Forging

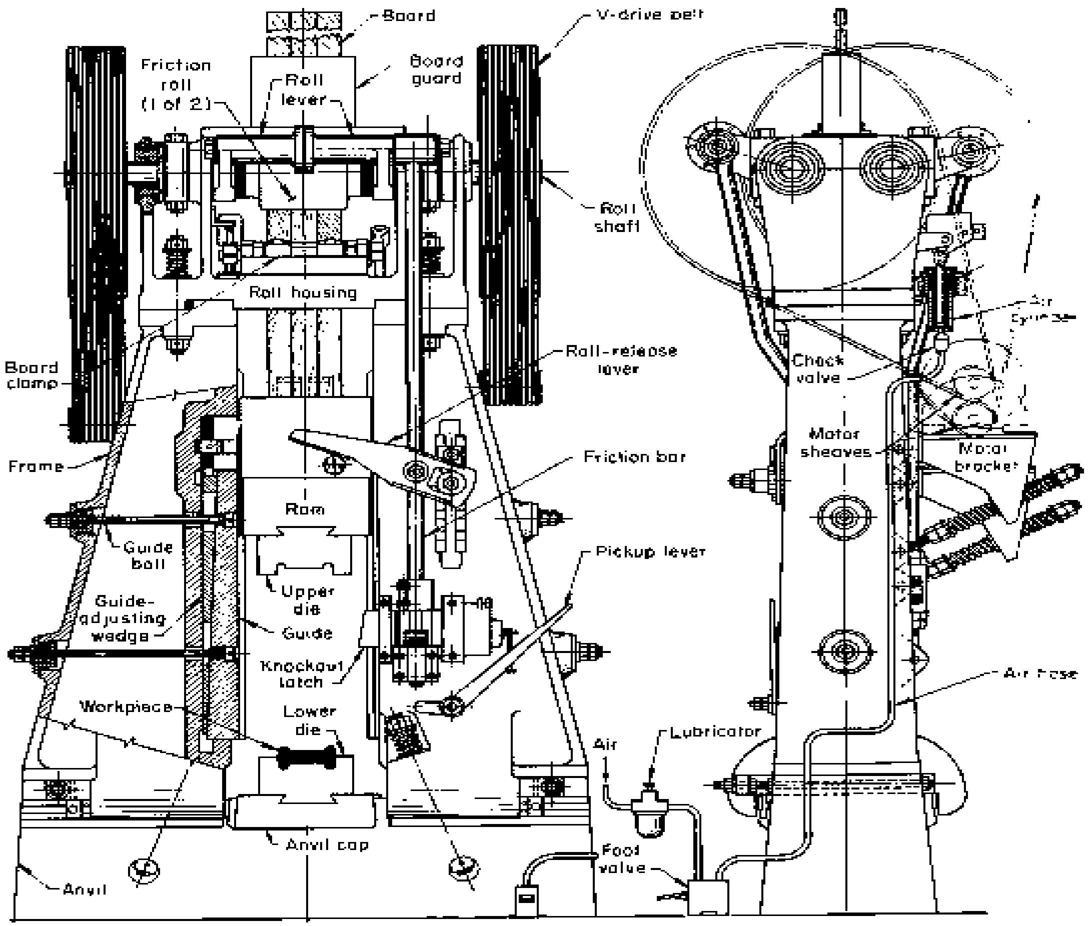
The term forging is applied to processes in which a piece of metal is worked in a machine to the desired shape by plastic deformation of the starting stock. The shape is imparted by the tools that contact the work piece and by control of the deformation process.

Forging Machinery

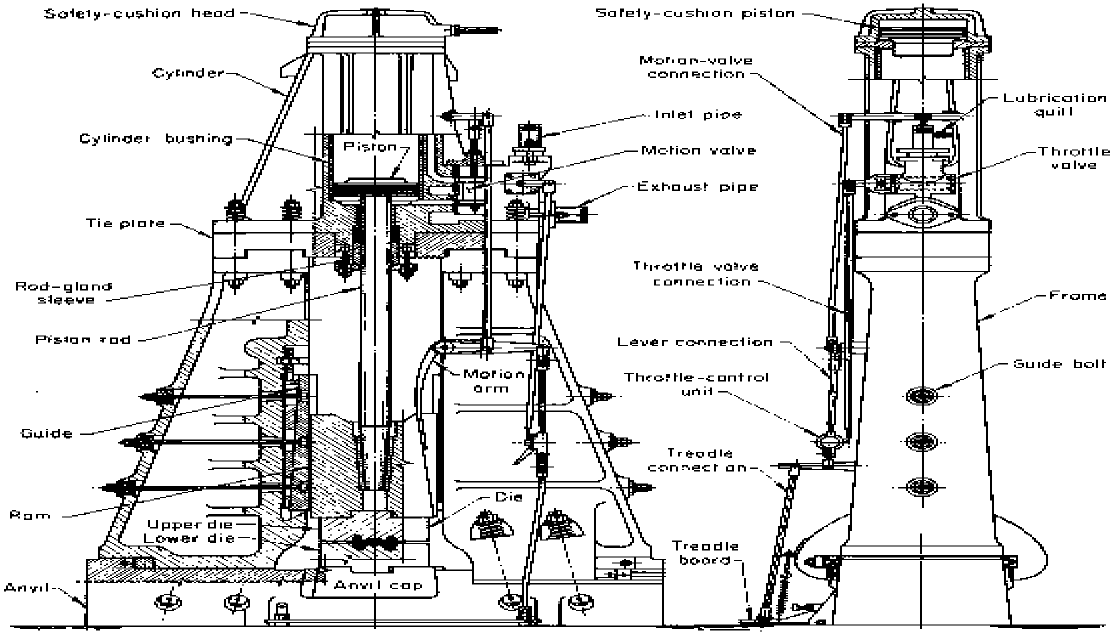
There are many types of forging machines that may be used in the forging process. They vary in factors such as the rate at which energy is applied to the work piece, and the capability to control the energy. Each type has distinct advantages and disadvantages, depending on the number of forgings to be produced, dimensional precision, and the material being forged.

Hammers

Hammers are considered the most flexible in the variety of forging operations they can perform. They are characterized by a heavy ram, which contains the upper die. The ram is raised and allowed to fall or is driven onto the work piece, which is placed on the bottom die. A large, heavy anvil supports the structure and holds the lower or stationary die. Hammers apply energy and cause deformation at very high rates.
Hammers are classified according to the way in which the ram is raised and whether it falls freely or is driven.



Board Hammers delivery their energy by gravity only. The ram is raised mechanically to a predetermined height and released. Cycle rates are high, as many as seventy per minute, and the energy imparted to the work piece is the same on each blow. Board hammers are rated by their falling weight. They range in size from 100 to 7000 pounds.



Power Hammers are similar to lift hammers except that the ram can be powered down onto the work piece by pressurized steam, hydraulic or air pressure, adding controlled energy and speed beyond gravity. Additionally the striking force can be varied on each stroke over the entire range from a light tap to full power. The complete control of each work stroke places higher requirements on operator skills than for other types of hammer. Many are being controlled by programmable systems. Steam, hydraulic and air hammers are the largest and most powerful of conventional forging hammers, and range in weight from 1000 to 50,000 pounds.

Air and hydraulic lift hammers

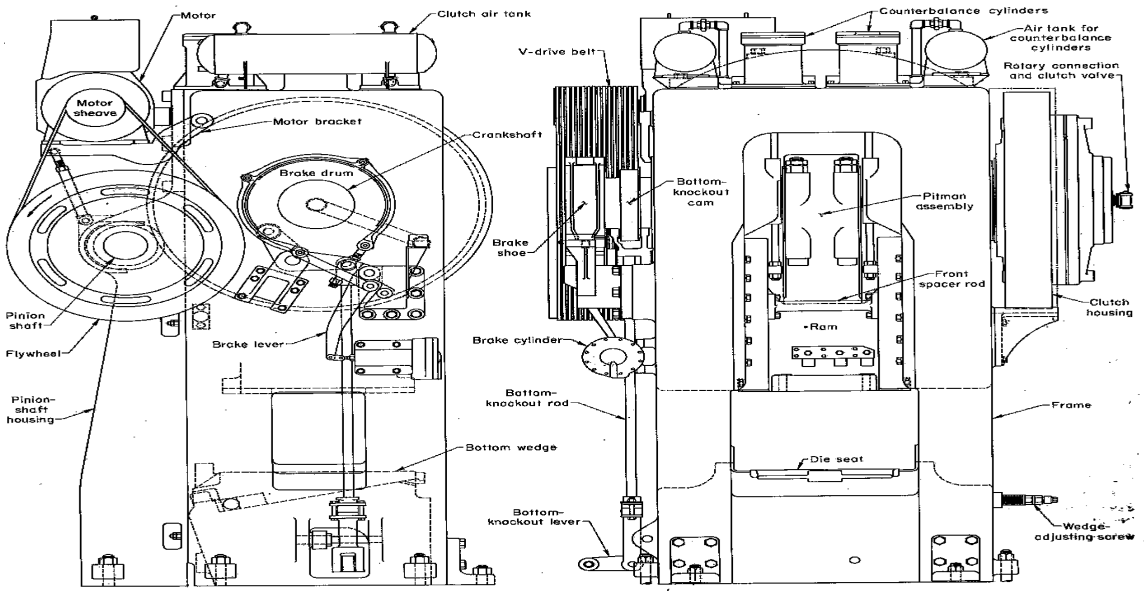
Are similar to board hammers except that the ram is raised by action of hydraulics or air cylinders. On some hammers, the height can be varied on each stroke, either by the operator or by pre-programmed blow control. Air-lift hammers range in size from 500 to 7,000 pounds falling weight. Hydraulic hammers range in size from 3000 to 10,000.

Other Types

Other types of hammers, such as vertical counterblow hammers where both top and bottom die move simultaneously and impacters where two rams of equal weight are propelled horizontally toward each other and impact in a central location are used less extensively. The largest hammers are often counterblow machines.

Presses

Presses are the second group of forging machines regularly used in forging. They are commonly classified based on the means used to deliver energy as mechanical, hydraulic and screw presses. They are used for all alloy groups, and are used in preference to hammers for alloys that require slow deformation rates. As with hammers, they usually operate vertically. The upper die is attached to the ram, and the downward stroke of the ram exerts force on the work piece. Presses are also classified according in the way in which the ram is raised and lowered.



Mechanical Presses typically store energy in a rotating flywheel, which is driven by an electric motor. The flywheel is engaged and disengaged to a mechanical drive such as a crankshaft, eccentric shaft, eccentric gear or knuckle levers, which convert flywheel rotation to vertical motion. The stroke is of set speed, length and duration. Mechanical presses therefore develop consistent forging results, offer high productivity and accuracy, and ease of automation and do not require as high a degree of operator skill as do other types of forging machines.

The applied force is maximum at the bottom of the work stroke, and the estimated load at a position just above this point is the basis for press rating capacity. Ratings typically range from 60 to 16,000 tons.

Hydraulic Presses are operated by large piston driven by high-pressure hydraulic systems. The basic difference between hydraulic press forging and other methods is that pressure is applied in a squeezing manner rather than by impact. Hydraulic presses operate at slower ram speed than hammers, mechanical presses and screw presses for this reason they are used for large and complicated forgings. Ratings typically range from 40 to 50,000 tons.

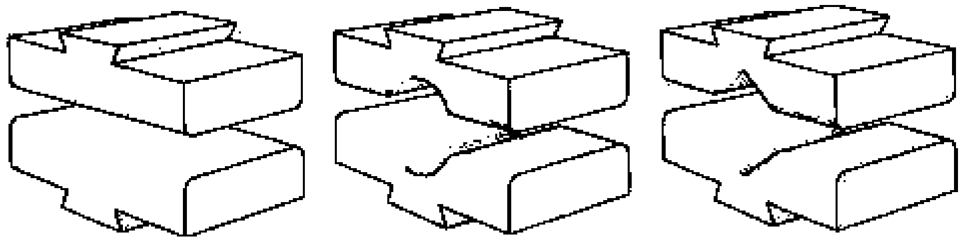
Screw Presses use energy stored in a flywheel to provide the force for forging. The rotating energy or inertia of the flywheel is converted to linear motion by a threaded screw attached to the flywheel on one end and the ram on the other.

Their main advantages are load control and ejector systems.

Ratings typically range from 400 to 3500 tons.

Forging Processes

Forging processes are generally classified under three basic methods. They are Open die forging, rolled ring forging and impression die forging.



The Open Die Process

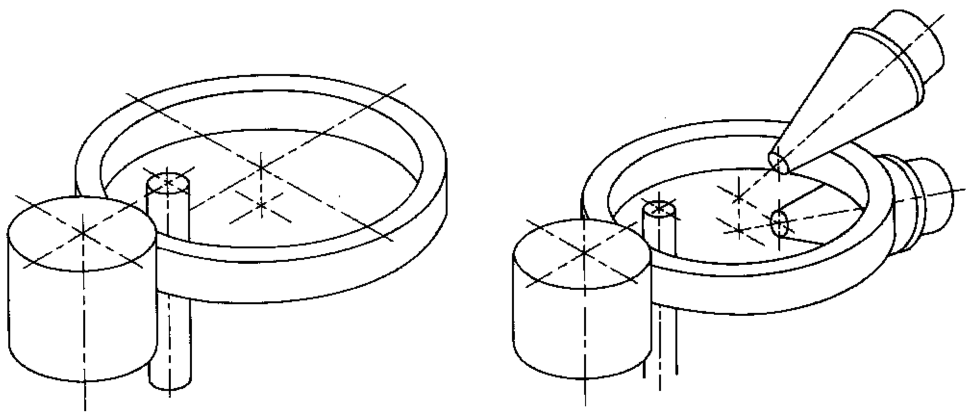
Open die forging is a hot forming process that uses standard flat, "V", concave or convex dies in presses. The process is used to form a virtually limitless range of component sizes from a few pounds to over 300 tons. The work piece is heated to improve its plastic flow characteristics and reduce the force required to work the metal. The work piece is systematically deformed by a series of strokes from the upper die while being supported on the lower die. The position is changed between strokes by a means such as the manipulator shown in Figure 5-1.

Open die forging processes allow the work piece freedom to move in one or two directions. The work piece is compressed in the direction of the movement of the upper die. Lateral dimensions are developed by controlling the amount of axial deflection, or by rotating the work piece.

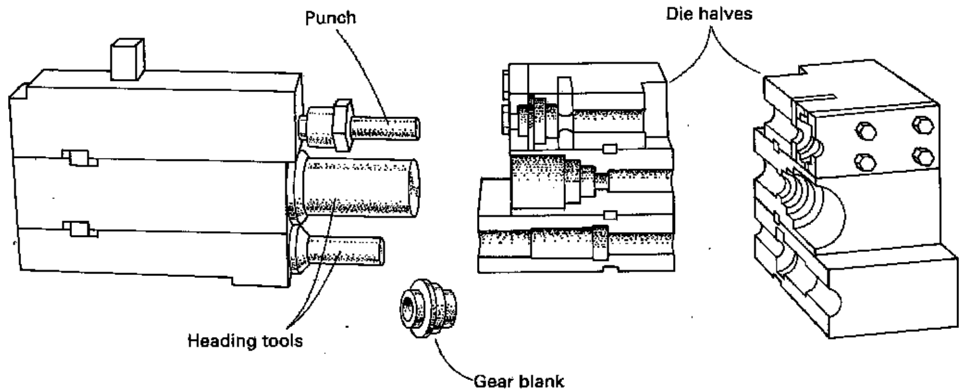
Ring Rolling

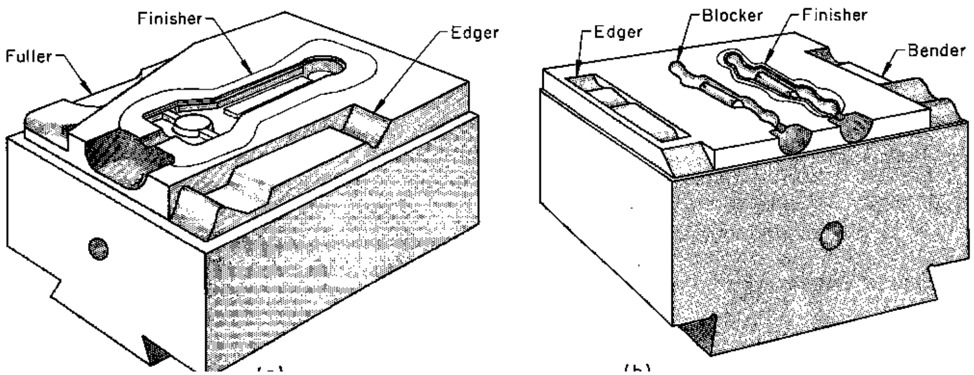
Rolled Ring Process

Rolled Ring Process is typically performed by punching a hole in a thick, round piece of metal creating a donut shape and then rolling and squeezing the donut into a thin ring over a mandrel. The process and equipment are similar in principle to rolling mills used for plate. In both processes, the metal is rolled between two rolls, which move toward each other to form a continuously reducing gap. In ring rolling, the rolls are of different diameters. The process is also highly material efficient.



(a) (b)


Punch
Die halves
Heading tools
Gear blank


Finisher
Fuller
Edger
Edger
Blocker
Finisher
Bender

Impression Die Process

Impression die forgings range in size from a few ounces to over 10,000 pounds, and vary in length from a fraction of an inch to over twenty-six feet.

Impression die forging provides three-dimensional control of the work piece, which provides much closer dimensional control than does open die forging.

In Hammers and most Presses the control is achieved by a pair of matched dies with specially fabricated impressions or cavities the shape of the desired forging. In Upsetters the dies are usually three piece impression dies.

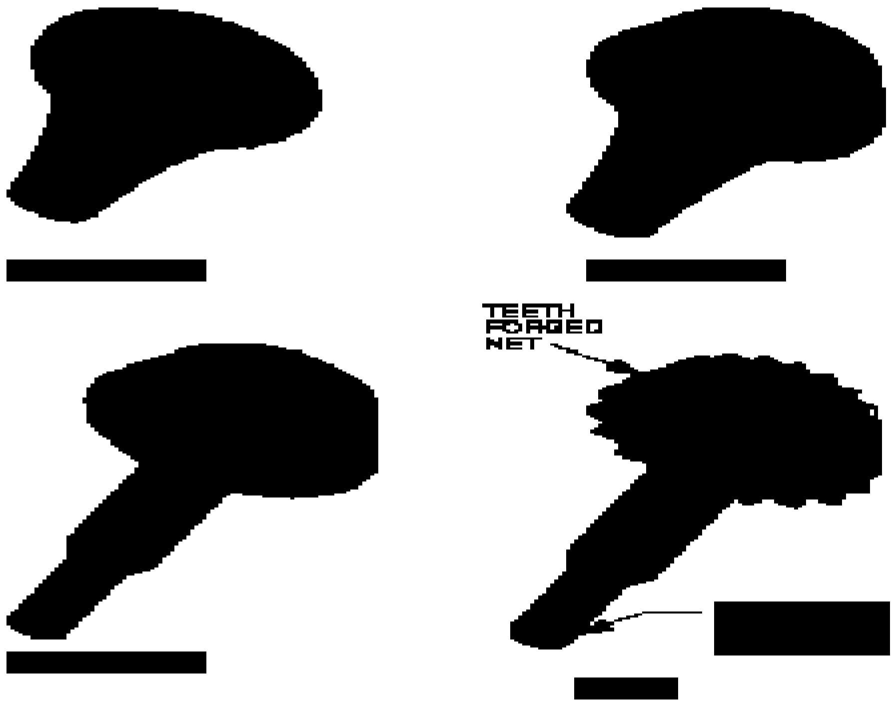
A Comparison of Open Die, Impression Die, and Rolled Ring Processes

The choice among the various forging processes is driven by component size, production quantities, and component shape. The following guidelines usually apply.

- When forgings are very large, when very few are required, or when delivery times are very short, open die forging is the typical choice.
- As shapes become more complex, and production quantities increase, impression die forging becomes the process of choice provided that the size does not exceed the capability of the impression die equipment. Shaft-like forgings with details on the ends or along the length are candidates for impression-upset forging.
- Seamless rings may be made by open die forging over a mandrel, impression die forging or ring rolling. Depending on size of part.

Impression Die Forging

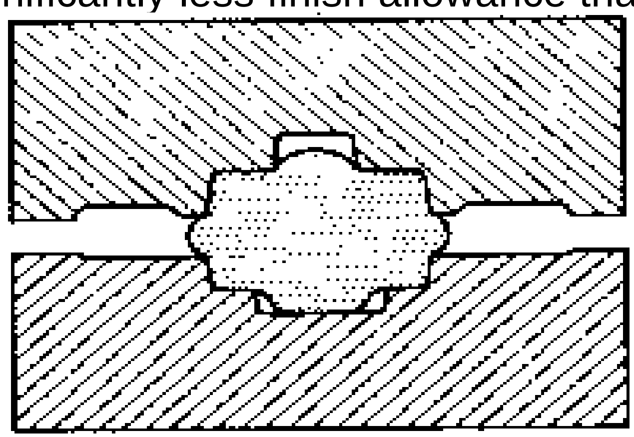
Impression Die Process is the process that accounts for the vast majority of all commercial forging made and the process used most often to supply Powers and Sons with forge product for steering and suspension parts.

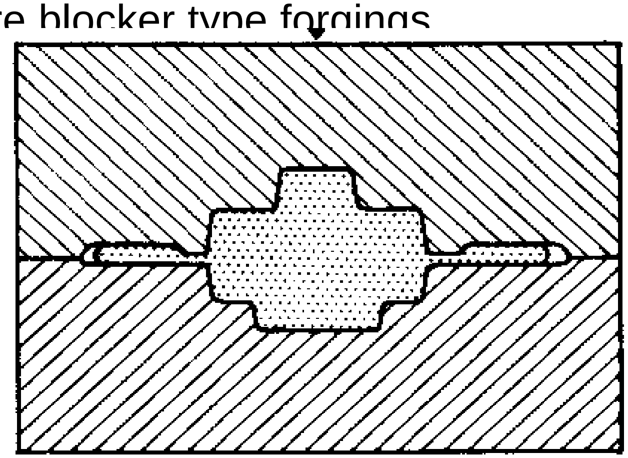


When impression die forging is chosen, four options are available: blocker type forgings, finished forgings, near-net forgings, and net shape forgings.

? **Blocker Type Forgings** are generally forged in a single impression die, with generous finish allowance.

? **Finished Forgings** are suitable for high production quantities. They are forged with significantly less finish allowance than are blocker type forgings.





? … vi … no machining,
a … e … ngs except they
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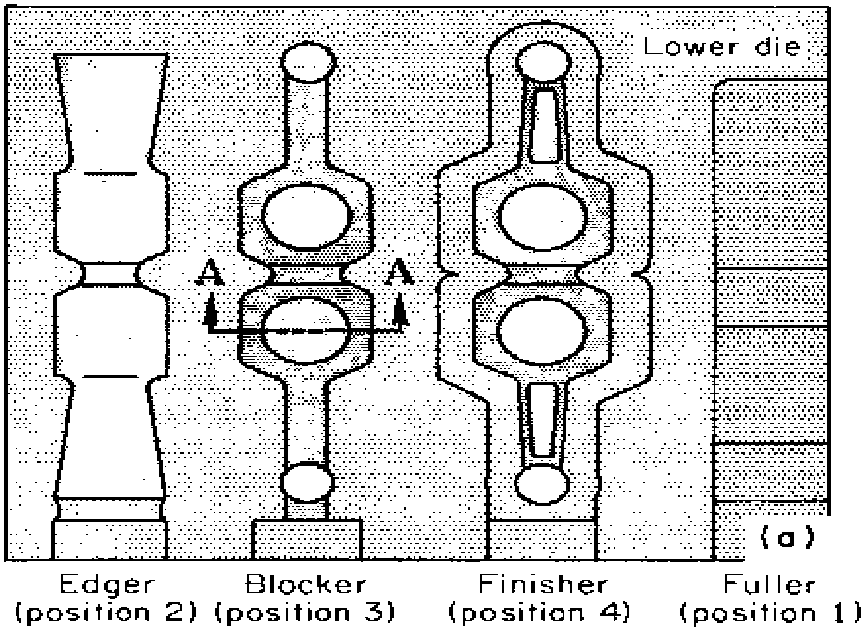
N … a … ctional surfaces
fo … g
A … **n** … **d below.**

As the two dies approach, the work piece undergoes plastic deformation, flowing laterally until it touches the sidewalls of the impression. A small amount of metal continues to flow outside of the impression, forming flash. As the dies continue to approach, the flash is thinned causing it to cool rapidly and offer increasing resistance to further deformation. The flash, in a sense, becomes part of the tool and helps to build up pressure inside of the cavity. The increased pressure promotes flow of metal into features of the impression previously unfilled.

Dimensional control of the forging in lateral directions is controlled by the walls of the die, and is ensured by complete die fill. Dimensional control in the axial direction is achieved by bringing the die faces to a predetermined position.

While flash can promote complete fill of the cavity, it does so at the cost of extremely high die pressures in the flash area. High pressures are undesirable because they reduce die life and require additional power. A flash gutter is often formed in the dies to receive the flash and allow the dies to reach the predetermined position at lower pressures.

A typical flash gutter is shown below



Using a sequence of forging operations, which are generally classified as “performing and finishing”, optimizes quality and production economy. Most of the work of deformation is accomplished in the preforming operations at relatively low pressures. Performing operations may include one or more bending, rolling or blocker stations in the die. Features such as large radii and generous draft angles, which minimize forging pressures, characterize blocker dies. Usually only the final operation is designated as a finishing operation. The finishing operation brings the forging to its final contour and precision.

The Cold Forging Process

The commonly accepted definition of cold forging is the forming of a material at room temperature with no heating of the initial slug. The term "no heating" does not include in-process annealing, which may be performed at intermediate stages to relieve the effects of work hardening.

The process produces greater dimensional accuracy than hot forming, and does not produce scale. However, the plastic flow characteristics of the work piece are not as good, so that higher forging pressures are required. Component size is generally limited to 50 pounds or less. The majority of cold forgings weigh less than 10 pounds. Carbon and standard alloy steels are most commonly cold-forged. The major advantages of cold forging are close dimensional tolerances, good surface finish quality, and the use of lower cost materials. While cold forging usually improves mechanical properties, the improvement is not useful in many common applications and economic advantages remain the primary interest. Tool design and manufacture are critical.

The Warm Forging Process

The temperature range for the warm forging of steel runs 800 to 1,800 degrees Fahrenheit. The process fills the niche between the closer tolerance, but sometimes expensive cold forging process and the somewhat lower precision hot forging process. It is being used to produce close tolerance components in steel alloys that were not feasible or impossible by cold forging. Compared with cold forging, warm forging has the potential advantages of: reduced tooling loads, reduced press loads, increased steel ductility, elimination of need to anneal prior to forging, and favorable as-forged properties that can eliminate heat treatment

The Hot Forging Process

Hot forging is the plastic deformation of metal at a temperature and strain rate such that re-crystallization occurs simultaneously with deformation, thus avoiding strain hardening. For this to occur, high work piece temperature (matching the metal's re-crystallization temperature) must be attained throughout the process, normally at temperatures of 2100 to 2300 degree Fahrenheit.

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Finishing Operations

Punching, trimming and straightening are commonly used to improve the dimensional accuracy of forgings. When tolerances closer than those that can be economically produced in the forging die are specified, coining and sizing operations are often employed. These processes cause plastic deformation of the forging, either by striking or squeezing a defined area. Coining may be performed either hot or cold, and can be accomplished before, during or after heat treatment.

Forgings generally employ essentially the same finishing operations for corrosion protection and enhanced appearance as castings and weldments made from equivalent alloys. When subsequent machining, painting or other coating operations are anticipated, blasting, tumbling, or pickling usually cleans the forgings. Blast or shot cleaning is the most common cleaning method.

Why Forgings?

Forgings are most suitable for applications requiring high levels of:

- Tensile strength
- Yield strength
- Fatigue strength
- Shear strength
- Impact toughness
- Fracture toughness
- Ductility

Forgings consistently outperform counterparts made by casting, powder metal processing, weldments, or products machined from plate or bar stock.

The degree of structural reliability achieved in a forging is unexcelled by any other metalworking process. There are no internal gas pockets or voids that could cause unexpected failure under stress or impact.

Forged components make possible designs that accommodate the highest loads and stresses.

The high ductility, impact toughness and fracture toughness usually achieved in forging often permits the design to include features that can be staked or crimped to reduce or eliminate fasteners.

To the designer, the structural integrity of forgings means safety factors based on material that will respond predictably to its environment without costly special processing to correct for internal defects.

A forging supplier can help maximize these properties by designing the forging process to develop the optimum grain flow and microstructure in the forging

Directional strength is a direct result of the forging process. In the forging process, controlled deformation results in greater metallurgical soundness and improved mechanical properties of the material. In most cases, forging stock has been pre-worked to remove porosity. This produces grain flow. Properly developed grain flow in forgings closely follows the outline of the component. In contrast, castings, bar stock and plate have unidirectional grain flow where any changes in contour will cut flow lines and exposing grain ends.

Forging Cost Drivers

The actual cost of a forging can be determined only by obtaining a cost analysis from a forging producer. The designer should be aware, however, of the factors that drive the cost of a forging. Five categories of cost drivers should be considered.

- Material cost
- Tooling cost
- Manufacturing cost
- Secondary operations
- Quantities produced

Materials Cost

Material cost is the cost to purchase and process enough material to ship the product. The raw material for forging is bars, billets, blooms or ingots.   Material chemistry has the largest effect on cost.

Manufacturing Cost

Manufacturing cost includes the cost of labor plus the cost of purchasing, maintaining and operating the required machinery and material handling equipment. Machinery typically includes saws, shears, furnaces, performing equipment, the forging press or hammer with its associated controls and trim presses. Material handling equipment typically includes cranes, lift trucks, conveyors.
Designs that reduce the number of operations, or reduce the size or complexity of the required forging machines will reduce cost.

Tooling Costs

Tooling cost quoted by forgers generally includes the cost of designing and manufacturing the tools used to produce the forging. Designing the forging to facilitate metal flow in the die and reduce forging pressures will reduce cost.

- This usually involves modifying sharp details to provide larger radii. In some cases it may be possible to use a smaller forging press with a lower hourly operating cost that produces more parts per hour. Lower forging pressures also tend to reduce tool maintenance and replacement cost.

Secondary Operations

Secondary operations are those required to bring the forging to the required shape, precision, mechanical properties or surface finish. These operations may include:

- Heat treatment
- Cold coining
- Straightening
- Machining
- Nondestructive testing
- Shot blasting
- Coatings such as paint and powder coat.

Quantities Produced

As with other manufacturing processes, there is a setup cost associated with the production of each order of forgings. This includes the cost of installing performing tools; forging dies, trim dies, and computer programs, as required for the forging. The cost is spread over the quantity produced, so that the effect on piece price decreases as the order quantity increases.
In forging as with any manufacturing operation, including the supplier in the development process before the design is finalized will reduce cost of product supplied and help to prevent costly changes.

Closing

The steering and suspension parts that Pioneer Forge produces for Powers and Sons are made on presses that range in size from 400 to 800 tons and on hammers that range in size from 4000 to 7000 pounds. We have 89 employees who operate the plant on 3 shifts. We have been a supplier to Powers and Sons and to Ford since our company was established in 1982. We are located in Pioneer, Ohio, which is eight miles north of Powers and Sons.