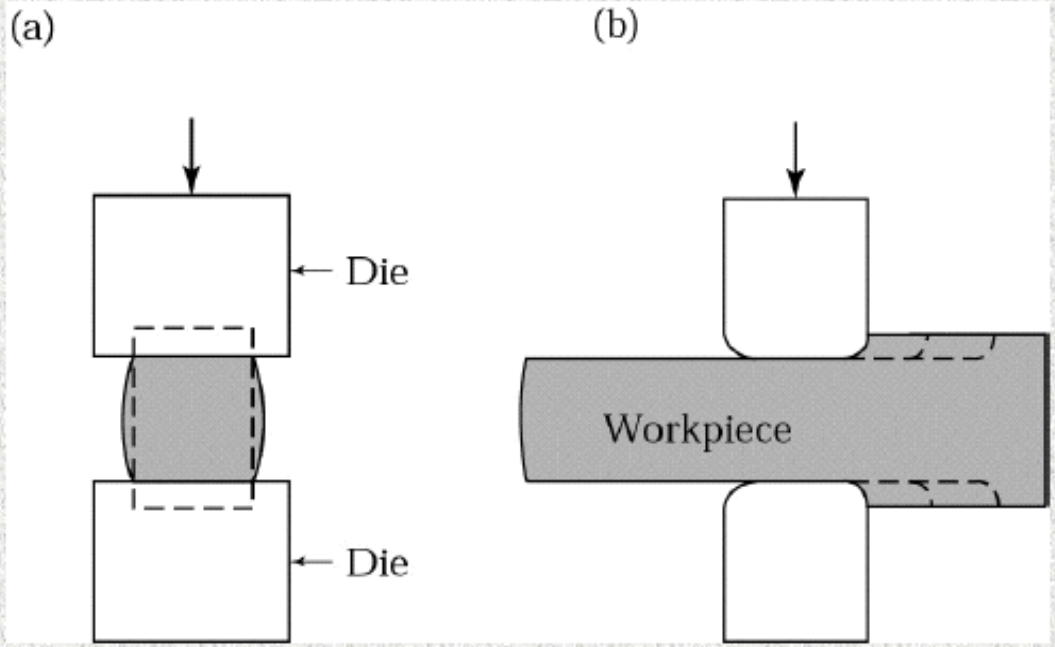


Figure 14.5 Two views of a cogging operation on a rectangular bar. Blacksmiths use this process to reduce the thickness of bars by hammering the part on an anvil. Note the barreling of the workpiece.

- Piercing

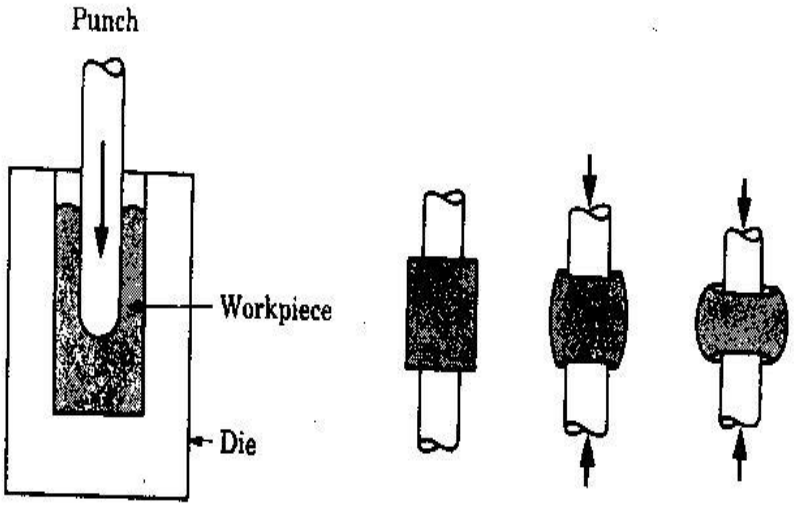


FIGURE 6.18 Examples of piercing operations.

Grain Flow Pattern of Pierced Round Billet

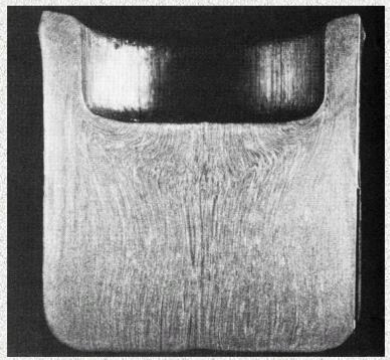
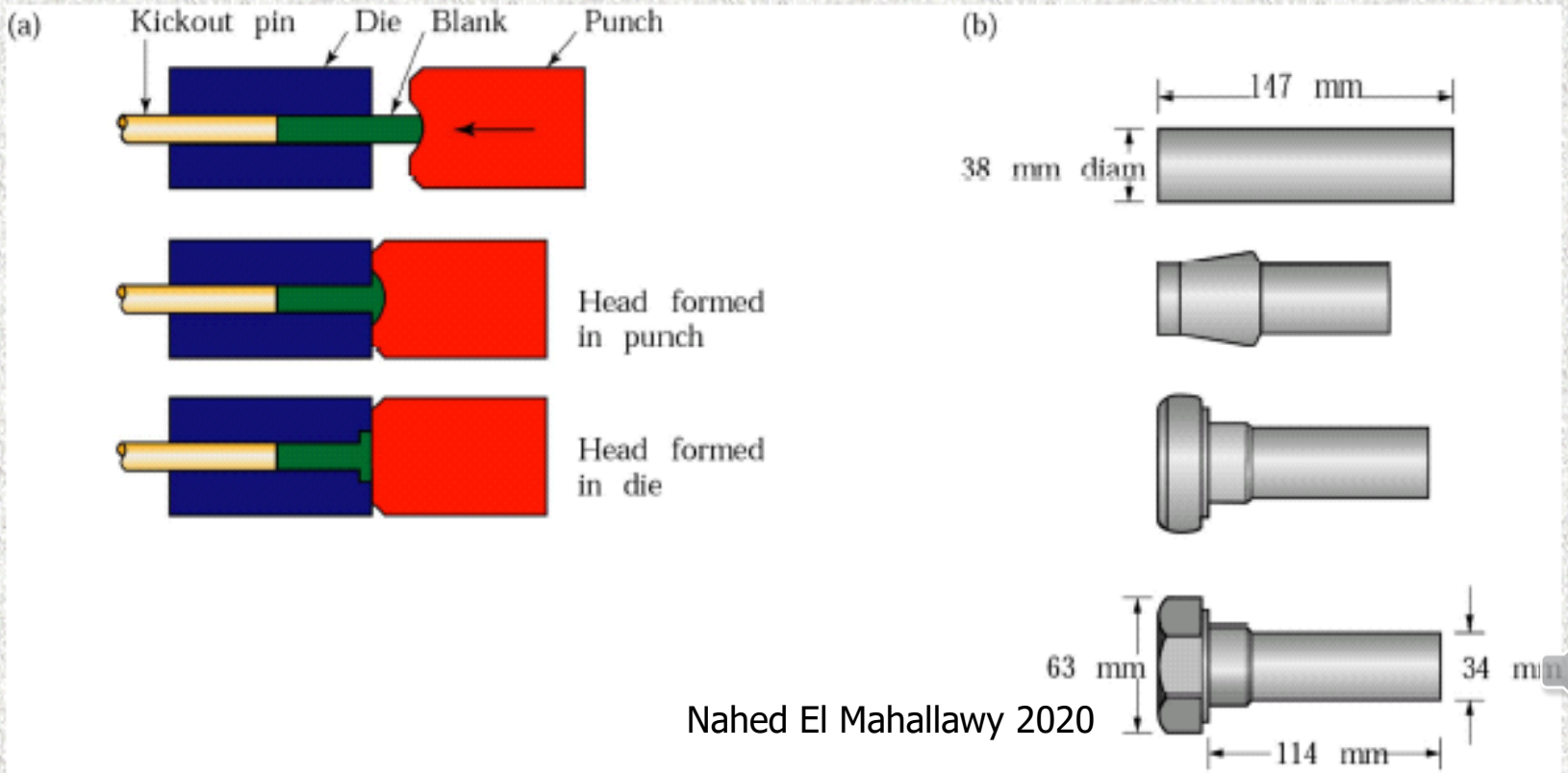


Figure 14.12 A pierced round billet, showing grain flow pattern. *Source*: Courtesy of Ladish Co., Inc.

- Heading /Upset Forging

Heading/Upset Forging



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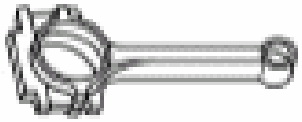
Impression-Die (Closed die)
1. Drop Hammer Forging

- For products of large or complicated shapes , a preliminary shaping operation using more than one set of dies may be required
- Forging temp. of
  - Steel 1100 C -1250 C
  - Cu and alloys 750C - 925C
  - Mg alloy 315C
  - Al alloys 370C



closed die or impression-die forging

Schematic of impression die forging showing partial filling and beginning of flash

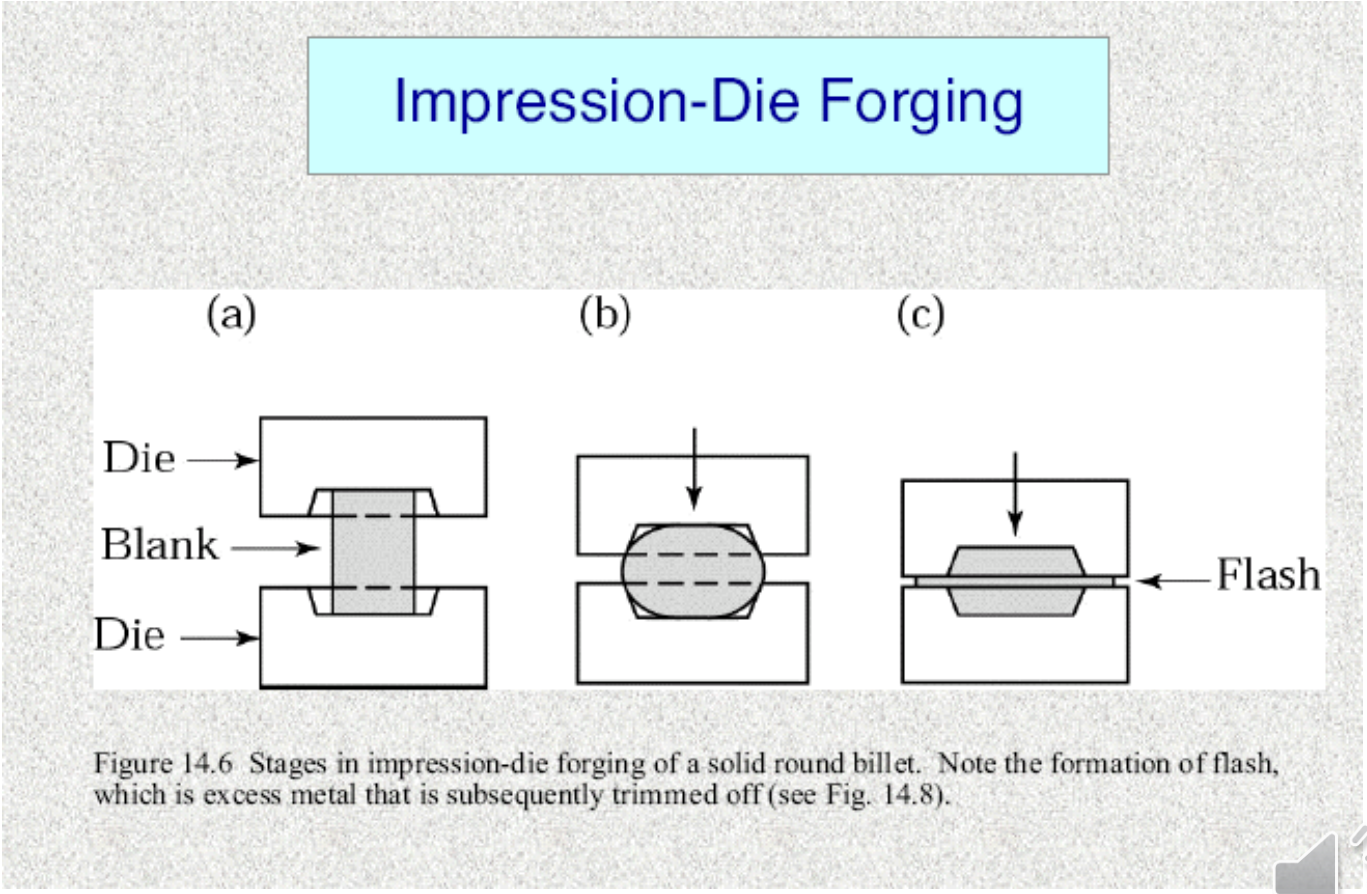
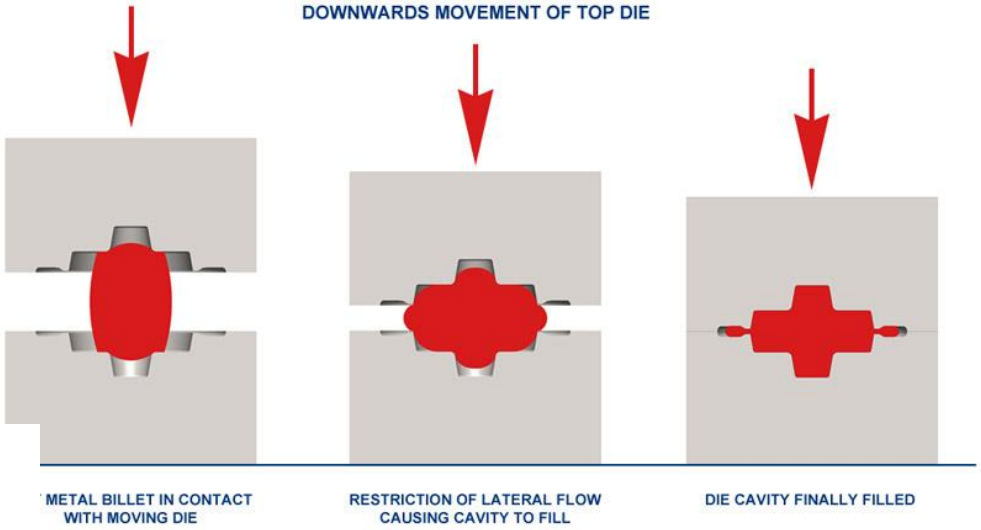
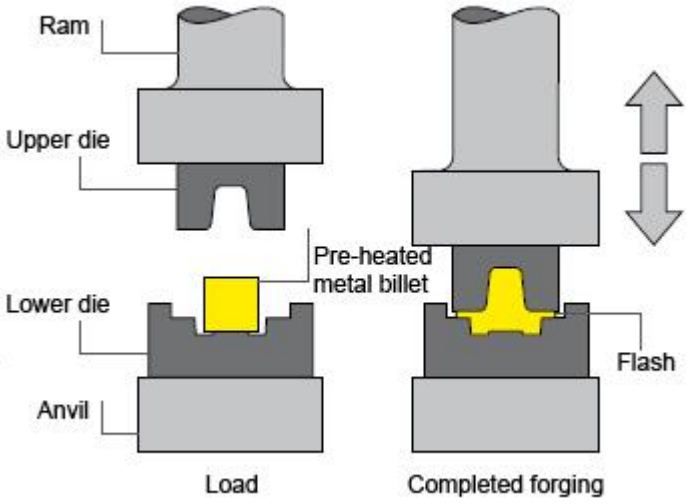


Figure 14.6 Stages in impression-die forging of a solid round billet. Note the formation of flash, which is excess metal that is subsequently trimmed off (see Fig. 14.8).

Closed die forging





Closed die forging: Formation of flash and related forging load

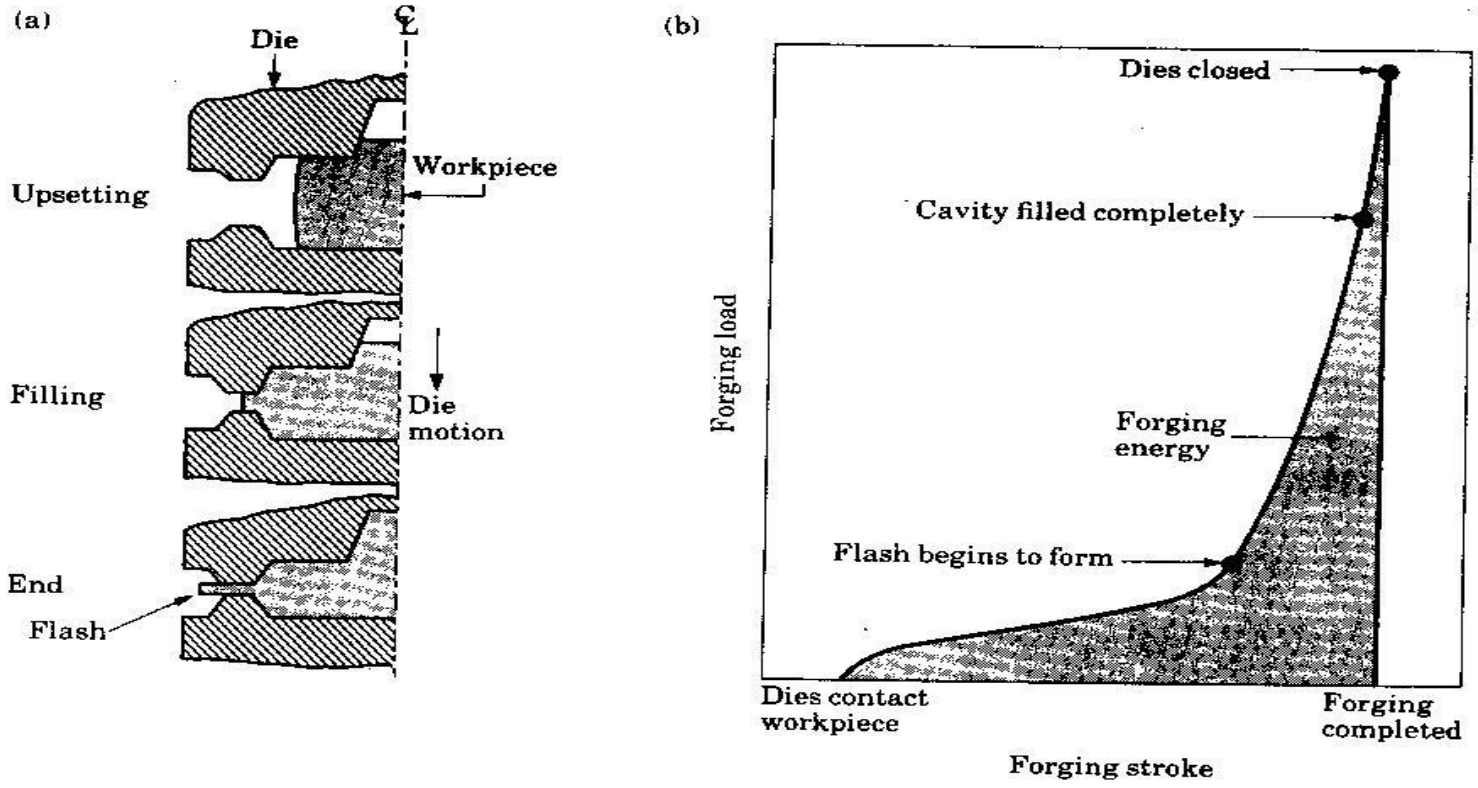


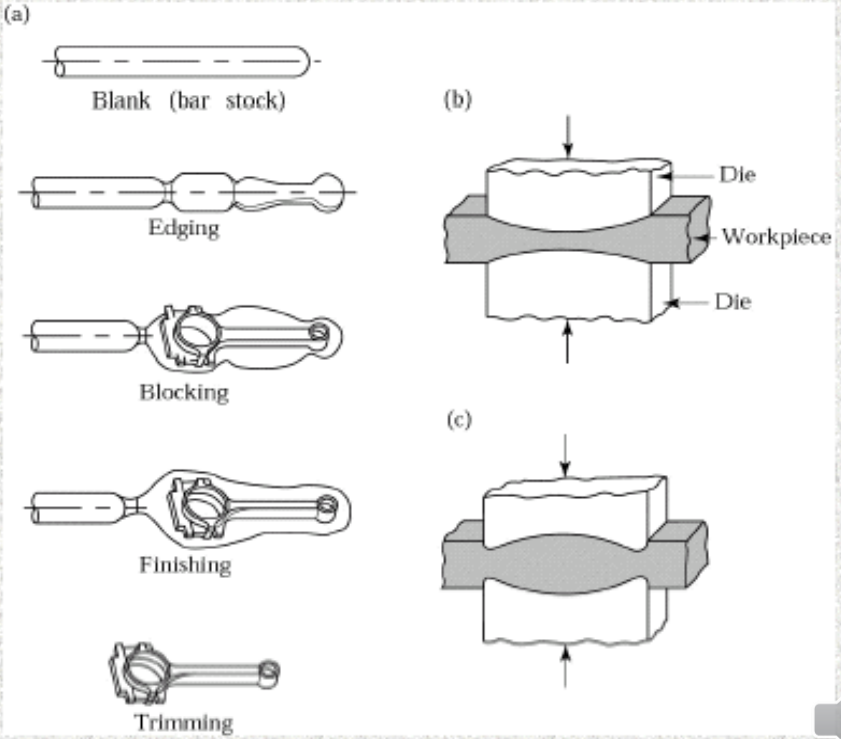
FIGURE 6.15 Typical load-stroke curve for closed-die forging. Note the sharp increase in load after the flash begins to form. In hot-forging operations, the flash requires high levels of stress because it is thin, that is, small *h*, and cooler than the bulk of the forging. *Source:* After T. Altan.

Case study: forging of connecting rod

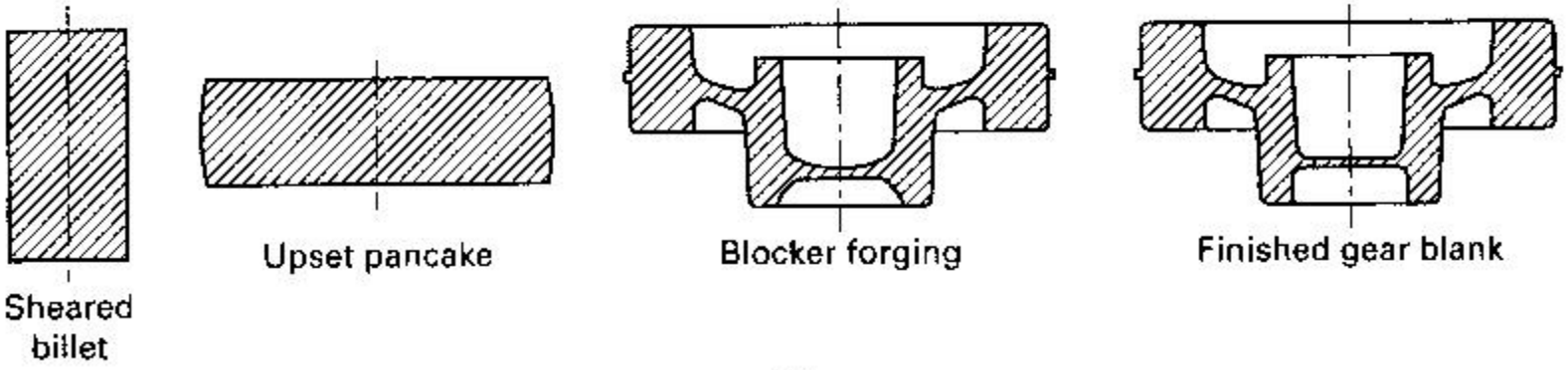
impression drop forging dies and steps for connecting rod

Forging a Connecting Rod

Figure 14.7 (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.



Typical 4-step sequence to produce a spur gear: The sheared billet is progressively shaped into an upset pancake , blocker forging and finished gear blank



Some forgings:
Bushing
Crankshaft
Control arm

Trimming Flash from a Forged Part

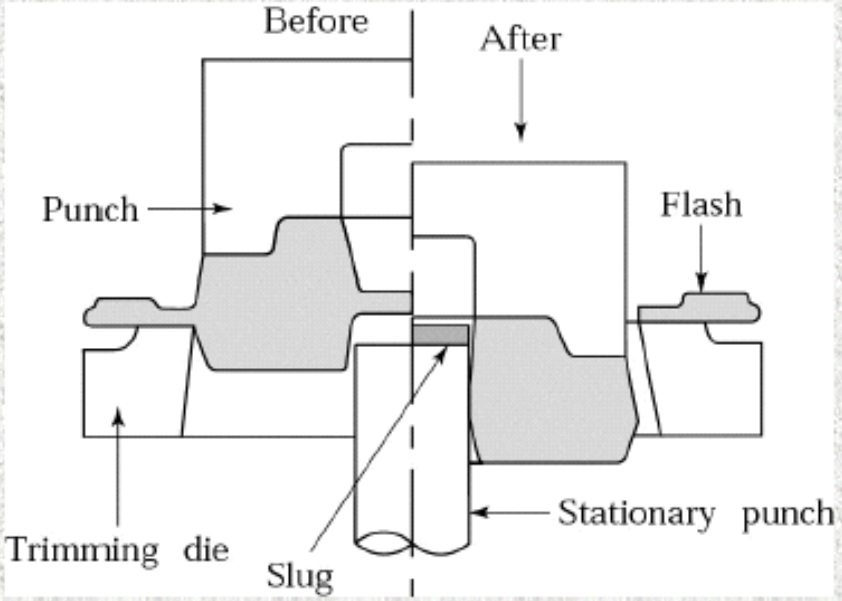


Figure 14.8 Trimming flash from a forged part. Note that the thin material at the center is removed by punching.

Design considerations of impression die forging and tooling

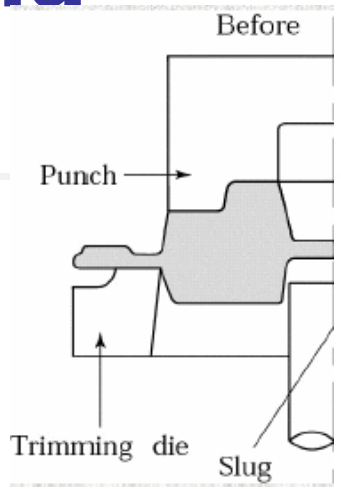
1- Forging dies:

- usually from high alloy steel or tool steel
- high impact resistance, wear resistance, high temp strength, thermal fatigue

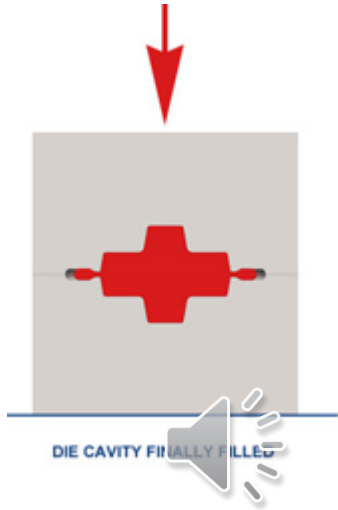
2- Design considerations for better and more economical results:

- flat parting plane
- the parting surface should pass by the center of the forging
- draft at least 3 deg for Al and 5-7 deg for steel

Design considerations of impression die forging and tooling



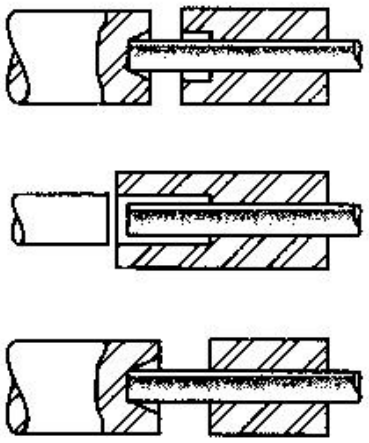
- generous fillets and radii
- ribs should be low and wide
- sections in the die should be balanced to avoid extreme differences in metal flow
- full advantage should be taken of fiber flow lines
- dimensional tolerances should not be closer than necessary



Design considerations of upset forging

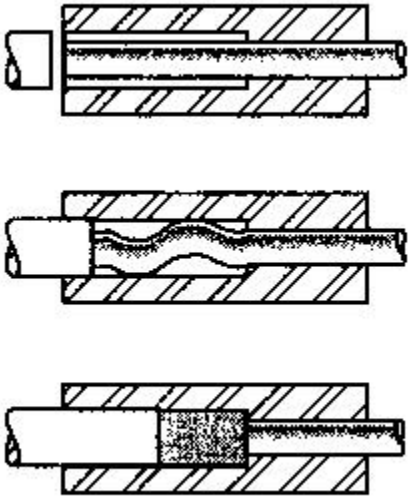
3 Rules for upset forging

Rule 1:length of unsupported metal should not exceed 3 times the diam of the bar



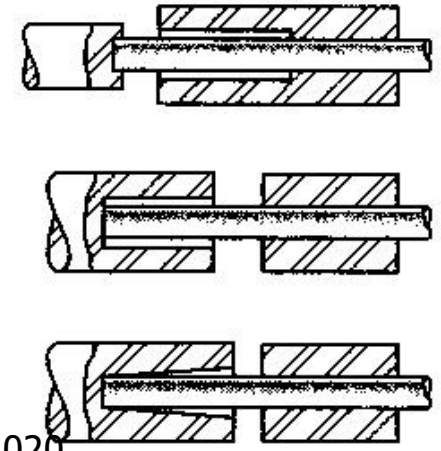
Applications of rule 1

Rule 2: length of stock greater than 3 times the diam may be upset if the diam of the upset is not more than 1.5 the diam of the bar



Applications of rule 2

Rule 3:in an upset requiring length of stock greater than 3 times the bar diam., and where the diam of the cavity is no more than 1.5 diam of the bar, the length of unsupported metal beyond the face of the die must not exceed the bar diam.



Applications of rule 3

Impression-Die (Closed die)
2. Press Forging

- Using presses rather than hammers
- Deformation in terms of forces rather than energy
- Uniform deformation is obtained across the thickness of workpiece
- Workpiece remains longer in contact with dies, therefore , may cool down, and may crack if large deformations are required
- Less draft and closer tolerances than in drop forgings
- Process can be automated

Precision forging (flashless forging)

- Near net shape product, only a few machining is required
- Dies of great accuracy
- Suitable for Al, Mg because of

low forging loads and temperatures.

- Good surface finish

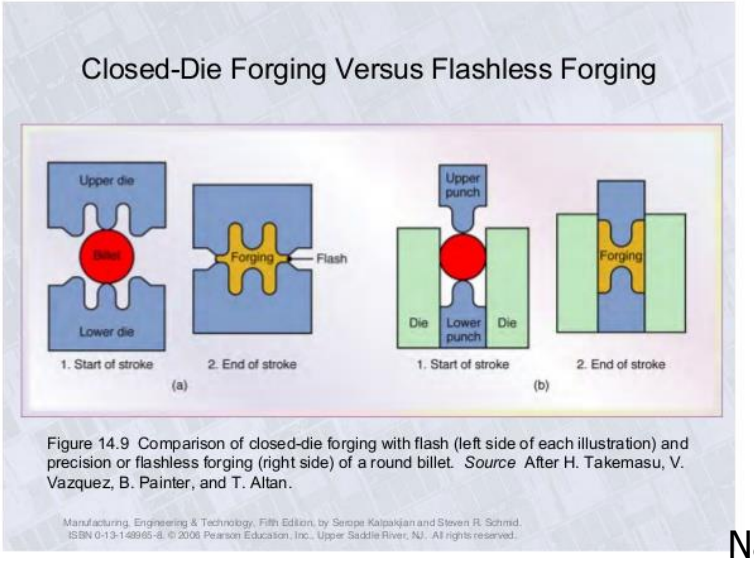
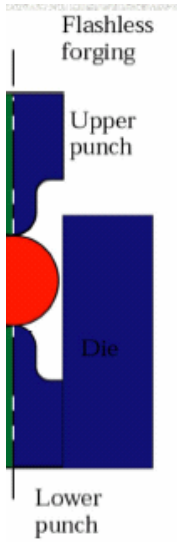
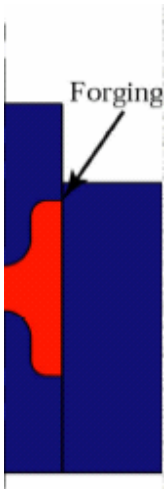


Figure 14.9 Comparison of closed-die forging with flash (left side of each illustration) and precision or flashless forging (right side) of a round billet. *Source* After H. Takemasu, V. Vazquez, B. Painter, and T. Altan.





Start of stroke

End of stroke

Isothermal Forging

- Dies are heated to metal temperature.
- No cooling of metal occurs
- Better flowability in die cavity
- Expensive dies made of Ni-base alloys
- Economic for large number of expensive material

Swagging

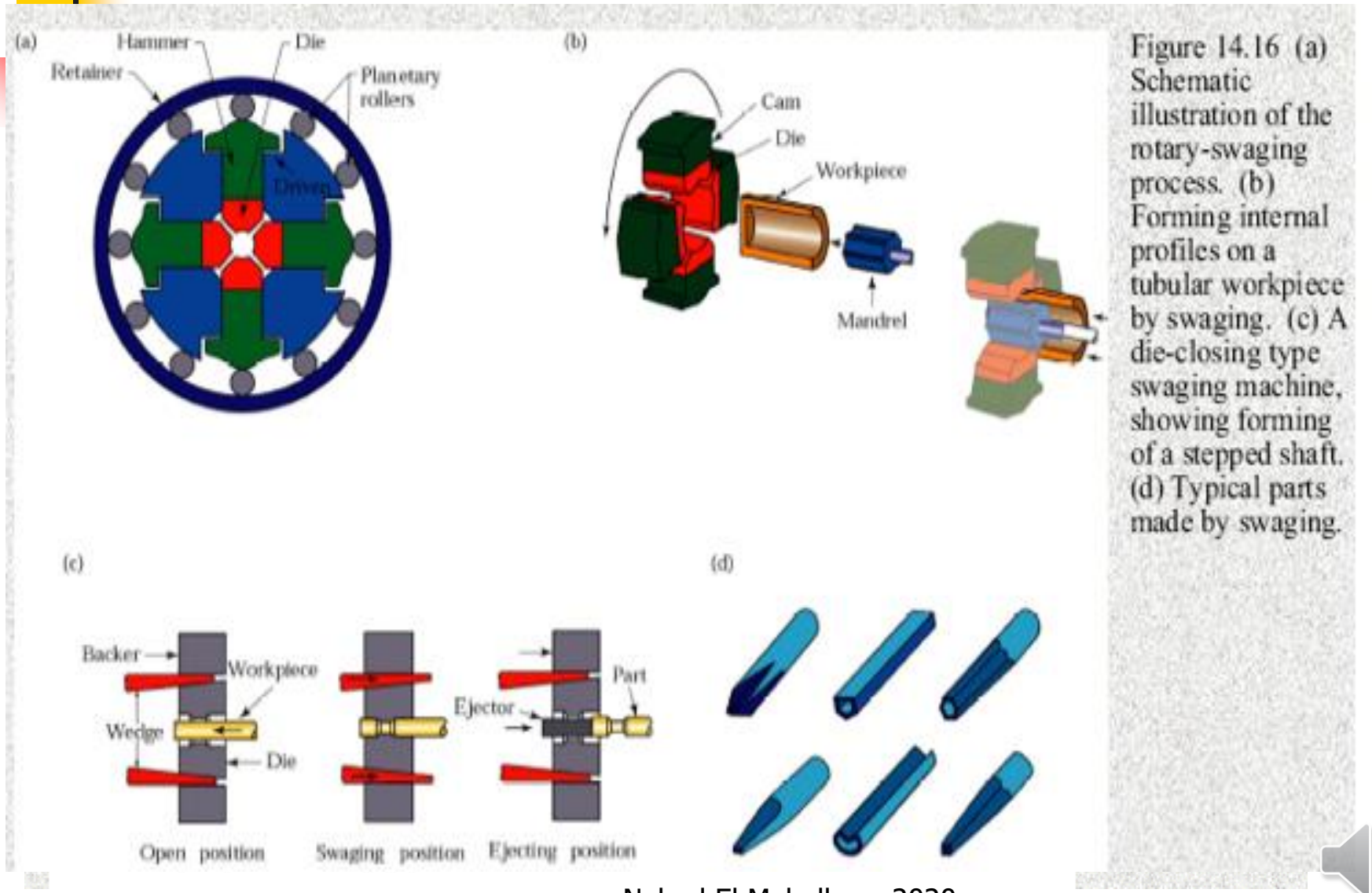


Figure 14.16 (a) Schematic illustration of the rotary-swaging process. (b) Forming internal profiles on a tubular workpiece by swaging. (c) A die-closing type swaging machine, showing forming of a stepped shaft. (d) Typical parts made by swaging.

swaging

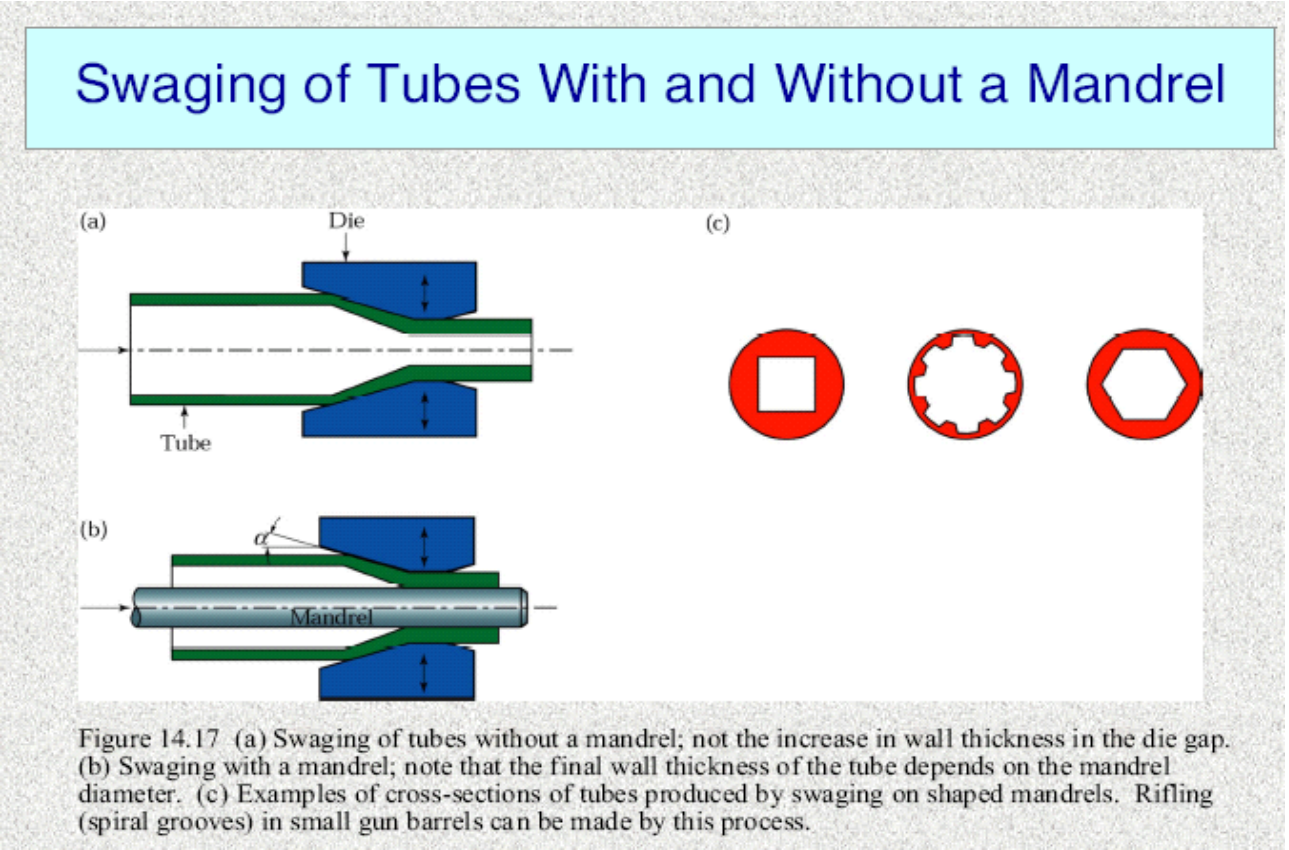


Figure 14.17 (a) Swaging of tubes without a mandrel; not the increase in wall thickness in the die gap. (b) Swaging with a mandrel; note that the final wall thickness of the tube depends on the mandrel diameter. (c) Examples of cross-sections of tubes produced by swaging on shaped mandrels. Rifling (spiral grooves) in small gun barrels can be made by this process.

swaging

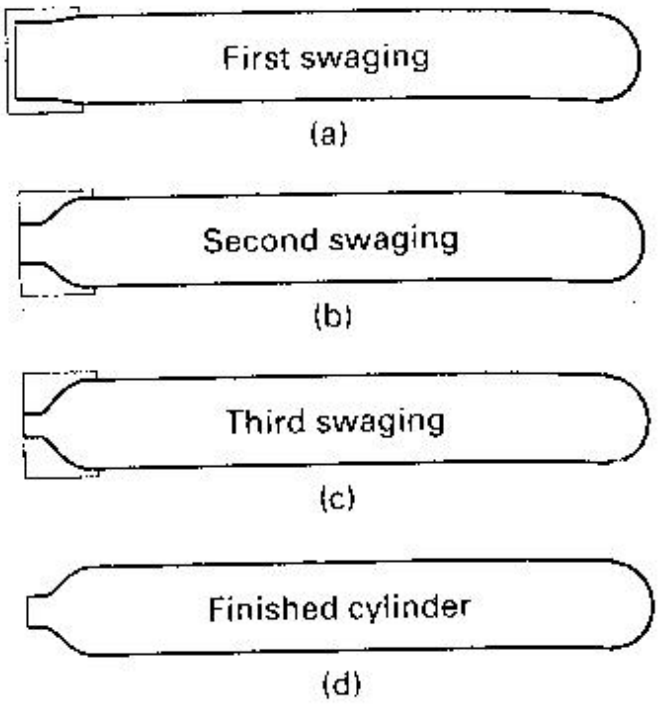
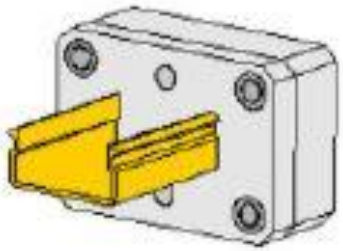
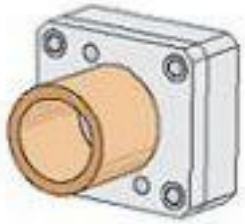


FIGURE 18-21 Steps in swaging a tube to form the neck of a gas cylinder.

Direct Extrusion





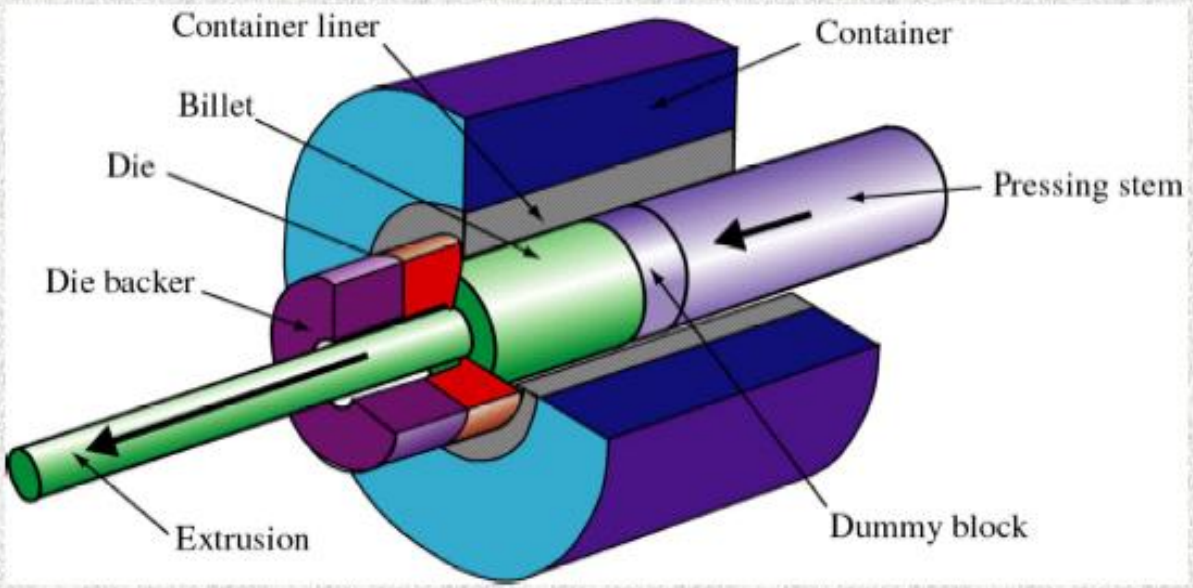
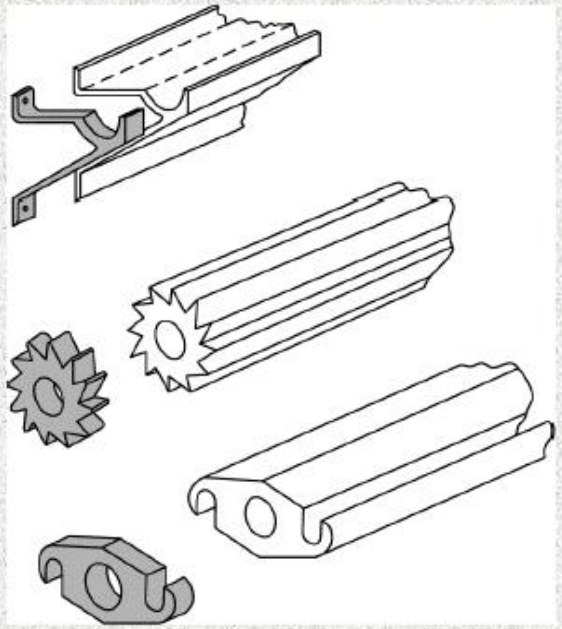
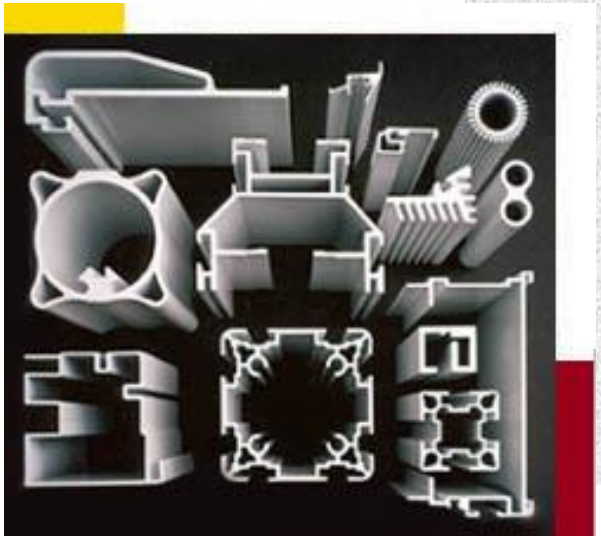


Figure 15.1 Schematic illustration of the direct extrusion process.

Extrusions

Figure 15.2 Extrusions, and examples of products made by sectioning off extrusions. *Source*: Kaiser Aluminum.





Hydraulic-Extrusion Press

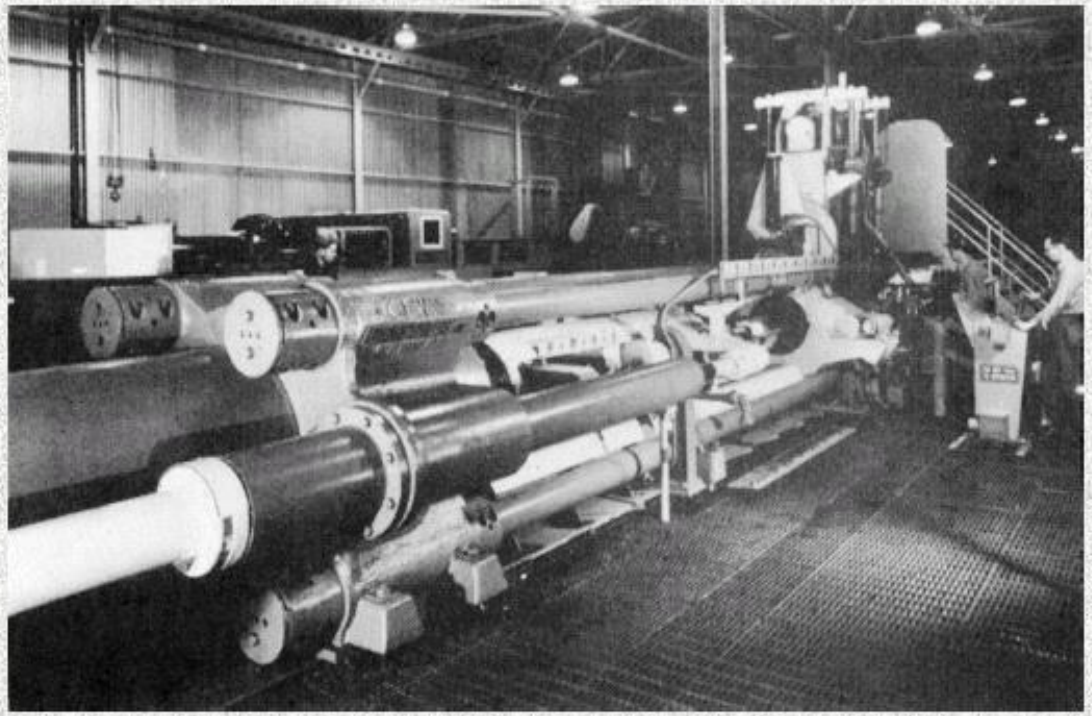
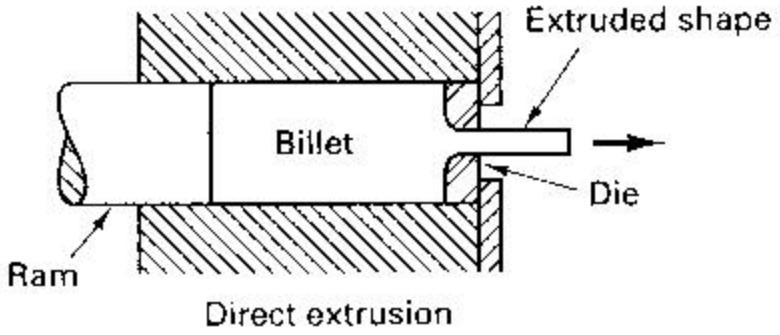
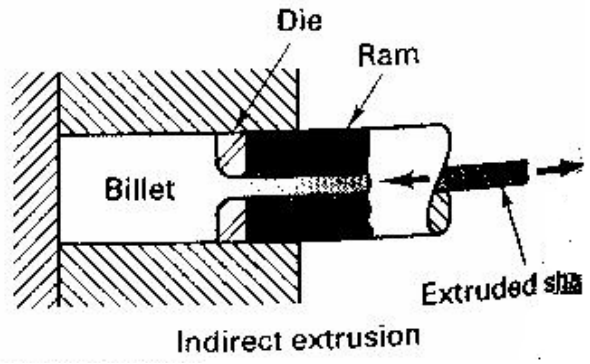
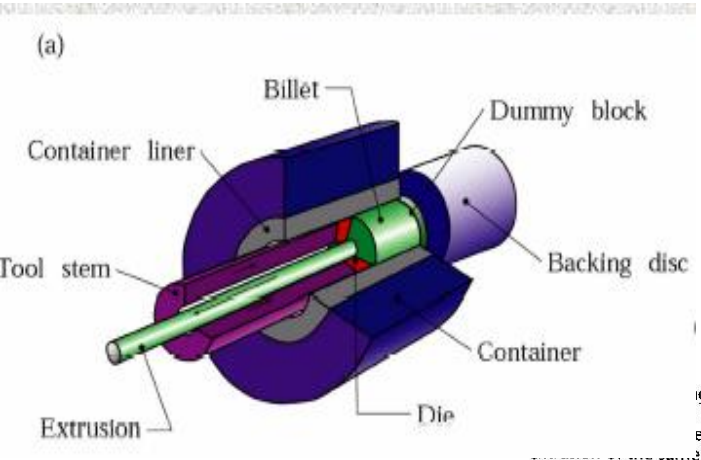


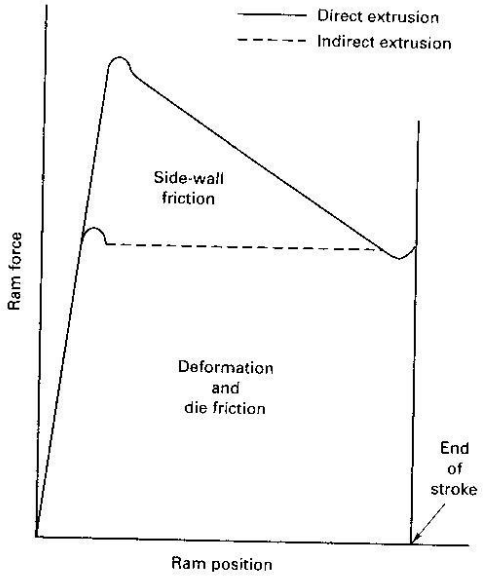
Figure 15.17 General view of a 9-MN (1000-ton) hydraulic-extrusion press. *Source*: Courtesy of Jones & Laughlin Steel Corporation.

Direct and indirect Extrusion

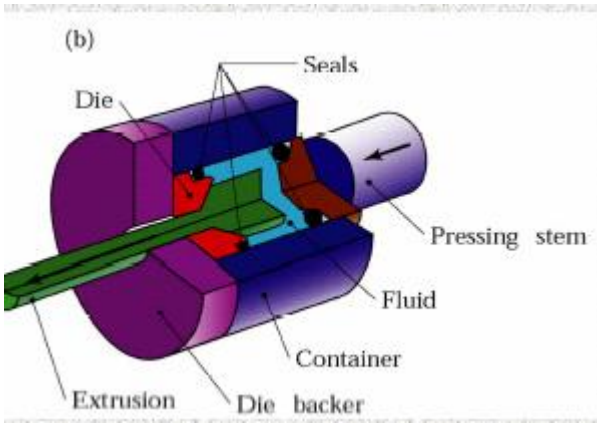






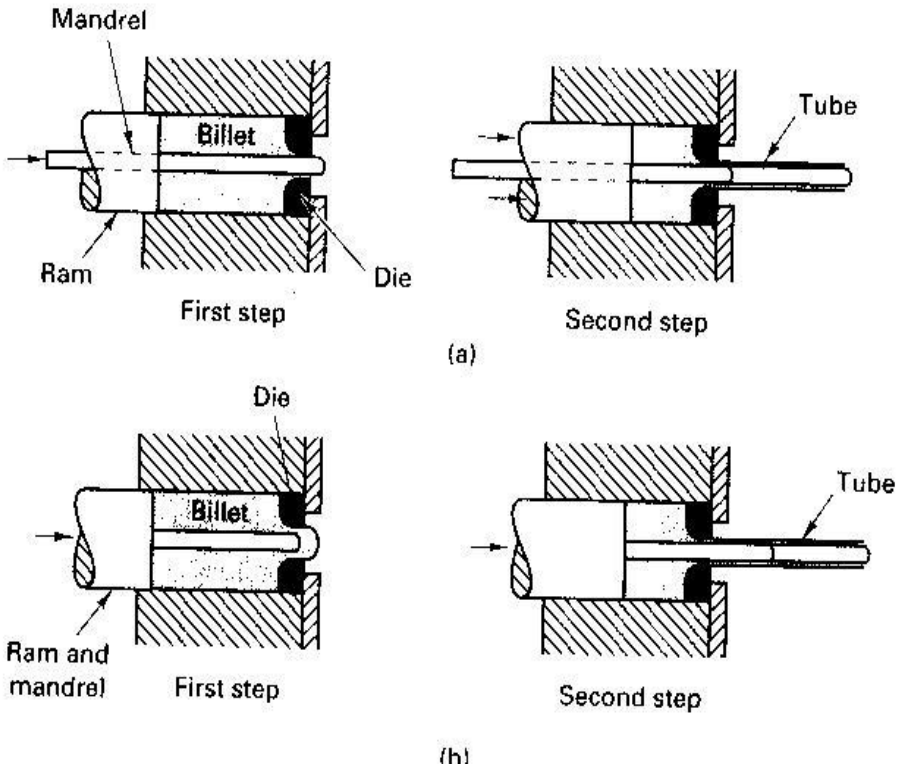


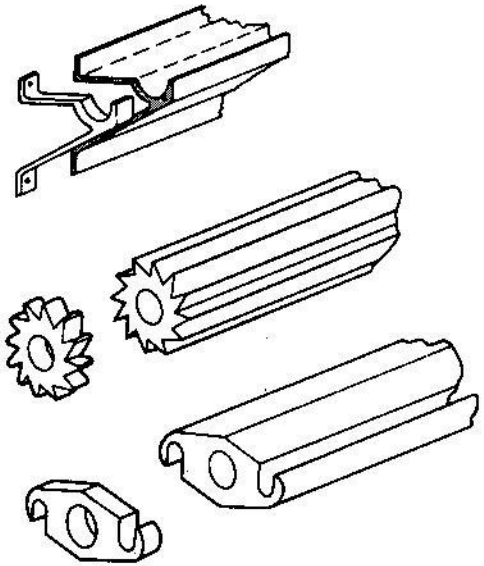
gram of the position for ect product. The area under the curve corresponds to the amount of work (force × distance) performed. The difference between the two curves is attributed to billet-chamber friction.



Extrusion of hollow shapes

FIGURE 18-26 Two methods of extruding hollow shapes using internal mandrels. In the upper schematic the mandrel and ram have independent motions; in the lower sequence they move as a single unit.





Hot drawing of sheet and plate

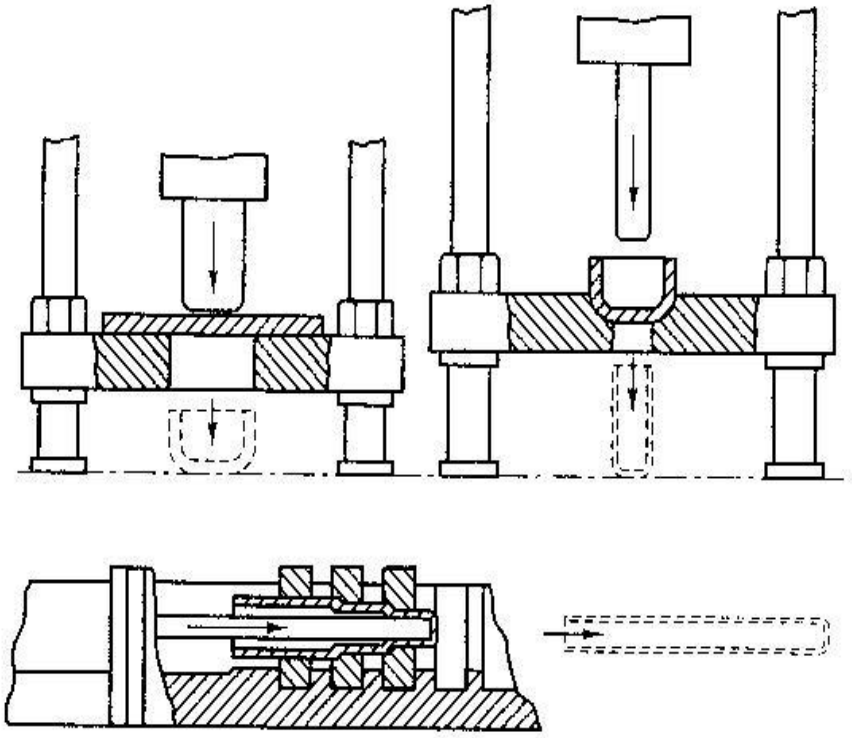


FIGURE 18-29 Methods of cup forming or hot drawing. (*Upper left*) First draw. (*Upper right*) Redraw operation. (*Lower*) Multiple-die drawing. *(Courtesy of USX Corporation.)*

Review questions

- What is meant by forming ? What are some advantages of forming of metals?
- What are the independent variables in metal forming processes? And what are the dependent variables?
- What is the role of plasticity, lubrication, resistance to deformation, temperature in forming operations?
- What is the grain flow? Give an example
- What are the limits of hot working, cold working and warm working- mention the advantages and disadvantages of each one.
- What are the main hot working processes - give examples of some products
- Sketch the following processes: rolling- open die forging- closed die forging- ring rolling- 4-high mill rolling-
- Why is the small roll diameter preferred and what is the limitation in the roll size?
- What products can be produced by rolling? By forging?
- What are the different extrusion processes? Use sketches
- How can hollow shapes be extruded?
- If a plate 50 mm thick and 1000, width is rolled with 20% reduction, what is the final thickness and the relative speed at the roll outlet
- Find the energy in forging a 2m diam. Inconel bar stock 2" long. Take Fi = 2.5 , Sf= 1.4