

Forging Process

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Deformation Process

- Permanent (plastic) deformation of a material under tension, compression, shear or a combination of loads.
- Types of Deformation
 - Bulk flow in (3) dimensions
 - Simple shearing of material
 - Compound to simple bending
 - Combination of above

Deformation Process

- Stresses used to produce change
 - Tension
 - Compression
 - Shear
 - Combination in multiple axis
- (2) Classifications
 - **Bulk** = Significant change in surface area, thickness and cross section reduced, and overall geometry changed.
 - **Sheet** = Some deforming of material, but initial material thickness remains the same

Definition of Hot Work vs. Cold Work

- HW is performed above the recrystallization temp of the material and CW is done below the recrystallization temp of the material.
- **Recrystallization Temp-** “The approximate minimum temperature at which complete grain growth and rearrangement of molecules of a worked metal occurs within a specified time.”
 - Approximate temperature ranges
 - HW- .6 melt temp.
 - CW - less than .3 melt temp.

Hot Working

- When HW a metal is in a plastic state and is easily formed. The forces required to deform the metal are less than CW. Some mechanical properties of the metal are improved due to process characteristics.
- At elevated temperatures, metal microstructures are rebuilding continually through the re-crystallization process which allows for much higher deformation.

Advantages to HW

- Porosity in metal is largely eliminated
- Impurities (inclusions) are broken up and distributed through the metal
- Course grains are refined
- Due to grain refinement, the physical properties are generally improved
 - Ductility and resistance to impact are improved
 - Strength is increased
- Amount of energy necessary to change the shape of the raw material in a plastic state is far less than if the material was “cold.”
- Economical compared to CW

Forging

- The plastic deformation of metals, typically at elevated temperatures, using compressive forces exerted through a die to conform the metal to a desired shape.
- Process advantages:
 - Closing of voids in the metal
 - Reduced machining time
 - Improve the physical properties of the starting metal

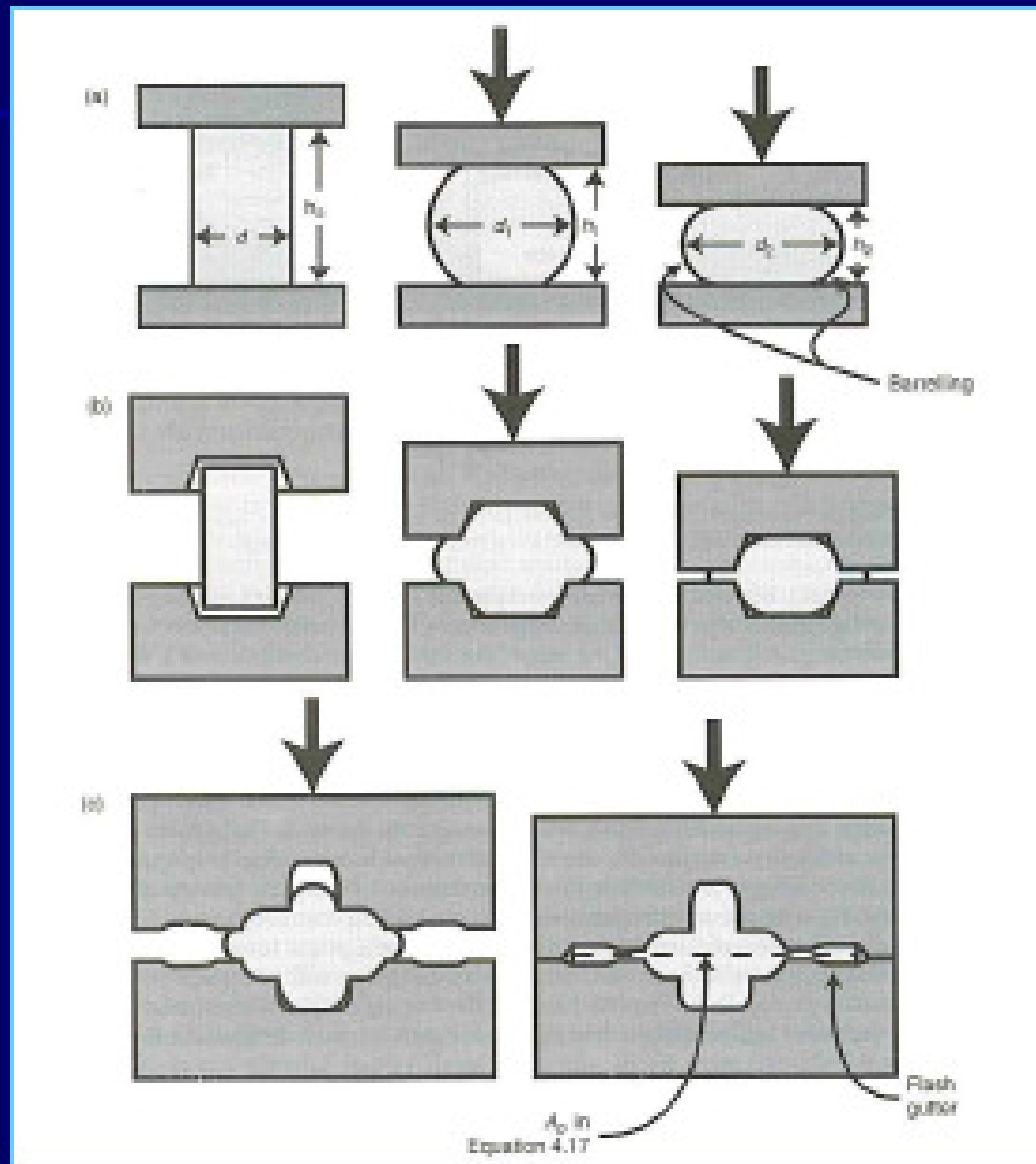
Forging Methods

- Open-Die Drop Hammer - heated metal is placed between dies—a force is delivered with a steam hammer.
 - Accuracy is not good
 - Complicated shapes are difficult to produce

Open Die Forging Machine



Closed and open die forging processes



Open-die forging

Closed-die forging

Impression-die forging

Hearth



Black smith operation on a red hot metallic workpiece



Tools of the Smithy Shop

- Most of the blacksmiths' work is done with hand tools.
- The most commonly used tools are
 1. Anvil
 2. Hammer.
 3. Tong

Steel anvils



Anvil

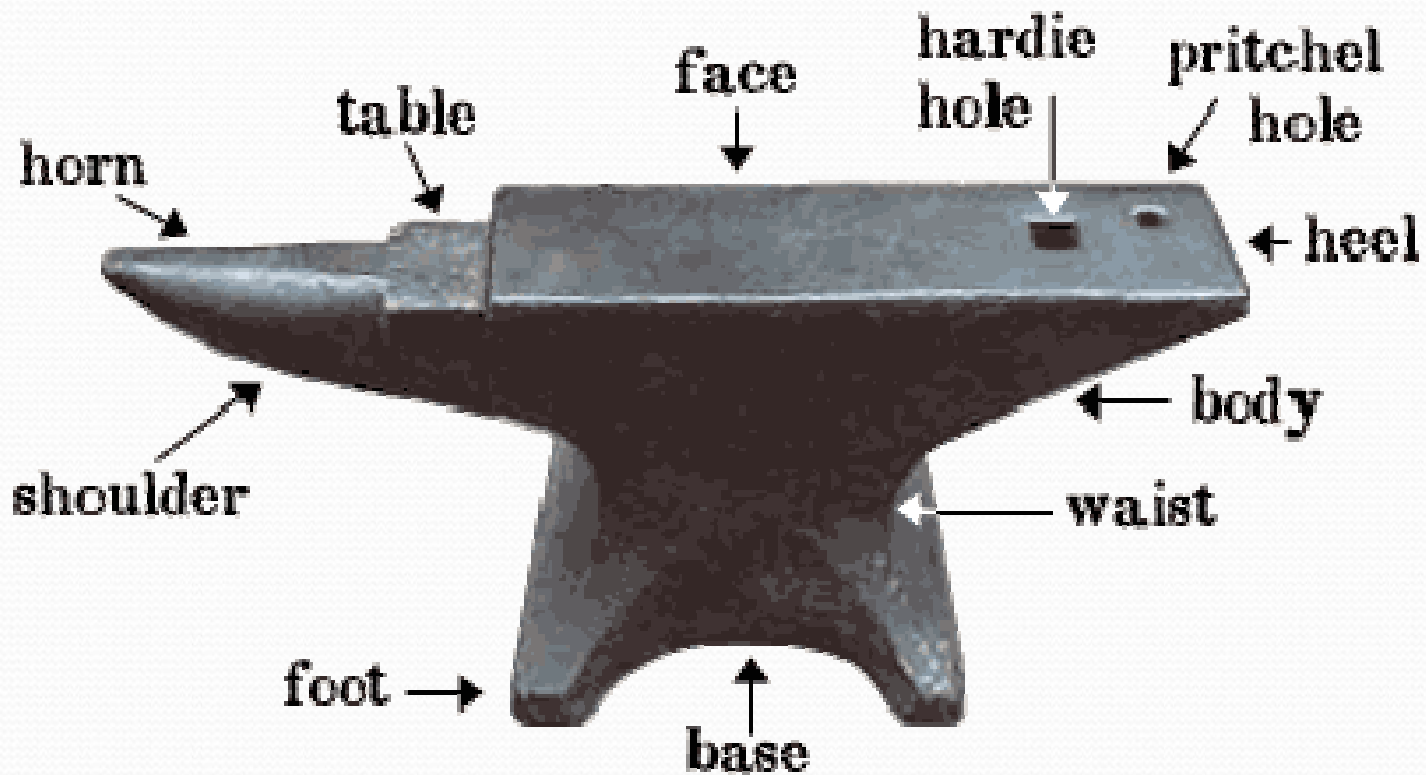
- To a inexperienced persons, all anvils look alike.
- Just a big lump of iron with pointed ends.
- In fact they are a deceptively sophisticated tool that are made in many styles, materials and sizes.

* The best anvils are made of selectively hardened tool steel with a well balanced attractive shape and various useful working surfaces.

- It has taken centuries to develop the shapes of anvils and similar to the violin some anvil styles were perfected long ago and will probably never change.

Different parts of the Anvil

The London Anvil (*Peter Wright, 100 lbs.*)



Information Source: Alex W. Bealer, *The Art of Blacksmithing*

Students working in a smithy shop



Types of Anvils

- There are five basic types of anvil,
 - Forging,
 - Shoeing (farrier's),
 - Sheet metal,
 - Bench
 - Jewelers.

Types of Anvils

- These types are different in both size and style.
- As with most tools there is a lot of overlap in application.
- A forging anvil or general shop anvil can also be used for making horse shoes and light forging can be done on a farrier's anvil.
- A heavy sheet metal stake can be used for light forging and bench work.

Types of Anvils

- Small bench work anvils can be used for jewelry but are clumsy for fragile work.
- However it is impossible to forge anything smaller than fine wire on a little (150 g) **Jewelers anvil** and difficult to use a large 200 pound (90kg) **Forging anvil** for jewelry work.
- Each task is best performed using the proper size tool.

Types of Anvils

- The size of the anvil should be proportional to the work and the hammer used to perform that work.
- For forging an average hand hammer to anvil ratio of about 50:1 is normal.
- Example, a heavy 4 pound (1800 gm) hammer and a 200 pound (90kg) anvil are a good match.

Forging anvil



Forging anvils

- These are also known as blacksmiths or general shop anvils.
- These range in weight from about 75 (one pound=450g) pounds to 500 pounds.
- They differ from farrier's anvils in that there is more mass in the body directly under the face and less distributed in the horn and heel.

Forging anvils

- Due to the prevalence of horse drawn transportation in the early part of the 20th century most popular anvils were a combination of farrier's and forging anvil.
- Today the Peddinghaus, Vaughans, Euro and Nimba are typical forging anvils.
- These are designed for heavy forging and have all the standard dimensions

Shoeing or Farriers anvils



Farriers anvils

- **Farriers anvils** may look like any other anvil to the neophyte but they are a highly specialized type of anvil.
- Modern farriers anvils put a high proportion of the mass in the horn and often have just enough in the heel to balance the anvil.
- The base has negligible mass.
- Most farrier's anvils are made in the portability range of 100 to 150 pounds (45 to 70kg).

Farriers anvils

- Modern farrier's anvils also have special features such as "clip horns" for forming toe clips and turning cams for ease of adjusting a shoe.
- Due to their very narrow waist most farrier's anvils are too bouncy for general forging work and should be avoided by non-farriers.
- All the currently available farriers anvils are cast steel or hardened ductile iron.

Classification of anvils

Type by Weight Range - Min. - Max.

Pounds	Type	Kilos
75 - 500	Forging	35 - 230
50 - 150	Farrier	23 - 70
5 - 100	Stake	2.3 - 45
5 - 50	Bench	2.3 - 23
0.3 - 5	Jewelers	0.14 - 2.3

Jeweler's Anvil



Jeweler's Anvil

- These anvils are made in an old style that has not changed for 300 years or more.
- They have a square body and long slender bicks.
- Some have stakes to embed in a bench and others a large base.
- Jewelers anvils are made of forged or cast tool steel and finely finished all over.
- Weights range from a few ounces to a few pounds.
- Jewelers anvils were also sold as silversmiths, watch and clockmakers anvils.

Bench Anvil



Bench Anvil

- These anvils are small anvils that range in size from 5 to 50 pounds.
- Generally the only definition of a bench anvil is that it is used on a bench for supporting work to be hammered.
- Styles vary from the familiar London pattern, European double horned or the classic double horned jewelers anvil with long slender bicks (horns).
- They can also simply be a convenient block of steel. English locksmith's bench anvils have a working end of 8 or 10" (200-250 mm) long and leg that goes to the floor.
- Many bench anvils have been made of structural steel and rail road rail

Quality Ranking of Anvils by Construction

Ranks	Material
1	Forged Tool Steel
2	Steel Plate on Wrought Body
3	Cast Tool Steel
4	Steel Plate on Cast Iron*
5	Hardened Ductile Iron
6	Chilled Cast Iron
7	Cast Iron (ASO**)

* Historical manufacturing method no longer used.

** ASO, Anvil Shaped Object

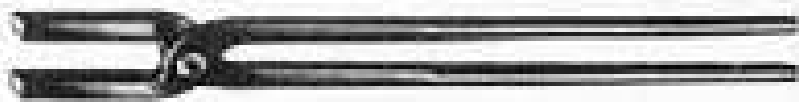
Tongs

- Tongs are used when a piece of metal is too hot or short to go from the forge to the anvil.
- Tongs come in every shape and size imaginable.
- The smith selects the pair most suited for the job he's doing.

Flat Jaw Tongs



Different Types of Tongs



Open Mouth Tongs



Rivet Tongs



Square Mouth Tongs



Universal Tongs

Different Types of Tongs



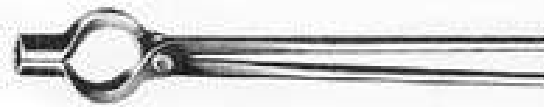
Pick up or dandy tongs



Single bow tongs



Crucible Lift out tongs



Bolt tongs

Hammers

- Hammers are used by a smith in order to give the required shape to the heated metal piece.
- Hand operated hammers are generally employed for shaping small and light components.
- Different classes of Hammers
 1. Ball peen hammer
 2. Cross peen hammer
 3. Straight peen hammer
 4. Sledge hammer

Ball Peen Hammer



Ball Peen Hammer

- A ball-peen hammer is a type of peening hammer used in metal working.
- Though the process of peening has become rarer in metal fabrication, the ball-peen hammer remains useful for many tasks such as tapping punches and chisels.
- The original function of the hammer was to "peen" riveted or welded material so that it will exhibit the same elastic behavior as the surrounding material.

Ball Peen Hammer

- The ball-peen hammer is also used to expand and light rivets and similar, "setting" the rivet in place to complete the joint.
- Peening is also the method by which steel drums are formed and tuned.
- A ball-peen hammer is also known as an engineer's hammer or a machinist hammer and may be graded by the weight of the head.
- It is the mechanics hammer of choice when making gaskets or driving drift pins.

Cross peen hammer



Cross peen hammer

- The peen is across i.e. at right angle to the axis of the handle of the hammer.
- Weight of the hammer is 0.22 to 0.91 kg.
- The cross peen hammer is used for bending, stretching and hammering into the inside positions of the component.

Straight peen hammer

- The peen is straight i.e. parallel to the axis of the handle of the hammers.
- Weight of the hammers is 0.11 0.91 kg.
- The straight peen hammer is used for stretching the metal.

Sledge Hammer



Sledge Hammer

- A sledge hammer is heavier than a Smith's hand hammer described earlier.
- The weights vary from 3 to 10 kg are used when heavy blows are required to be imparted to the jobs.
- The striking surface of the sledge hammer is made slightly convex and smooth.
- The aim is that the work-piece metal is not spoiled by the edges of the hammer if they are sharp.

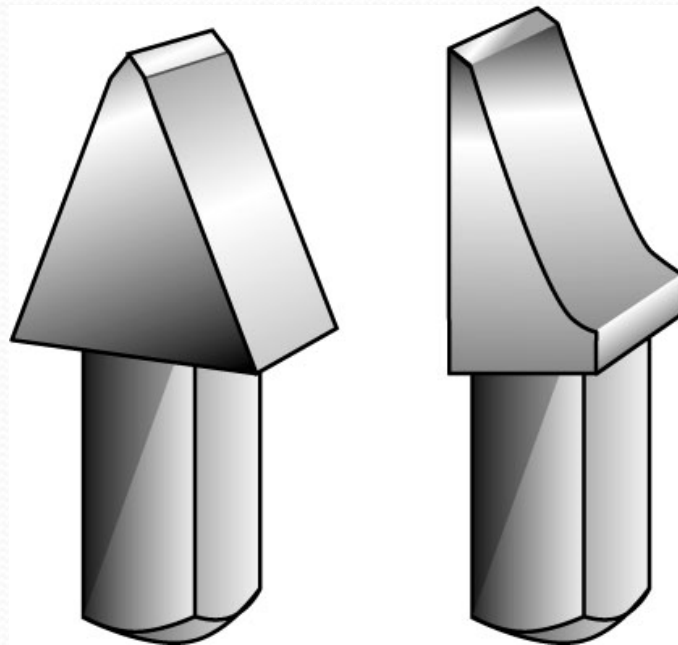
Different tools used in smithy shop

- **S32 Bottom Swage,**
- **S34 Bottom Fuller**
- **S37A Hardie**
- **S37A Shoecropper**



Hardie

- A hardie is chisel.
- It has a square shank and is mounted in the hardie hole of the anvil.
- To cut a bar the hardie and cold set are used together.



Hot set

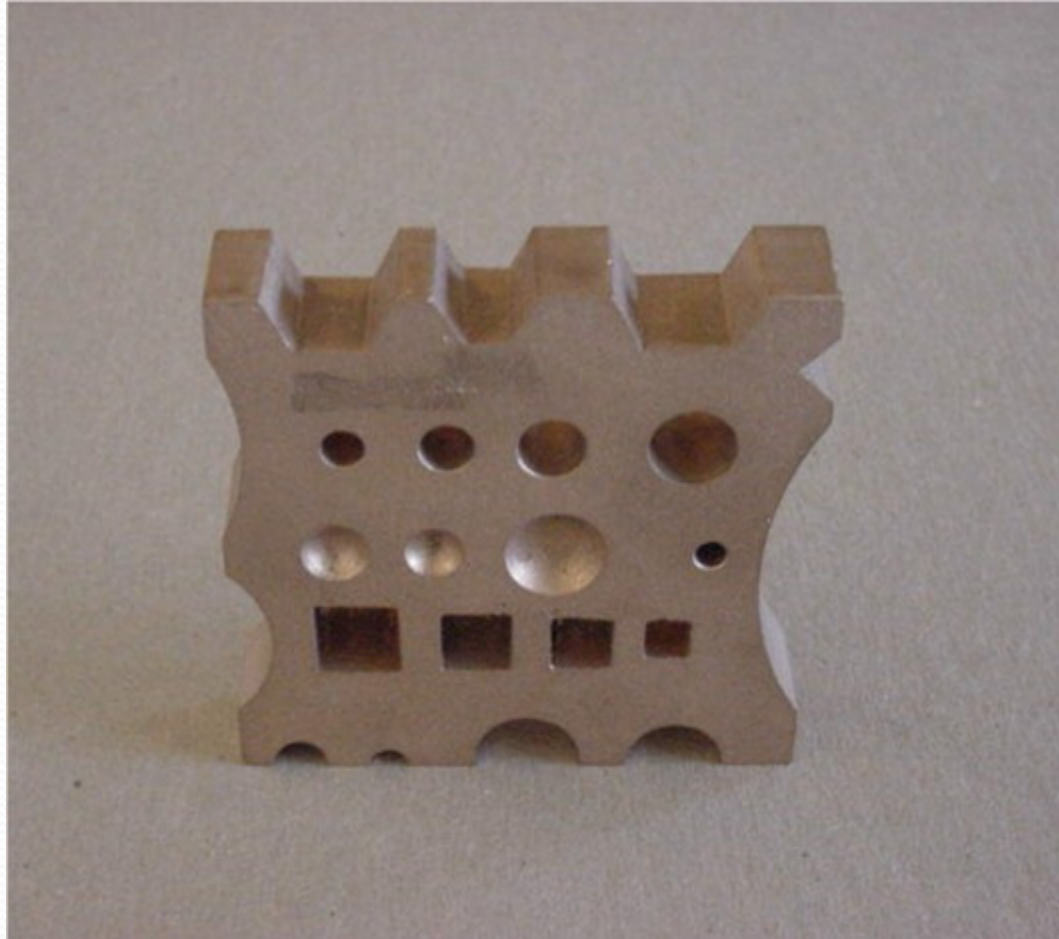
- A hot set is a chisel used for cutting hot metal pieces during the forging process.
- A hot set is made up of hard steel but is of larger diameter and of a shorter length than the cold chisel.

Swage Blocks



- Swaging is done to reduce and finish work to desired size and shape usually either round or hexagonal.
- For small jobs top and bottom swage pair is employed where as for large work, the swage block can be used.

Bronze Swage Block

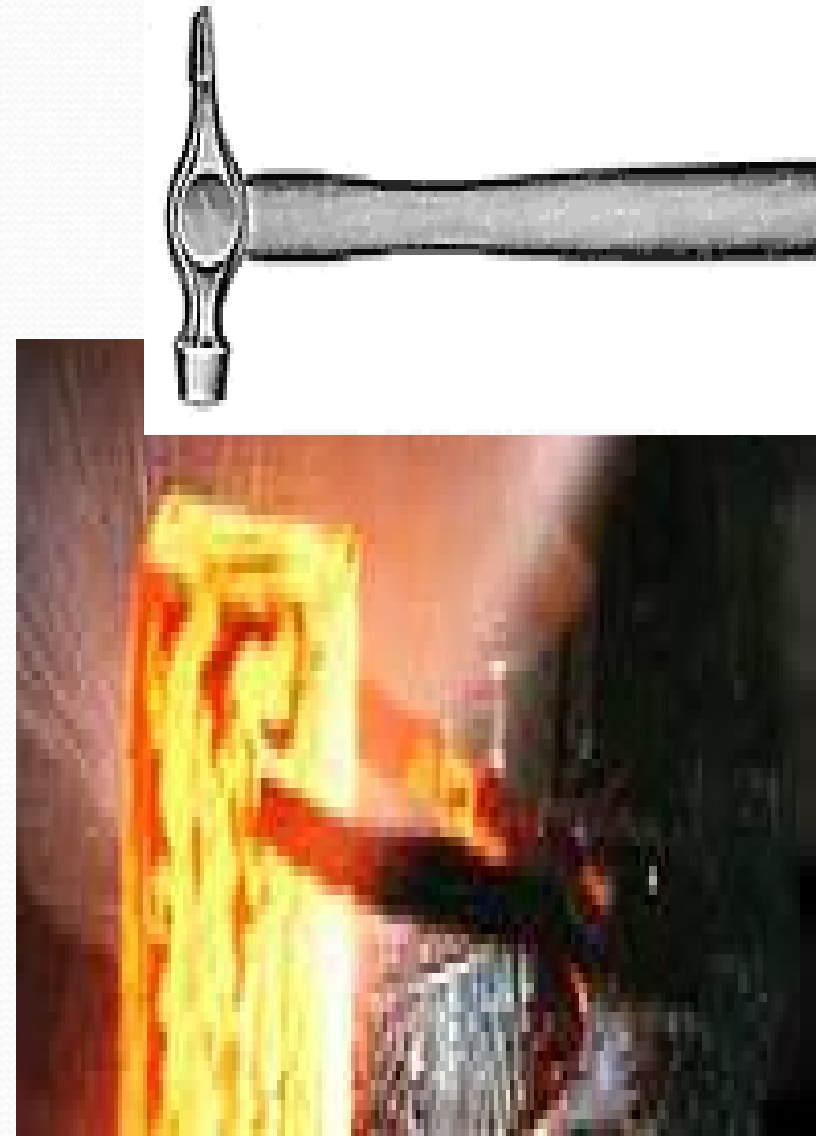


Operations of Smithy Shop

- Smith forging is done on anvil.
- The operations of smith forging are
 - **upsetting or jumping**
 - **drawing down**
 - **bending**
 - **cutting**
 - **punching and drifting**
 - **fullering**
 - **setting down**
 - **flatting**
 - **swaging and forge welding**

Upsetting or Jumping

- It is an operation to carry out to increase the thickness (or diameter) of a bar and to reduce its length.
- Generally the increase in thickness is local as in the case of forming a bolt head.
- Only that portion of the bar which is to be upset is heated locally.

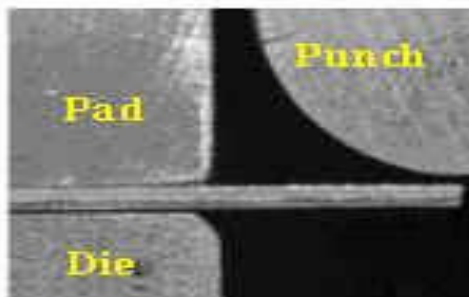


Drawing down

- Drawing down is to reduce the thickness of a bar and to increase its length.
- It is may be carried out by working the metal over the horn of the anvil then by hammering it on the anvil face.
- The rounded horn of the anvil acts as a blunt edge which forces the hot metal to flow lengthwise when struck by the hammer.
- For drawing down very heavy work fuller may be used.

Bending

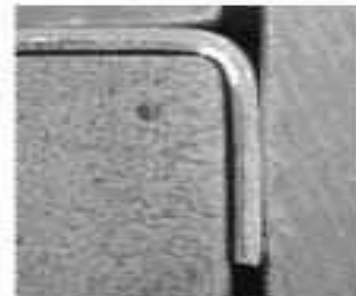
- Bending is a very common forging operation.
- The simplest method of bending a piece of metal in hand forging is to support it on the anvil and to strike its free end with a hammer.
- When bent the metal of the work-piece tins out round bend causing weakness.
- This can be overcome by upsetting prior to bending.



Start



During



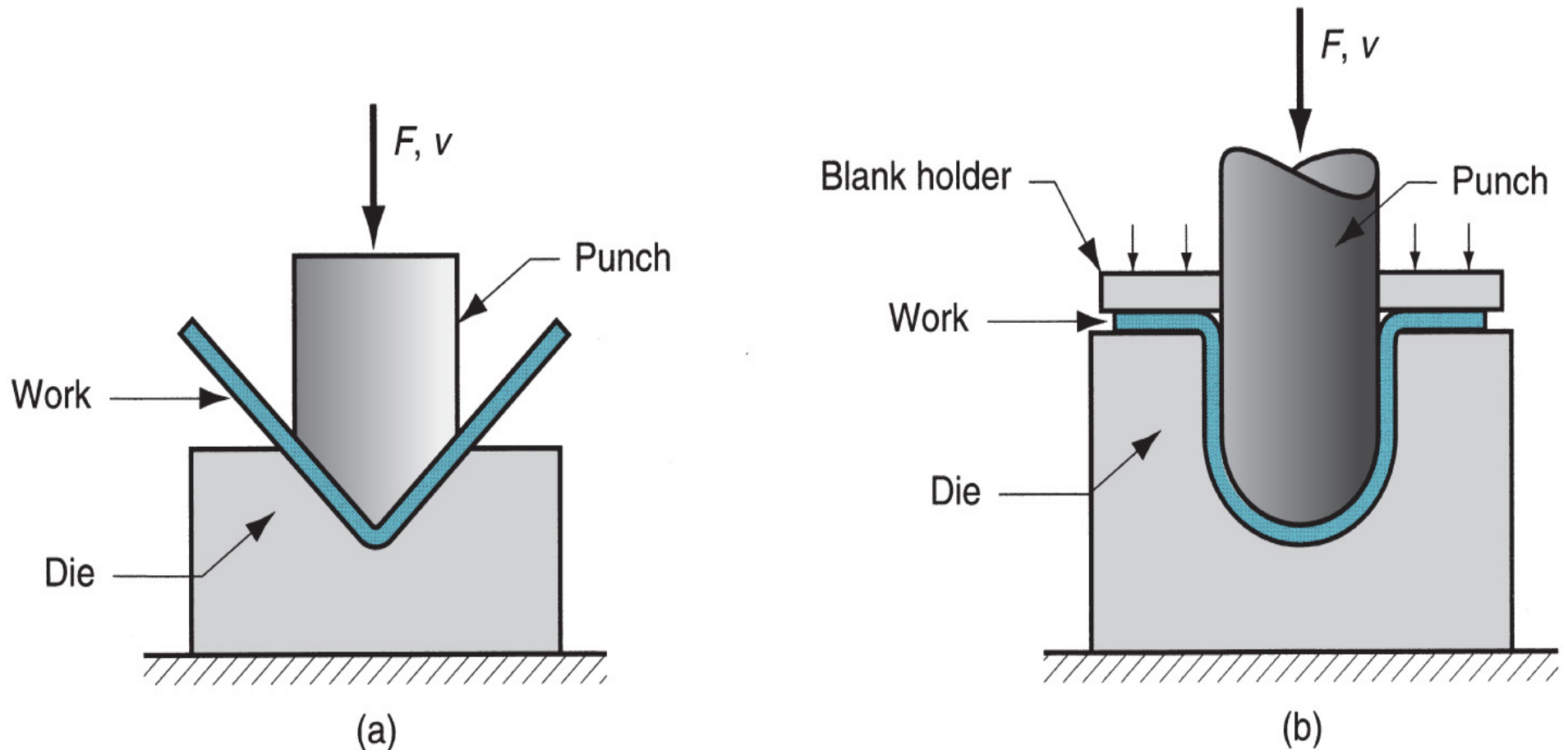
Final



Springback

Sheet Metalworking

- (a) Bending and (b) deep drawing



Hot Cutting

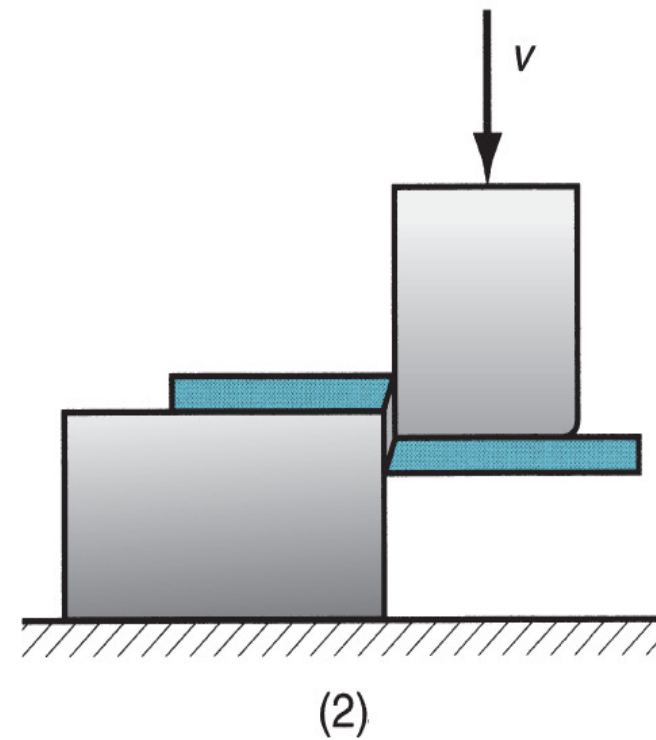
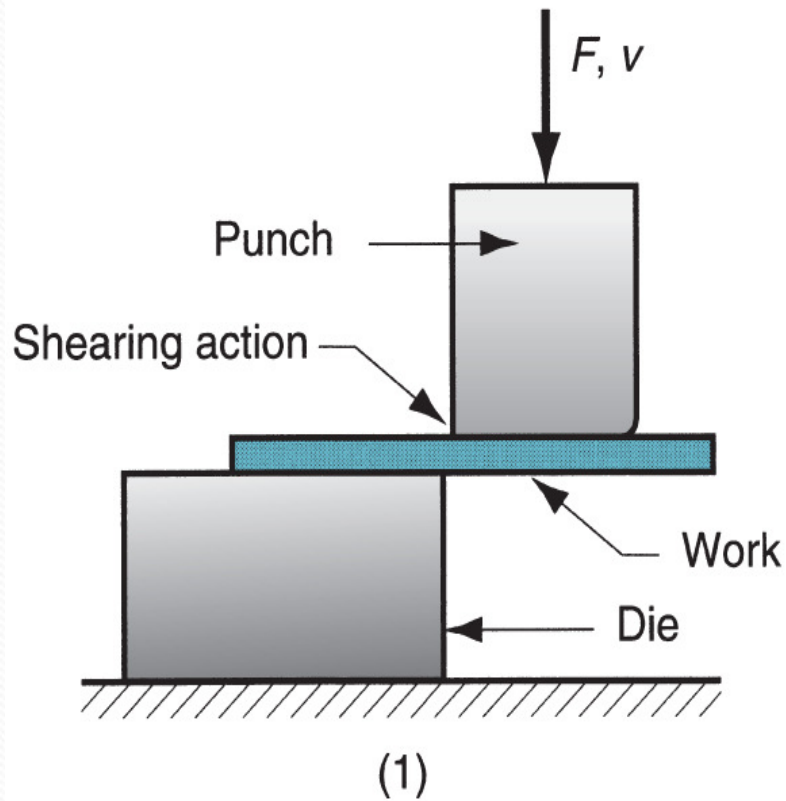
- A hot set (chisel) is used for cutting heated metal bars in a smithy shop.
- The hot set does not required to be hardened or tempered.
- Hot sets are manufactured from the tough variety of steel in order that they may cut through relatively soft red hot metals with ease.

Punching

- For punching a hole the metal workpiece must be at near welding heat.
- The punch is driven part way through the workpiece with the hammer blows .
- The work is then turned over and the hole is completed from the other side.
- The above mentioned part is adopted for a thicker workpiece.

Punching used in Sheet Metalworking

- (1) punch first contacting sheet



Fullering

- Fullering reduces the thickness of a heated metal work-piece having a thicker section.
- The bottom fuller is held in the **hardie hole** of the anvil and the work-piece is rapidly reduced in thickness in moving it between the top and the bottom fullers while striking the top fuller with the sledge hammer.
- Fullers are also used for making shoulders or grooves across the metal.

Flattening and setting down

- Fullering leaves a grooved surface on the job.
- Even after a job has been forged into shape with a hammer, the marks of the hammer remain on the upper surface of the job.
- To remove the hammer marks or corrugations and in order to obtain a smooth surface on the job a flatter or a set hammer may be used.

Forge Welding

- Wrought iron and low carbon steel can be satisfactorily forge welded.
- Forge welding can be carried out with metal thickness upto above 30 mm.

Temperature of Different colors in Smithy

Sl. No.	Colors	Temperature
1	Dark red	700° C
2	Cherry red	760° C
3	Orange red	980° C
4	Yellow red	1090° C
5	White red	1300° C

Forming Processes - Definition & Types -

Forming processes are those in which the shape of a metal piece is changed by **plastic deformation**

Forming processes are commonly classified into **hot-working** and **cold-working** operations.

Typical forming processes are:

Rolling

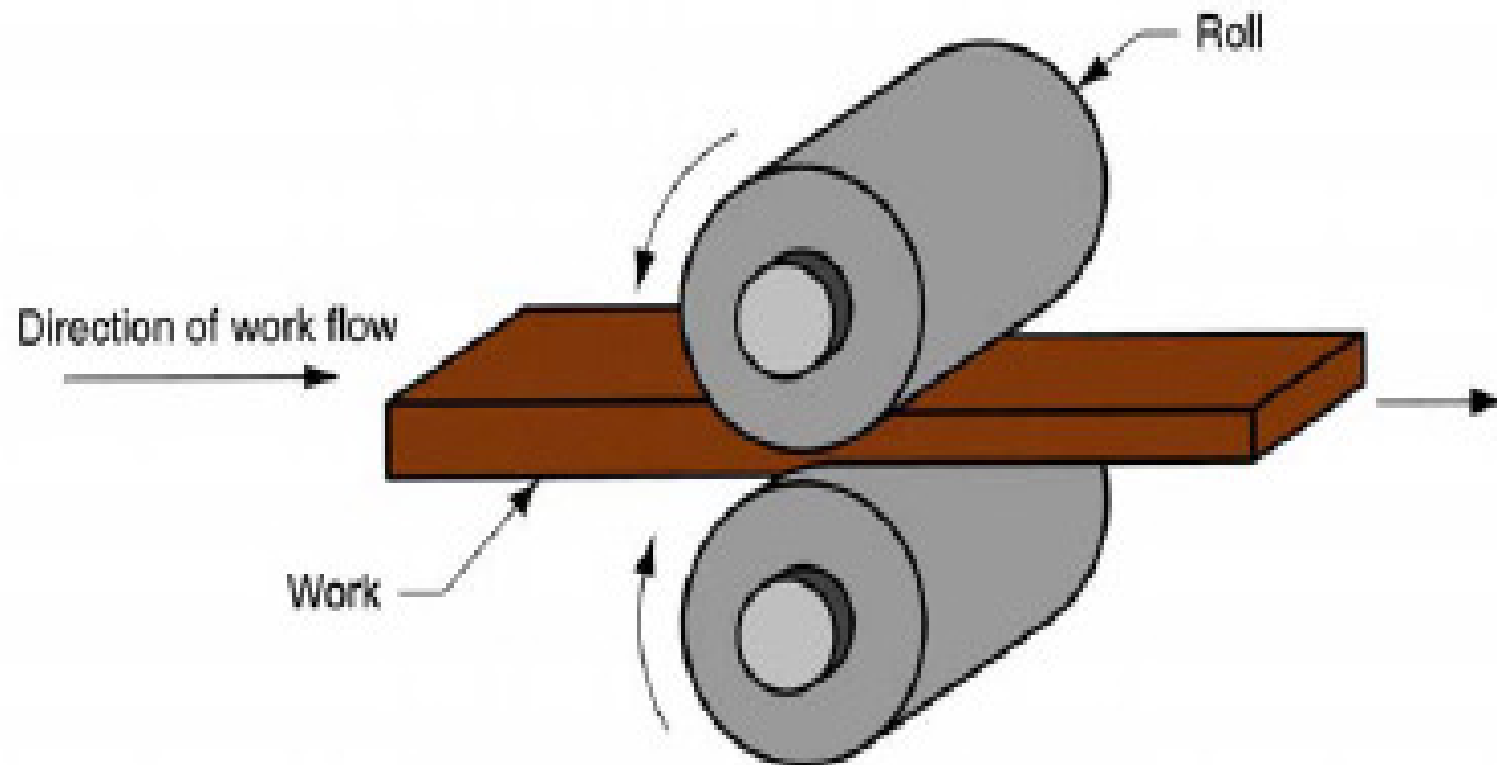
Extrusion

Forging

Drawing

Forming Processes - Rolling -

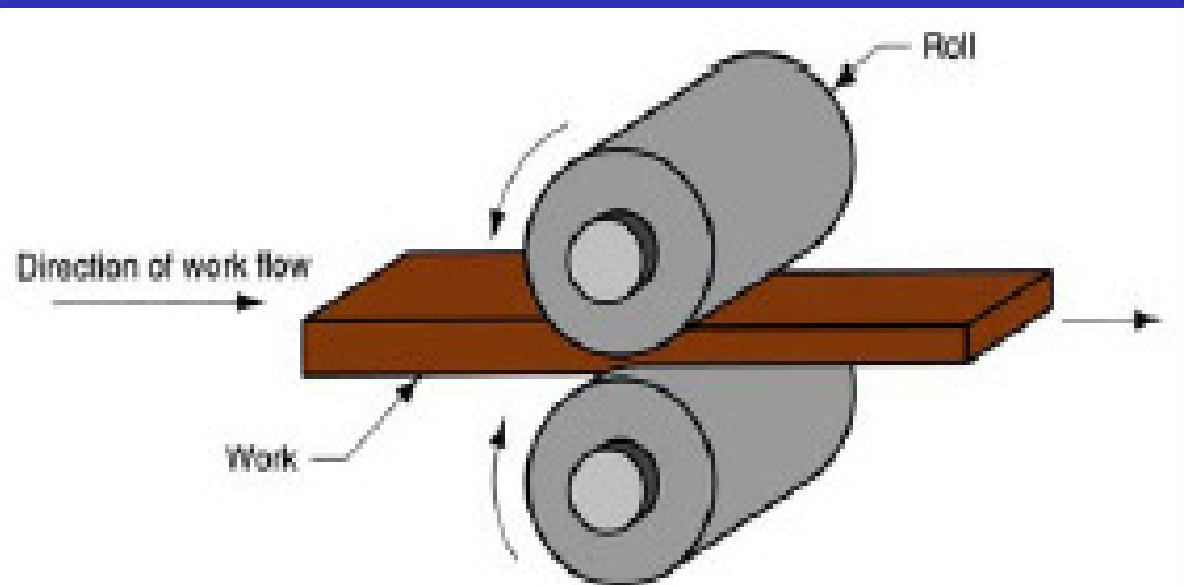
Rolling is a process of reduction of the cross-sectional area or shaping a metal piece through the deformation caused by a pair of rotating in opposite directions metal rolls.



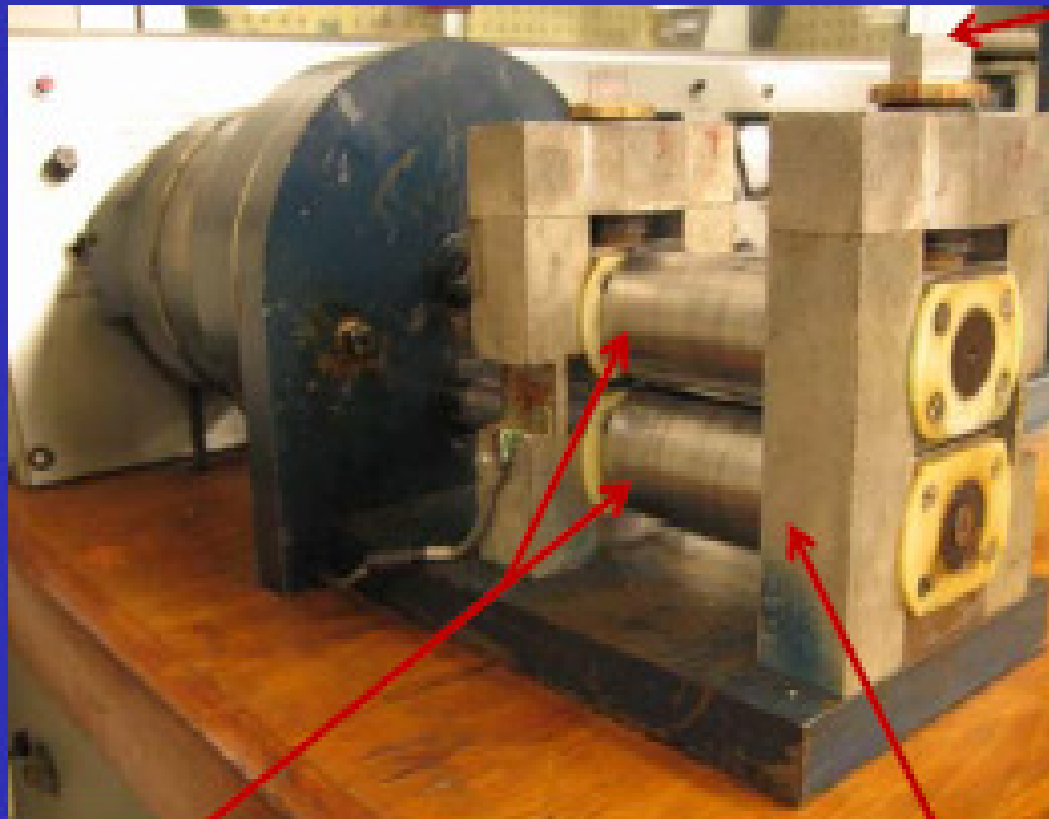
Forming Processes - Rolling -

The gap between the rotating rolls is less than the thickness of the entering bar therefore a friction force is necessary in order to bite the bar and to pull it through the rolls.

A metal bar passing through the rotating rolls is squeezed, and it elongates while its cross section area decreases.



Equipment – Picture 1



Adjusting
Screw

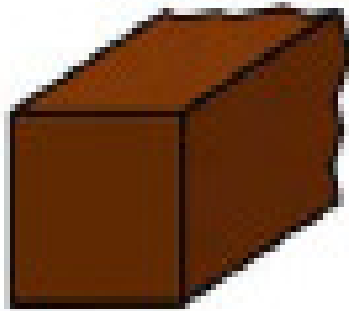
Rolls

Rolls Housing/ Stand

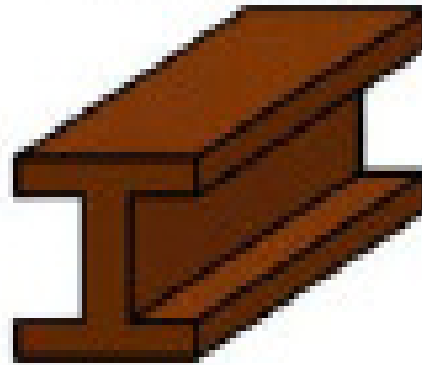
Intermediate rolled form

Final rolled form

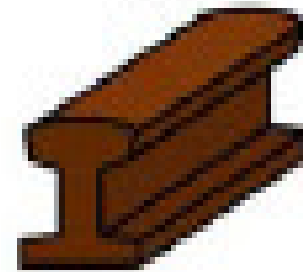
Bloom



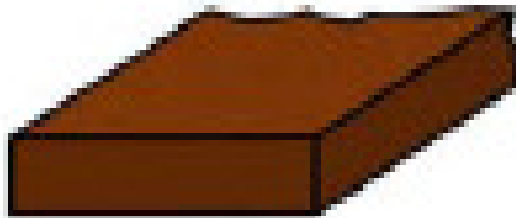
Structural shapes



Rails



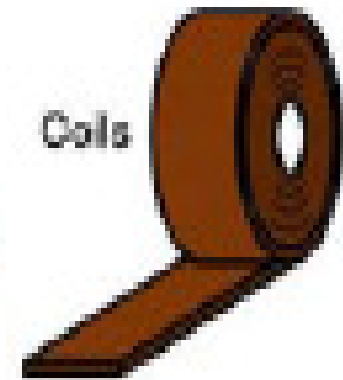
Slab



Plates, sheets



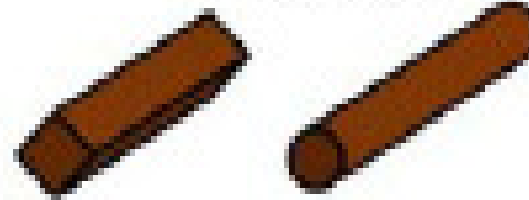
Coils



Billet



Bars, rods



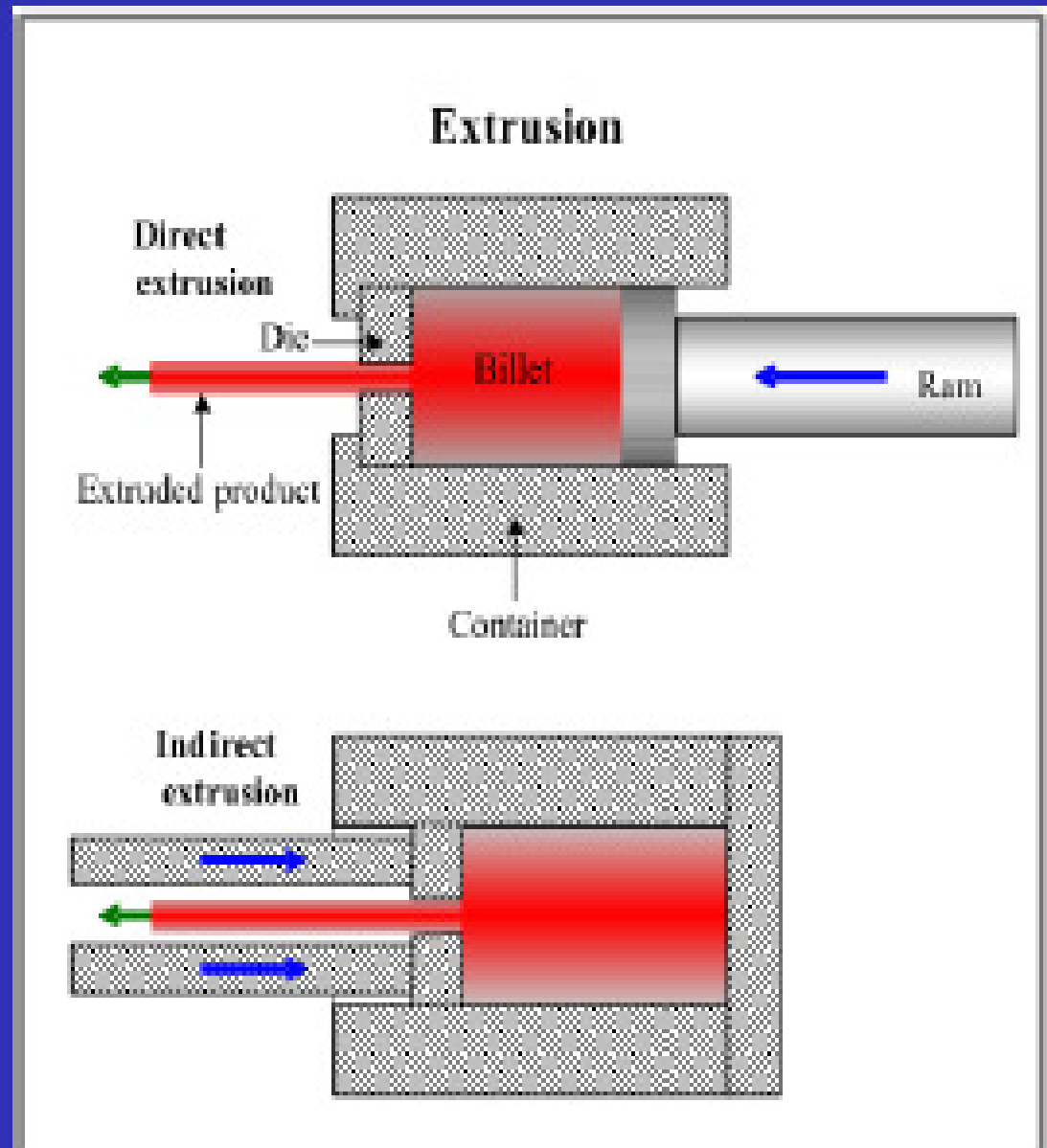
Rolling Mills

- **Equipment is massive and expensive**
- **Rolling mill configurations:**
 - **Two-high:** two opposing rolls
 - **Three-high:** work passes through rolls in both directions
 - **Four-high:** backing rolls support smaller work rolls
 - **Cluster mill:** multiple backing rolls on smaller rolls
 - **Tandem rolling mill:** sequence of two-high mills

Forming Processes - Extrusion -

Extrusion is a metal forming process involving shaping a metal billet (hot or cold) by forcing it through a die with an opening.

The two possible schemes of extrusion are presented in the picture:

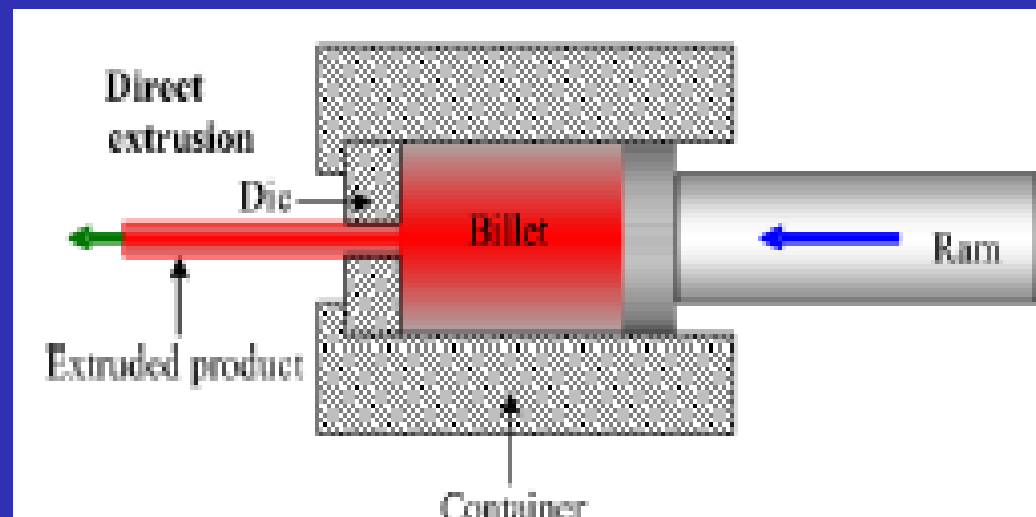


Forming Processes - Direct Extrusion -

The metal billet is placed to the container of the extrusion press. The die with an opening is mounted at the end of the container.

When the hydraulically driven ram presses the billet, the metal starts to flow through the opening forming the extruded product of the required cross section.

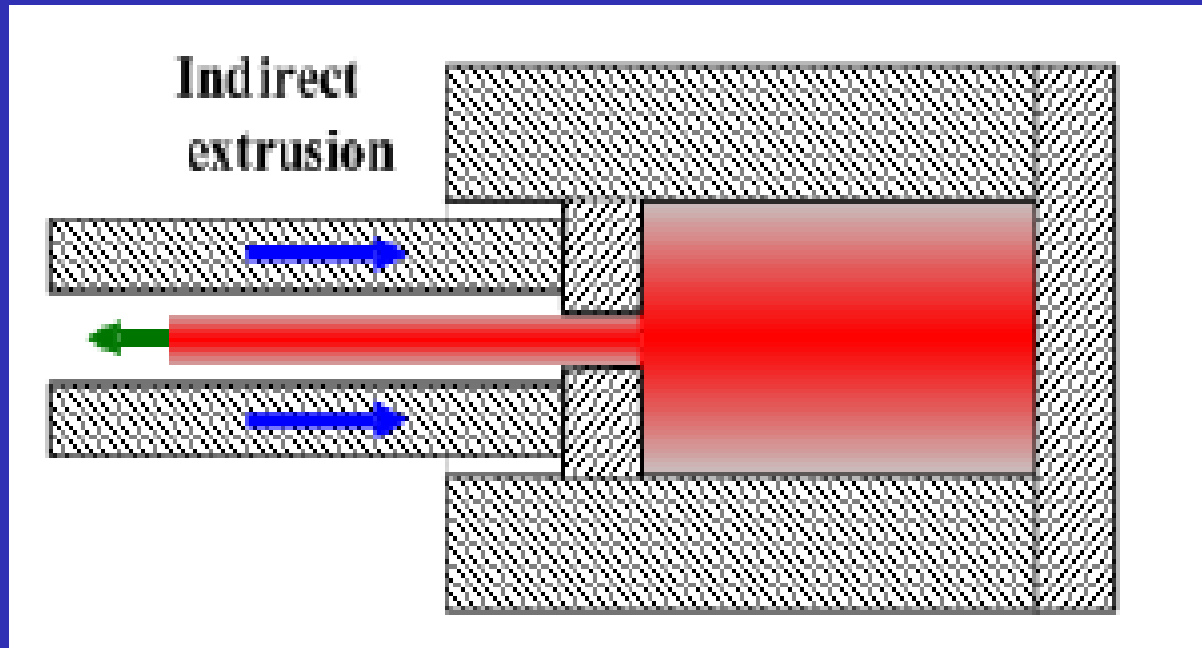
In the direct extrusion the extruded metal flows in the direction of the ram motion.



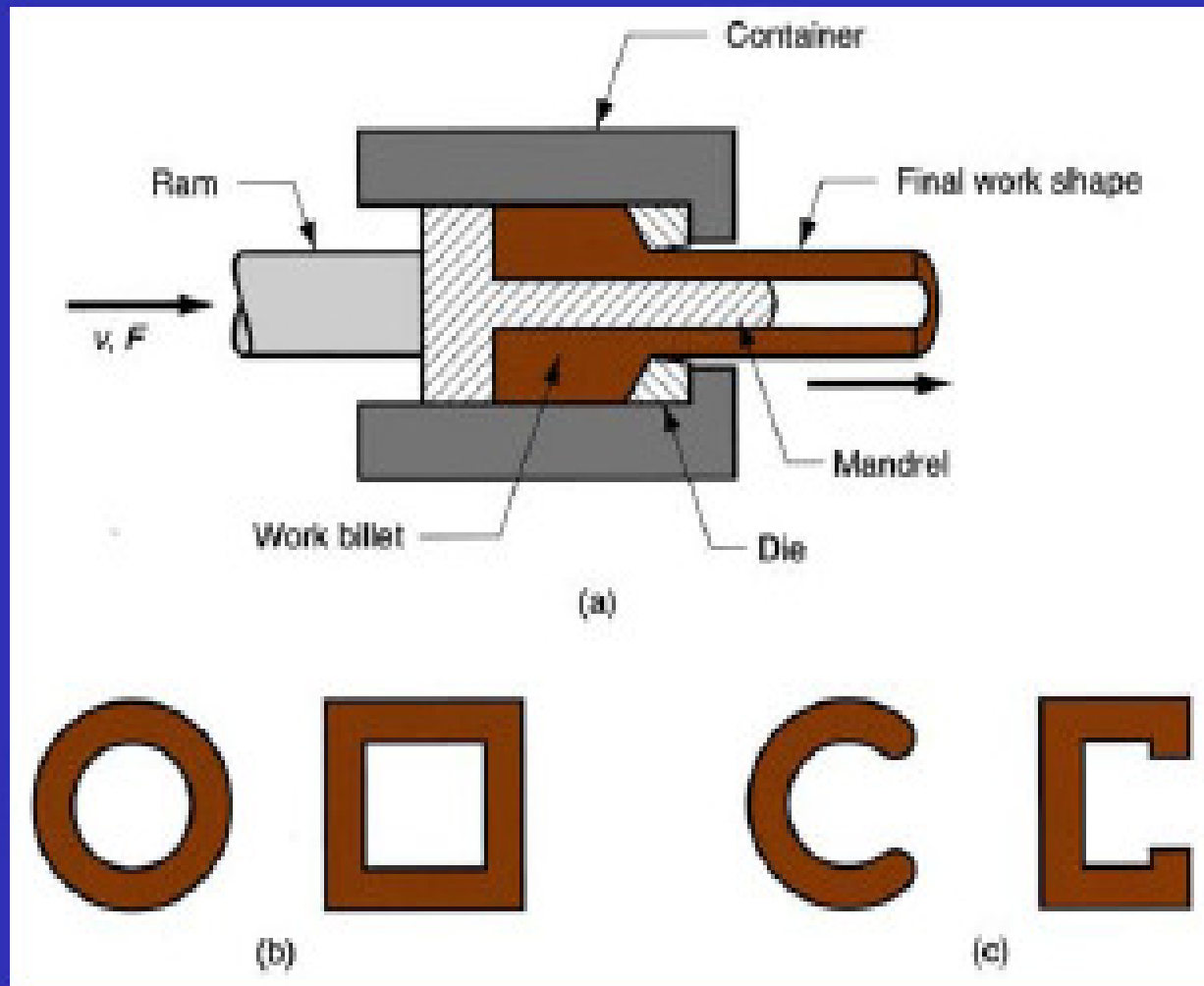
Forming Processes - Indirect Extrusion -

In the indirect extrusion the metal flows in the direction opposite to the ram motion.

Indirect extrusion requires a lower force than direct process as there is no friction between the billet and inside walls of the container.



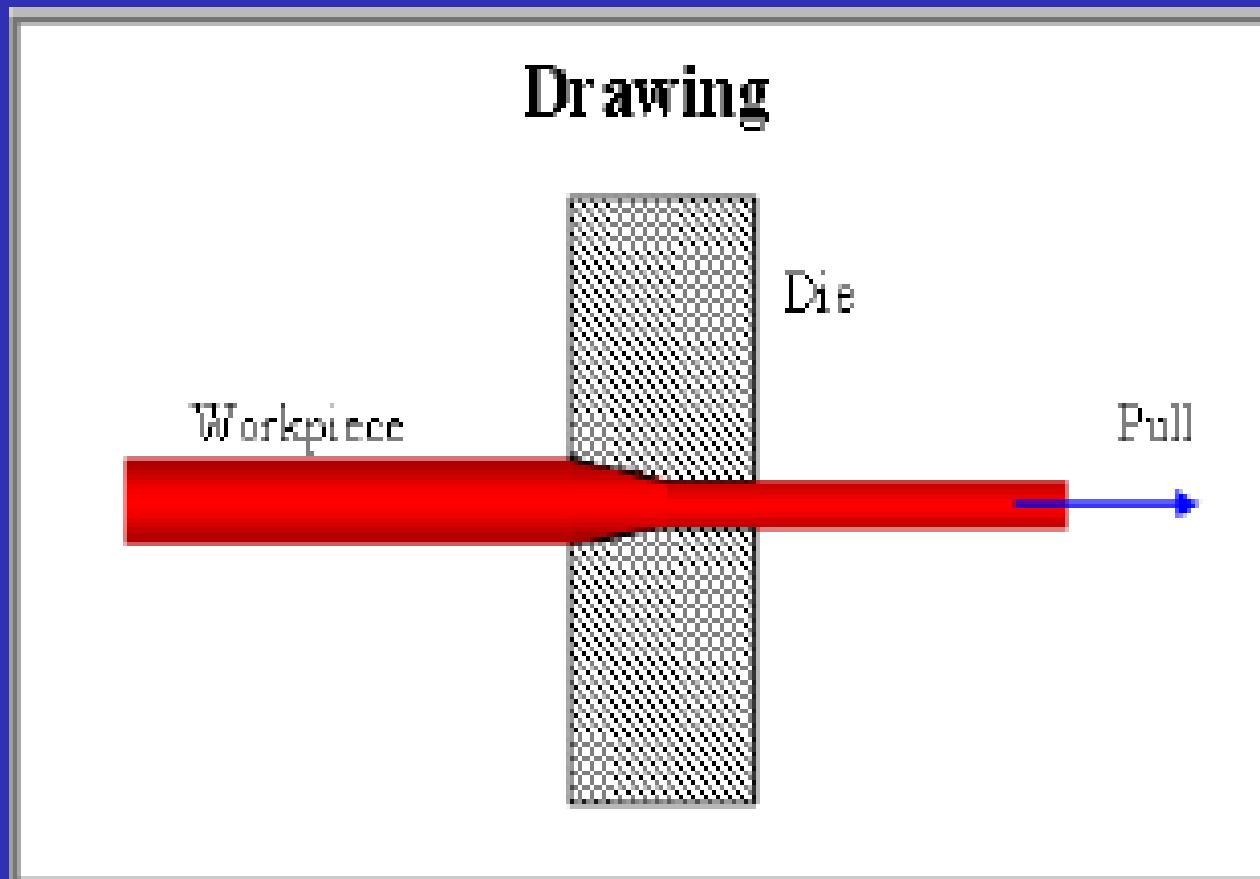
Hollow and Semi-Hollow Shapes



(a) Direct extrusion to produce a hollow or semi-hollow cross sections; (b) hollow (c) semi-hollow cross sections.

Forming Processes - Drawing -

Drawing is a metal forming process involving pulling a workpiece (cold or hot) through a die providing reduction of the cross section of the workpiece.



Forming Processes - Drawing -

Drawing is the process most commonly used to make **wires** from round bars; this process is very similar to extrusion, except that instead of pressure from the back end, in drawing, the wire is pulled from the side where it emerges from the circular die.

Dies are made of specially **hardened tool steels**, or tungsten carbide. Diamond dies are used for drawing very fine wires. Drawing may be hot (the stock is heated to a high temperature for processing), or cold (the stock is not heated).

Safety Rules for Smithy shop

- One should not touch the job with bare hands unless it is at room temperature.
- One has to wear tight cloth and shoes.
- One has to hold the job tightly and keep it flat on the face of the anvil.

Safety Rules for Smithy shop

- One has to examine the hammer to make sure that it is in working order.
- Job should be tightly held in vice before starting work.
- Check if the hacksaw blade is fitted properly.
- wear safety shoes, hand gloves, gloves, goggles for eye protection.
- first aid for burn injury should be available.