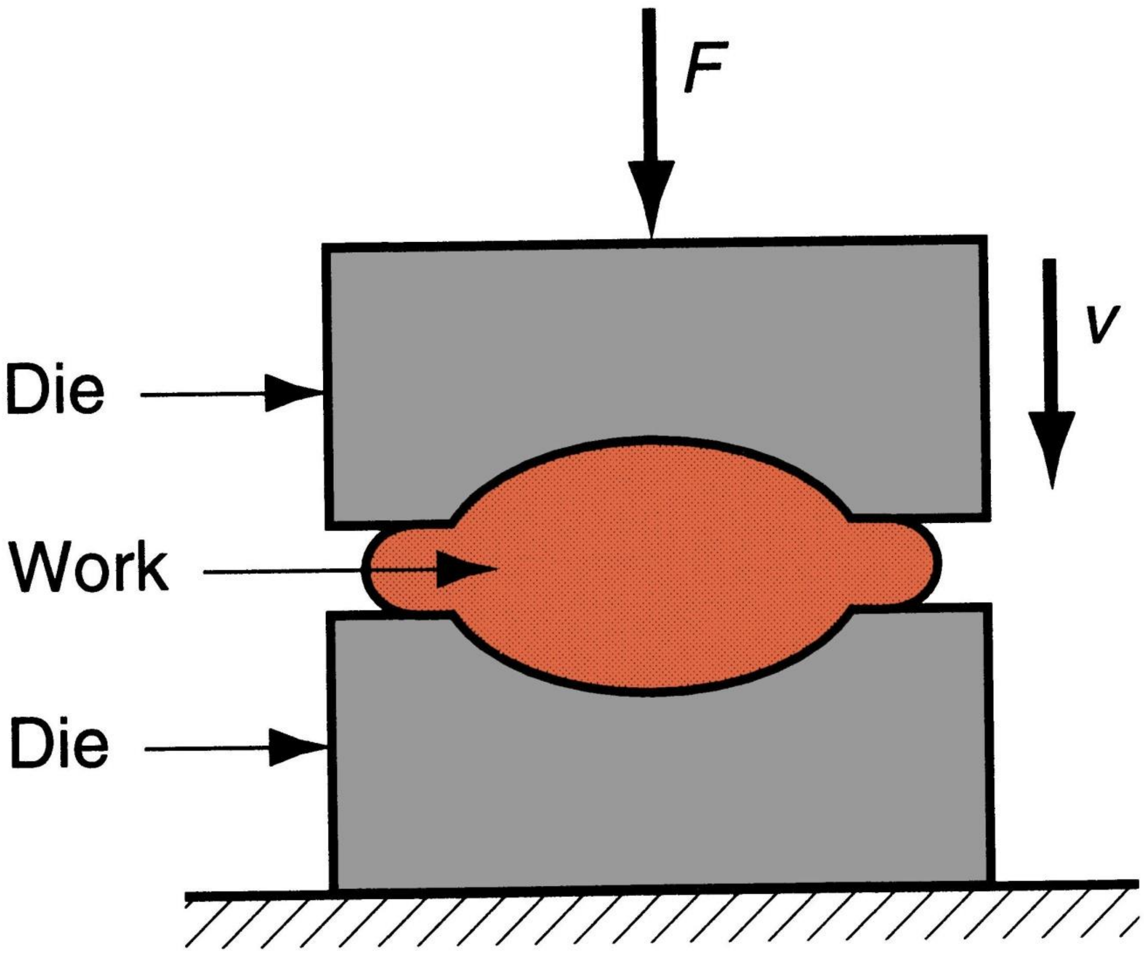
(2) FORGING

- Forging is a ***deformation process*** in which the work is ***compressed*** between two ***dies***, using either impact or gradual pressure to form the part.
- It is the oldest of the metal forming operations, dating back to perhaps 5000 BC.
- Today, forging is an important industrial process used to make a variety of ***high-strength components*** for ***automotive, aerospace, and other applications.***

(2) FORGING



(2) FORGING

- These components include engine ***crankshafts and connecting rods***, ***gears***, aircraft structural components, and jet engine turbine parts.

(2) FORGING CLASSIFICATION

- One way to classify the operations is by working ***temperature***.
- ***Hot or warm forging*** – most common, due to the significant deformation and the need to reduce strength and increase ductility of work metal
- ***Cold forging*** – advantage: increased strength that results from strain hardening

(2) FORGING CLASSIFICATION

- Either ***IMPACT OR GRADUAL pressure*** is used in forging.
- The distinction derives more from the type of equipment used than differences in process technology.
- A forging machine that applies an ***impact load*** is called a ***forging hammer***, while one that applies ***gradual pressure*** is called a ***forging press***.

(2) FORGING CLASSIFICATION

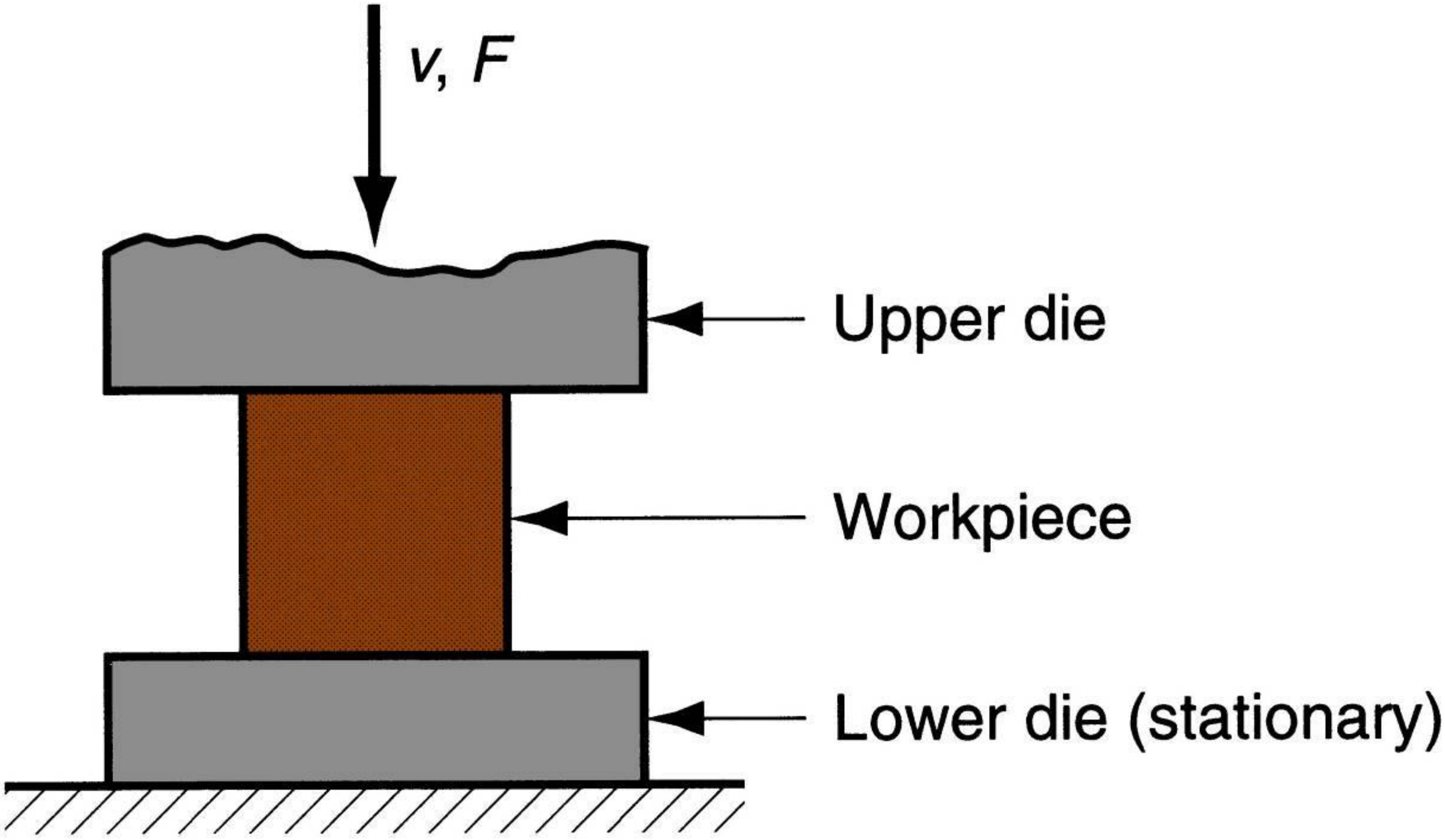
- Another difference among forging operations is the degree to which the ***flow*** of the work metal is ***constrained by the dies***.
- By this classification, there are three types of forging operations, shown in Figure :

(a) Open-die Forging,

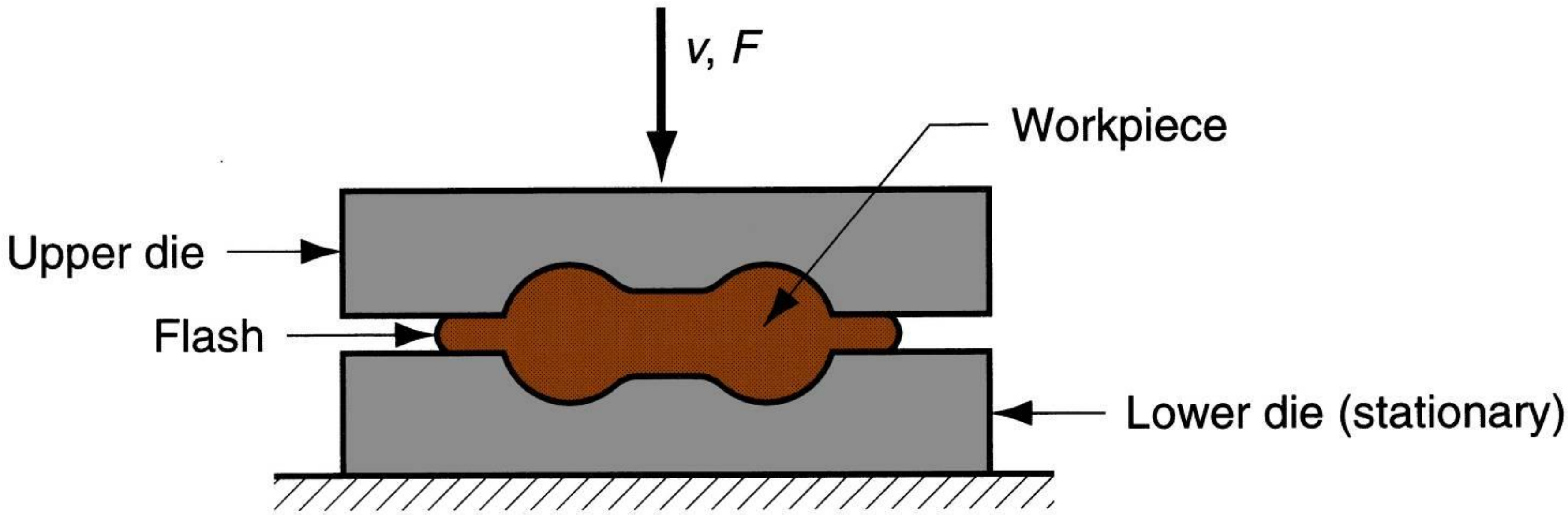
(b) Impression-die Forging, and

(c) Flashless Forging.

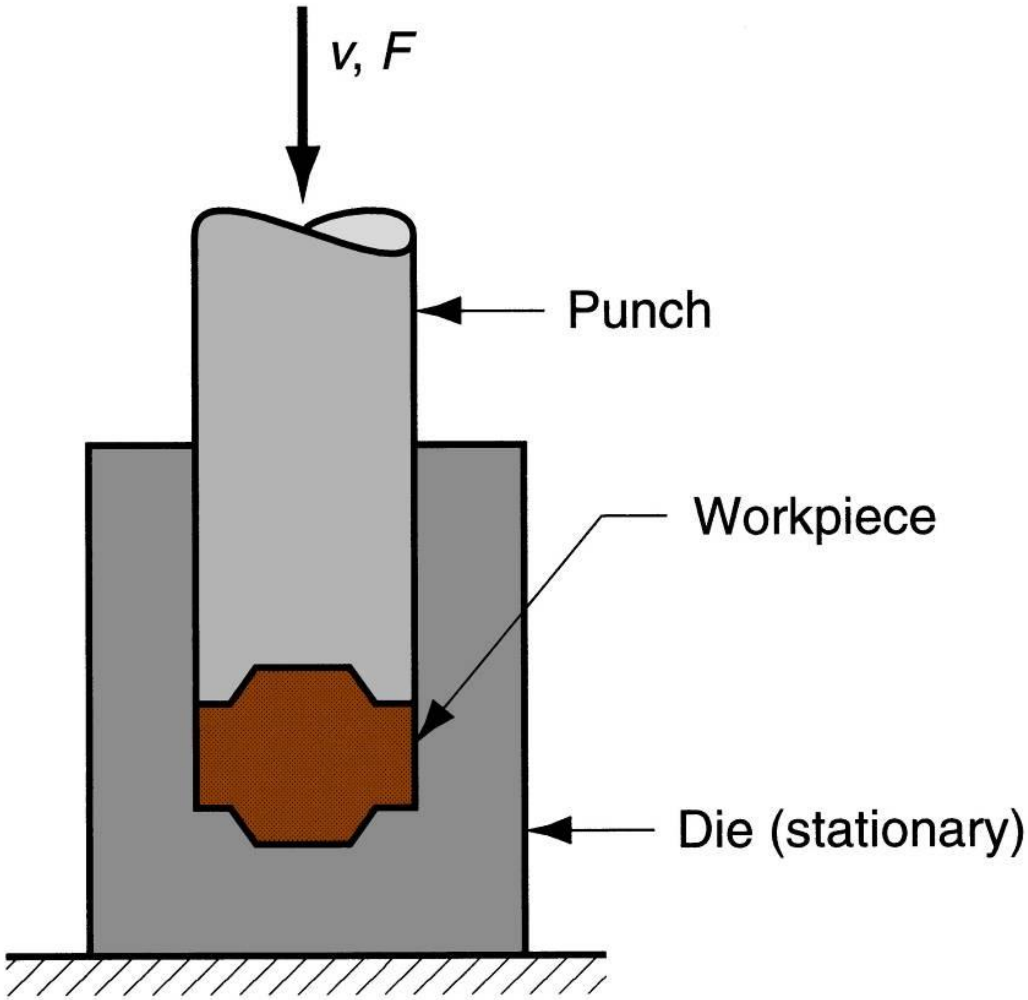
(2) CLASSIFICATION- Open-die Forging



(2) CLASSIFICATION- Impression-die Forging



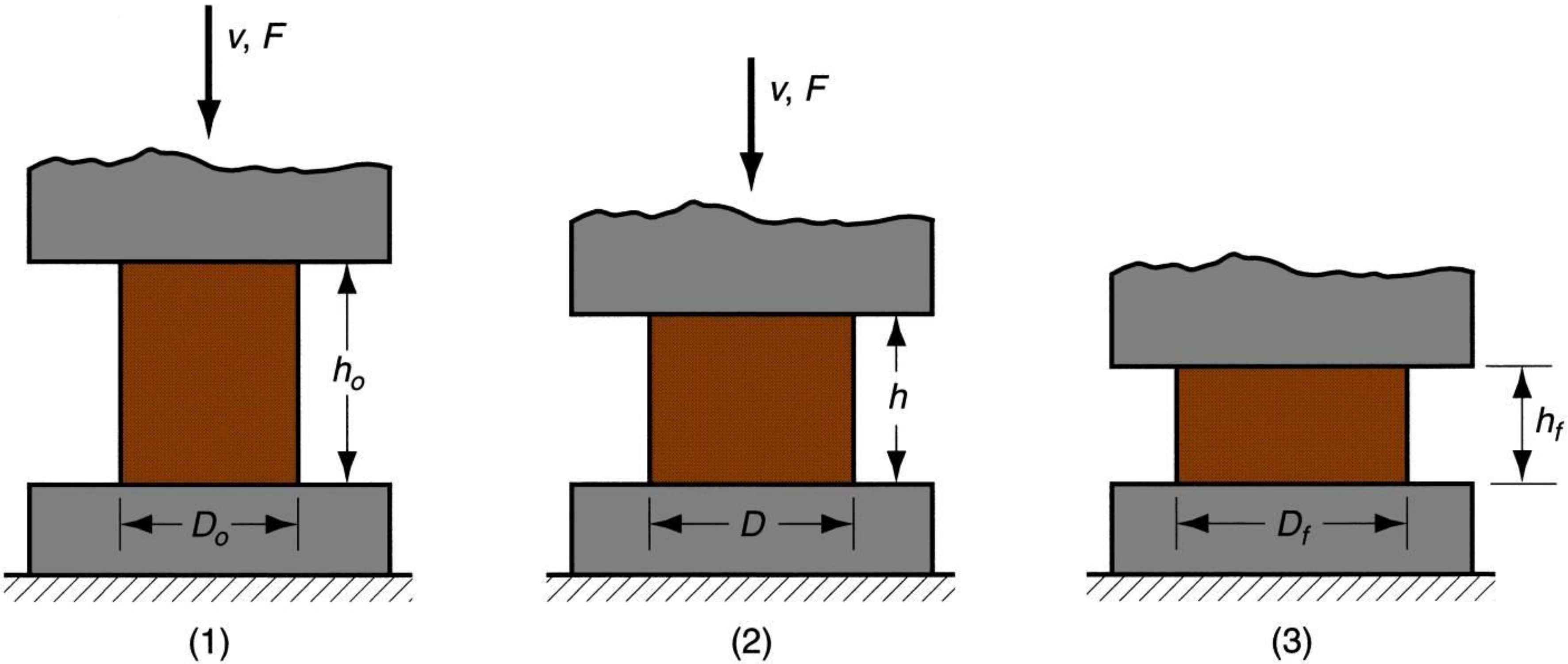
(2) CLASSIFICATION- Flashless Forging



(2.1) OPEN-DIE FORGING

- The simplest case of open-die forging involves compression of a workpart of cylindrical cross section between two flat dies.
- This forging operation, known as ***upsetting or upset forging*** , ***reduces the height*** of the work and ***increases its diameter***.

(2.1) OPEN-DIE FORGING with No-Friction

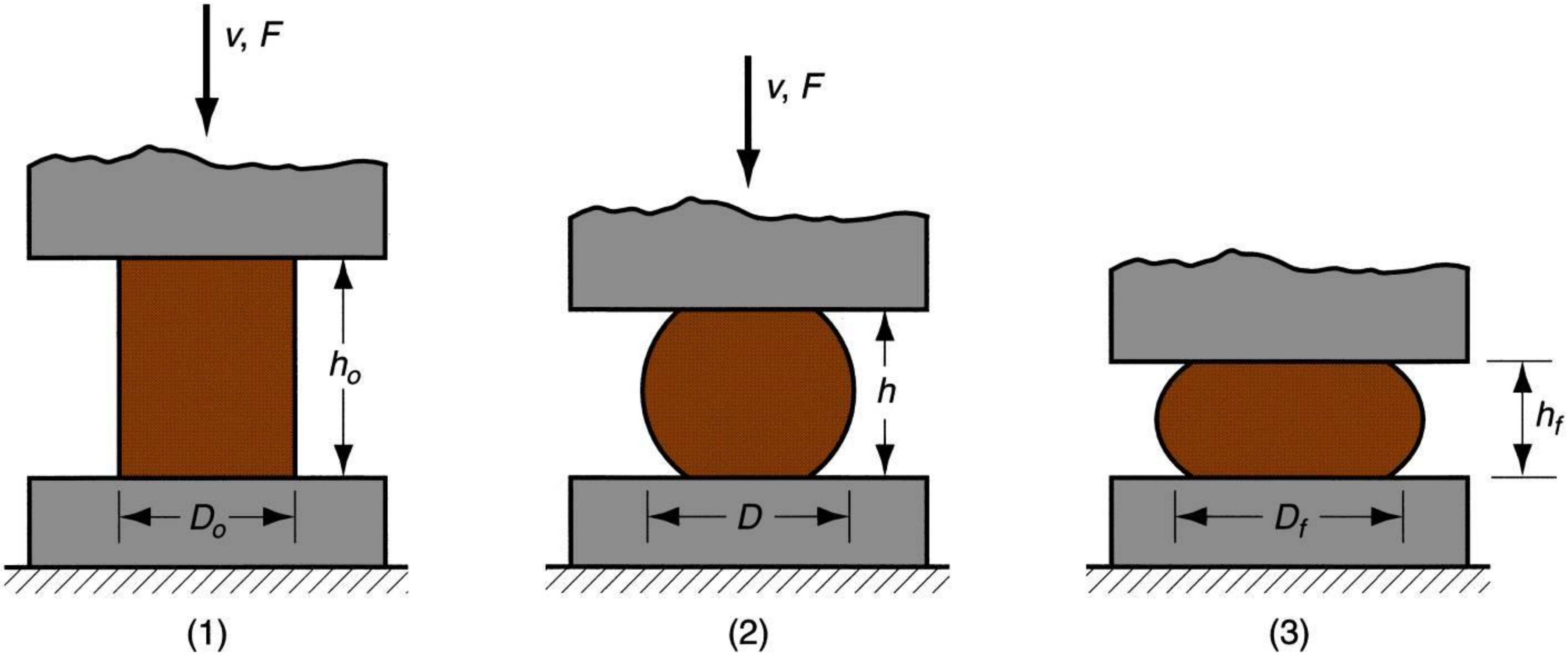


Homogeneous deformation of a cylindrical workpart under ideal conditions in an open-die forging operation: (1) start of process with workpiece at its original length and diameter, (2) partial compression, and (3) final size.

(2.1) OPEN-DIE FORGING with Friction

- ***Friction*** between work and die surfaces constrains lateral flow of work, resulting in ***barreling effect***.
- When performed on a hot workpart with cold dies, the barreling effect is even more pronounced.
- This results from a ***higher coefficient of friction*** typical in hot working and heat transfer at and near the die surfaces, which cools the metal and increases its resistance to deformation.
- The hotter metal in the middle of the part flows more readily than the cooler metal at the ends.

(2.1) OPEN-DIE FORGING with Friction

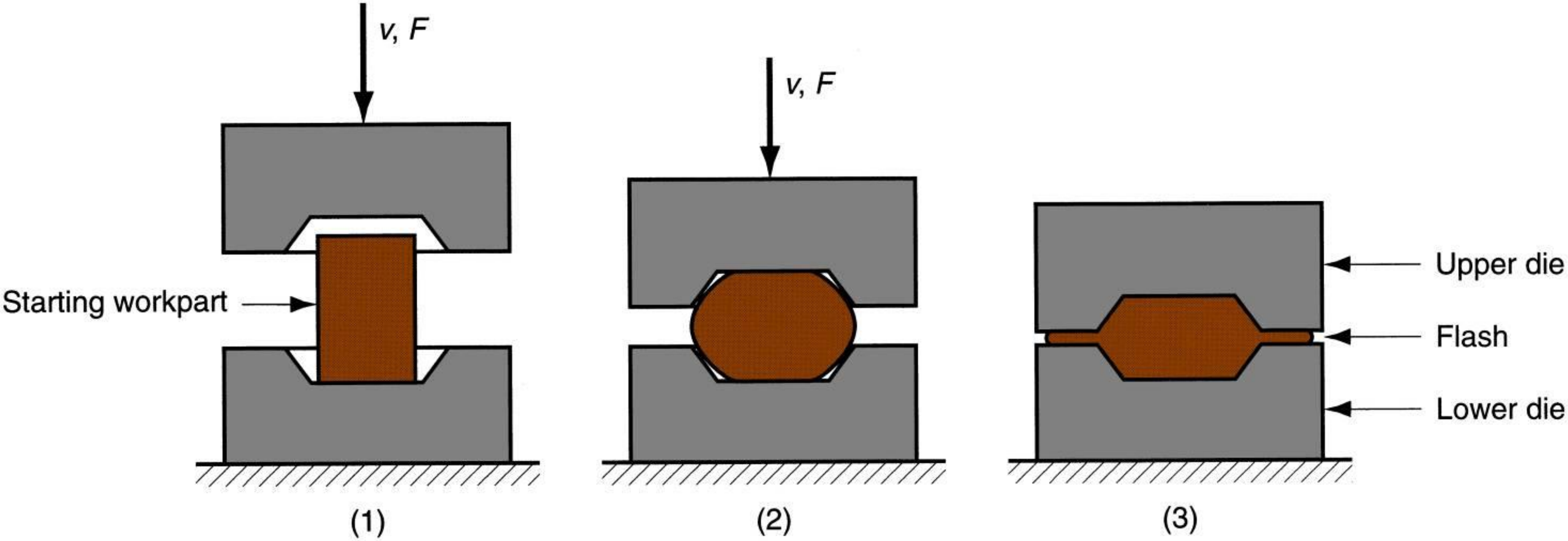


Actual deformation of a cylindrical workpart in open-die forging, showing pronounced *barreling*: (1) start of process, (2) partial deformation, and (3) final shape.

(2.2) IMPRESSION-DIE FORGING

- Impression-die forging, sometimes called ***closed-die forging*** , is performed with dies that contain the inverse of the desired shape of the part.
- The process is illustrated in a three-step sequence in Figure.
- The raw workpiece is shown as a cylindrical part similar to that used in the previous open-die operation .

(2.2) IMPRESSION-DIE FORGING

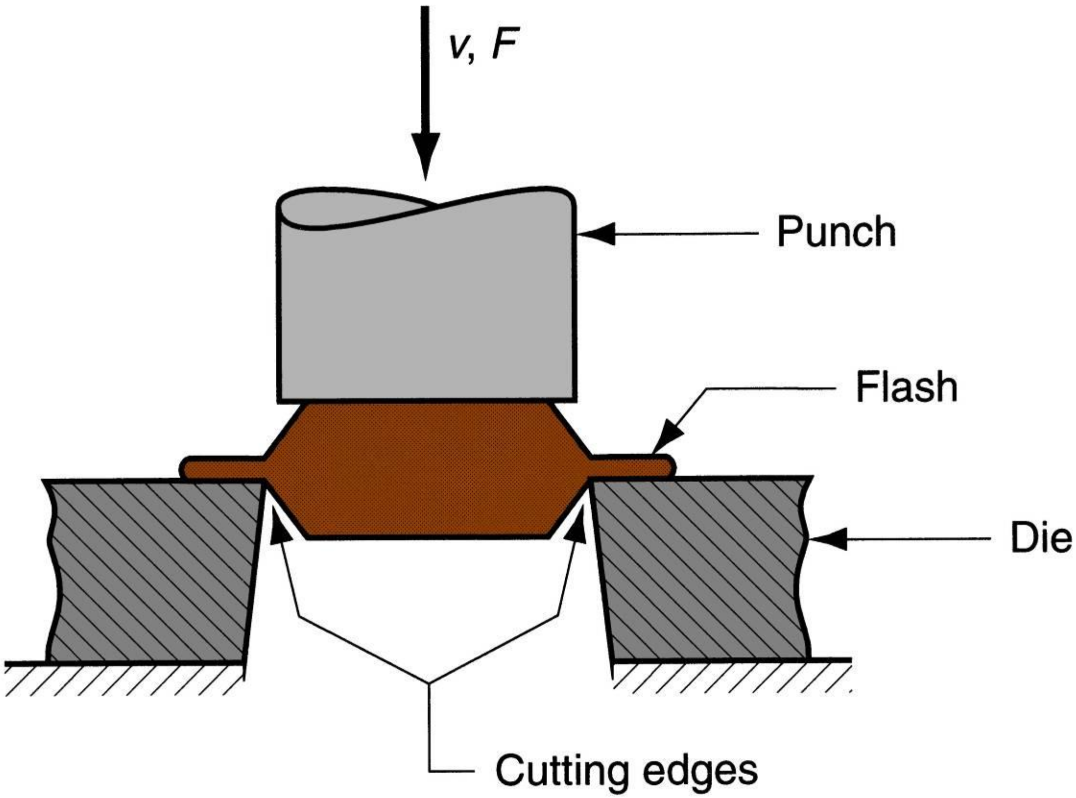


Sequence in impression-die forging: (1) just prior to initial contact with raw workpiece, (2) partial compression, and (3) final die closure, causing flash to form in gap between die plates.

(2.2) IMPRESSION-DIE FORGING

- As the die closes to its final position , ***flash is formed*** by metal that flows beyond the die cavity and in to the small gap between the die plates.
- Although this flash ***must be cut away*** from the part in a subsequent trimming operation, it actually serves two important functions during impression-die forging.
  - *As flash forms, friction resists continued metal flow into gap, constraining material to fill die cavity*
  - *In hot forging, metal flow is further restricted by cooling against die plates*

(2.2) IMPRESSION-DIE FORGING

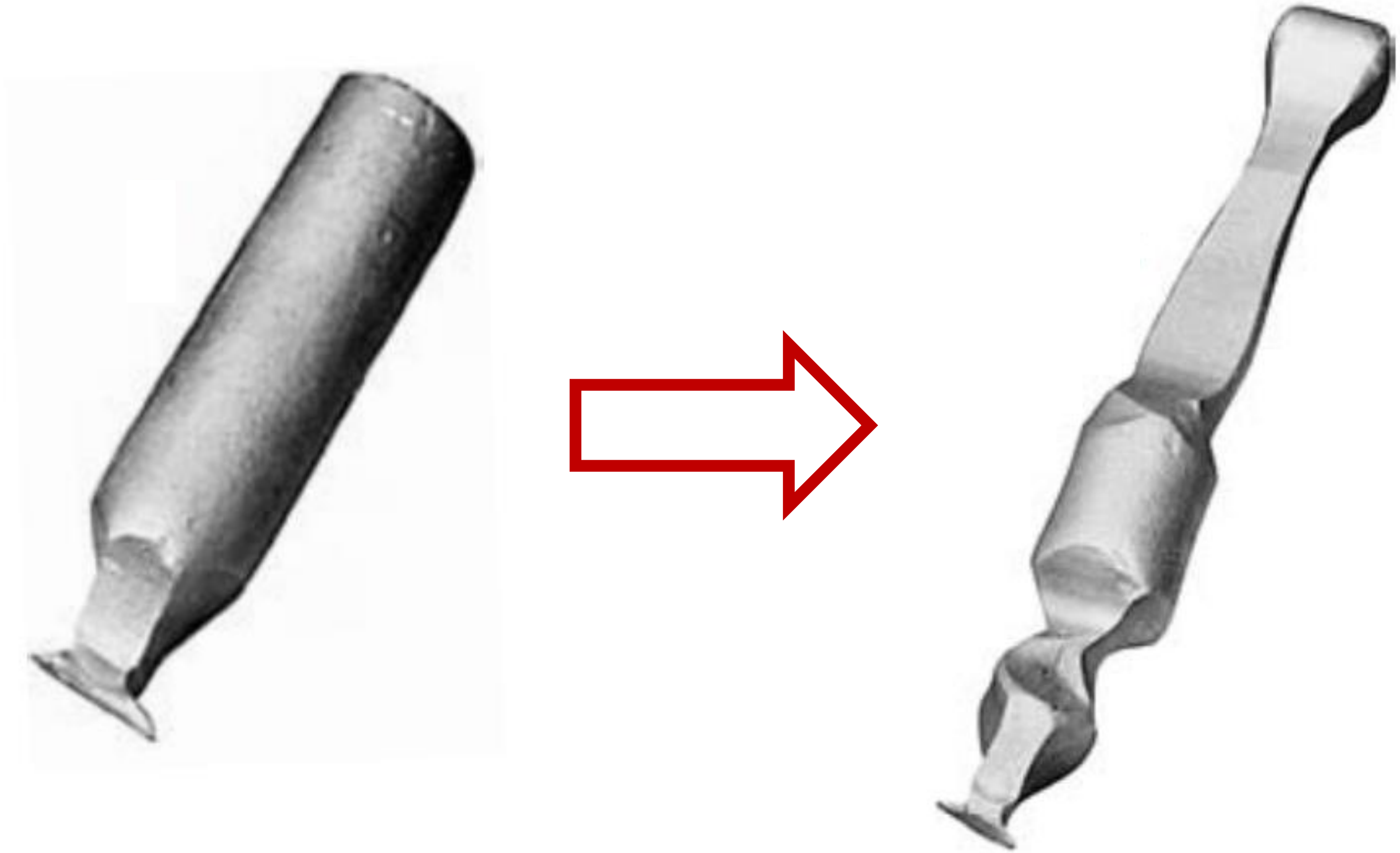


Trimming operation (shearing process) to remove the flash after impression-die forging.

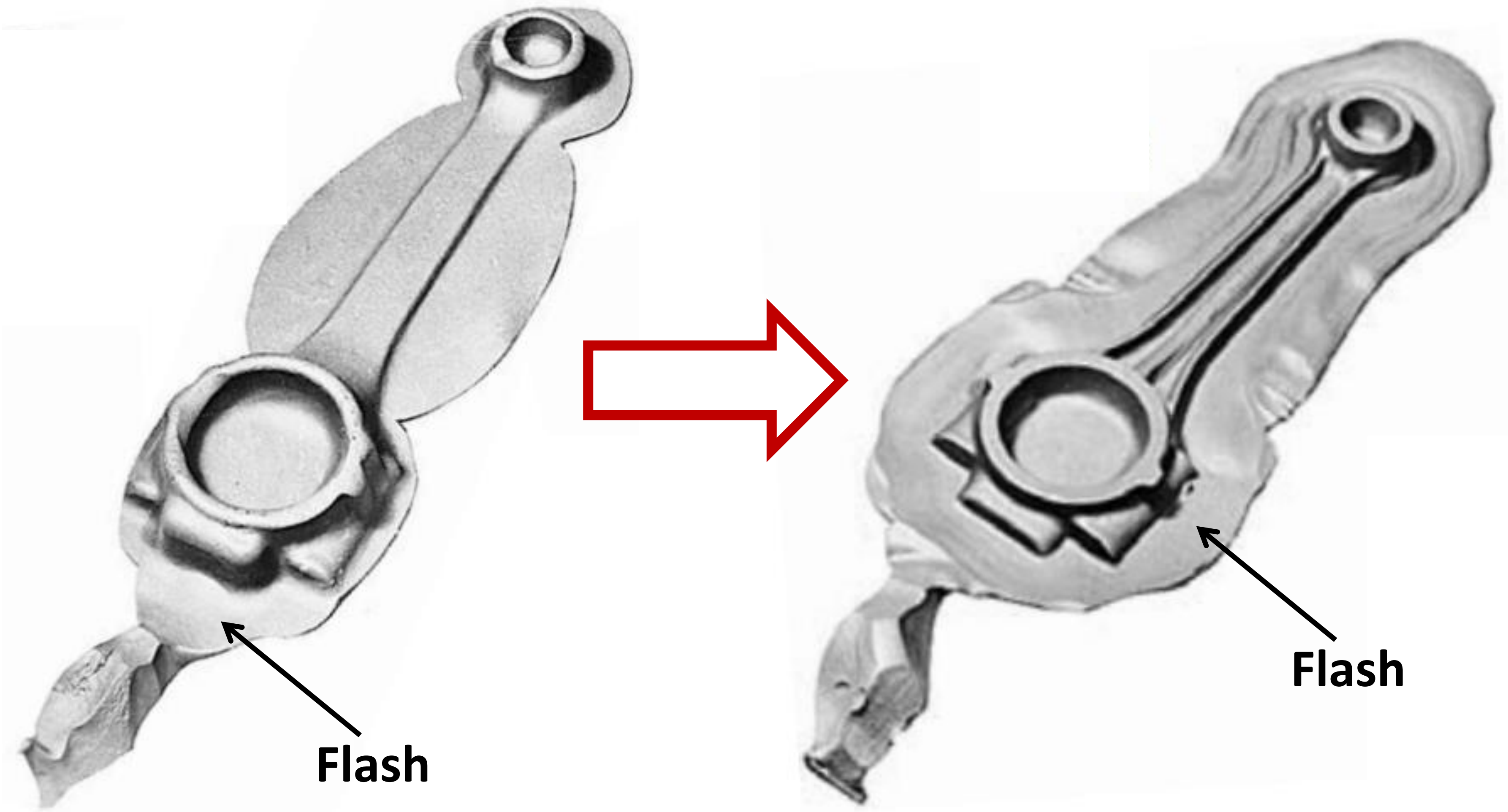
(2.2) IMPRESSION-DIE FORGING

- ***Advantages*** of impression-die forging compared to machining :
  - Higher production rates
  - Less waste of metal
  - Greater strength
  - Favorable grain orientation in the metal
- ***Limitations***:
  - Not capable of close tolerances
  - Machining often required to achieve accuracies and features needed

(2.2) IMPRESSION-DIE FORGING (connecting rod)



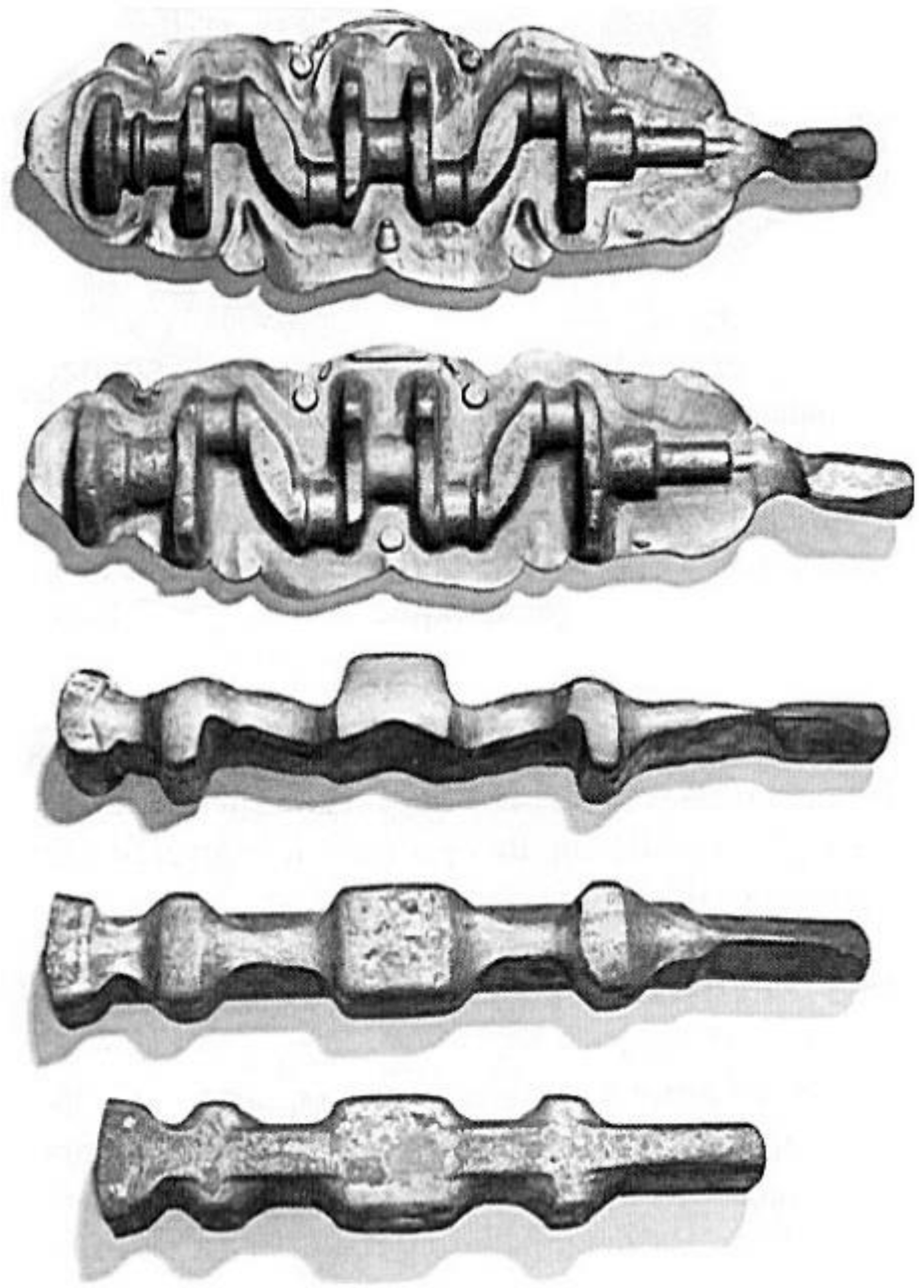
(2.2) IMPRESSION-DIE FORGING (connecting rod)



(2.2) IMPRESSION-DIE FORGING (connecting rod)

(2.2) IMPRESSION-DIE FORGING (open wrench)

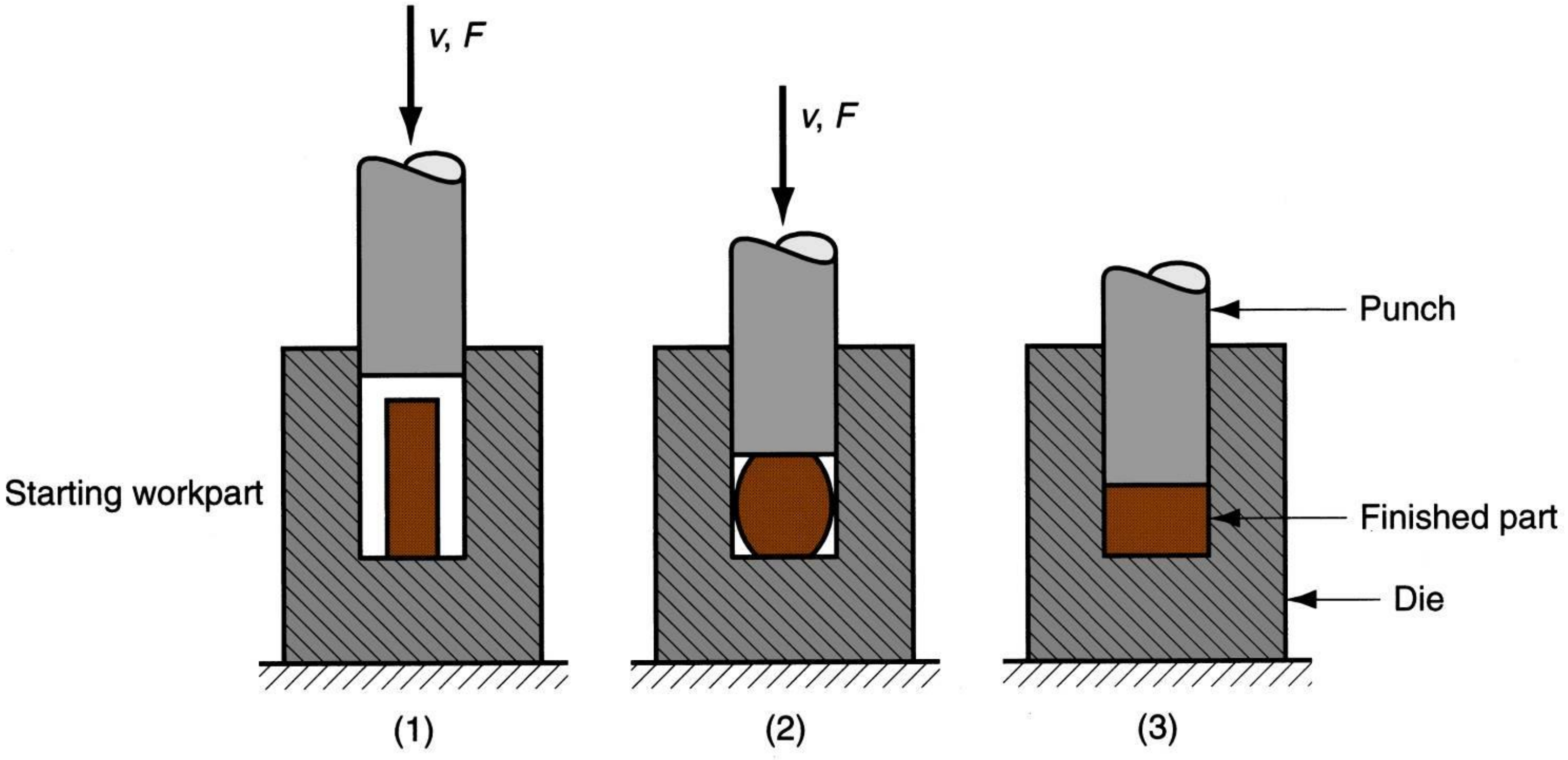
(2.2) IMPRESSION-DIE FORGING (crank shaft)



(2.3) FLASHLESS FORGING *(PRECISION FORGING)*

- As mentioned above, ***impression-die*** forging is ***sometimes called closed-die forging*** in industry terminology.
- However, there is a technical ***distinction*** between impression-die forging and true closed-die forging.
- The distinction is that in ***closed-die forging***, the raw workpiece is ***completely contained*** with in the die cavity during compression , and ***no flash is formed*** .
- The process sequence is illustrated in Figure.

(2.3) FLASHLESS FORGING *(PRECISION FORGING)*



Flashless forging: (1) just before initial contact with workpiece, (2) partial compression, and (3) final punch and die closure.

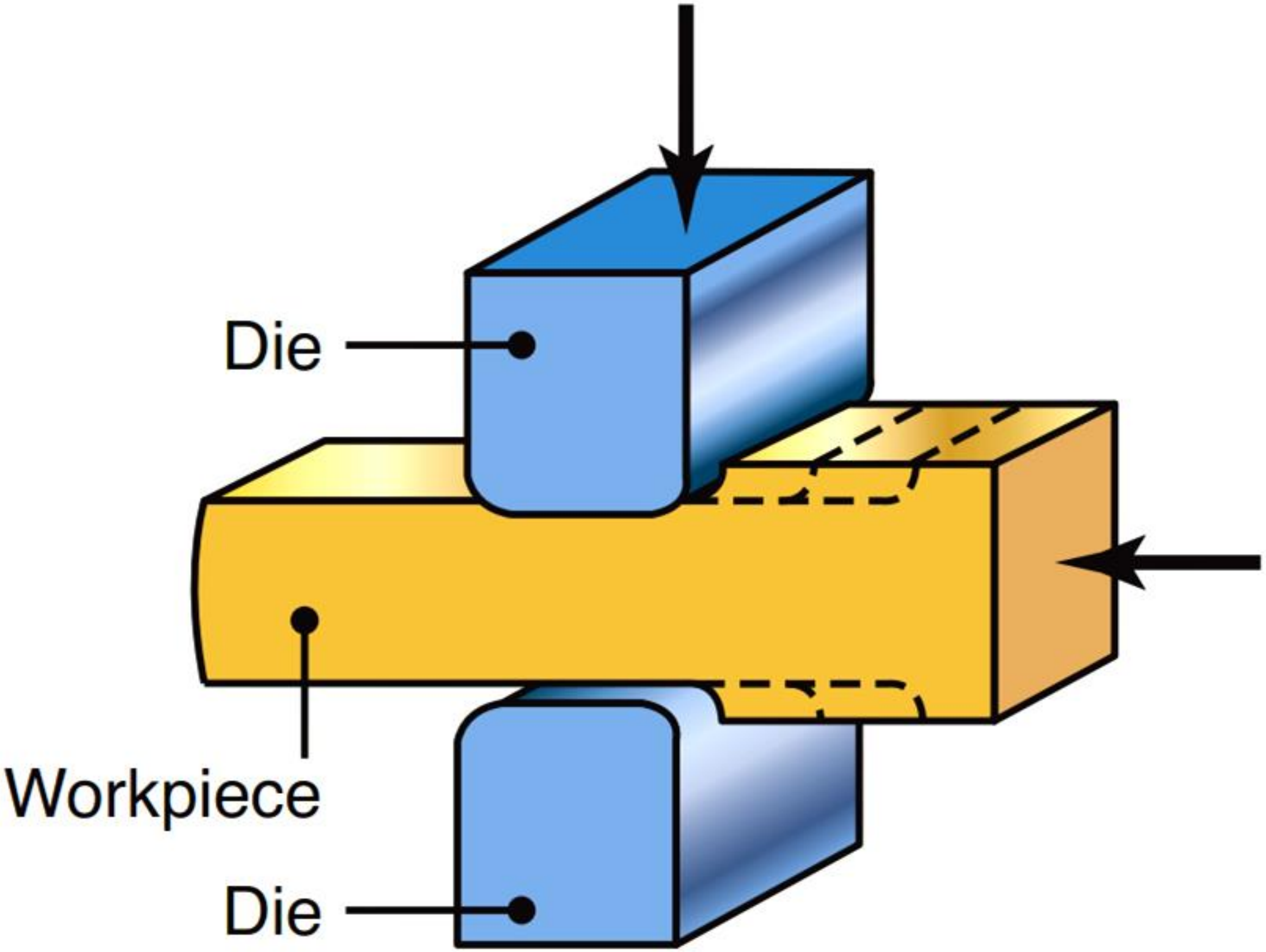
(2.3) FLASHLESS FORGING *(PRECISION FORGING)*

- ***Flashless*** forging imposes requirements on process control that are more demanding than impression- die forging.
- Most important is that the ***work volume must equal the space*** in the die cavity with in a very close tolerance.
- If the starting blank is too large, ***excessive pressures may*** cause ***damage*** to the ***die*** or press.
- If the ***blank is too small*** , the ***cavity*** will ***not*** be ***filled***.

(2.3) FLASHLESS FORGING *(PRECISION FORGING)*

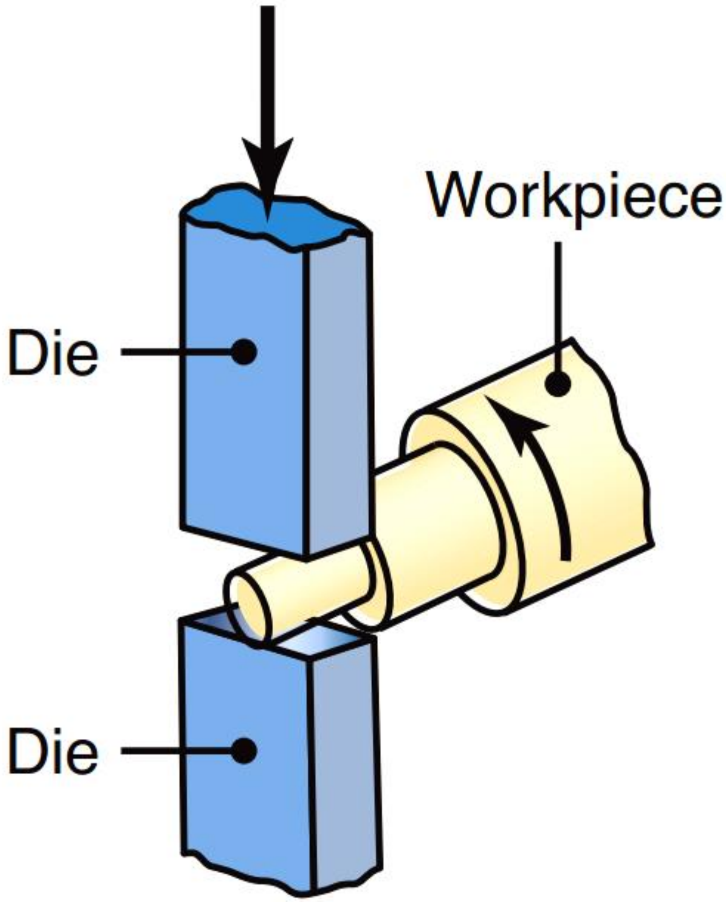
- Because of the special demands made by flash less forging, the process lends itself best to ***part geometries*** that are usually ***simple and symmetrical***, and to work materials such as aluminium and magnesium and their alloys.
- Flashless forging is often referred as a ***precision forging process.***

Examples: Open Die Forging



Schematic illustration of a cogging operation on a rectangular bar. Blacksmiths use a similar procedure to reduce the thickness of parts in small increments by heating the workpiece and hammering it numerous times along the length of the part.

Examples: Open Die Forging

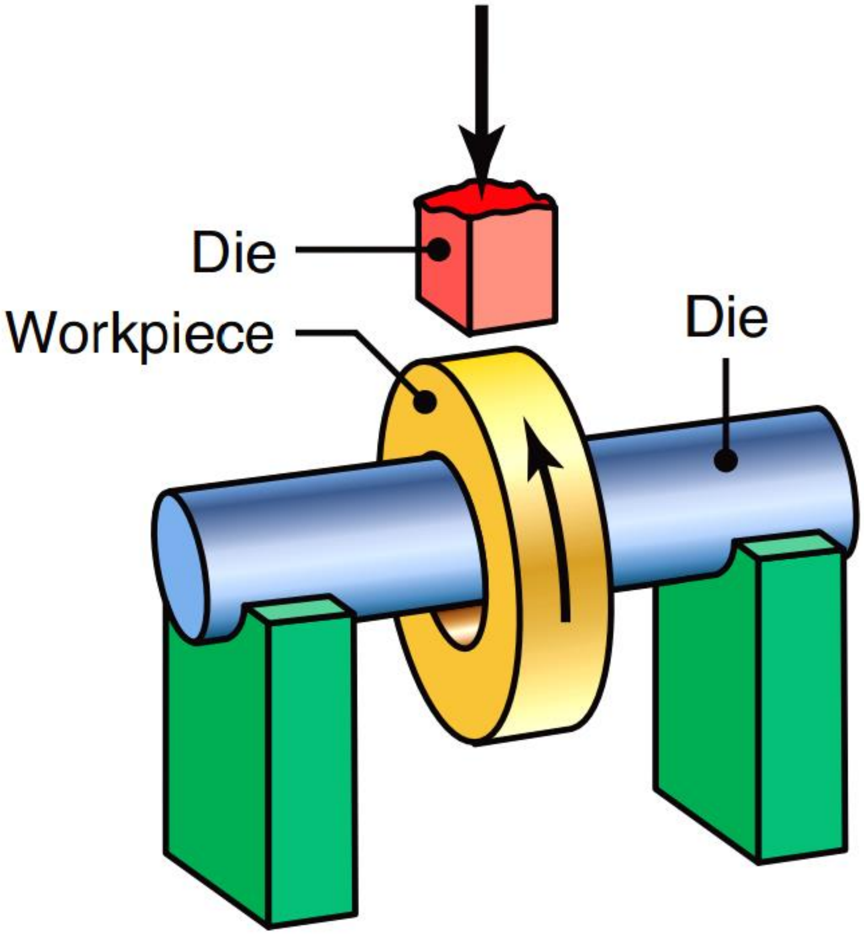


Reducing the diameter of a bar by open-die forging

Or

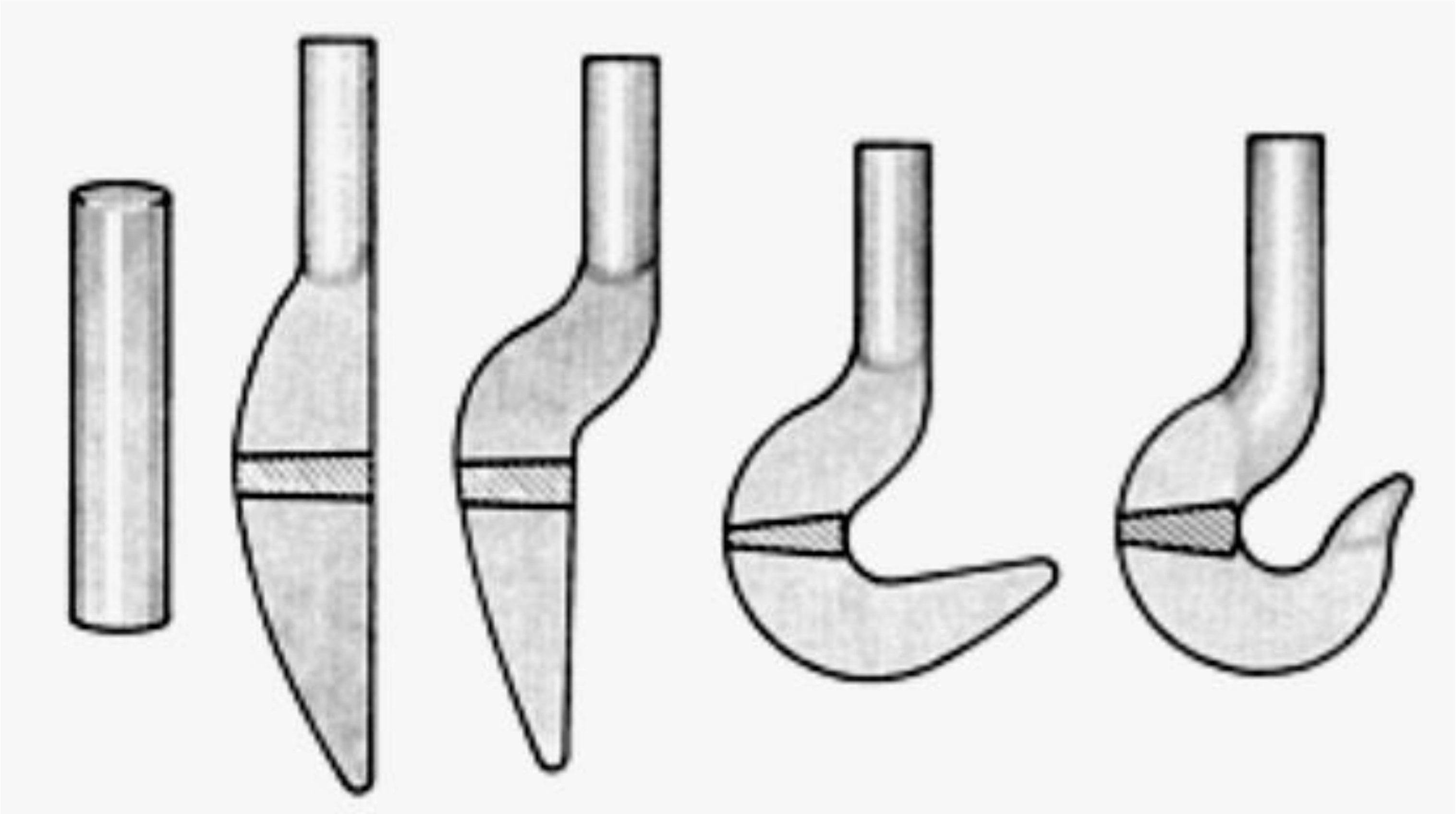
Open Die Forging of a multi diameter shaft

Examples: Open Die Forging



The thickness of a ring being reduced by open-die forging

Examples: Open Die Forging



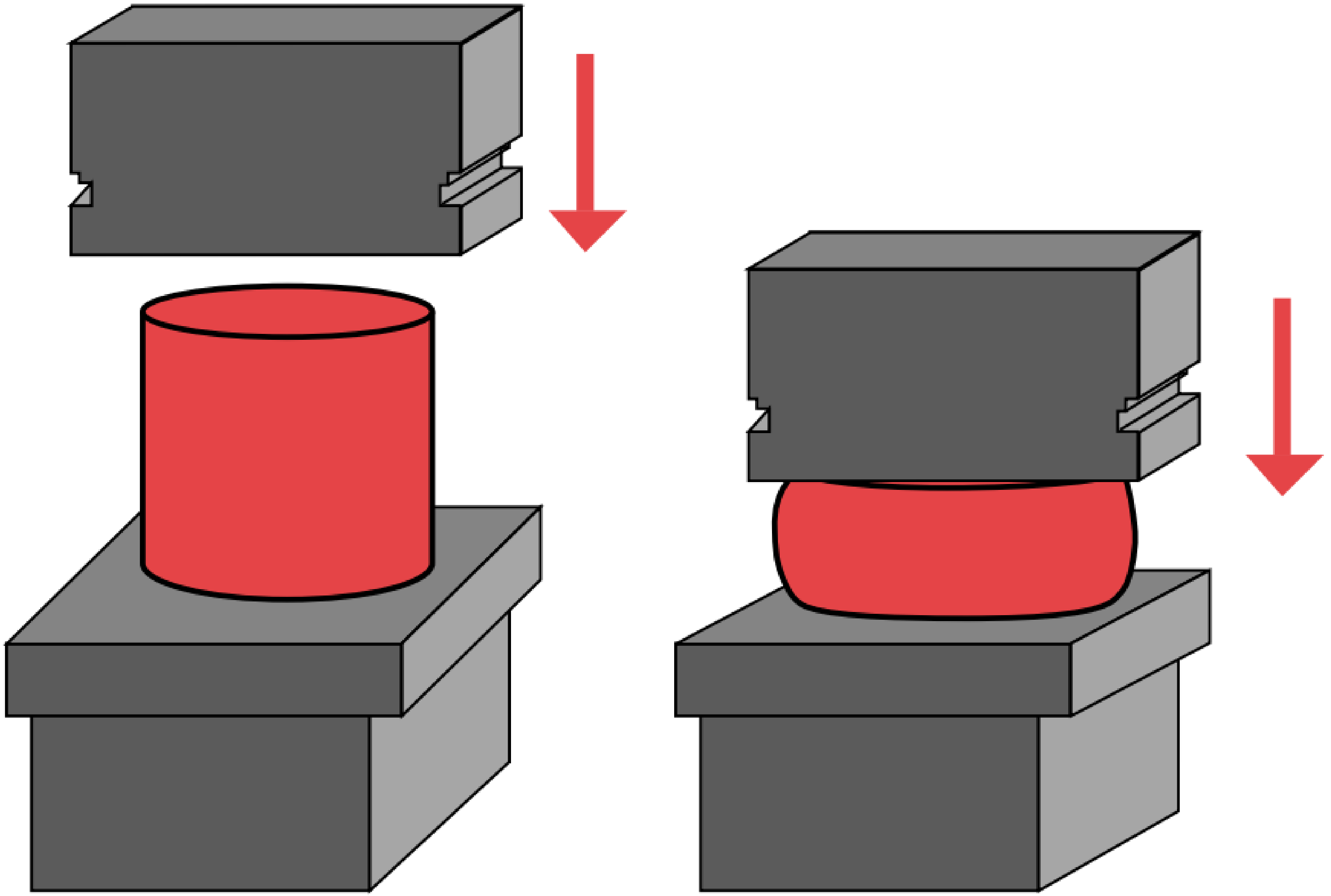
Making of a crane hook by open die forging

Seamless Rolled Ring Forging Process Operations

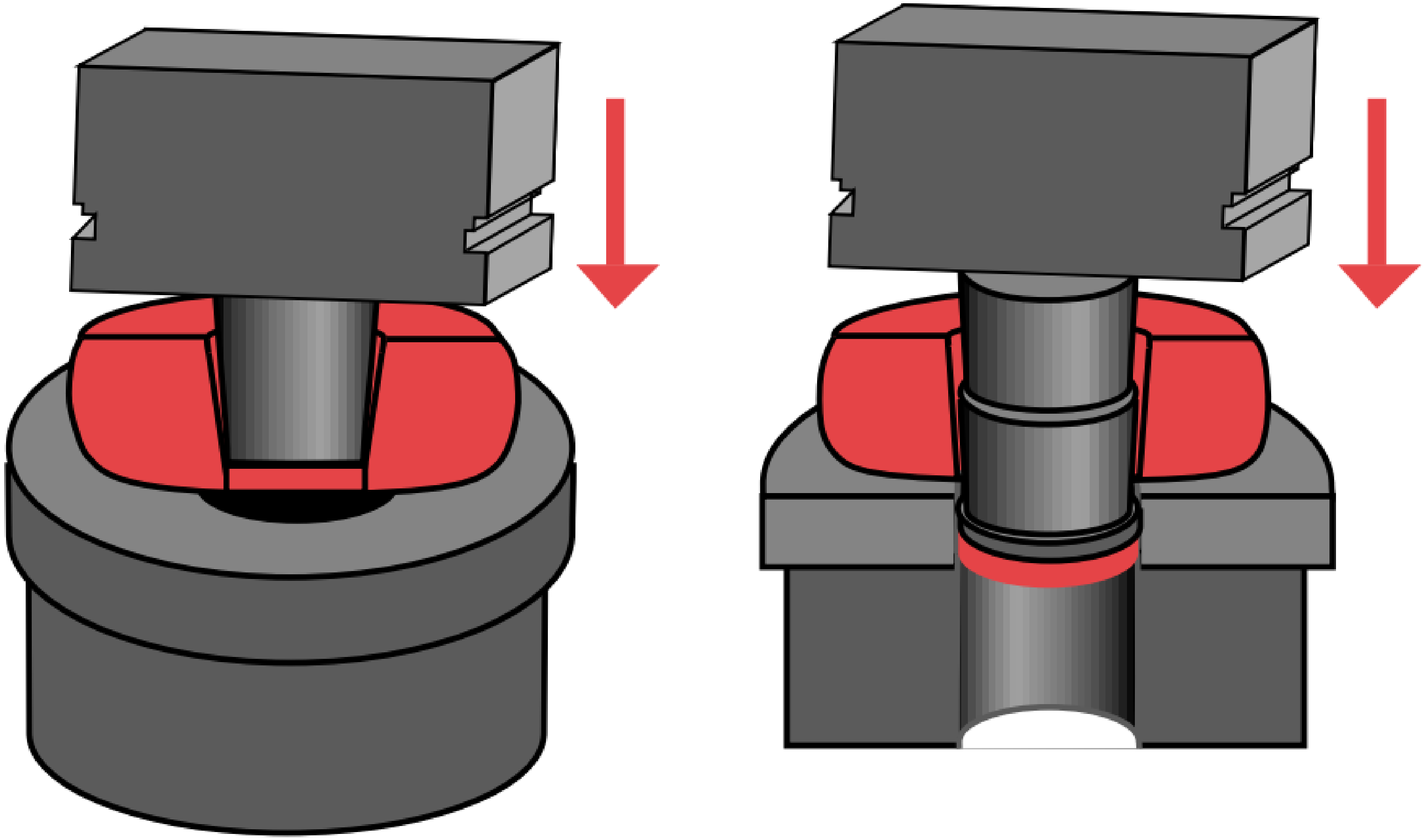
- The production of seamless forged rings is often performed by a process called ring rolling on rolling mills.
- The process starts with a circular preform of metal that has been previously upset and pierced (using the open die forging process) to form a hollow "donut".
- This donut is heated above the recrystallization temperature and placed over the idler or mandrel roll.

Seamless Rolled Ring Forging Process Operations

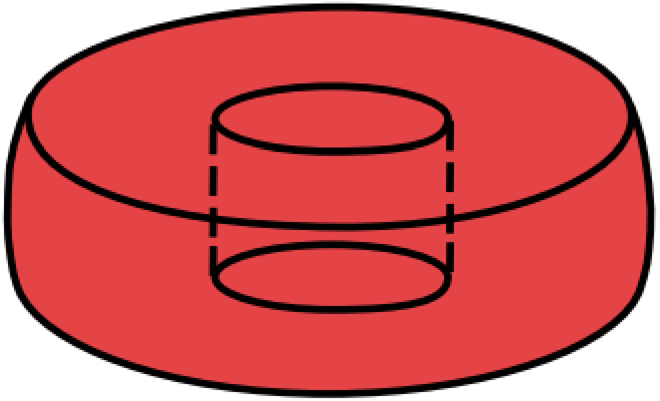
- This idler roll then moves under pressure toward a drive roll that continuously rotates to reduce the wall thickness, thereby increasing the diameters of the resulting ring.



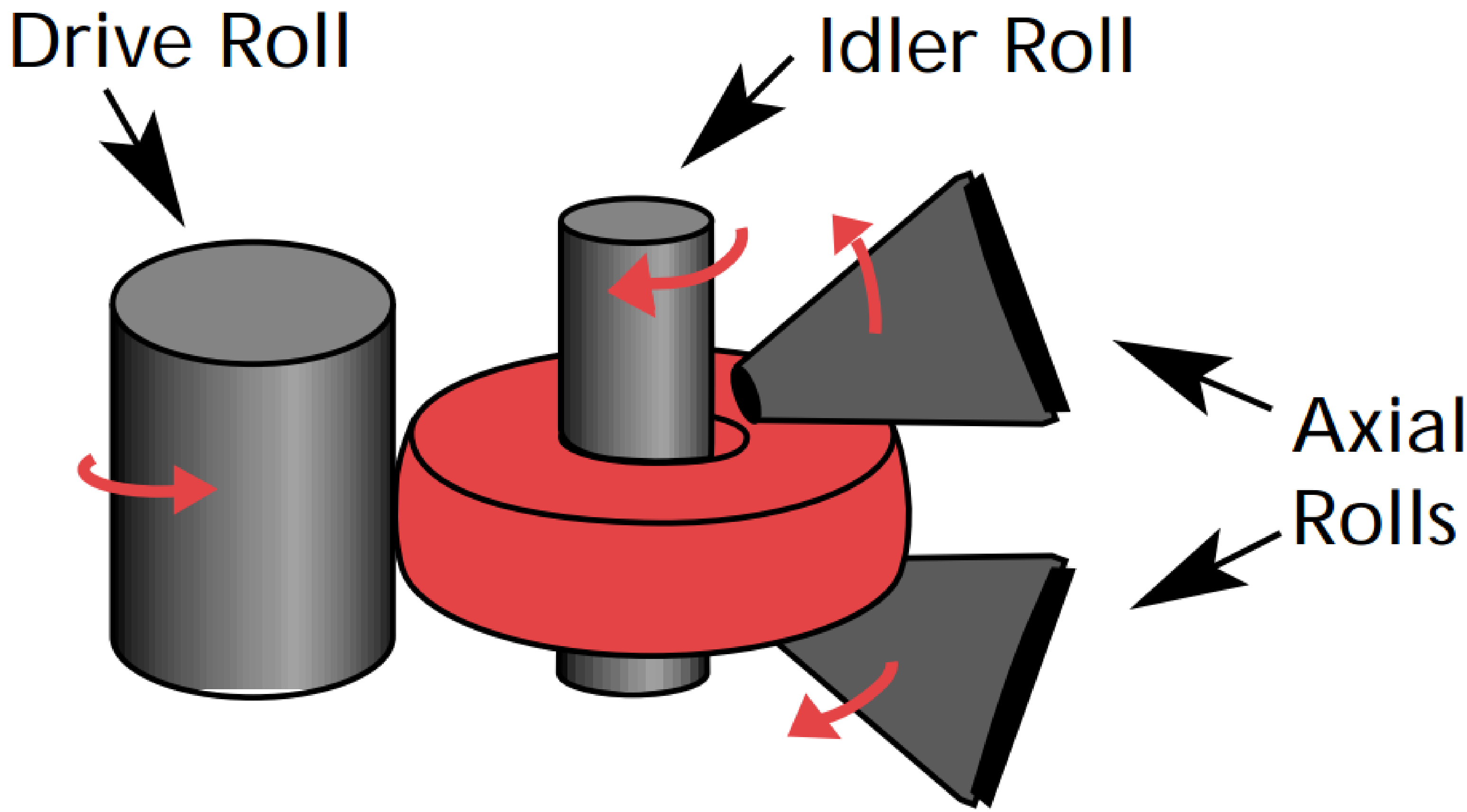
Starting stock cut to size by weight is first rounded, then upset to reduce the height.



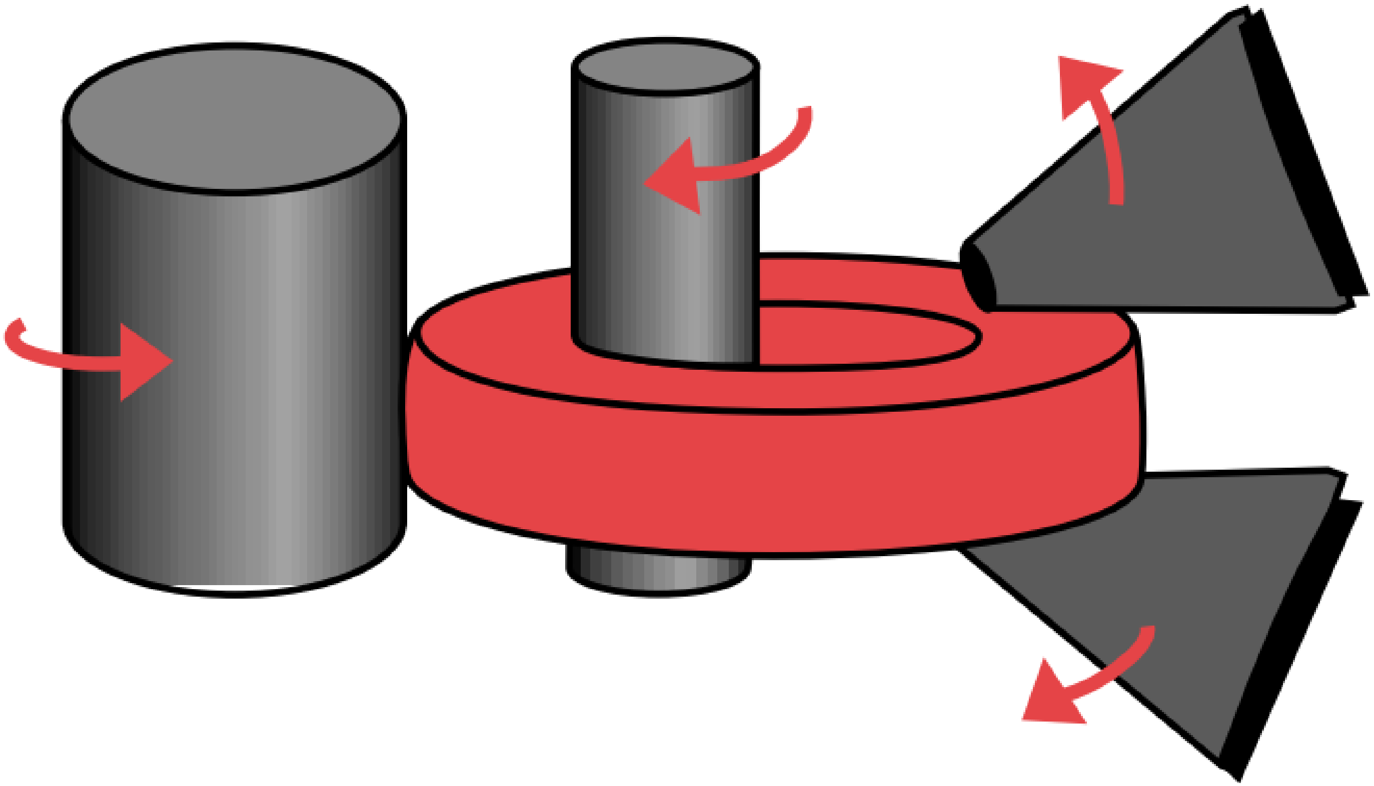
Workpiece is punched, then pierced to achieve starting "donut" shape needed for ring rolling process.



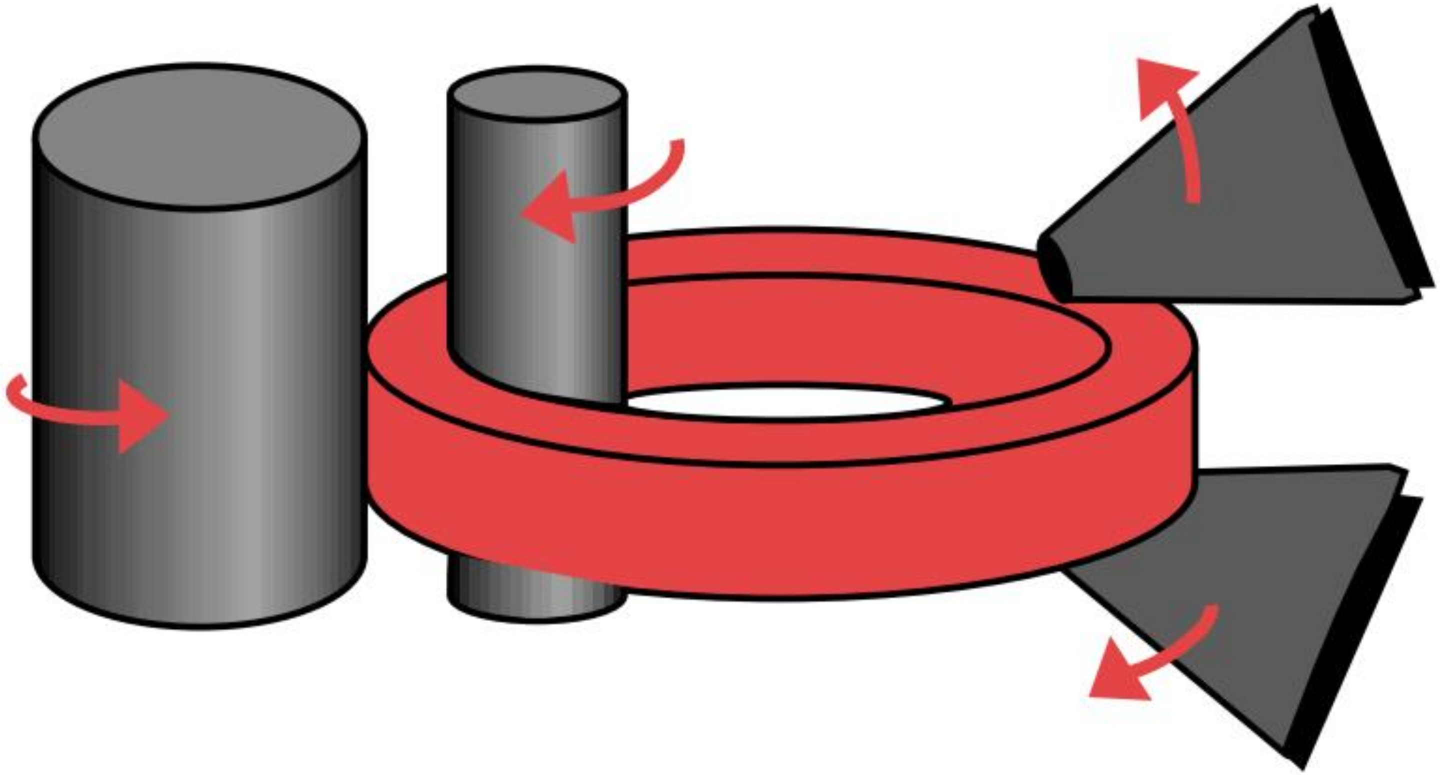
Completed preform ready for placement on ring mill for rolling.



Ring rolling process begins with the idler roll applying pressure to the preform against the drive roll.



Ring diameters are increased as the continuous pressure reduces the wall thickness. The axial rolls control the height of the ring as it is being rolled.



The process continues until the desired size is attained.

Forging Hammers (Drop Hammers)

Apply impact load against workpart

- Two types:
  - ***Gravity drop hammers*** - impact energy from falling weight of a heavy ram
  - ***Power drop hammers*** - accelerate the ram by pressurized air or steam
- Disadvantage: impact energy transmitted through anvil into floor of building
- Commonly used for ***impression-die forging***

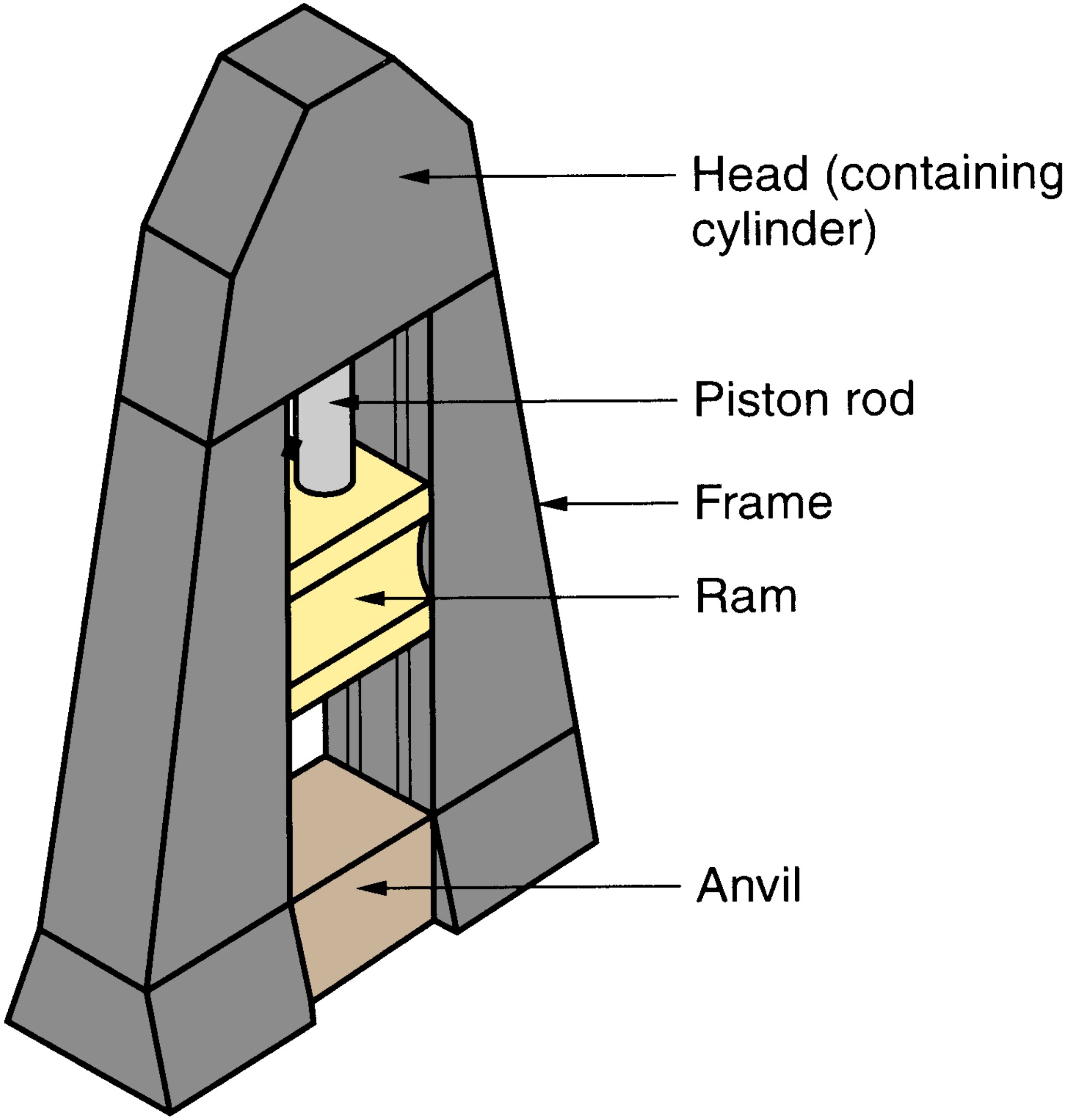
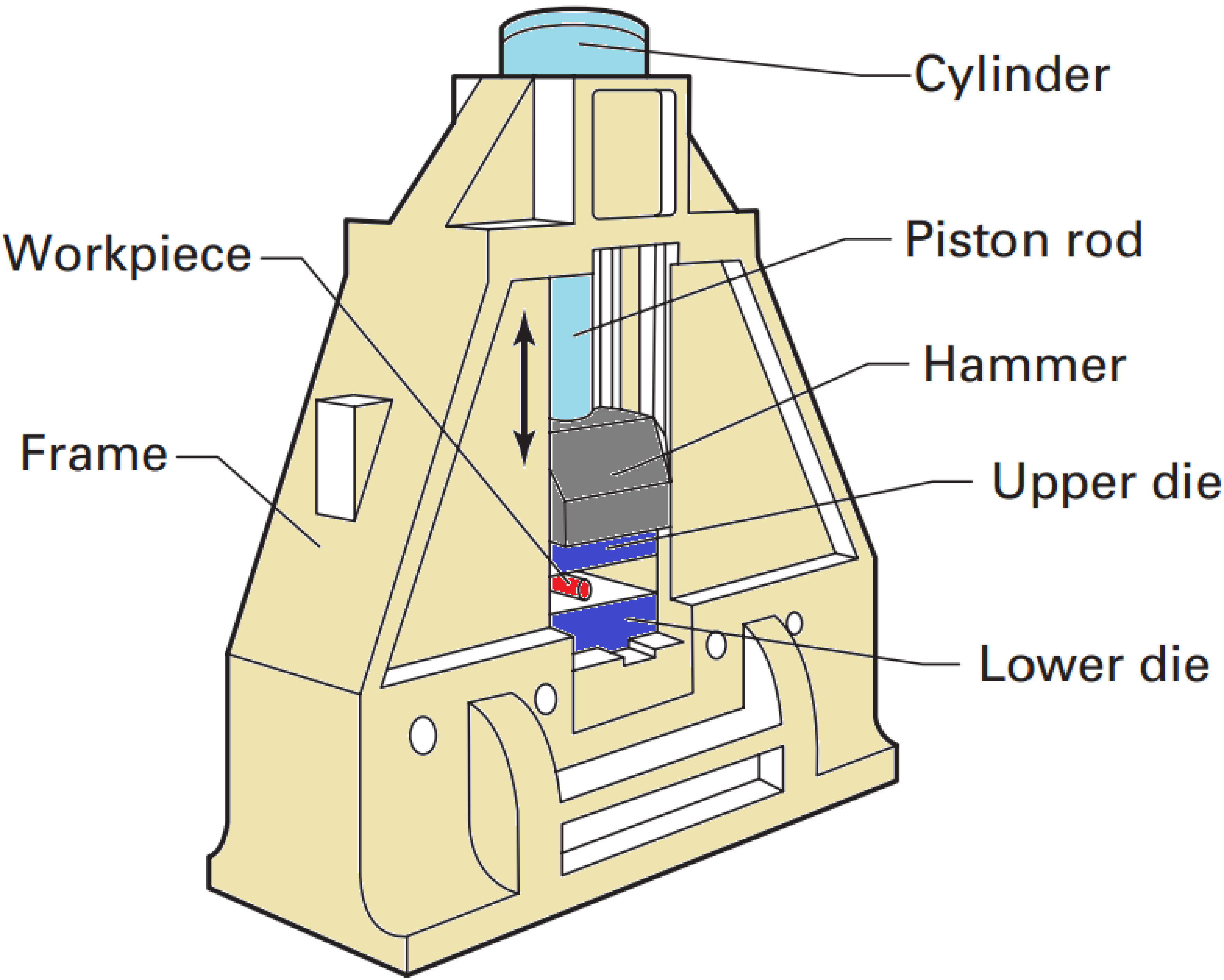


Diagram showing details of a drop hammer for impression-die forging.

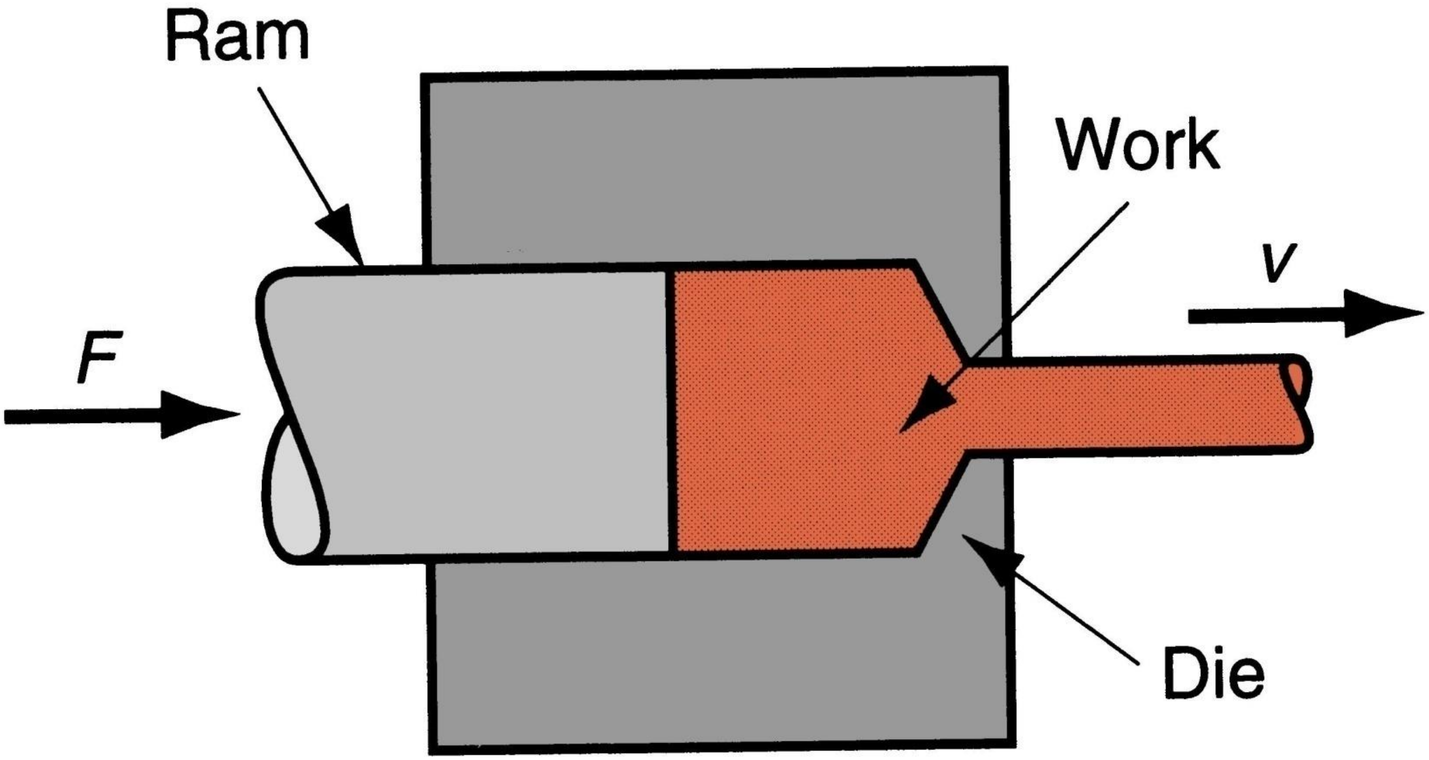

Cylinder
Workpiece
Piston rod
Hammer
Frame
Upper die
Lower die

(3) EXTRUSION

(3) EXTRUSION

- Extrusion is a ***compression process*** in which the work metal is ***forced to flow*** through a ***die*** opening to produce a ***desired cross-sectional shape.***
- The process can be likened to ***squeezing toothpaste*** out of a toothpaste tube.

(3) EXTRUSION



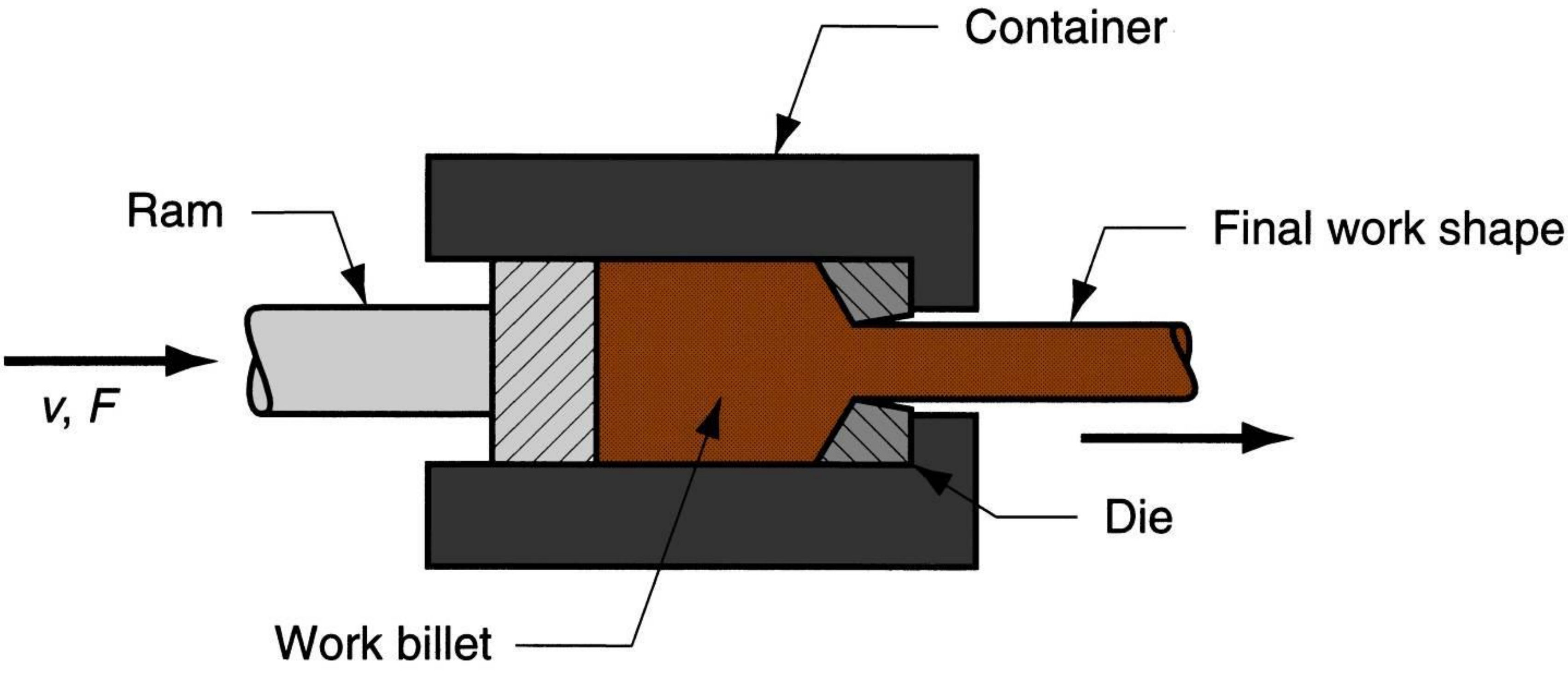
(3) TYPES OF EXTRUSION

- In general, extrusion is used to **produce long parts** of **uniform cross sections**
- Two basic types:
  - **Direct extrusion**
  - **Indirect extrusion**

(3) TYPES OF EXTRUSION (DIRECT)

- ***Direct extrusion*** (also called ***forward extrusion***)is shown in Figure.
- A ***metal billet*** is loaded into a container, and a ***ram compresses*** the material, forcing it to ***flow*** through one or more ***openings*** in a die at the opposite end of the container.
- As the ram approaches the die, a small portion of the billet remains that cannot be forced through the die opening.

(3) TYPES OF EXTRUSION (DIRECT)



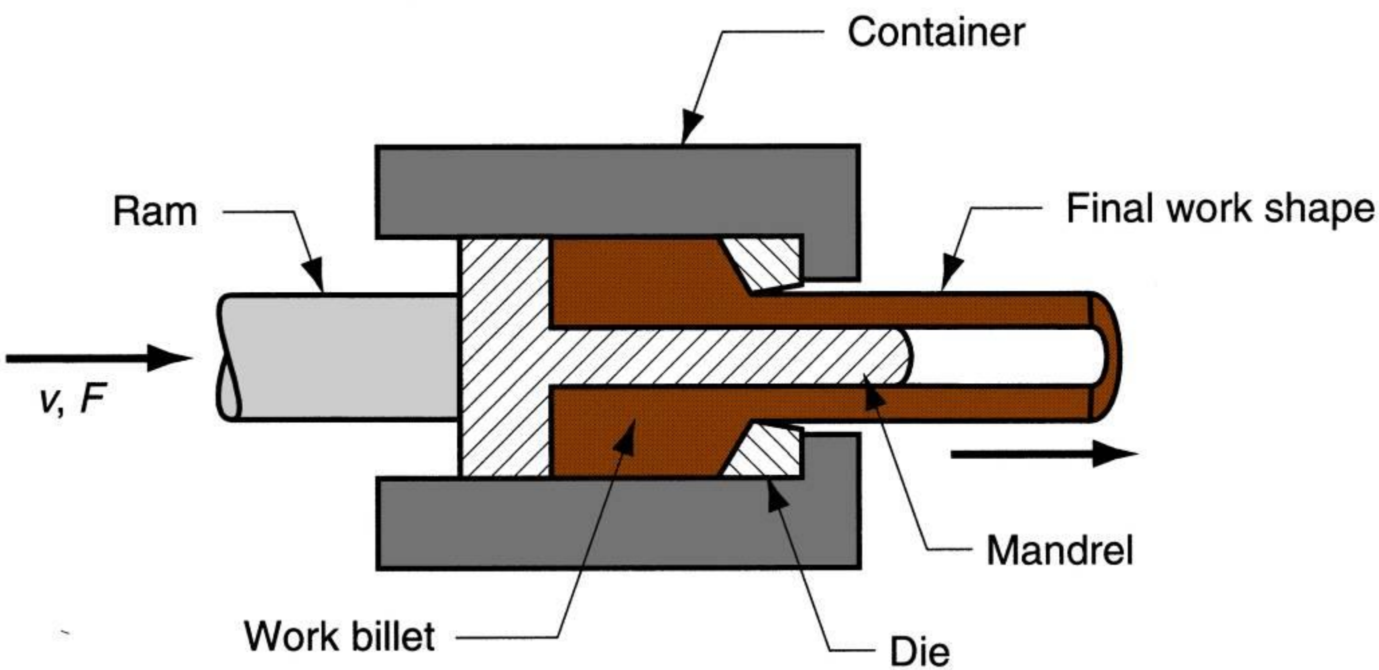
(3) TYPES OF EXTRUSION (DIRECT)

- This extra portion, called the ***butt*** ,is separated from the product by ***cutting*** it just ***beyond the exit of the die.***
- One of the problems in direct extrusion is the significant ***friction*** that exists between the ***work surface and the walls*** of the container as the billet is forced to slide to ward the die opening.
- This friction causes a substantial increase in the ram force required in direct extrusion.

(3) TYPES OF EXTRUSION (DIRECT)

- Hollow sections (e.g., tubes) are possible in direct extrusion by the process setup in Figure.

(3) TYPES OF EXTRUSION (DIRECT)(hollow sections)



(a)

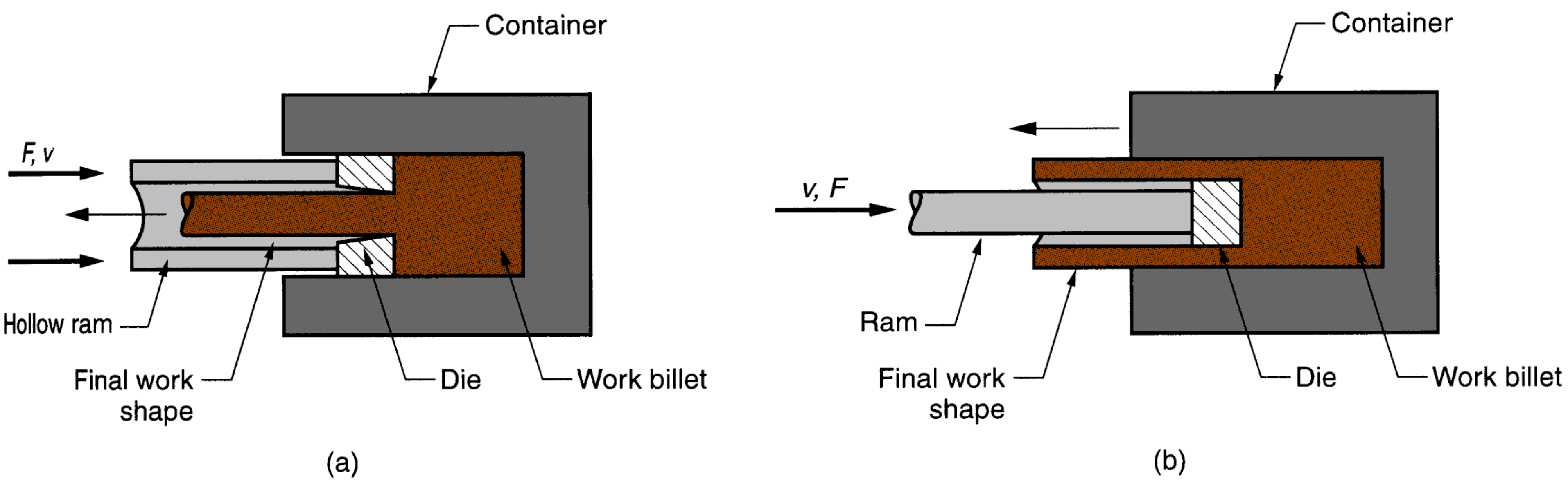
(3) TYPES OF EXTRUSION (INDIRECT)

- In ***indirect*** extrusion, also called ***backward*** extrusion and ***reverse*** extrusion, the ***die is mounted to the ram*** rather than at the opposite end of the container.
- As the ram penetrates into the work, the ***metal*** is forced to ***flow*** through the ***clearance*** in a ***direction opposite*** to the motion of the ram.

(3) TYPES OF EXTRUSION (INDIRECT)

- Since the billet is not forced to move relative to the container, there is ***no friction*** at the container walls, and the ram force is therefore lower than in direct extrusion.
- ***Limitations*** of indirect extrusion are imposed by the ***lower rigidity of the hollow ram*** and the ***difficulty in supporting*** the extruded product as it exits the die.
- Indirect extrusion can produce hollow (tubular) cross sections, as in Figure.

(3) TYPES OF EXTRUSION (INDIRECT)



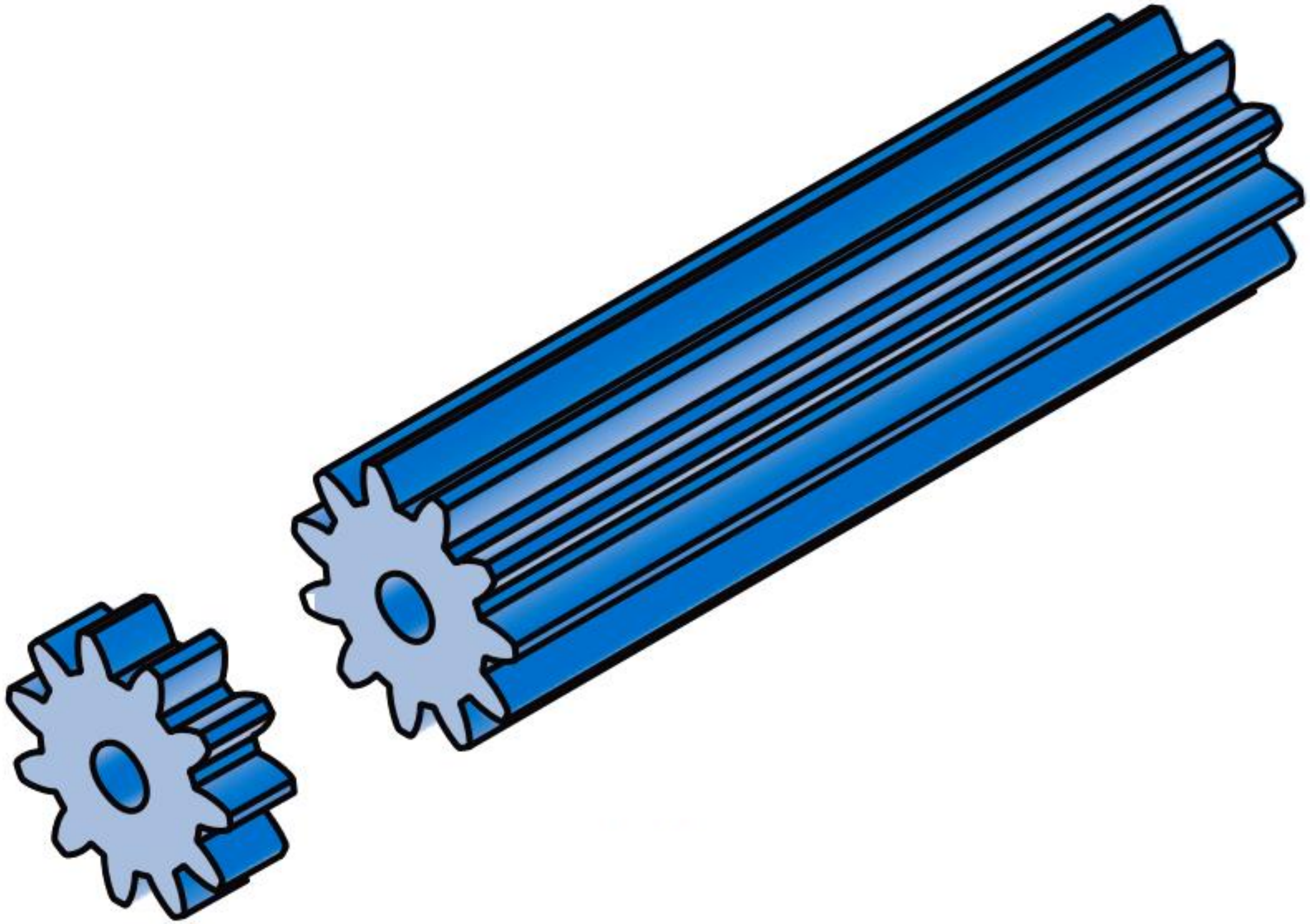
(3) TYPES OF EXTRUSION (HOT vs COLD)

- ***Hot extrusion*** - prior heating of billet to above its recrystallization temperature
  – Reduces strength and increases ductility of the metal, permitting more size reductions and more complex shapes
- ***Cold extrusion*** - generally used to produce discrete parts
  – The term impact extrusion is used to indicate high speed cold extrusion

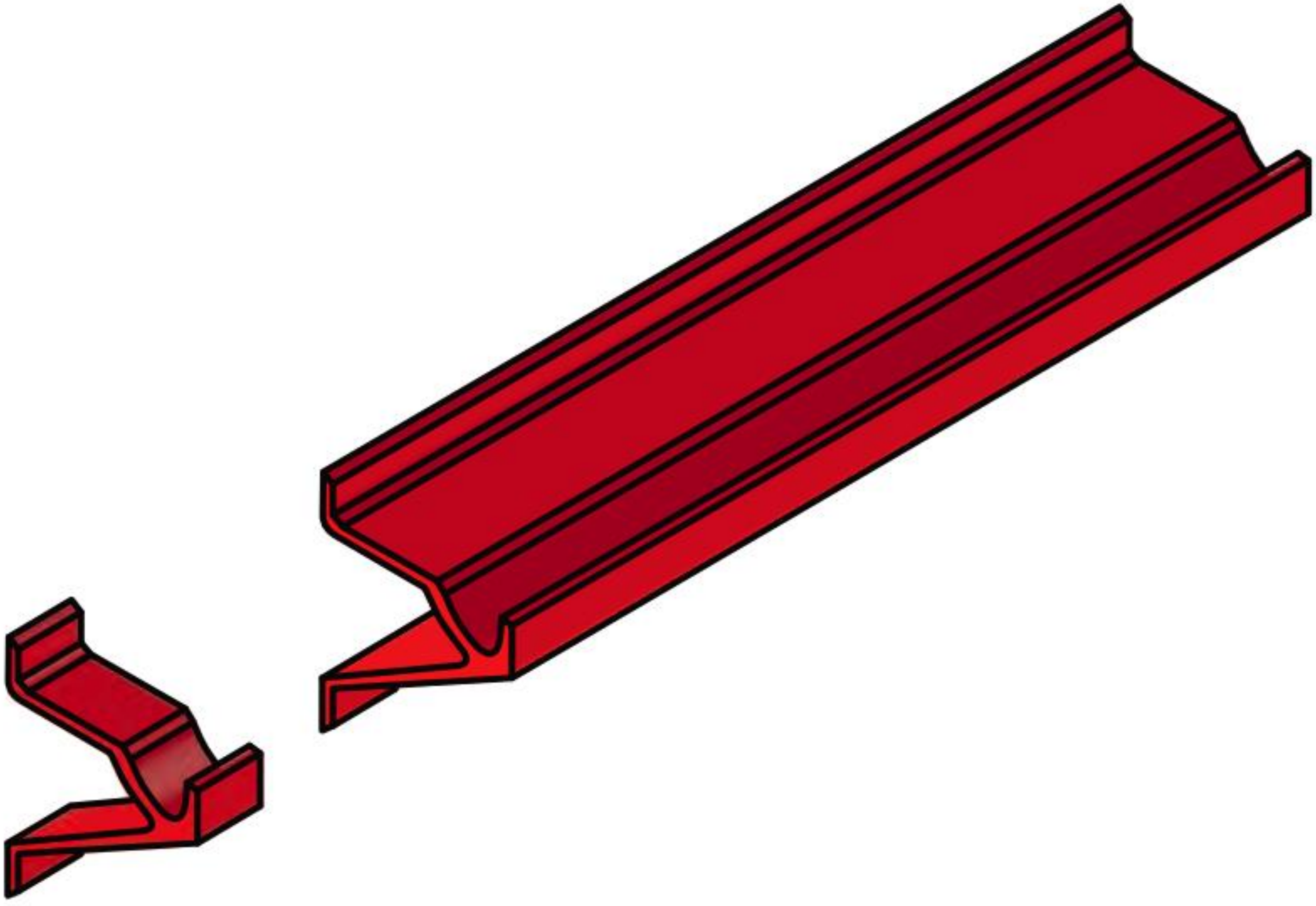
(3) TYPES OF EXTRUSION (HOT vs COLD))

- Variety of shapes possible, especially in ***hot extrusion***
  - ***Limitation***: part cross section must be uniform throughout length
- Grain structure and strength enhanced in cold and warm extrusion
- Close tolerances possible, especially in cold extrusion
- In some operations, little or no waste of material

Types Of Extruded Products



Types Of Extruded Products



Types Of Extruded Products