FORGING SOLUTIONS

Design Engineering Information From FIA

Addressing these processes:

Impression Die ✔
Open Die ✔
Rolled Ring ✔
Cold ✔

THE LANGUAGE OF FORGING: KEY TERMS AND DEFINITIONS

Like other technical fields and engineering disciplines, forging technology has a language all its own. Knowing what these terms mean and how they are applied can be of enormous help in seeking quotations, specifying forged products over other alternatives, and understanding why forged components deliver superior performance over non-forged parts.

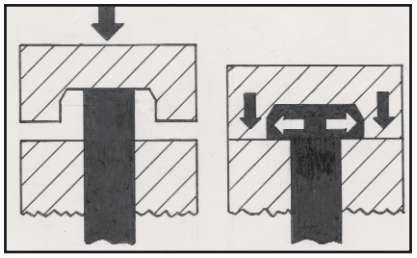

Figure 1. Cold heading or upsetting is a cold forging process where steel is gathered in the head and in other locations along the length of the part, if required. Metal flows at right angles to the ram force, increasing diameter and reducing length.

General metallurgical and other terms not related explicitly to forging are not covered. Not all terms can be covered; only the most common terms are presented.

Aluminum precision forging: a process to plastically deform an aluminum alloy to a finished part shape in special dies. By design, little or no subsequent machining/processing is required as a result of close tolerances, thin sections, small radii and minimum draft angles.

Alloy steel forging: once made from a steel containing additional alloying elements other than carbon (e.g. Ni, Cr, Mo) to enhance physical and mechanical properties and/or heat-treat response.

Bar: a section hot rolled from a billet to a round, square, rectangular, hexagonal or other shape with a cross-section less than 16 sq.in.

Billet: a semi-finished section (width less than twice the thickness), hot rolled from a metal ingot, generally having a cross-section ranging from 16 to 64 in2. Also applies to a hot-worked forged, rolled or extruded round or square.

Blank: raw material or forging stock from which a forging is made.

Bloom: same as a billet, but with a cross-sectional area greater than 36 in2.

Blocker-type forging: one with the general shape of the final configuration, but featuring a generous finish allowance, large radii, etc.

Carbon steel forging: one made from steel whose major alloying element, carbon, produces the resultant properties and hardness.

Close-tolerance forging: one held to closer-than-conventional dimensional tolerances.

Closed die forging: see impression die forging.

Coining: a post-forging process for hot or cold parts to attain closer tolerances or improved surfaces.

Cold-coined forging: one that is re-struck cold to improve selected tolerances or reduce a specific section thickness.

Cold forging: various forging processes conducted at or near ambient temperature to produce metal components to close tolerances and net-shape. These include bending, cold drawing, cold heading, coining, extrusion (forward or backward), punching, thread rolling, and others.

Cold heading: plastically deforming metal at ambient temperatures to increase the cross-sectional area of the stock (either solid bar or tubing) at one or more points along the longitudinal axis. See Figure 1.

Cold working: imparting plastic deformation to a metal or alloy at a temperature below recrystallization to produce hardness and strength increases via strain hardening.

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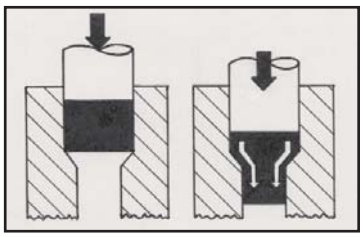

Figure 2. Forward extrusion, a basic cold forging process, reduces slug diameter while increasing length. Stepped shafts and cylinders are typical examples of this process.

Controlled cooling: process used to attain required properties and/or corresponding microstructural phase changes; applies to heat-treatable steels (e.g. quenching) and to microalloyed steels, which require no heat treatment, but only controlled cooling to attain final properties.
Conventional forging: one that, by design, requires a specified amount of finish (or machining) to reach the final dimensional requirements.
Counterblow forging: one made by equipment incorporating two opposed rams, which simultaneously strike repeated blows on the work piece.
Cross forging: the practice of working stock in one or more directions to make resultant properties more isotropic (equal in three directions), for example, by upsetting and redrawing the material.
Directional properties: refers to the inherent directionality within a forging such that properties are optimally oriented to do the most good under in-service conditions. Typically, maximum strength is oriented along the axis that will experience the highest loads.
Disk: a "pancake" shaped forging (flat with a round cross-section), such as a blank for gears, rings, and flanged hubs.
Draft: the necessary taper on the side of a forging to allow removal from the dies; also applies to the die impression. Commonly expressed in degrees as the draft angle.
Draftless forging: a forging with zero draft on vertical walls.
Drawing: 1) reducing the cross-section of forging stock while simultaneously increasing the length; 2) in heat treating, the same as tempering.
Drop forging: one produced by hammering metal in a drop hammer between impression dies.
Extrusion: forcing metal through a die orifice in the same direction as the applied force (forward extrusion) or in the opposite direction (backward extrusion). See Figure 2.
Finish: 1) the material remaining after forging that is machined away to produce the final part; 2) the surface condition of a forging after machining.
Finish all over (F.A.O.): designates that forgings be made sufficiently larger than dimensions shown to permit machining on all surfaces to given sizes.
Finish allowance: amount of stock left on the surface of a forging to be removed by subsequent machining.
Flash: excess metal that extends out from the body of the forging to ensure complete filling of the finishing impressions.
Flashless forging: "true" closed die forging in which metal deformed in a die cavity permits virtually no excess metal to escape.
Flow lines: patterns that reveal how the grain structure follows the direction of working in a forging.
Forgeability: relative ability of a material to deform without failure or fracture.
Forging reduction: ratio of the cross sectional area before and after forging; sometimes refers to percentage reduction in thickness.
Forging stock: wrought rod, bar, or piece used as the raw material or stock in forging.
Free machining steel forgings: those made from steels with special alloying-element additions to facilitate machining.
Grain flow: fiber-like lines that show (via macroscopic etching) the orientation of the microstructural grain pattern of forgings achieved by working during forging processes. Optimizing grain flow orientation maximizes mechanical properties.
Hammer forging: one produced on a forging hammer, usually between impression dies but sometimes flat dies; the process of forging in a drop hammer (see drop forging).
Hand forging: one made by manually controlled manipulation in a press without impression dies, usually between flat dies with progressive forging of the work piece; also referred to as flat die forging.
Heat treatment: heating or cooling operations, sometimes isothermal, to produce desired properties in forgings.
High energy rate forging (HERF): forgings made on equipment that utilizes very high ram velocities.
Hogout: product machined from bar, plate, slab, or other material.
Hollow forging: a cylindrical open die forging; namely, thick-walled tubes or rings. See Figure 3 on the next page.

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FORGING SOLUTIONS CONTINUED

Hot die forging: a process in which dies are heated close to the forging temperature of the alloy being forged; used for difficult-to-forge alloys.

Hot forging: same as hot working-plastically deforming an alloy at a temperature above its recrystallization point, i.e. high enough to avoid strain hardening.

Hub: a boss in the center of a forging that forms an integral part of the body.

Impact extrusion: a reverse extrusion process in which metal is displaced backwards between a punch and a die to form a hollow part. See Figure 4.

Impression die forging: one formed to shape and size in die cavities or impressions; also commonly referred to as closed die forging. See Figure 5.

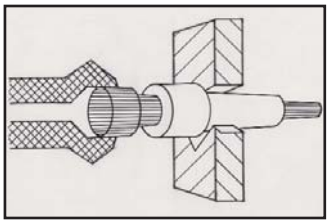

Figure 3. Hollow die forging is an open die forging option, which starts with a punched or pierced disk on a tapered draw bar. Progressive reduction of the outside diameter increases the overall length of the sleeve, while the inside diameter remains constant.

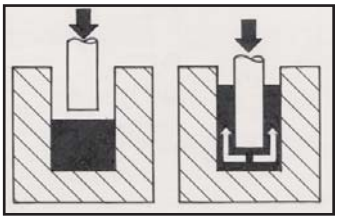

Figure 4. Impact extrusion, another cold forging process, produces hollow parts. Here, the metal flows back around the descending ram.

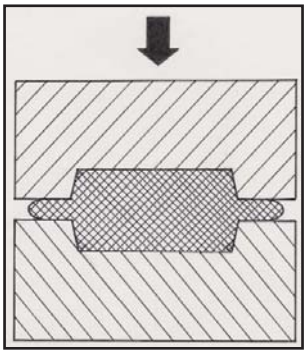

Figure 5. In impression die forging, a workpiece is plastically deformed between two dies filling the die cavity. A small amount of material of "flash" that flows outside the die impression cools rapidly, creating resistance that facilitates material flow into unfilled impressions.

Isothermal forging is most commonly conducted at about 2000˚F under a controlled atmosphere or vacuum to prevent oxidation while forging superalloys.

Machine forging (upsetter forging): one made in a forging machine or upsetter, in which a horizontally moving die in the ram forces the alloy into the die cavities.

Mandrel forging: see saddle/mandrel forging.

Match: aligning a point in one die half with the corresponding point in the opposite die half.

Microalloyed steel forging: one made from a microalloyed steel requiring only controlled cooling to reach optimum properties, which is in contrast to conventional quenched-and-tempered steels that require traditional heat treatments to achieve the same results.

Microstructure: the microscopic structure of metals/alloys as seen on a mounted, ground, polished, and etched specimen to reveal grain size, constituent phases, etc.

Near-net-shape forging: forging components as close as possible to the required dimensions of the finished part.

Open die forging: one produced by working between flat or simply contoured dies by repetitive strokes and continuous manipulation of the work piece; sometimes called hand forging. See Figures 6 to 8.

Parting line: the plane that divides the two die halves used in forging; also applies to the resulting forging and impression dies.

Piercing: forming or enlarging a hold via a tapered or cylindrical punch.

Plastic deformation: permanent distortion of a material without fracturing it.

Plate: a flat hot rolled metal or alloy product whose thickness is much less than its width.

Precision forging: any forging process that produces parts to closer tolerances than conventional forging processes.

Preform: forging operation in which stock is preformed or shaped to a predetermined size and contour prior to subsequent die forging operations; also, ring blanks of a specific shape for profile (contour) ring rolling.

Press forging: the shaping of metal between dies on a mechanical or hydraulic press.

Quenched and tempered steel forging: one that is quenched and tempered to produce the required hardness and properties; should more accurately be referred to as hardened-and-tempered. (Hardening and tempering are heat treatments that follow austenitizing, which is usually the first heat treatment performed on carbon and alloy steel forgings.)

Restriking: a salvage operation following a primary forging operation-rehitting forgings in the same die in which they were last forged.

Rib: a forged wall or vertical section generally projecting in a direction parallel to the ram stroke.

Rib and web forging: one whose basic configuration consists of ribs and webs.

Ring rolling: forming seamless rings from pierced discs or thick-walled, ring-shaped blanks between rolls that control wall thickness, ring diameter, height and contour.

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FORGING SOLUTIONS CONTINUED

Roll forging: shaping stock between power driven rolls that incorporate contoured dies; used for preforming and to produce finished parts. See Figure 9.

Rough machining: an initial machining operation that leaves adequate stock for subsequent finish machining.

Saddle/mandrel forging: rolling and forging a pierced disc over a mandrel to yield a seamless ring or tube.

Slab: a flat shaped semi-finished, rolled metal ingot with a width not less than 10 in. and a cross sectional area not less than 16 in2.

Standard tolerance: an established tolerance for a certain class of product; preferred over "commercial" or "published" tolerance.

Straightening: a finishing operation for correcting misalignment in a forging or between different sections of a forging.

Structural integrity: inherent microstructural soundness of forgings as a result of achieving 100% density, uniform metallurgical structure and grain size, as well as the absence of porosity, segregation, large inclusions and other non-forged part defects.

Swaging: reducing the size of forging stock; alternately, forging in semi-contoured dies to lengthen a blank.

Target machining: incorporating a "target" (benchmark or gauge point) on a forging to facilitate machining; coined locating surfaces and drilled centers are commonly used.

Tolerance: the specified permissible deviation from a specified or nominal dimension; the permissible variation in the size of a part.

Trimming: performed hot or cold, the mechanical shearing of flash or excess material from a forging by use of a trimmer in a trim press.

Upset forging: one made by upset of an appropriate length of bar, billet, or bloom; working metal to increase the cross-sectional area of a portion or all of the stock.

Upsetter (forging machine): a machine with horizontal action used to produce upset forgings. See Figure 10.

Warm forging: forging of steel at temperatures ranging from about 100˚F to just below the normal hot working range of 1900 to 2300˚F.

Web: a relatively flat, thin portion of a forging, generally parallel to the forging plane, that connects ribs and bosses.

Wide tolerance: any special tolerance wider than "standard."

Space constraints make it impossible to include all terms and definitions that apply to forging processes. For a more comprehensive listing, please refer to the glossary of the *Forging Handbook*.

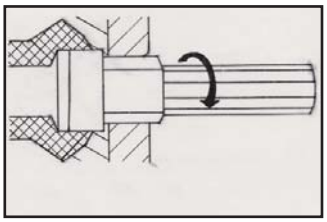

Figure 6. Open die forging of shafts consists of manipulating the sock and progressively forging the component to shape. Turning on a lathe brings the shaft to near net shape.

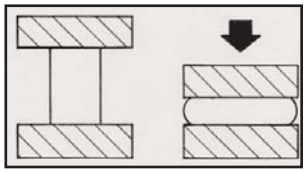

Figure 7. Open die forging of disk shapes involves progressive upsetting/forging to reach desired dimensions. Pierced disks are often used a preforms for saddle/mandrel rings and hollow forgings.

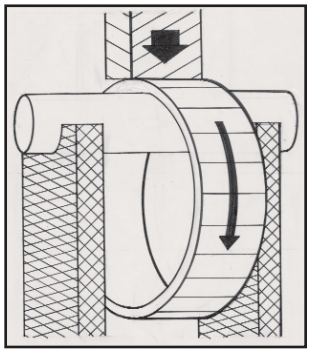

Figure 8. Open die forging of rings starts with a preform on a saddle/mandrel. Progressive reduction of the wall thickness to increase the diameter achieves the required dimensions. Subsequent machining delivers near net shape.

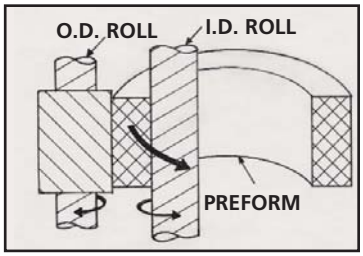

Figure 9. Seamless ring rolling starts with a donut shaped preform, which is squeezed between a free truning I.D. roll and a driven O.D. roll. The ring mill makes the section thinner while increasing the ring diameter.

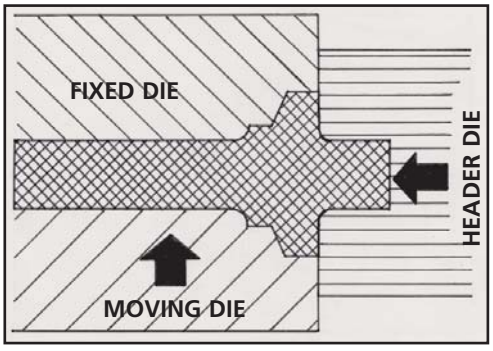

Figure 10. Upsetters or horizontal forging machines produce impression die forgings similar to those made on hammers or presses. "Grip dies" (the fixed die and the moving die) correspond to the bottom die on a hammer or press. The ram operated header die corresponds to the top die on a hammer or press.

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