

Aluminum Extrusion Backgrounder

(edited from AEC's website: www.aec.org)

Benefits

Aluminum in general (and extruded aluminum profiles in particular) offers a number of advantages over other materials (and other forming processes). Other materials may offer some of the beneficial characteristics of aluminum profiles, but aluminum can offer a complete range of benefits at once. Aluminum extrusion is a versatile metal-forming process that enables designers, engineers, and manufacturers to take full advantage of a wide array of physical characteristics:

- **Lightweight.** Aluminum weighs less by volume than most other metals. In fact, it is about one-third the weight of iron, steel, copper, or brass. Lightweight aluminum is easier to handle, less expensive to ship, and is an attractive material for applications in fields such as aerospace, high-rise construction, and automotive design.
- **Strong.** Profiles can be made as strong as needed for most applications. Cold-weather applications are particularly well-served by aluminum because, as temperatures fall, aluminum actually becomes stronger!
- **Exhibits High Strength-to-Weight Ratio.** Aluminum offers a unique combination of light weight and high strength. Without aluminum, space travel might never have been realized. Engineers are discovering that bridge decks constructed from extruded aluminum can bear heavier live loads, in part because the aluminum bridge deck itself weighs so much less than a conventional steel deck.
- **Resists Corrosion.** Aluminum offers excellent corrosion resistance; it does not rust. Aluminum is protected by its own naturally occurring oxide film, a protection that can be further enhanced by anodizing or other finishing techniques.
- **Excellent Thermal Conductor.** Based on weight and overall cost, aluminum conducts heat (and cold) better than other common metals. These factors make aluminum ideal for applications requiring heat exchangers, especially because extrusion, as a metal-forming process, is well-suited to produce shapes that make optimal use of thermal conduction properties.
- **Does Not Emit Sparks.** Because aluminum is nonsparking, it is appropriate for applications involving explosive materials or taking place in highly flammable environments.
- **Conducts Electricity.** Bulk power transmissions generally take place via aluminum because, pound-for-pound, aluminum is twice as conductive as copper.
- **Nonmagnetic.** Because aluminum does not acquire a magnetic charge, it is useful for high-voltage applications, as well as for electronics, especially where magnetic fields come into play or where sensitive magnetic devices are employed.
- **Resilient.** Aluminum combines strength with flexibility and can flex under loads or spring back from the shock of impact.
- **Reflective.** Highly reflective aluminum can be used to shield products or areas from light, radio waves, or infrared radiation. Aluminum is not combustible. Aluminum does not burn and, even at extremely high temperatures, does not produce toxic fumes.

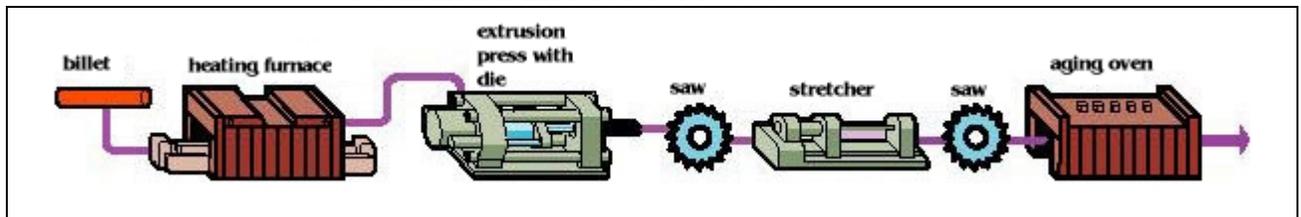
- **Suited to Extreme Cold.** The strength of aluminum actually increases under very cold temperatures, making it especially useful for cryogenic applications and in the extreme cold of outer space, as well as for aircraft and for construction in high latitudes.
- **Recyclable.** Aluminum retains a high scrap value. It can be recycled indefinitely without losing any of its superior characteristics, making it especially appealing according to both environmental and economic criteria.
- **Accepts a Variety of Common Finishes.** Aluminum can be finished with liquid paint (including acrylics, alkyds, polyesters, and others), powder coatings, anodizing, or electroplating.
- **Seamless.** Complex shapes can be realized in one-piece extruded aluminum sections without having to effect mechanical joining methods. The resultant profile typically is stronger than a comparable assemblage, less likely to leak or loosen over time.
- **Can be Joined in Many Ways.** Extruded aluminum sections can be joined by all major methods in use today, including welding, soldering, or brazing, as well as through use of adhesives, clips, bolts, rivets, or other fasteners. Integral joining methods may be especially useful for certain designs.
- **Economical.** Extrusion tooling is relatively inexpensive and may not require long lead times. Even short-run prototypes often can be produced at moderate cost.

Applications

There are three basic categories of applications for aluminum extrusion:

- **Building and Construction:** a wide range of products from residential windows to high-rise curtainwall
- **Transportation:** covers numerous component parts in the automotive, truck, rail, aerospace, and marine sectors
- **Engineered Products:** includes all other products from consumer goods (air conditioners) to electrical items (power units) to machinery and equipment (irrigation pipes) to food display and refrigeration.

Aluminum Extrusion Process

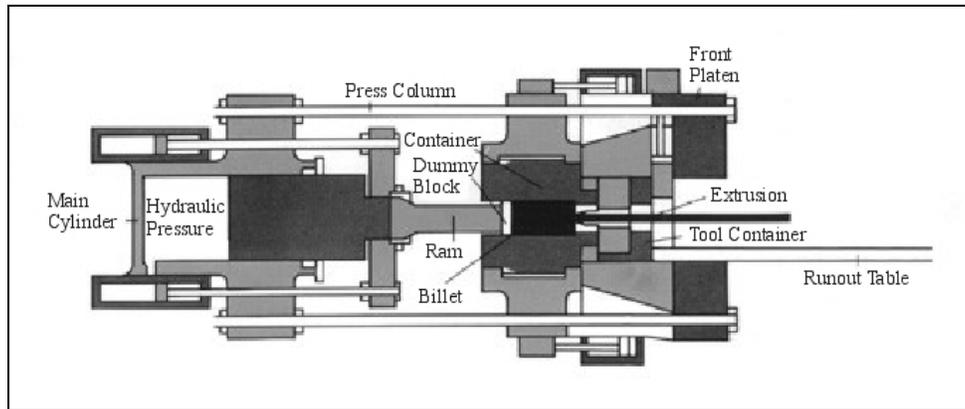


Basic steps involved in extruding an aluminum profile.

Process Overview: Direct and Indirect Extrusion

The aluminum extrusion process really begins with the design process, for it is the design of the product--based on its intended use--that determines many of the ultimate production parameters. Questions regarding machinability, finishing, and environment of use will lead to the choice of alloy to be extruded. The function of the profile will determine the design of its form and, hence, the design of the die that shapes it.

Once the design questions have been answered, the actual extrusion process begins with billet, the aluminum material from which profiles are extruded. The billet must be softened by heat prior to extrusion. Using the direct extrusion process, the heated billet is placed into the extrusion press, a powerful hydraulic device wherein a ram pushes a dummy block that forces the softened metal through a precision opening, known as a die, to produce the desired shape.



Typical horizontal hydraulic extrusion press; direction of extrusion shown is from left to right.

Direct extrusion is the most common method in use today. Indirect extrusion is a similar process, but with some important differences. In the direct extrusion process, the die is stationary and the ram forces the alloy through the opening in the die. In the indirect process, the die is contained within the hollow ram, which moves into the stationary billet from one end, forcing the metal to flow into the ram, acquiring the shape of the die as it does so.

The extrusion process has been likened to squeezing toothpaste out of a tube. When pressure is applied at the closed end, the paste is forced to flow through the open end, accepting the round shape of the opening as it emerges. If the opening is flattened, the paste will emerge as a flat ribbon. Complex shapes can be produced by complex openings. Bakers, for example, use a collection of shaped nozzles to decorate cakes with fancy bands of icing; they're producing extruded shapes.

Billet

Billet is the starting stock for the extrusion operation. Extrusion billet may be a solid or hollow form, commonly cylindrical, and is the length charged into the extrusion press container. It is usually a cast product but may be a wrought product or powder compact. Often it is cut from a longer length of alloyed aluminum, known as a log.

Alloys are metals composed of more than one metallic element. Aluminum extrusion alloys contain small amounts (usually less than five percent) of elements such as copper, manganese, silicon, magnesium, or zinc. These alloying elements enhance the natural properties of aluminum and influence the extrusion process.

Billet length varies according to a number of factors, including the desired length of the finished profile, the extrusion ratio, the length of the runout, and the requirements of the extrusion press. Standard lengths may run from about 26 inches (660 mm) up to 72 inches (1,830 mm). The outside diameter may range from 3 inches (76 mm) to 33 inches (838 mm); 6-inch (155 mm) to 9-inch (228 mm) diameters are the most common.

Dies and Tooling

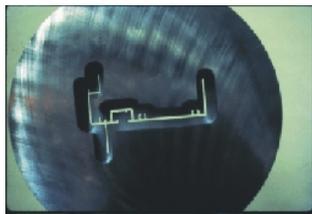
Dies can be made to form a virtually limitless array of shapes and sizes.

A typical extrusion operation will make use of a die assembly, including the die itself, which, together with a backer, is enclosed within a die ring, placed in front of a bolster, with a sub-bolster behind, all held together as a unit by a tool carrier. The backer, bolster, and sub-bolster provide the necessary support for the die during the extrusion process.

The extrusion die, itself, is a steel disk (normally H13) with an opening, the size and shape of the intended cross-section of the final extruded product, cut through it.

Dies are broadly grouped as solid (or flat) dies, which produce solid shapes, and hollow dies, which produce hollow or semihollow shapes. Combinations of solid, semihollow, and/or hollow shapes may be incorporated into a single die.

- **Solid die:** may have one or more orifices or apertures through which the softened alloy is forced (extruded). Multiple apertures in a single die produce multiple extrusions with each stroke of the press.
- **Semihollow die:** extrudes a shape that is nearly hollow, partially enclosing a void, the area of which (the area of the die tongue) is large in comparison with the gap where the tongue is connected to the main body of the die.
- **Hollow dies:** take a variety of forms, the most common being porthole and pancake. *Bridge, porthole, and spider dies*, for example, include a fixed stub mandrel as an integral part of the die. Each type of hollow extrusion die serves certain functions and carries its own advantages and disadvantages. The manufacturing methods and costs vary widely. The choice of design, and even manufacturing methods, will depend on the profile, press and container size, and production requirements.



Solid die



Semihollow die



Hollow die

A critically important characteristic of extrusion dies is that the effective bearing length controls the metal flow through the die. The objective is to have all parts of the profile emerge from the die at the same speed. The longer the bearing length, the greater the resistance to the flow of aluminum and the shorter the bearing length, the less resistance to flow. Through effective design, the thick parts of a profile can be slowed through the use of longer bearings to match the speed of the thinner parts with short bearings.

Direct Extrusion Operation

Once the shape of the final product has been identified, the proper alloy selected, and the die prepared, to make ready for the actual extrusion process, the billet and extrusion tools are preheated. During extrusion, the billet is still solid, but has been softened in a heating furnace. The melting point of aluminum varies with the purity of the metal, but is approximately 1,220° Fahrenheit (660° Centigrade). Extrusion operations typically take

place with billet heated to temperatures in excess of 700°F (375°C), and--depending upon the alloy being extruded--as high as 930°F (500°C).

The actual extrusion process begins when the ram starts applying pressure to the billet within the container. Various hydraulic press designs are capable of exerting anywhere from 100 tons to 15,000 tons of pressure. This pressure capacity of a press determines how large an extrusion it can produce. The extrusion size is measured by its longest cross-sectional dimension, sometimes referred to as its fit within a circumscribing circle diameter (CCD).

As pressure is first applied, the billet is crushed against the die, becoming shorter and wider until its expansion is restricted by full contact with the container walls. Then, as the pressure increases, the soft (but still solid) metal has no place else to go and begins to squeeze out through the shaped orifice of the die to emerge on the other side as a fully formed profile.

About 10 percent of the billet, including its outer skin, is left behind in the container. The completed extrusion is cut off at the die, and the remainder of the metal is removed to be recycled. After it leaves the die, the still-hot extrusion may be quenched, mechanically treated, and aged.

Extrusion rates vary, depending on the alloy used and the shape of the die. A hard alloy, given a complex shape, may emerge from the press as slowly as one or two feet per minute; a soft alloy taking on a simple shape may be extruded at a rate of 180 feet per minute, or even faster.

Depending on billet size and die opening, a continuous extrusion as much as 200 feet long may be produced with each stroke of the press. The newly-formed extrusion is supported on a runout conveyor as it leaves the press. Depending on the alloy, the extrusion is cooled after emerging from the die, either naturally or through the use of air or water quenches. This is a critical step to ensure sufficient metallurgical properties after aging. The extrusion is then transferred to a cooling table.

Stretching

A stretcher and/or straightener may be employed, after the profile has been quenched (cooled) to straighten the extrusion and correct any twisting that may have occurred subsequent to extrusion. (The stretcher may also be used to impart cold work to the extrusion.) Conveyors feed the work to the saw.

Cutting

Typically, a finish cut saw is used to cut the profile to the specified commercial length. Circular saws are the most common in use today and are generally similar to a radial arm saw that cuts across the profile at a perpendicular angle to the length of the extrusion. Other saws may swing down onto the profile (like a power miter saw), or may operate more like a table saw, with the circular blade rising up to make the cut, then dropping down below the table for the return pass.

- A typical, circular, finish cut saw may be 16 - 20 inches in diameter, with more than a hundred carbide-tipped teeth. Larger saws are used for larger-diameter presses.
- Lubricated saws are equipped with delivery systems that feed the lubricant through the teeth of the saw for optimal efficiency and cut surface.
- Automatic devices clamp profiles in place for sawing. Saw chips are collected for later recycling.

Aging

Some extrusion alloys reach their optimal strength through the aging process, sometimes known as age-hardening. Natural aging occurs at room temperature. Artificial aging takes place through controlled heating in an aging oven and is sometimes referred to as precipitation heat-treating. The aging process ensures the uniform precipitation of fine particles through the metal, yielding maximum strength, hardness, and elasticity for the specific extrusion alloy.

When the profile emerges from the press, it is in a semi-solid state but rapidly solidifies as it cools or is quenched (whether by air or water). Non-heat-treatable aluminum alloys (such as those utilizing manganese or magnesium) derive their strength through natural aging and cold working. Heat-treatable alloys (such as those utilizing copper, zinc, and magnesium with silicon) are further strengthened or hardened through controlled thermal treatments that affect the metallurgical structure of the alloys.

Packaging

After sufficient aging, whether in an aging oven or at room temperature, the profiles are moved to other areas of the plant for finishing or fabricating, or to be packed and prepared for shipment to the customer.

Most extrusion plants are equipped to accommodate any likely packaging requirement. Profiles are palletized in such a way as to be protected from surface damage, twisting, or other hazards. Customers may specify their own packaging requirements, or the type of extruded product may suggest a particular method of packaging for ease of storage or delivery.

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