Forging

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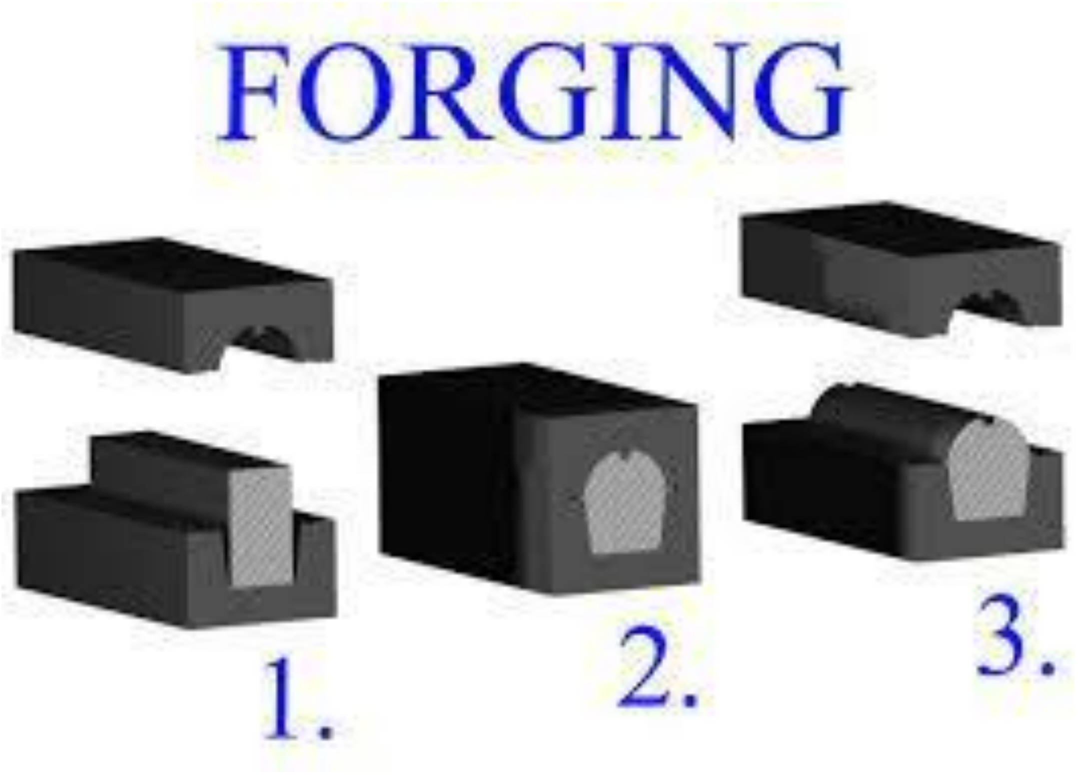
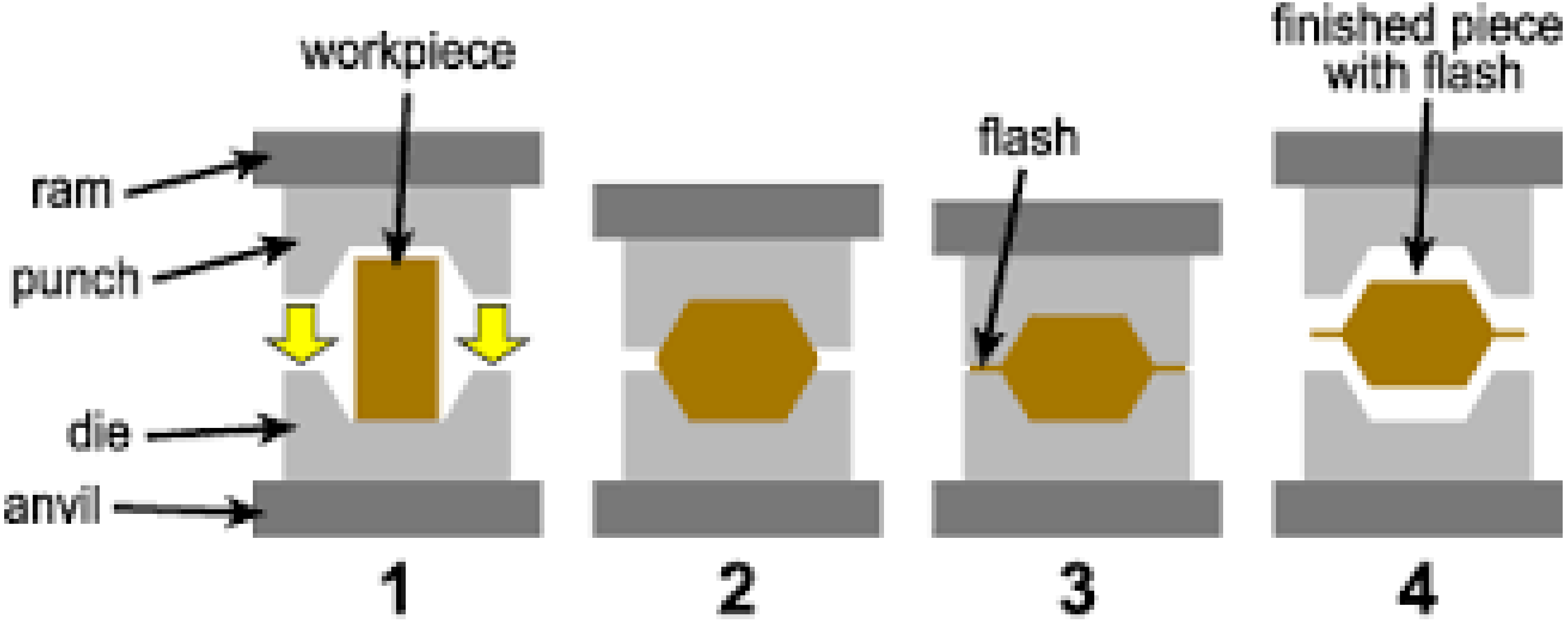
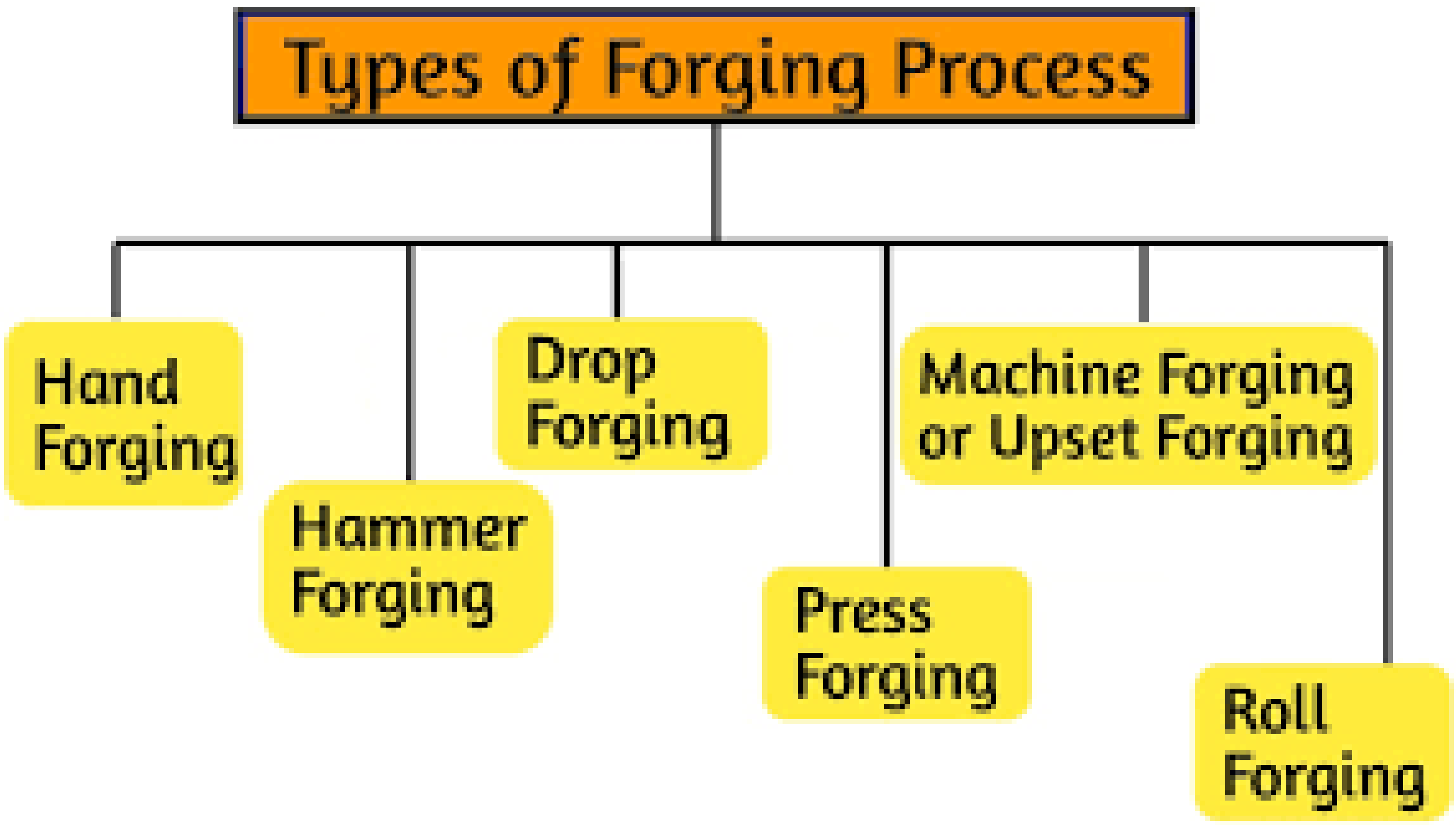
FORGING

- Forging is a metal working process that manipulates, shapes, deforms, and compresses metal to achieve a desired form, configuration, or appearance outlined by a metal processing design or diagram. Depending on the type of metal and the requirements of the design, the forging process can be completed using either hot or cold forging processes.

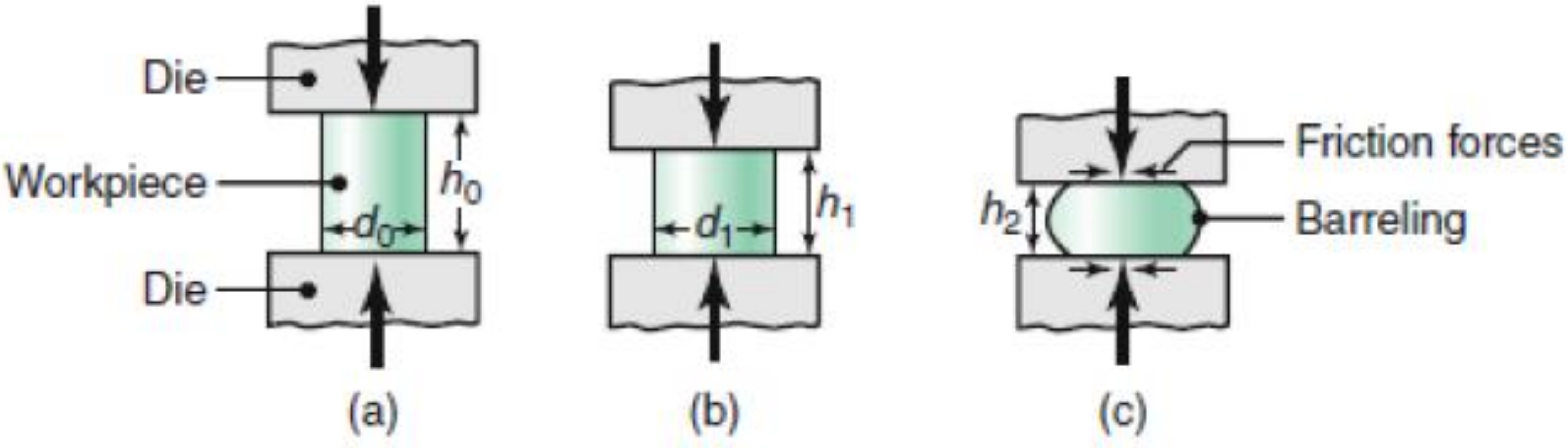



workpiece
ram
punch
die
anvil
1
2
flash
3
finished piece
with flash
4


Types of Forging Process
Hand Forging
Hammer Forging
Drop Forging
Press Forging
Machine Forging or Upset Forging
Roll Forging

OPEN-DIE FORGING

Open-die forging is a hot forging process in which metal is shaped by hammering or pressing between flat or simple contoured dies. In open die forging the dies do not completely cover the workpiece. Instead, there are open spaces that allow various aspects of the workpiece to move from direct hot die contact, and to cooler open areas. In this type of forging, metals are worked above their recrystallization temperatures. Because the process requires repeated changes in workpiece positioning. The workpiece cools during open die forging below its hot-working or recrystallization temperature. It must be reheated before forging can continue.



Operations performed on open die presses

1. Drawing out or reducing the cross-section of an ingot or billet to lengthen it.
2. Upsetting or reducing the length of an ingot or billet to a larger diameter.
3. Upsetting, drawing out, and piercing-processes sometimes combined with forging over a mandrel for forging rough-contoured rings. Practically all forgeable ferrous and non-ferrous alloys can be open-die forged, including some exotic materials like age-hardening super alloys and corrosion-resistant refractory alloys.

Applications

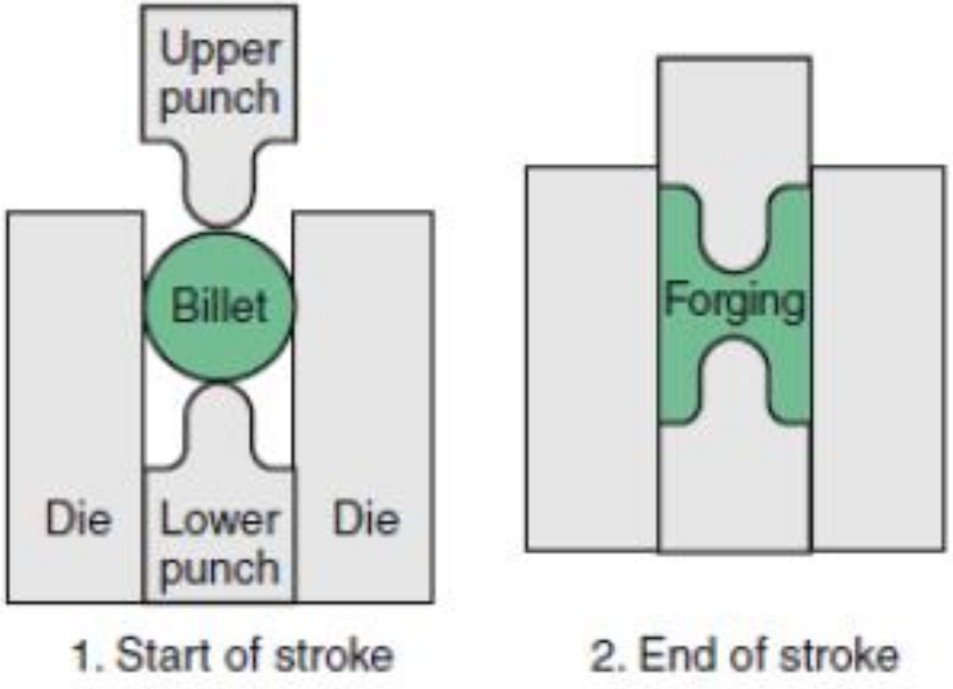
Open-die processes can produce:

1. Step shafts, solid shafts (spindles or rotors) whose diameter increases or decreases at multiple locations along the longitudinal axis.
2. Hollow cylindrical shapes, usually with length much greater than the diameter of the part Length, wall thickness, internal and outer diameter can be varied as needed.
3. Contour-formed metal shells like pressure vessels, which may incorporate extruded nozzles and other design features.

CLOSED-DIE FORGING

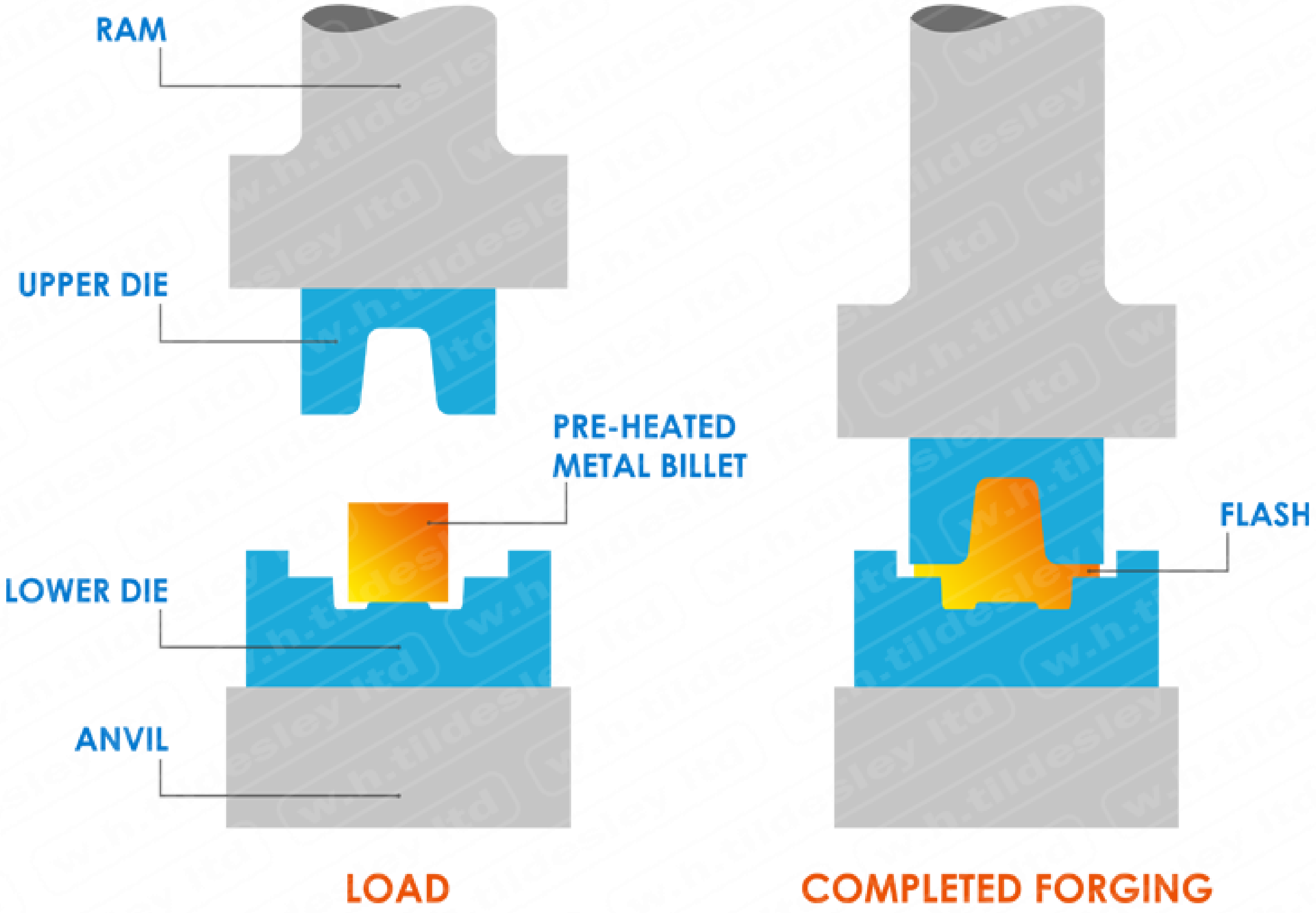
In closed-Die Forging, no flash is formed and the workpiece is completely surrounded by the dies. In this process, a billet with carefully controlled volume is deformed (hot or cold) by a punch in order to fill a die cavity without any loss of material. Therefore, proper control of the volume of material is essential to obtain a forging of desired dimensions.

Undersized blanks in closed-die forging prevent the complete filling of the die, while oversized blanks may cause premature die failure or jamming of the dies.



Drop Forging

- Drop forging is a metal forming process.
- A workpiece is inserted into a die and then hammered until it has assumed the shape of the die.
- The lower die is a stationary part, while the upper part is a moving hammer dropped onto the workpiece in order to deform it.
- Drop forging can be performed both at high or ambient temperature.
- This manufacturing process has a long tradition in the metal shaping industry and it has been used for hundreds of years.
- The mechanics of the process are still the same, but all involved machinery has greatly advanced to turn drop forging into a high-precision manufacturing process.
- Similar to all other forging techniques, drop forging enhances the material properties of the final piece.


RAM
UPPER DIE
PRE-HEATED
METAL BILLET
LOWER DIE
ANVIL
LOAD
FLASH
COMPLETED FORGING

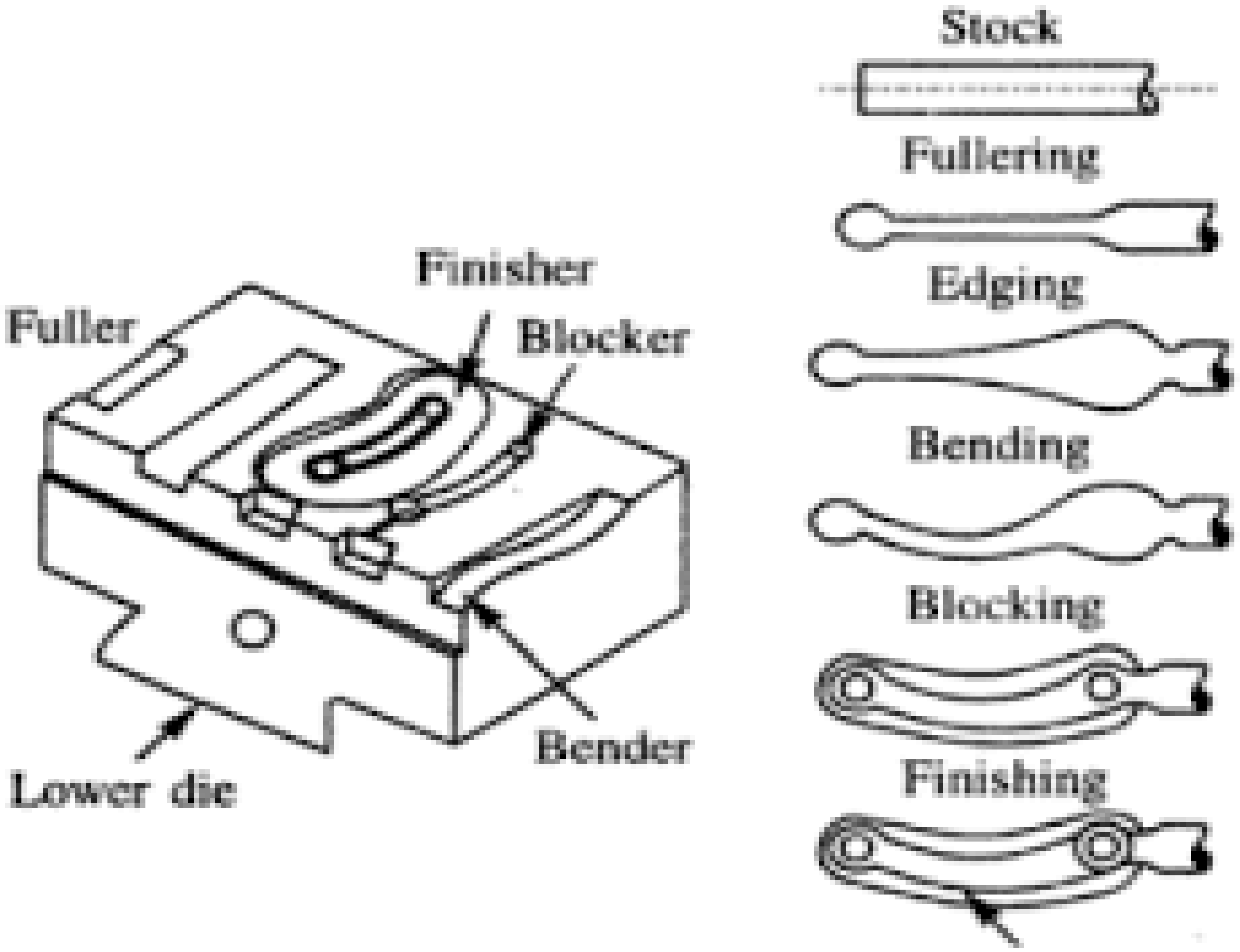
Benefits of Drop Forging

- Good surface finish
- Enhanced mechanical properties
- Recyclable flash
- Improved metal strength by aligning the grain along the lines of potential stress

Typical Drop Forged Components

- Railroads
- Crankshafts
- Levers
- Gears
- Connecting rods
- Spanners
- Pedal cranks
- Gear blanks

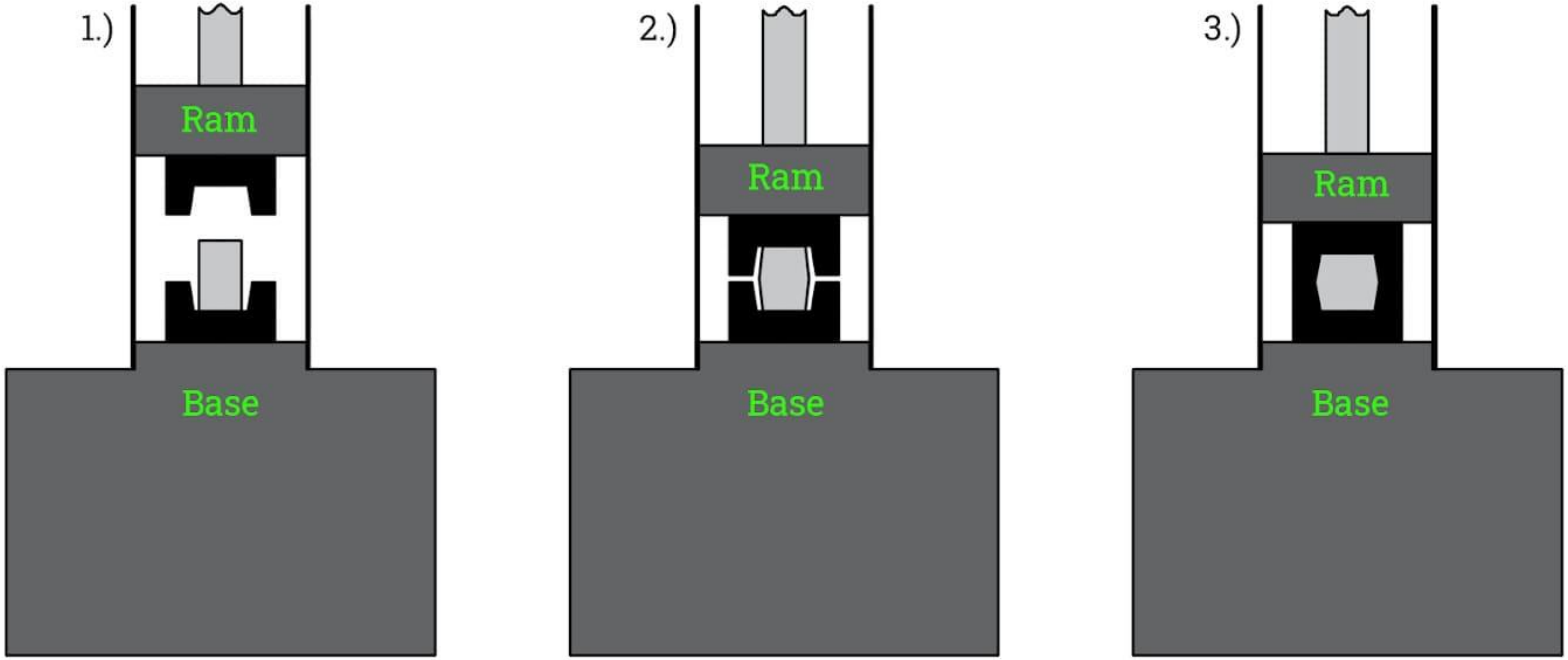
Stock material to Lever by Drop forging


Fuller
Finisher
Blocker
Bender
Lower die
Stock
Fullering
Edging
Bending
Blocking
Finishing

Press Forging

- A forging press uses a vertical ram to apply gradual, controlled pressure to a die holding a workpiece.
- It is a similar process to drop forging, but it uses slow pressure instead of a series of blows.
- The slow movement of the ram penetrates deeper into the workpiece so that the workpiece undergoes uniform plastic deformation.
- Press forging dies can be open or closed. In open die forging, the die does not completely enclose the work-piece.
- In the closed die method, also known as impression die forging, the die completely surrounds the workpiece.

Forging Press Process



Force Moves The Upper Die Toward The Billet

The Downward Pressure Deforms The Billet

The Mold Closes Over The Billet To Complete The Forging Process

Types of Forging Presses

The three main types of forging presses used for press forging are listed below:

- •Mechanical Press – converts the rotation of the motor into linear motion of the ram.
- •Hydraulic Press – hydraulic motion of the piston moves the ram.
- •Screw press – screw mechanism actuates the ram movement.

Advantages of Press Forging

- •Deforms the work piece completely
- •Compression rate of the work piece can be controlled
- •More economical for high volume productions
- •Any size and shape can be created
- •Requires less draft and produces lesser scrap.

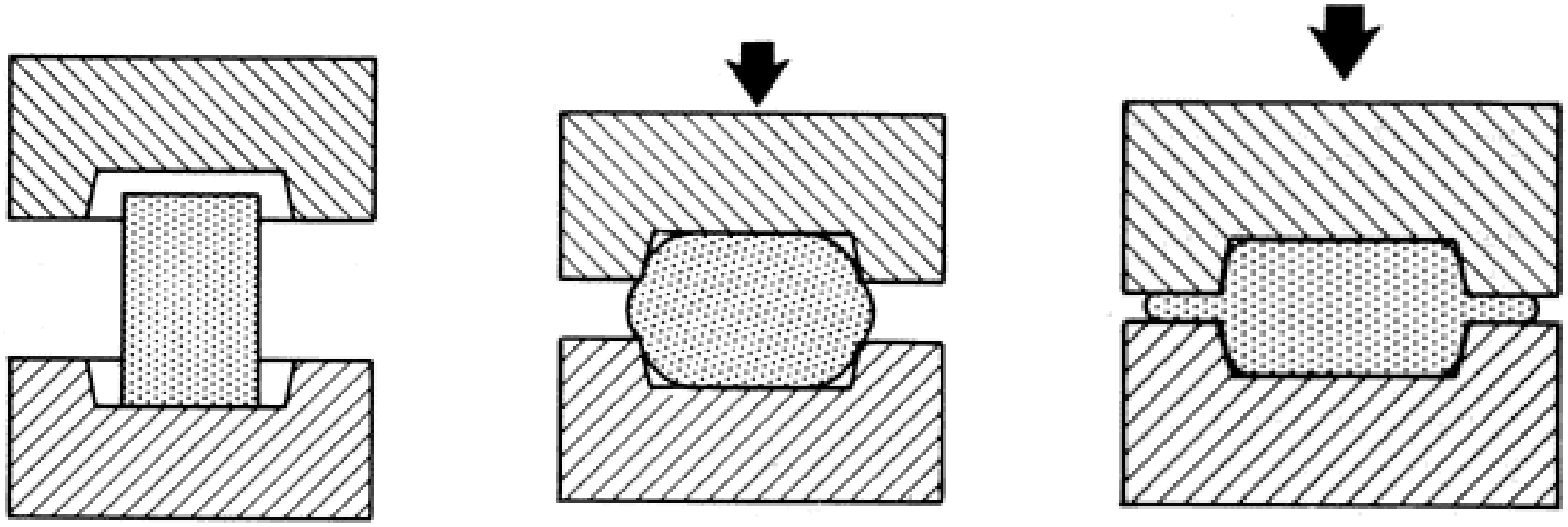
Industrial Applications

- Making of coins and silver articles
- Automatic forging.

Impression Die Forging

- Impression die forging is a metal deformation technique in which a billet is compressed between two sets of die to form a complex part.
- “Impression” refers to the pre-cut profile of the dies used during the forging process, which are customized based on the part that is being produced.
- During the impression die forging process, a pre-cut billet that’s been heated to a pre-determined temperature is placed between two sets of custom dies/tooling.
- As previously mentioned, each die contains a pre-cut profile (or cavity) that resembles what the final product will look like.
- The billet then undergoes controlled deformation as it is compressed between the two dies.
- Depending on the forging being made, there may be more than one set of dies involved in the process.
- While the billet is being compressed, excess metal (flash) will flow and cause pressure to build up within the die.
- Since flash cools down more quickly than the metal inside the die, it blocks more hot metal from escaping and turning into more flash.
- This also ensures that the remaining hot metal fills up the die and creates a more uniform product.
- Once this forging process is complete, the flash is removed, and the final product is left to cool.
- Once the forging has cooled, it’s cleaned off and inspected.

Impression Die Forging process

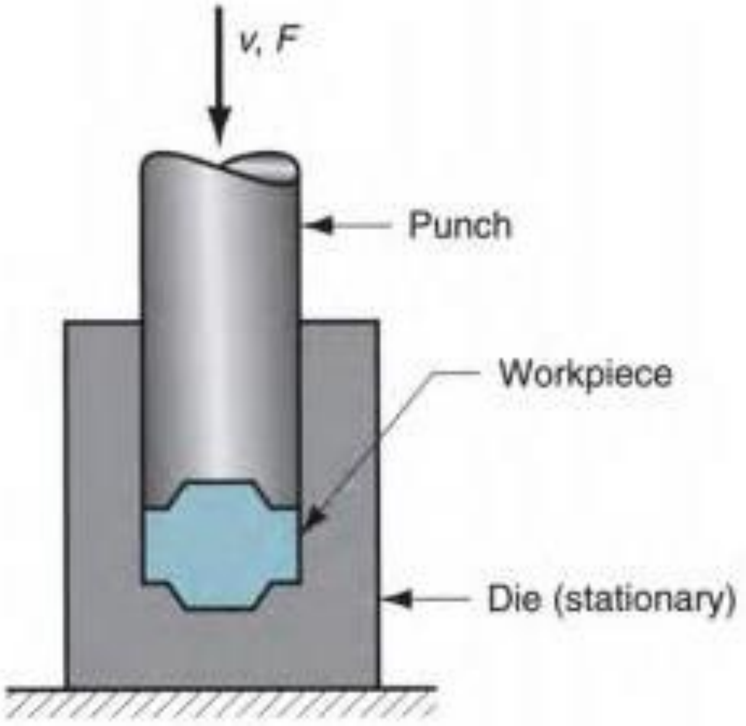


Advantages

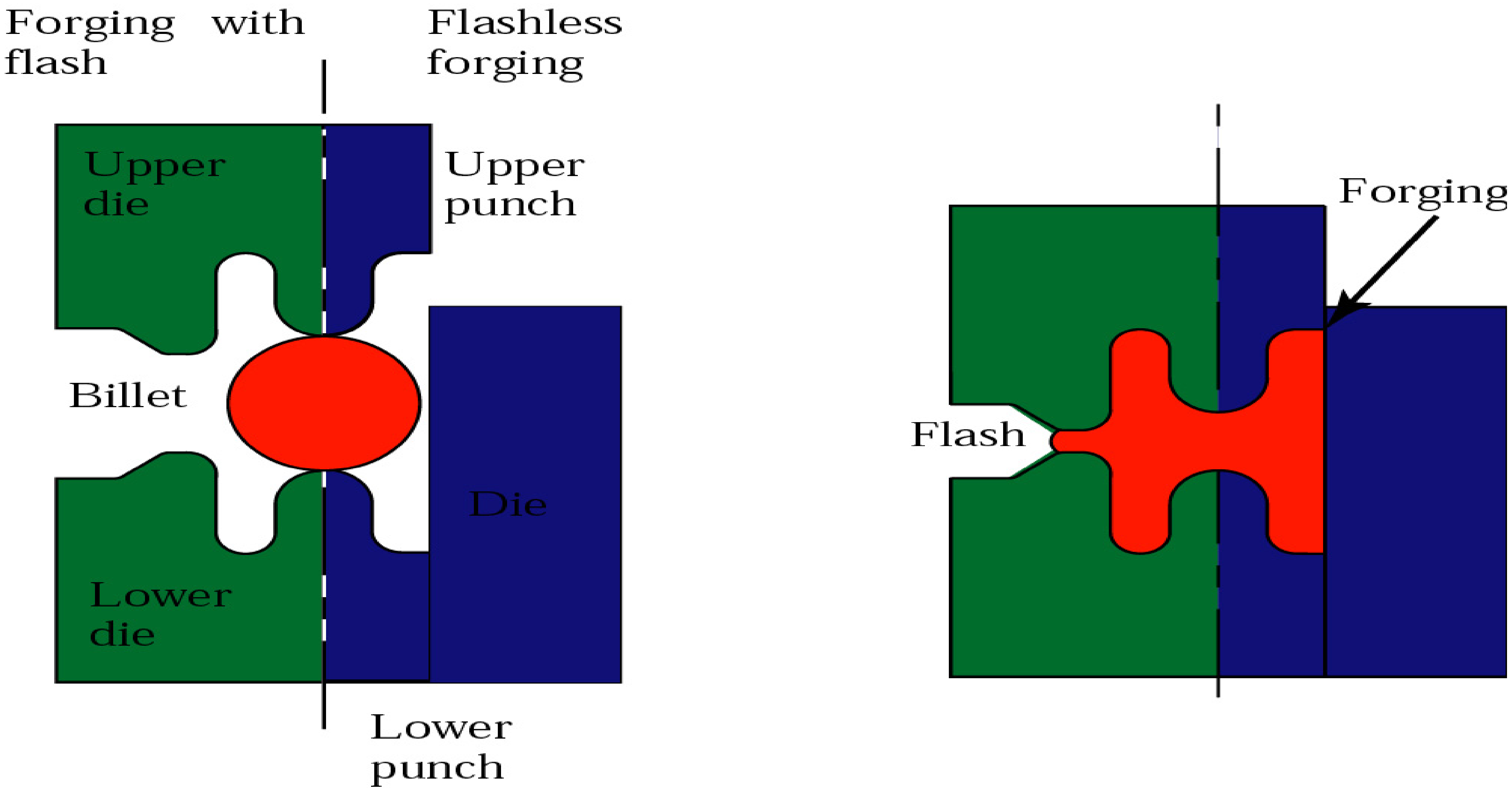
- Impression die forging is very effective for shaping aluminum, steel, titanium, and a wide range of metal alloys.
- By enclosing the hot metal inside sets of dies, many kinds of complex three-dimensional shapes can be produced.
- This includes simple forms such as cubes, disks and spheres, but it can also be applied to multi-section parts that incorporate thin delicate webs and long, spindly shapes.
- Impression die forging is also useful for parts with holes, pockets and protrusions, and even asymmetrical parts can be produced through this process.
- Thanks to this forging process, high-quality components can be manufactured at a relatively reasonable cost.
- The resulting parts resist both fatigue and impact, are very durable and have higher strength-to-weight ratios.
- Sometimes, these parts are up to 20% stronger than those produced by other forging methods.
- Impression die forging also generates less wasted metal, and this refined method is capable of higher production rates than other techniques.

Precision Forging

- Precision forging is an innovative manufacturing process for the flashless, near-net shape production of high-performance components.
- Outstanding material characteristics as well as a reduced process chain and a high material efficiency are the essential advantages of precision forging.
- Precision forging is worked in a close to final shape or close-tolerance forging way.
- It is a refinement forging techniques compare to traditional closed die forging technology.
- When you need a product with near net shape or net shape, precision forging is the right choice to source, such forging technic will refine the product to little or no machining.



Conventional vs Precision Forging



(a) Start of stroke

(b) End of stroke

Advantages

- High material utilization. As there is no flash in precision forging, according to the designed processes, material will be forged into desired shape after plastic deformation.
- Good working performance. Parts produced by precision forging, the metal fiber is evenly distributed along the contour shape, dense and continuous.
- For precision forgings without flash, there will not exist leakage of metal fiber that caused by removing flash, this will be good for improving stress corrosion resistance and fatigue resistance of products.
- Complicated shape parts are available in precision forging.
- High precision. After precision forging, we will get net or near net shape products, such high precision will require just very little or even no machining job.

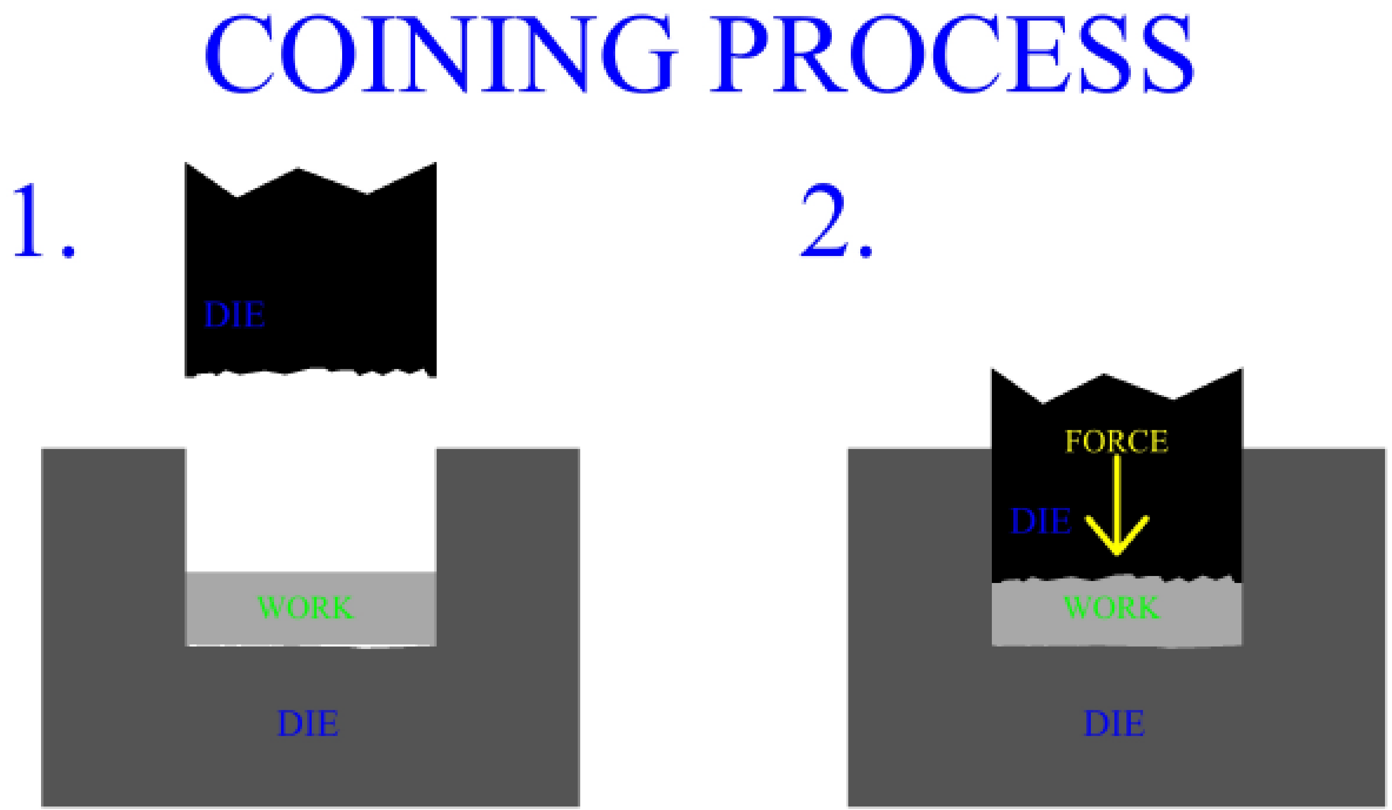
Grain Flow

The grain flow in metal refers to the directional orientation of the metal grains, which is an important factor in determining the mechanical properties of the metal.
In summary, the main difference between the grain flow in forging and casting is that forging results in a continuous, unbroken grain flow that follows the shape of the forging, while casting results in a non-continuous grain flow that depends on the shape and orientation of the casting.

- A casted component does not have uniform grain structure, grain flow, or directional strength.
- During the casting process, slurry is poured into a mold, and as this slurry cools, dendrites form, which eventually turn into grains.
- These grains are not uniform, as some may be small, large, coarse, and/or fine, which results in grain boundary voids.
- When that billet is machined, it often means that the unidirectional grain flow pattern has been cut, and its contour has changed.
- Machining exposes the grain ends and makes the material more prone to sensitive stress, corrosion cracks, and fatigue.
- Forging produces components in which the grains are deliberately aligned in the direction of maximum strength, resulting in exceptional fatigue and impact resistance.
- During the forging process, the metal then undergoes controlled deformation under (typically) elevated temperatures.
- The benefit of forging, when compared to other manufacturing processes, is that grain flow can be controlled.

Coining

- Coining is a closed die forging process, in which pressure is applied on the surface of the forging in order to obtain closer tolerances, smoother surfaces and eliminate draft. Closed die forging is a process in which forging is done by placing the work piece between two shaped dies. This process may be done in hot or cold working conditions, but is predominantly a cold work process.



Technique of Coining

- Completely closed dies are used for this process.
- High pressure is applied on the closed die containing the metal work piece.
- As a result of the high deformative stress, the metal conforms to the shape of the die.
- Coining produces finer details and provides a smooth surface finish to the metal work piece.

Advantages of Coining

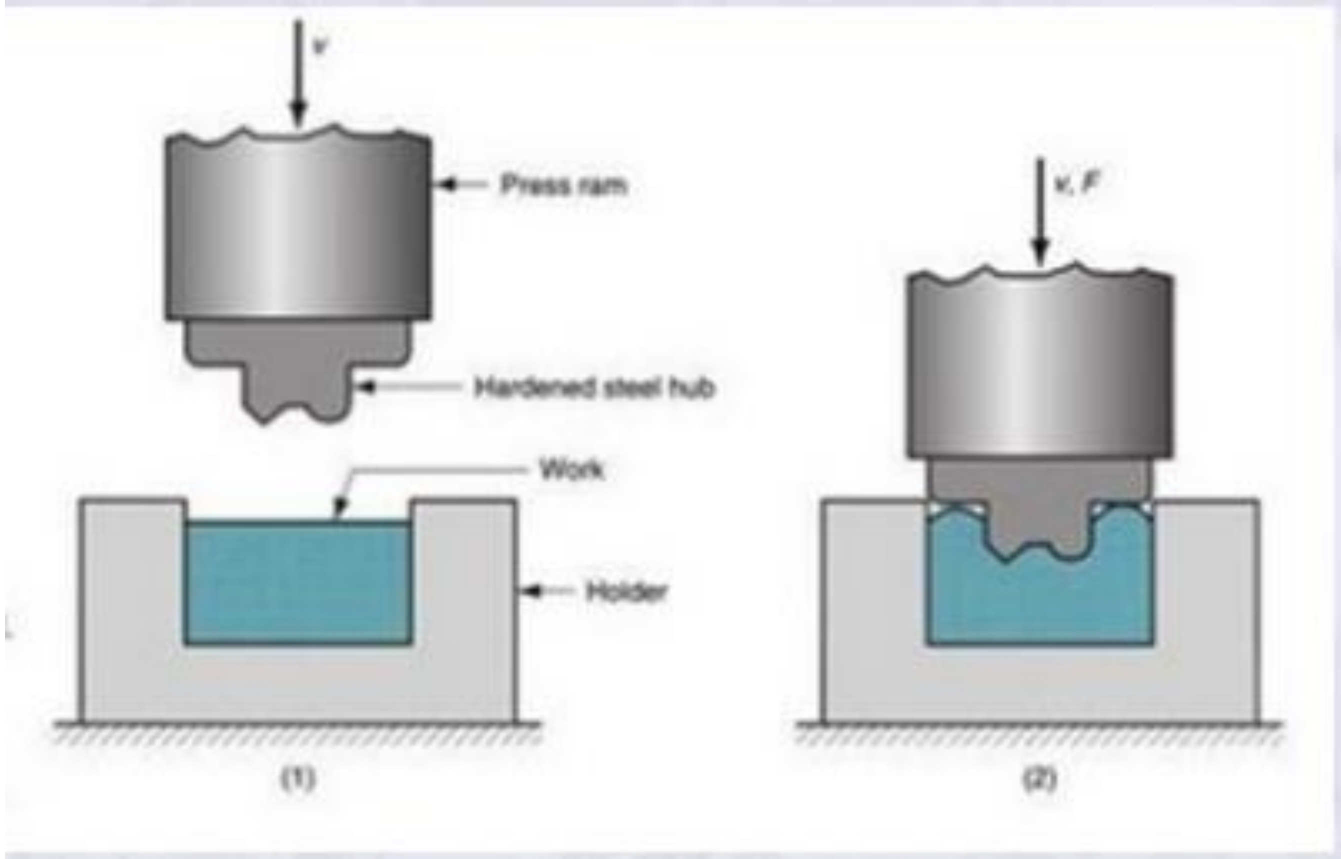
- Produces finer and detailed surface finish
- Provides accurate bends in a consistent manner
- Does not require expensive machinery
- The work hardened surface can resist impact and abrasion
- Eliminates the need for complex finishing processes
- Plastic flow reduces the surface grain size and work hardens the surface.

Industrial Applications

- Minting of coins and medallions
- Making of jewelry
- Making badges, buttons, precision-energy springs
- Making complex electronic parts
- Making precision parts that require finer polished surface finishes.

Coining is a forging process that involves pressing a piece of metal between two dies to produce a specific shape or design with high accuracy and detail. The process is typically used to create coins, medallions, and other small, intricate metal objects.

Hubbing

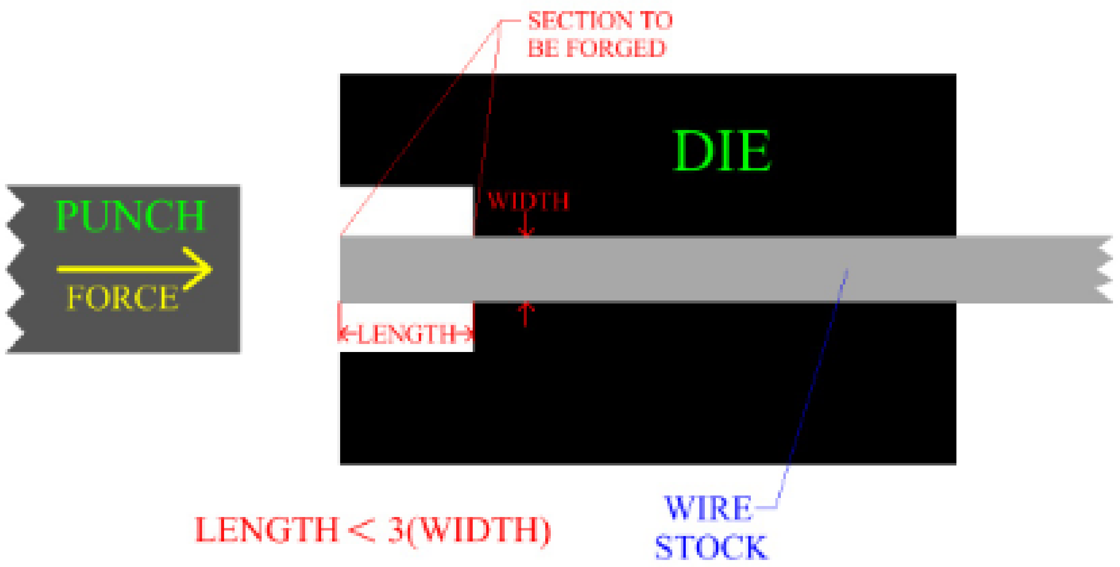


- This process consists of pressing a hardened punch with a particular tip geometry into the surface of a block of metal.
- The cavity produced is subsequently used as a die for forming operations.
- The die cavity usually is shallow, but for deeper cavities, some material may be removed from the surface by machining prior to hubbing.

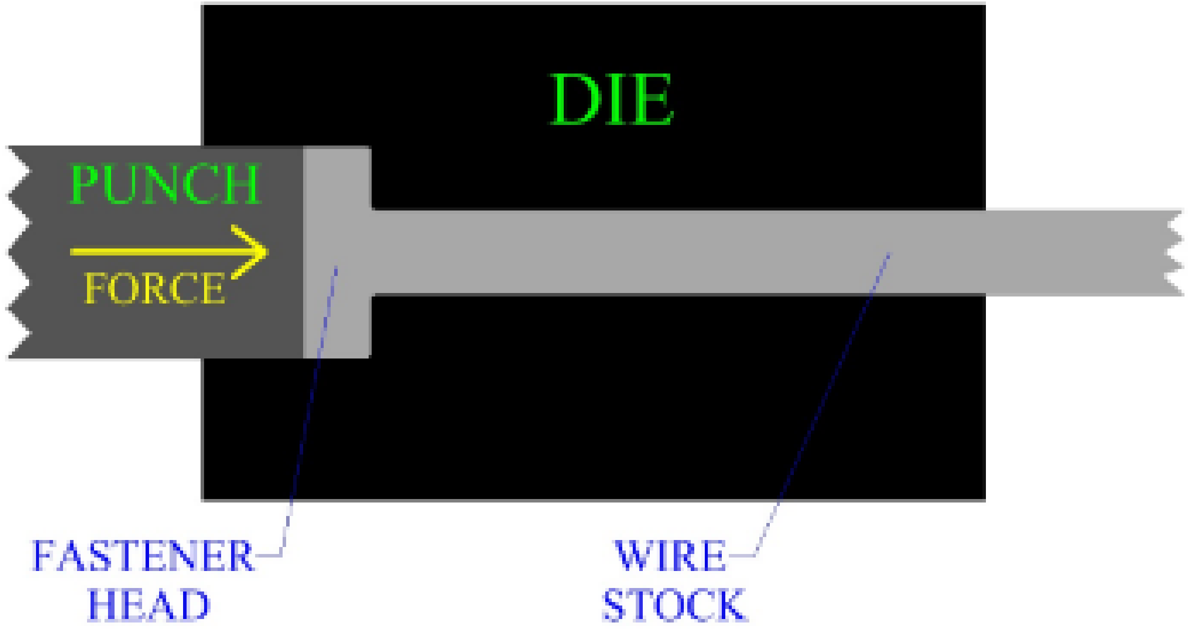
Heading

- Heading or upset forging is a process by which stock, (typically cylindrical), is upset at its end in order to increase the cross section of the material in this area.
- This metal forging process may be hot, but is often a cold working operation.
- Cold working will take advantage of the strengthening of the material in the region worked.
- For typical industrial applications, heading, is mostly performed horizontally, as shown in the diagrams.
- Heading is a manufacturing process used extensively in the production of fasteners that include nails, screws, nuts and bolts.
- Due to the enormous quantity of fasteners produced in modern manufacturing industry, heading is the most commonly used metal forging process in the world today.
- The impression in the head may be forged in either the punch, the die, or both.

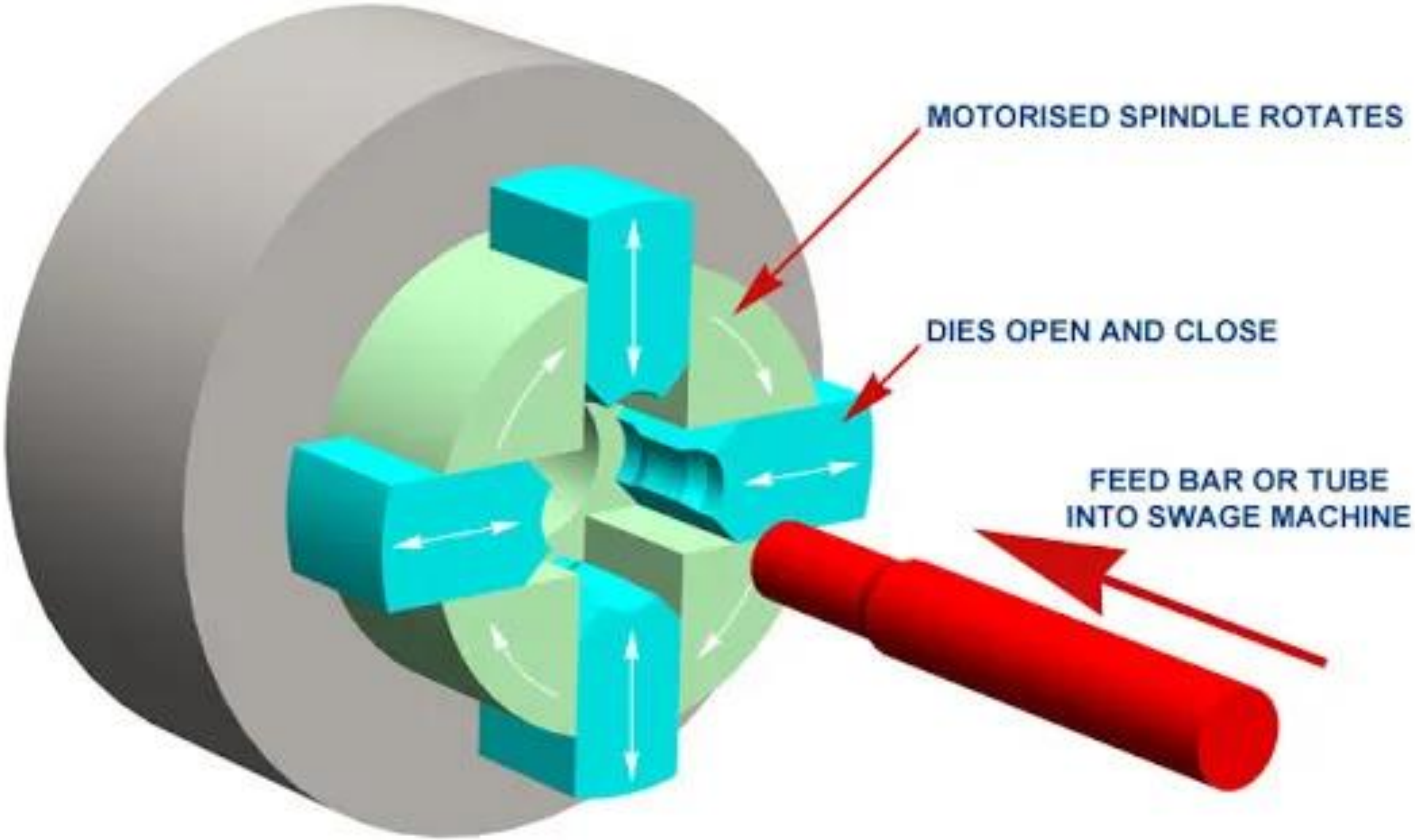
Heading Process

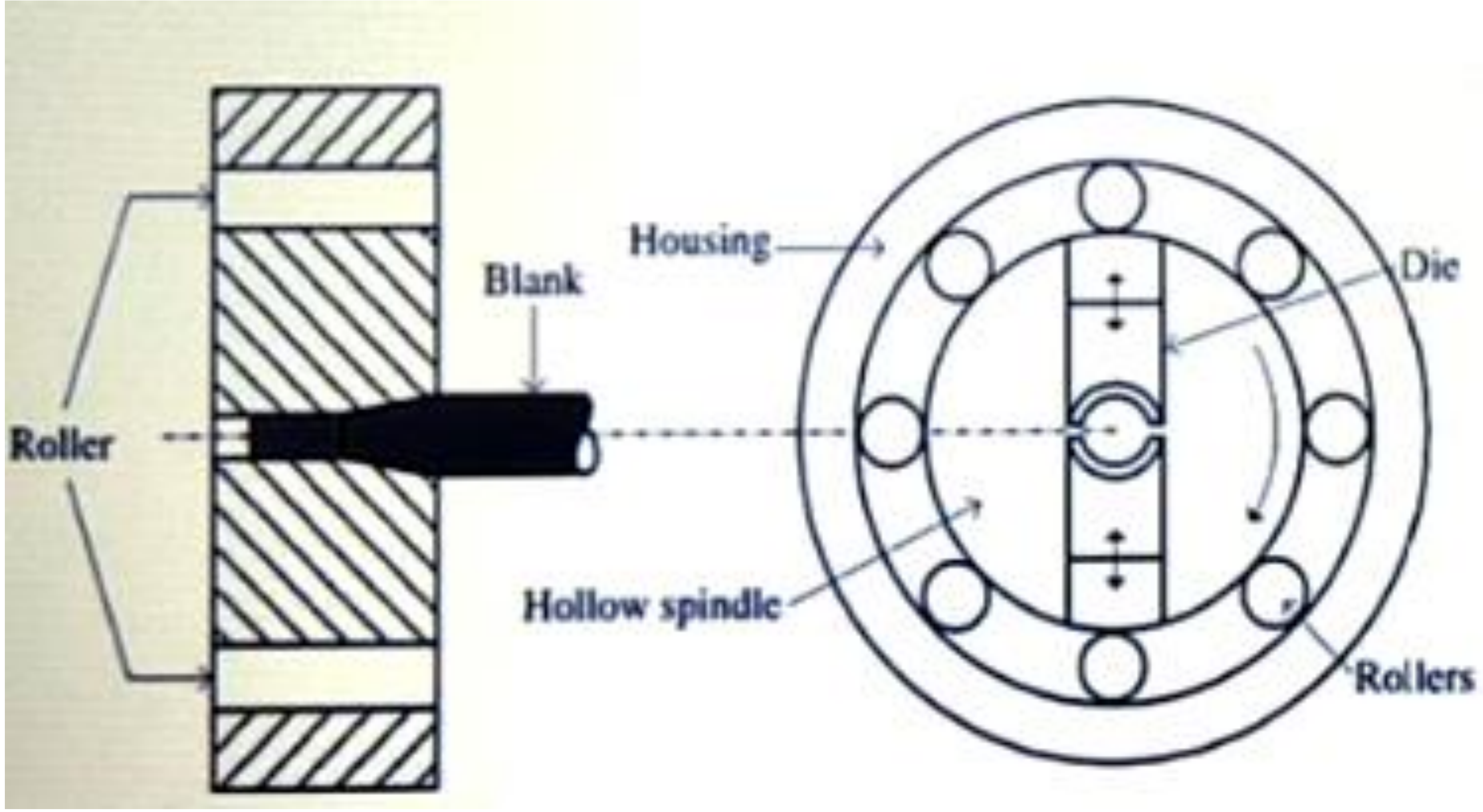


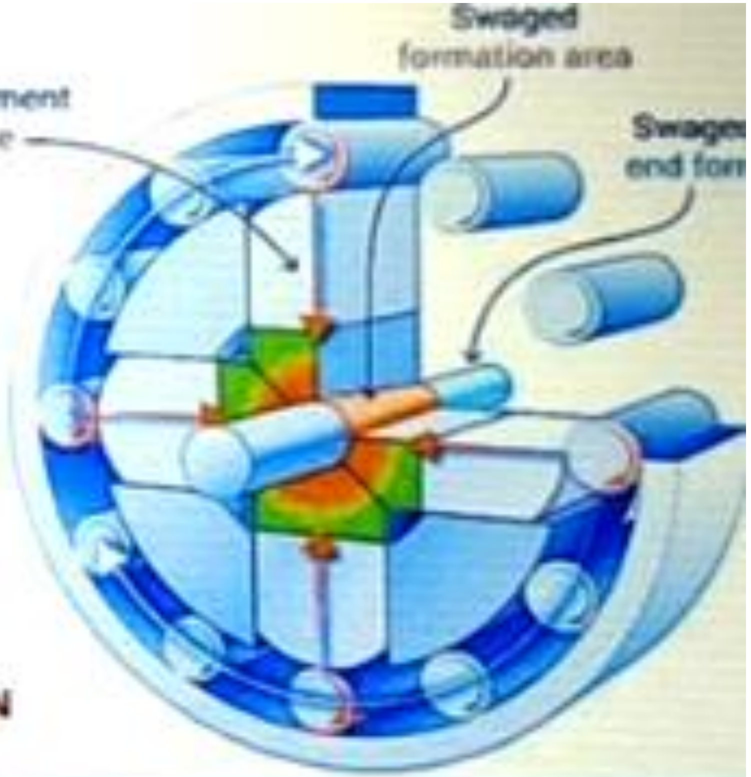
Overall, the heading process is a versatile and efficient forging process used to create complex shapes and features on the end of a metal rod or wire. It is commonly used in the manufacture of fasteners, such as bolts, screws, and rivets, as well as other small metal parts.



Swaging Process




Roller
Blank
Housing
Die
Hollow spindle
Rollers



Housing surrounds spindle & Number of Steel Ball (Rolls) are provided between Spindle and Housing

- It is also known as rotary swaging in which rod or work piece made by other processes is held stationary into a swaging die and a movable die will rotate around it.
- This rotating die has some reciprocating components which allow to strike the work piece at a rate 10 – 20 stroke per second.
- Many blows are required for complete forming of work piece.
- It will form a cavity according to the die on the work piece.
- This process is mainly used to point the end of the work piece or convert the end into desire shape as required in screw drivers, small hand tools etc.
- It is also used to produce hollow drive shaft, shock absorber etc.

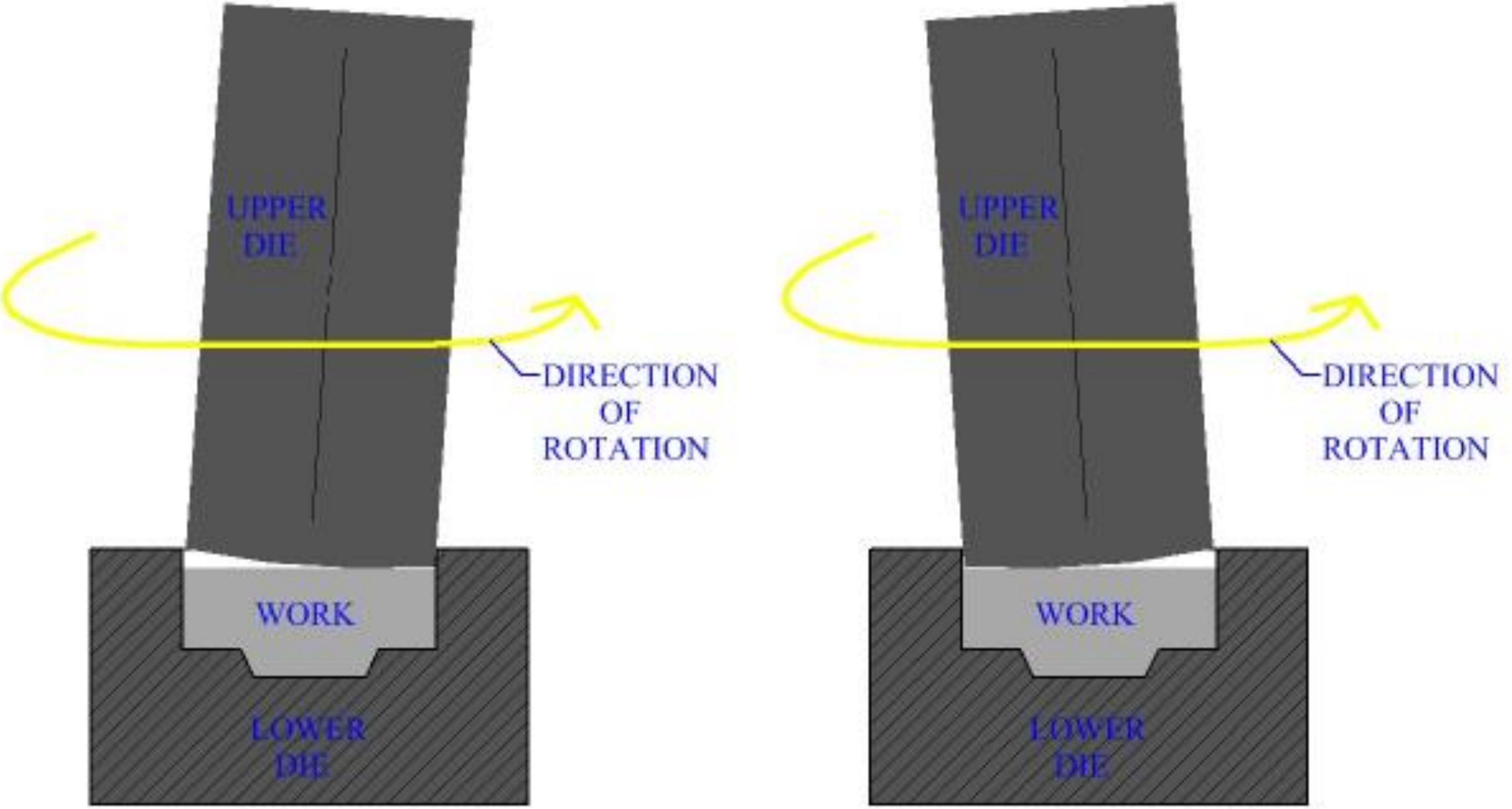
Advantages:

- It can use for mass product.
- The process is easy and does not require any skilled operator.
- Low manufacturing cost.
- High surface finish.
- No material wastage because it does not form any chips.
- High accuracy can obtain by this process.
- Any material can be formed by this process.

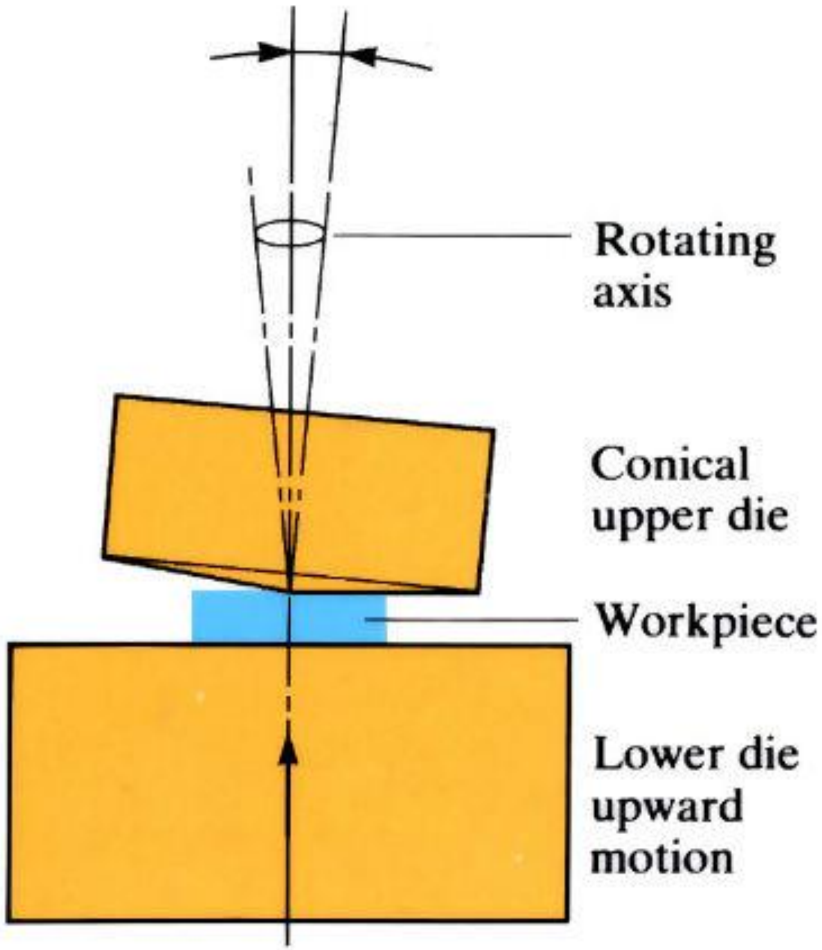
Disadvantage:

- It is noisy operation.
- This process is limited according to diameter of rod and die.

ORBITAL FORGING

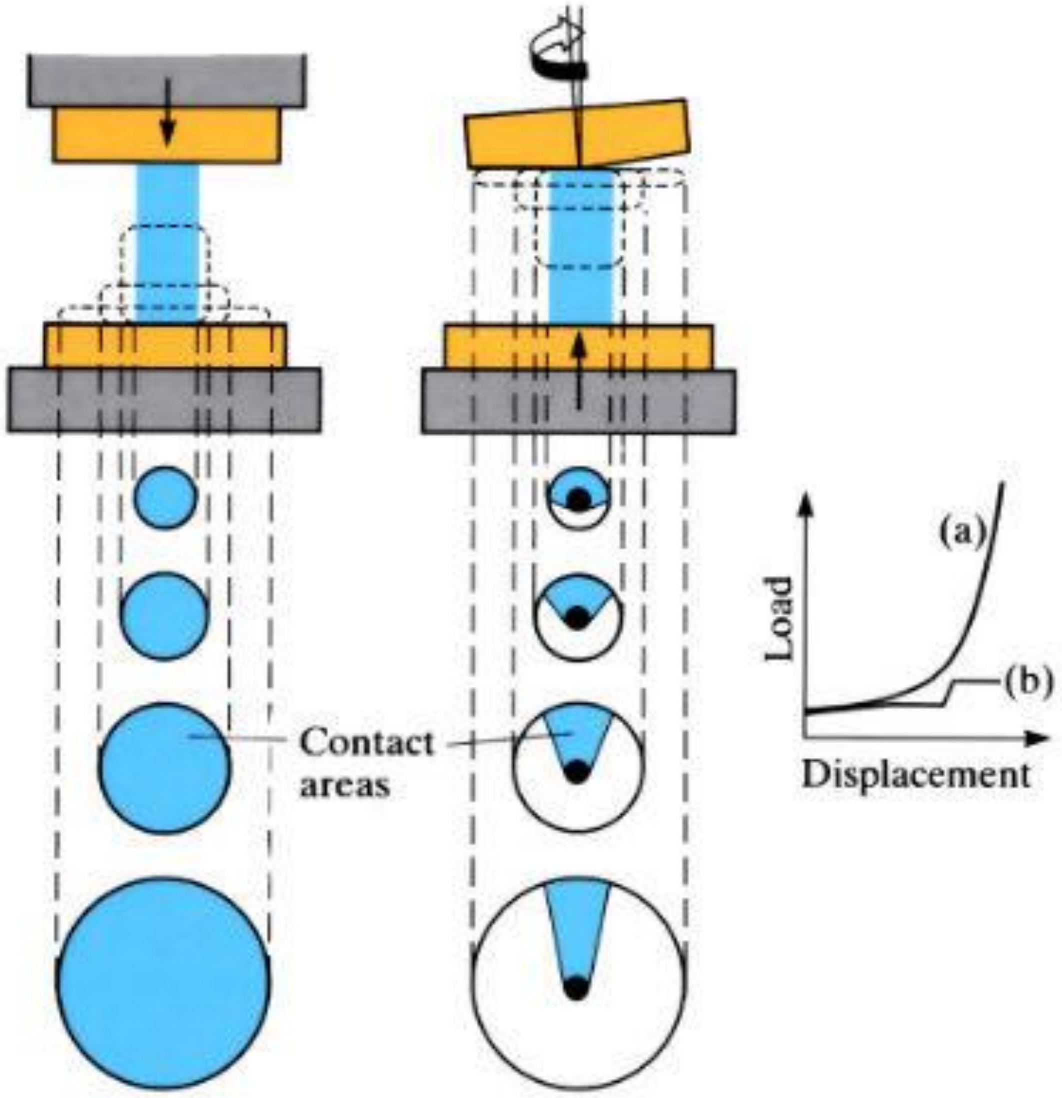


- Orbital forging is a manufacturing process by which a part is held in a forging die cavity and forged by compressive forces applied through the upper die.
- The upper die applies these forces as it travels in an orbital path.
- This upper die revolves on an inclined axis, and thus through its revolution it will only apply force to a small portion of the work at a time.
- Forging force will be administered to the entirety of the work with the completion of a revolution of the upper die on its inclined orbit.



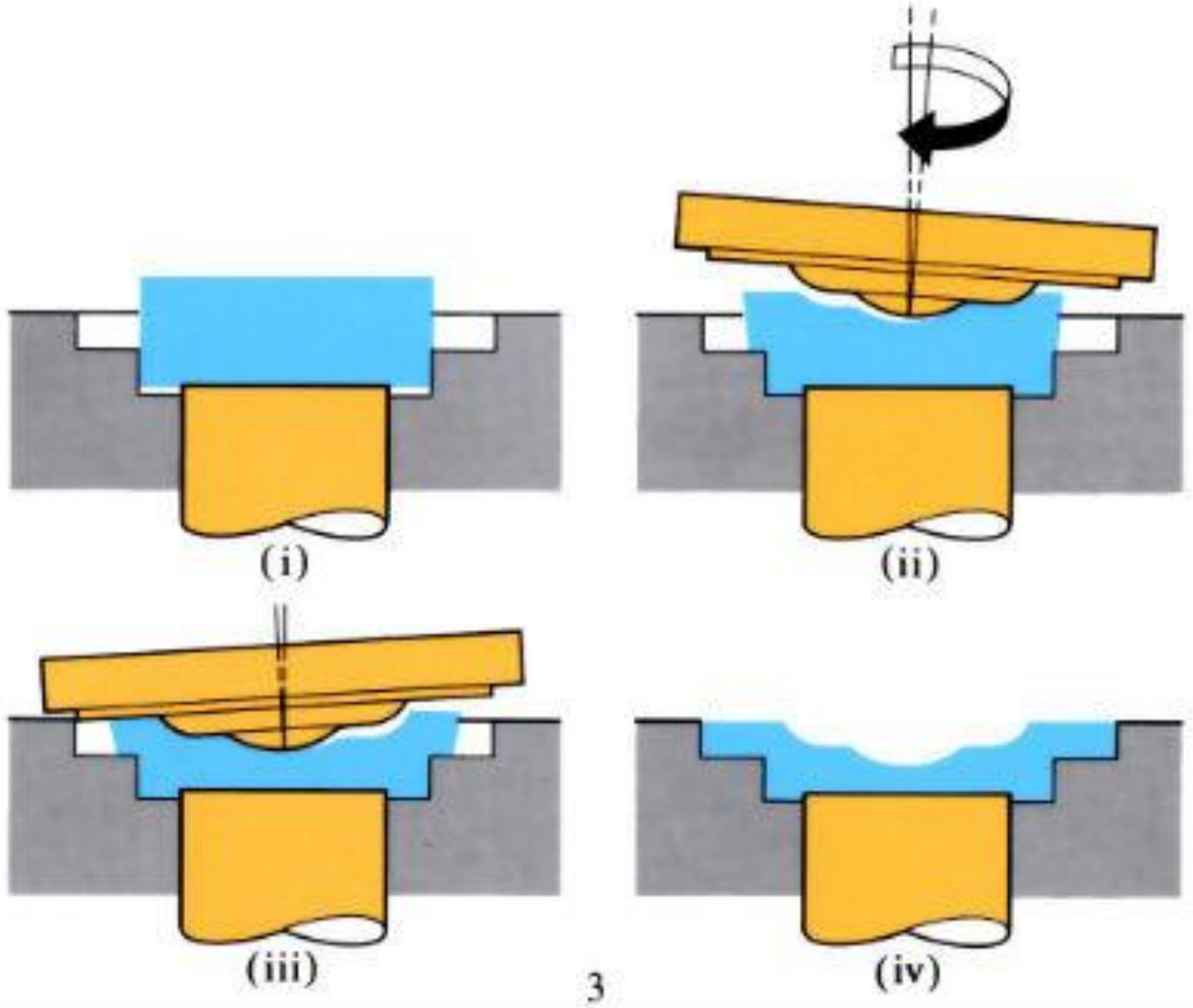
1

1. Top die can be orbited by a few degrees (a°) about the vertical axis, while the lower die is moved upwards during the forging operation.



(a) 2 (b)

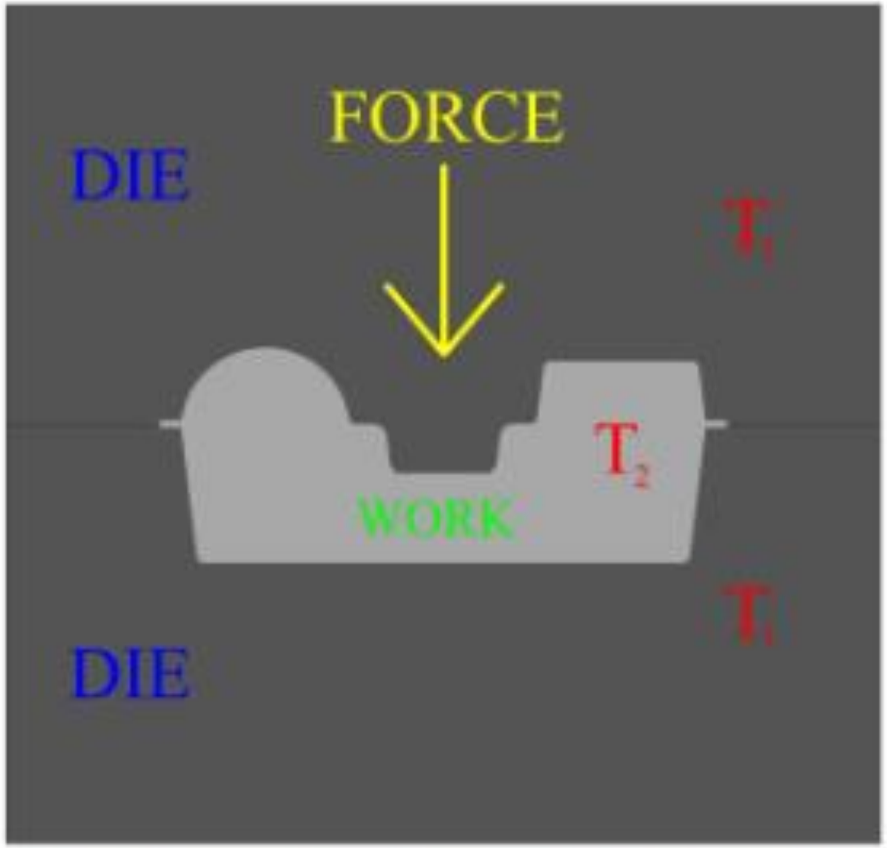
2. Only a small area of contact, reduces forging loads to only 10% of that of conventional forging at the end of the stroke.



3. Best used for components with large-diameter flanges.

- The advantage of orbital forging, is that since only a portion of the work is forged at a time, lower forces are required to perform this process.
- Another advantage is that this metal forging technique does not produce a lot of noise.
- Typically in manufacturing practice 10 to 20 revolutions of the upper die will be needed to forge a part.
- Conical and disk shaped parts, such as gears, are commonly manufactured by orbital forging.

ISOTHERMAL FORGING



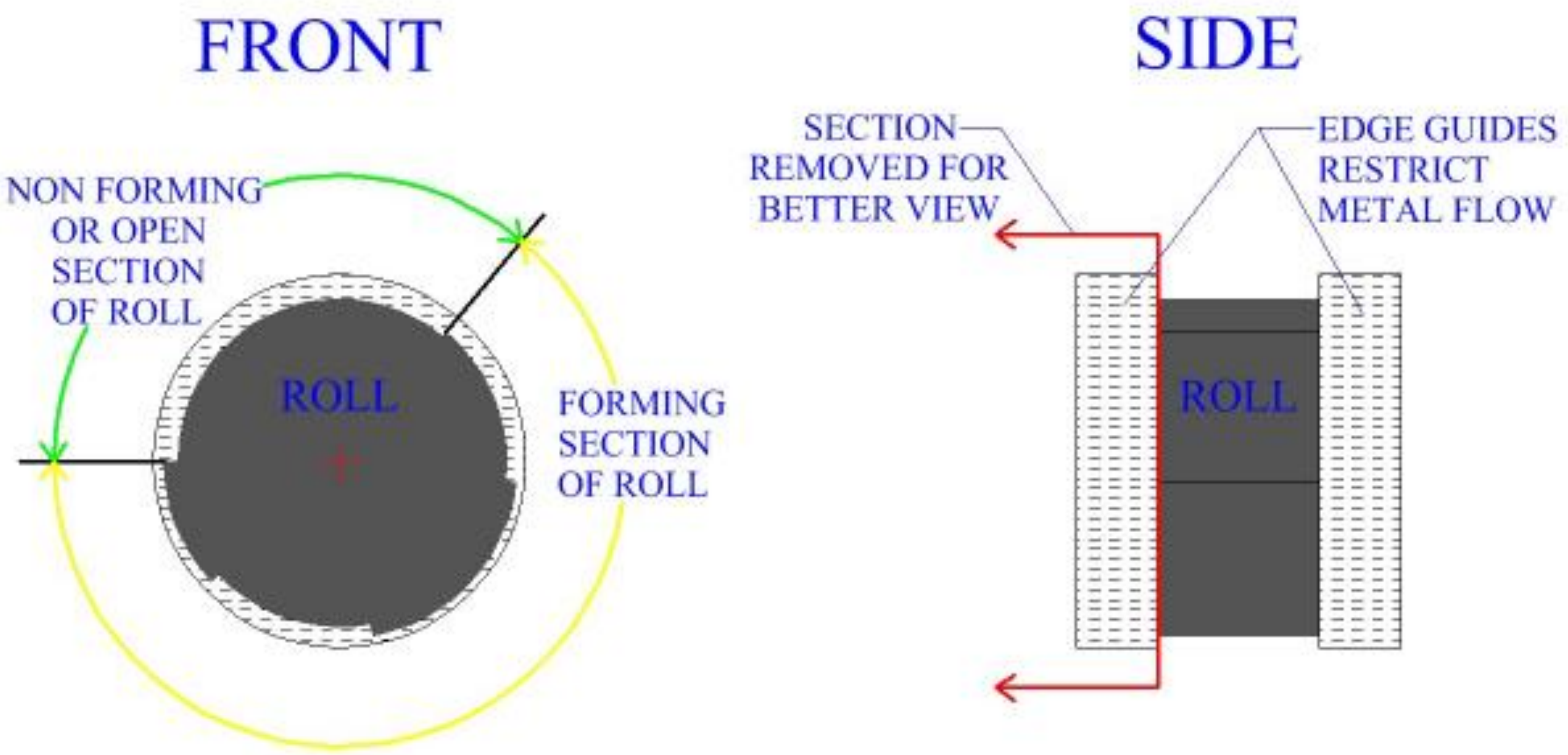
T_1 = Temperature of the mold

T_2 = Temperature of the work

$T_1 = T_2$

- Forging super alloys and other materials that have a low forgeability, can create difficulties during a metal forging process.
- Also, mechanical properties of some metals may vary greatly over small temperature ranges.
- To help eliminate some of the problems associated with manufacturing with these types of materials, particularly with regard to more complex parts, isothermal forging may be employed.
- This process is also called hot die forging.
- Isothermal forging is a hot working process that attempts to maintain the work piece at its maximum elevated temperature throughout the entire operation.
- This is achieved by heating the die to the temperature of, or slightly below the temperature of the starting work piece.
- As forces exerted by the die form the work, cooling of the work piece between the mold work interface is eliminated, and thus flow characteristics of the metal are greatly improved.
- Because the workpiece remains hot, its low strength and high ductility are maintained during forging; the forging load is low and material flow within the die cavity is improved.
- Complex parts with good dimensional accuracy can be forged to near net shape by one stroke in a hydraulic press.
- The dies for hot forging are usually made of nickel and molybdenum alloys.

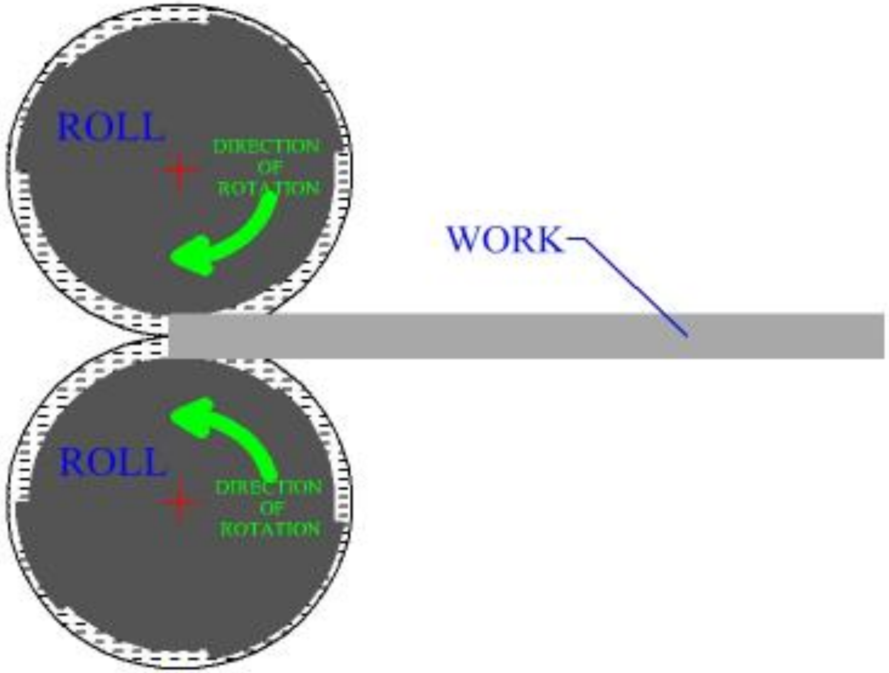
ROLL FORGING



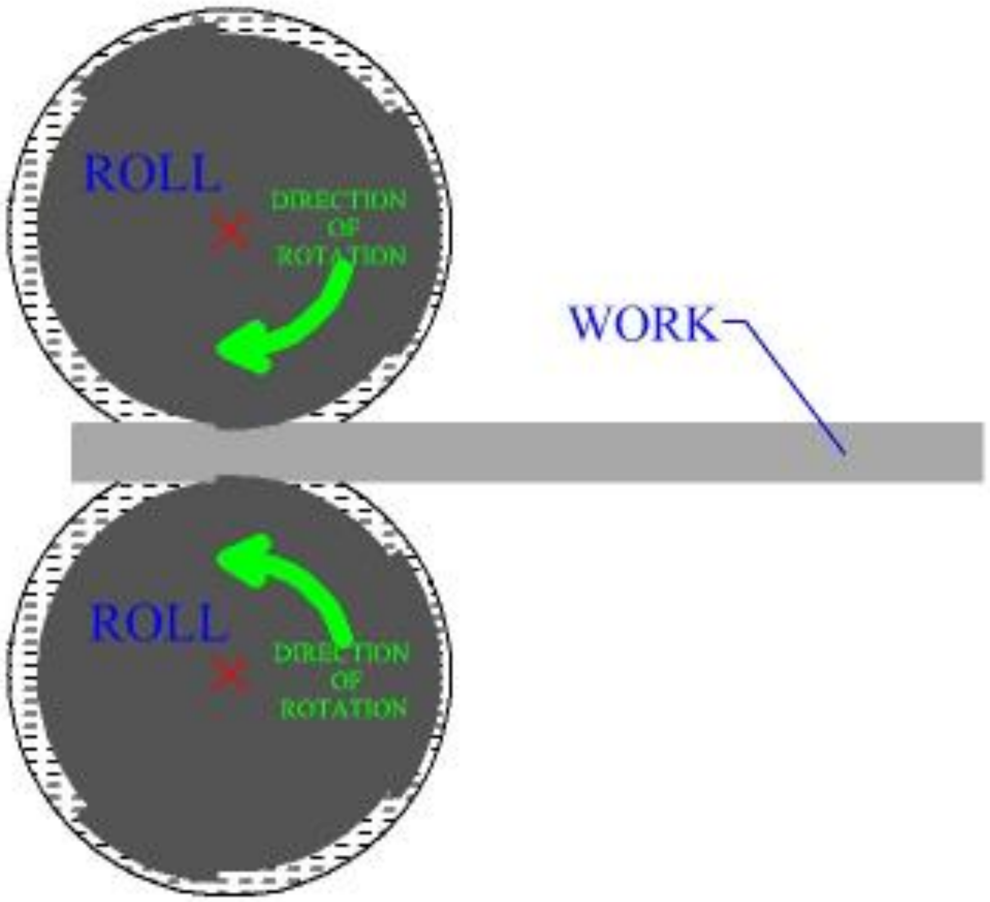
ROLL FORGING PROCESS

STOCK

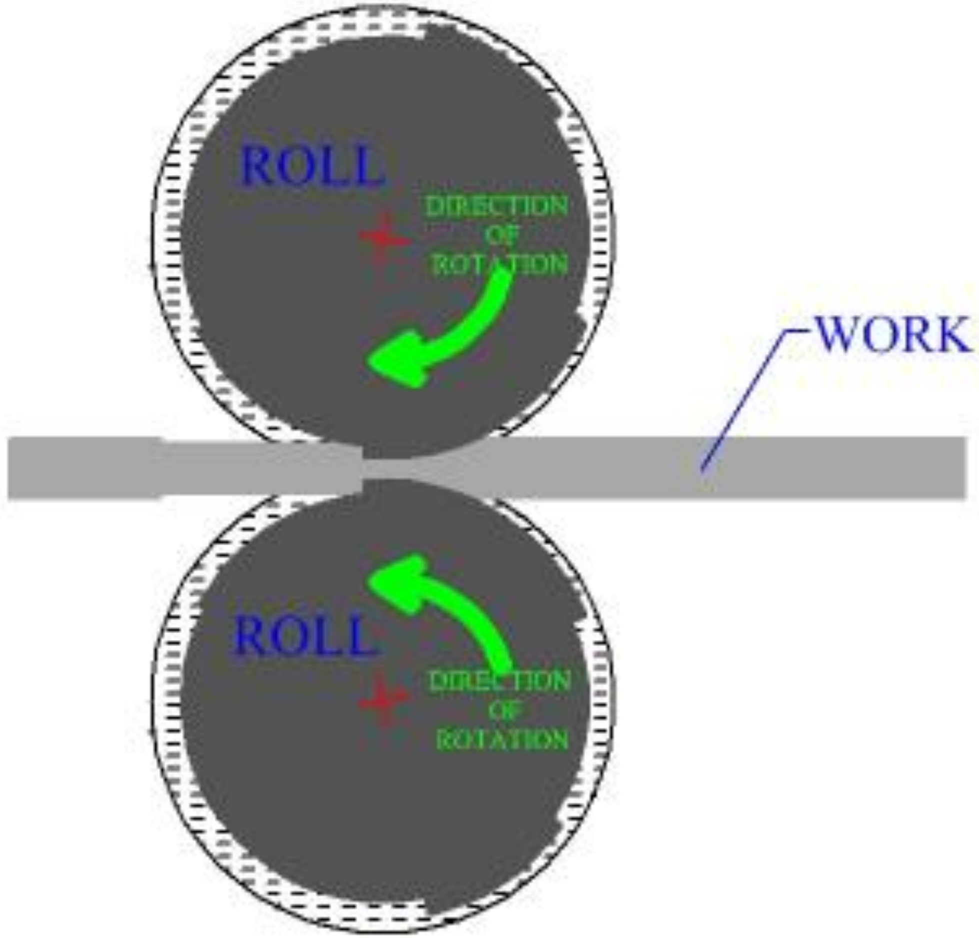
FORGED PART



1.


ROLL
DIRECTION OF ROTATION
WORK
ROLL
DIRECTION OF ROTATION

2.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ROLL
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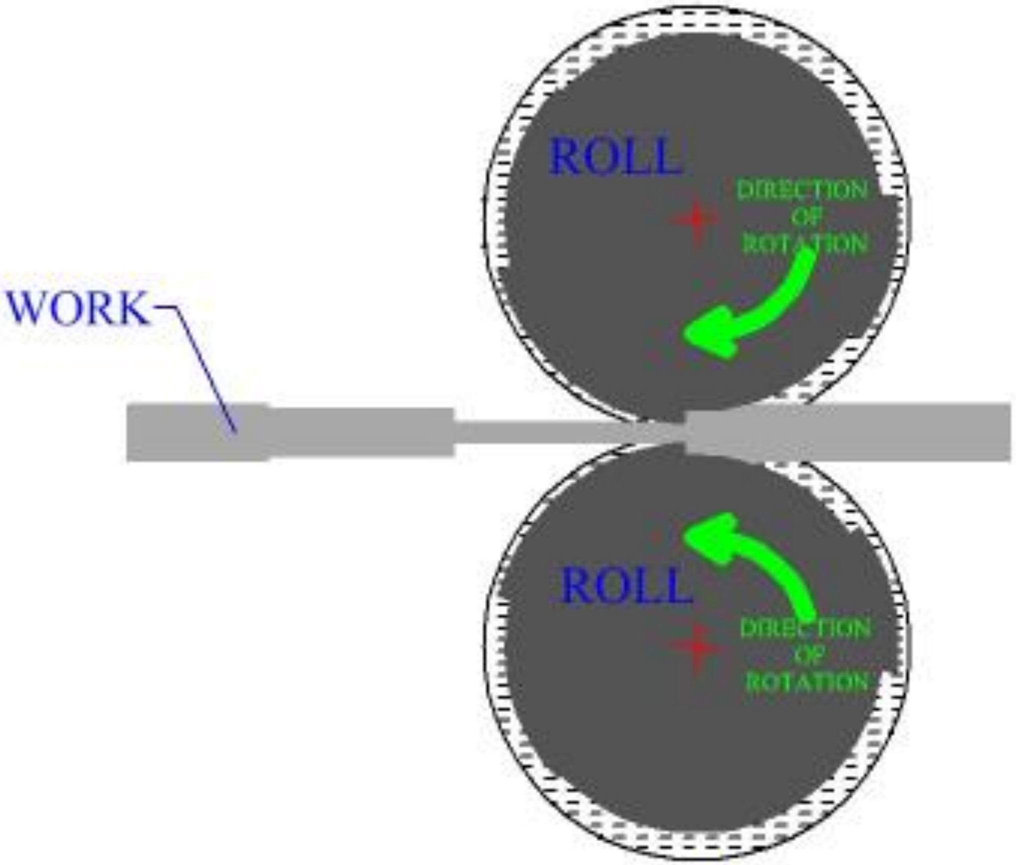
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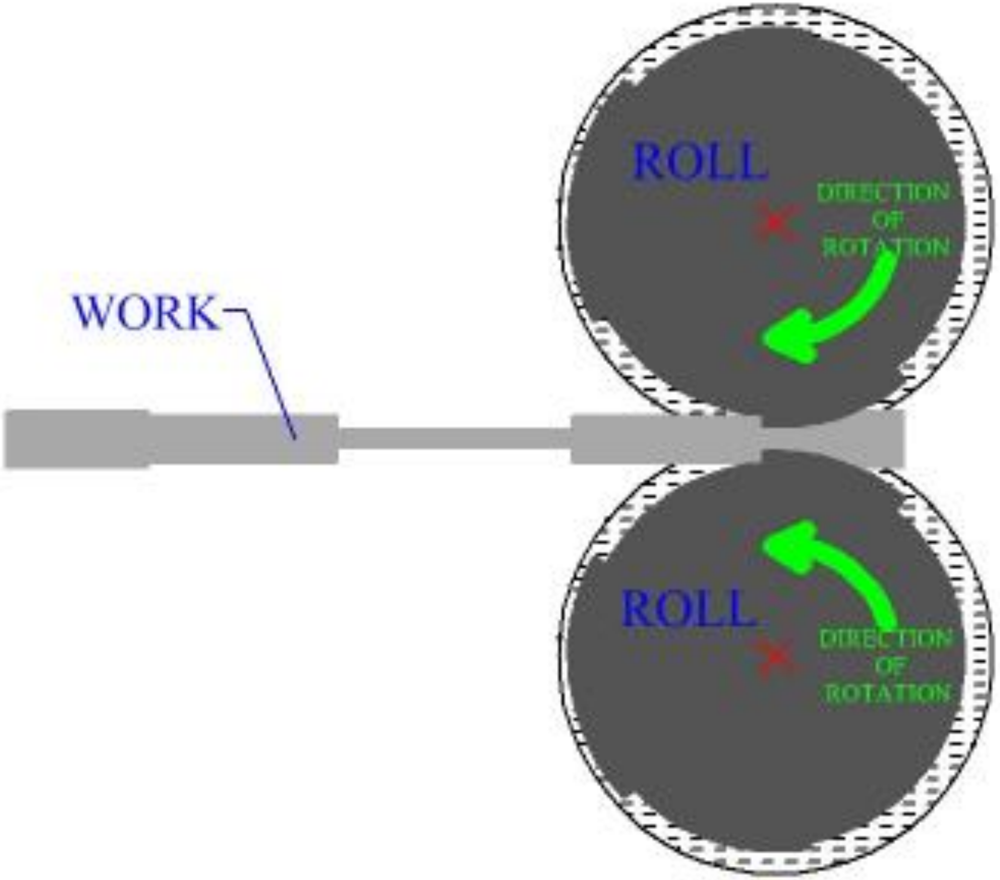
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ROLL
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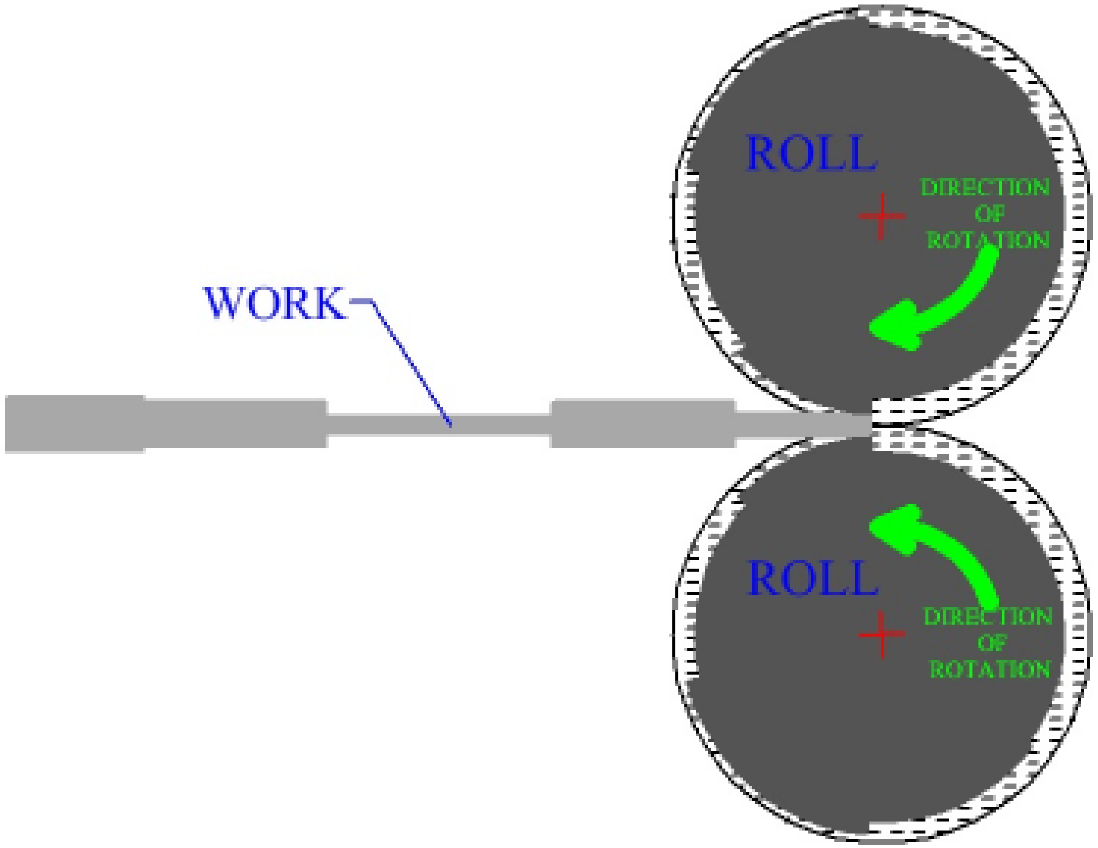
5.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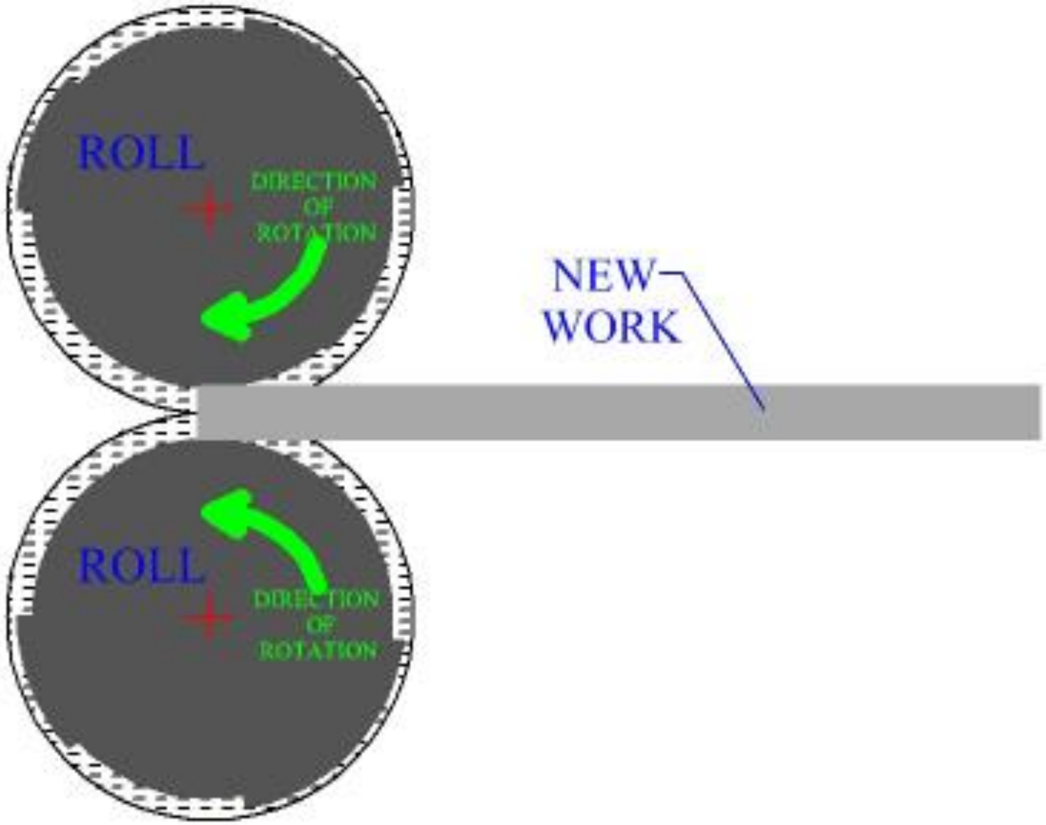
6.


ROLL
DIRECTION OF ROTATION
NEW WORK
ROLL
DIRECTION OF ROTATION

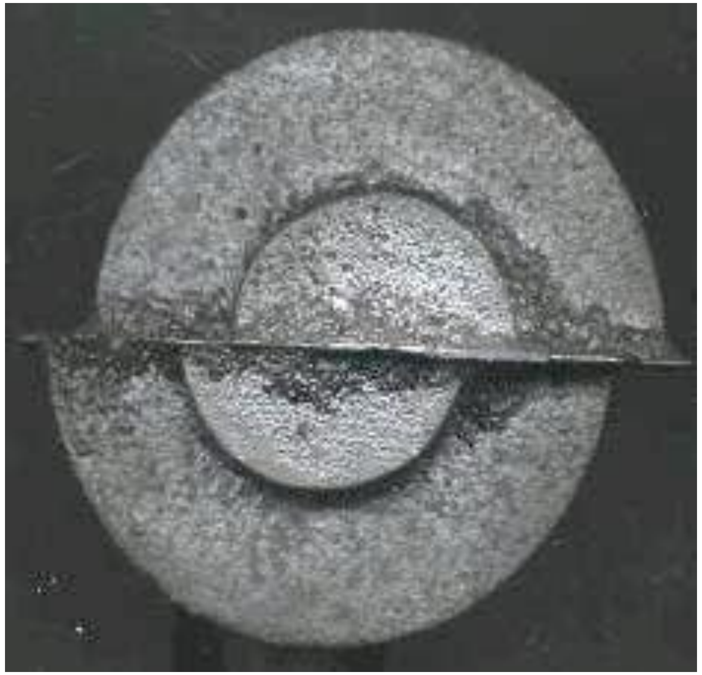
7.

Forging Defects

Unfilled section:
These types of forging defects left some portions in the object unfilled. It is caused by poor design of die, less raw material, poor forging techniques, and poor heating. To avoid the occurrence of the defect, proper care must be taken on the die design, heating, and there should be enough raw materials.

Cold shut:
These types of forging defects occur as small cracks at the corners of the object. It is caused by improper design of the forging die, sharp corners of the object, and excessive chilling of the forged product. These forging defects can be avoided when the fillet radius of the die is increased.

Die shift:
Die shift forging defect is caused when the upper and lower dies are not aligned with each other. This will result in improper dimensions of the product. The defect can be avoided when the die is properly aligned. It can be done by placing half portion of the workpiece on the upper die and half on the lower die so that both portions can match.



Flakes:
These types of forging defects occur due to improper cooling of the forged product. It is internal cracks caused when the forged products cool quickly, and it reduces the strength of the forged product. Flakes can be avoided when proper cooling is performed.

Scale pits:
This forging defect occurs due to improper cleaning of the forged surface. Scale pit is usual in forging carried out in an open environment. It causes irregular deputations on the forging surfaces. This defect can be avoided by adequate cleaning of the forged surface.

Residual Stress in Forging

A residual stress is a phenomenon caused by non-proper cooling of the forging parts during the forging process. Residual stresses result in significant plastic deformation, leading to the distortion of an object.
The main reason for this type of defect is excessive rapid cooling. The risk of this happens is also quite high when there is a rapid cooling of the forged piece, but it can be prevented by slow cooling as well.

Cracking at the Flash

There are several cracks in this flash when it is trimmed off. One of these cracks penetrates the interior of the flash. Such crack is known as cracking at the flash. This is usually due to a very thin flash.

In addition to this defect, several things can also be adjusted to prevent this defect, such as increasing the thickness of the flash, moving the flash to a less critical region of the forging, trimming hot, and relieving stress on the forging.

Internal Cracks

The formation of internal cracks is also a type of forging defect. It is usually caused by secondary tensile stresses that are induced during the forging process. There is a way to avoid this defect by maintaining a proper die design during the manufacturing process.