

Aluminum Extrusion Design

7 Decisions that Increase
Your Die Tooling Costs

Introduction

With its low price point and numerous benefits, such as strength, lightweight, and thermal conductivity, aluminum has quickly gained favor among design engineers across a number of industries. With the unique capability to create complex shapes and combine functions within a single profile—a capability that helps reduce part count, improve functionality, eliminate machining and tooling, and minimize overall manufacturing cost—more designers are leveraging aluminum extrusions.

Unfortunately, many designers still overlook extruded aluminum manufacturing in favor of stamped or machined parts, believing extrusions to be an expensive process based solely on the initial cost of an extrusion die. While an aluminum extrusion die can range from \$1,500 to \$5,000, depending on several

variables, the die tooling cost is considerably lower than that of other manufacturing methods (as shown below). In addition, the normal lead time to produce an extrusion die is about 10 to 14 days. Other processes, such as punch tools, injection molding, and die casting, can take 10 weeks or more.

| Process | Typical Tooling Cost | Typical Tooling Lead Time |
|---------------------|----------------------|---------------------------|
| Vinyl Extrusion | \$500 - \$2,500 | 3-4 weeks |
| Injection Molding | \$1K - \$100k+ | 2-10+ weeks |
| Die Casting | \$50k - \$300k+ | 10-14+ weeks |
| Roll Forming | \$15k - \$50k+ | 10-12 weeks |
| Metal Stamping | \$1,500 - \$50k+ | 6-12 weeks |
| Aluminum Extrusions | \$1,500 - \$5,000 | 1-3 weeks |

Extrusion die tooling costs can vary dramatically based on several factors that most engineers don't consider or are simply unaware of. This guide discusses seven factors that impact the cost of creating an extrusion die and provides guidance for designers working with aluminum extrusions.

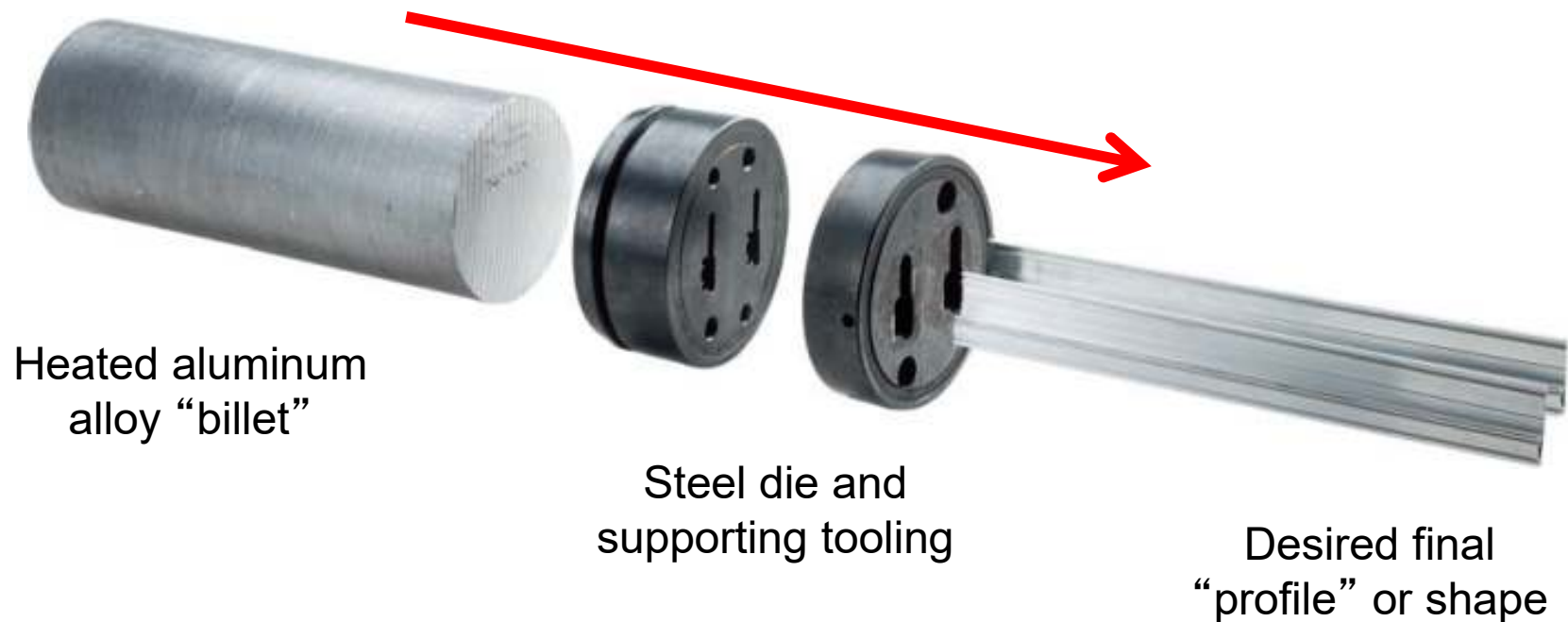
Understanding Die Types

If you're new to aluminum extrusions, it's important to understand what an extrusion die is before diving into how different design decisions impact the cost of a die. Extrusion dies are essentially thick, circular steel disks containing one or more openings to create the desired profile. They are normally constructed from H-13 die steel and heat-treated to withstand the pressure and heat of hot aluminum as it is pushed through the die.



While it may appear that aluminum is a very soft metal, the reality is that it takes tremendous pressure to push a solid log (billet) of aluminum through a thin, multi-holed die to create the desired shape. In fact, it takes 100-125,000 psi of force to push a billet through an 8-inch press.

To put that force into context, a power washer to clean a car pushes out water at around 2,500 psi. Increasing that pressure to 5,000 psi can destroy the brick on a building. The pressure produced in an extrusion press is 20 times that amount.



Die Profile Categories

While there are a multitude of shapes that can be created using aluminum extrusions, the dies used fall into three categories: solid, semi-hollow, and hollow.

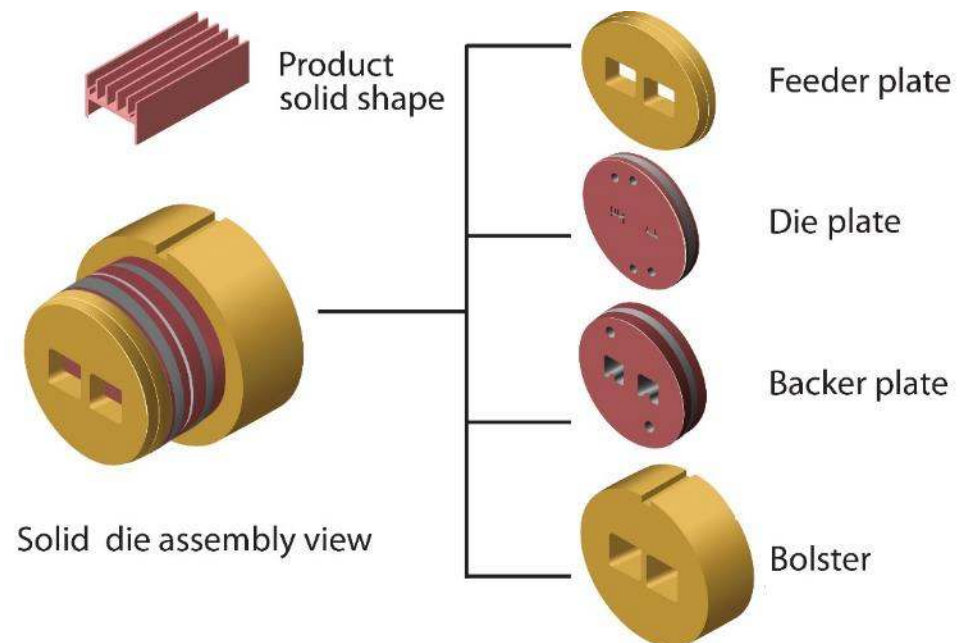
Solid Dies

A solid die creates a final shape that has no enclosed voids/openings, such as a rod, beam, or angle. As such, a solid die is typically less expensive to manufacture than other die types.

To produce a solid profile requires a set of parts called a "die stack." This stack is made up of:

- Feeder plate - controls the metal flow through the die orifice.
- Die - forms the shape.
- Backer plate - supports the tongue of the die to prevent collapse or distortion.

- Bolster - supports the extrusion load transmitted from the die and backer.

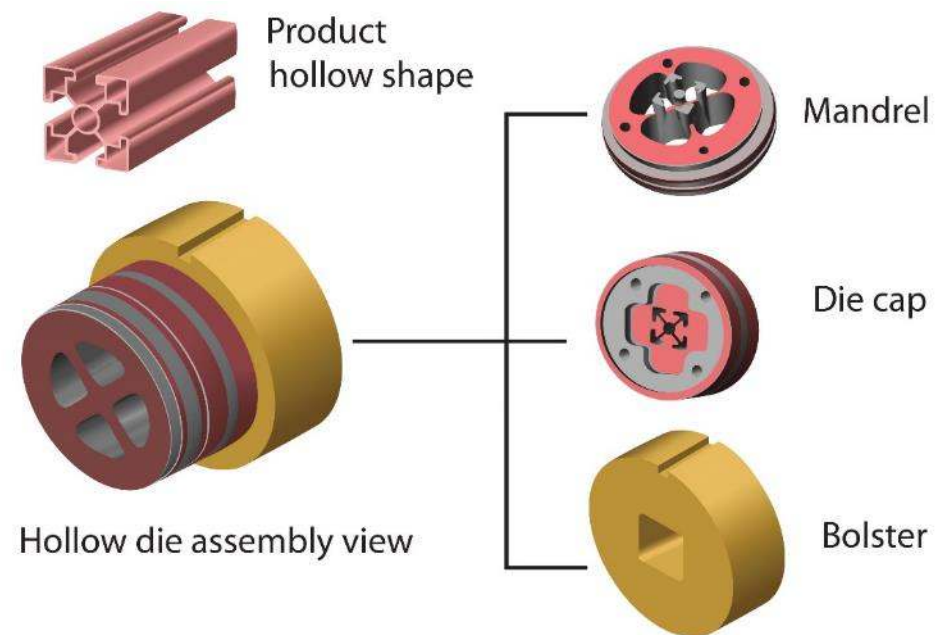


Hollow Dies

A hollow die produces profiles with one or more voids, such as a simple tube with a single void or a complex profile with multiple detailed voids. To produce a hollow shape requires a different die set, which includes:

- Mandrel - Located inside the die, a mandrel has two or more port holes to generate the internal features of the profile and to control the flow of metal. During extrusion, the aluminum billet separates into each port and rejoins in the weld chamber before entering the bearing area. The ports are separated by webs, also known as legs, which support the core or mandrel section. Because of these extra components, a hollow die has higher material and tooling costs and typically becomes more expensive as more voids are included.
- Die Cap - multi-piece die which makes the shape.
- Bolster - supports the extrusion load transmitted

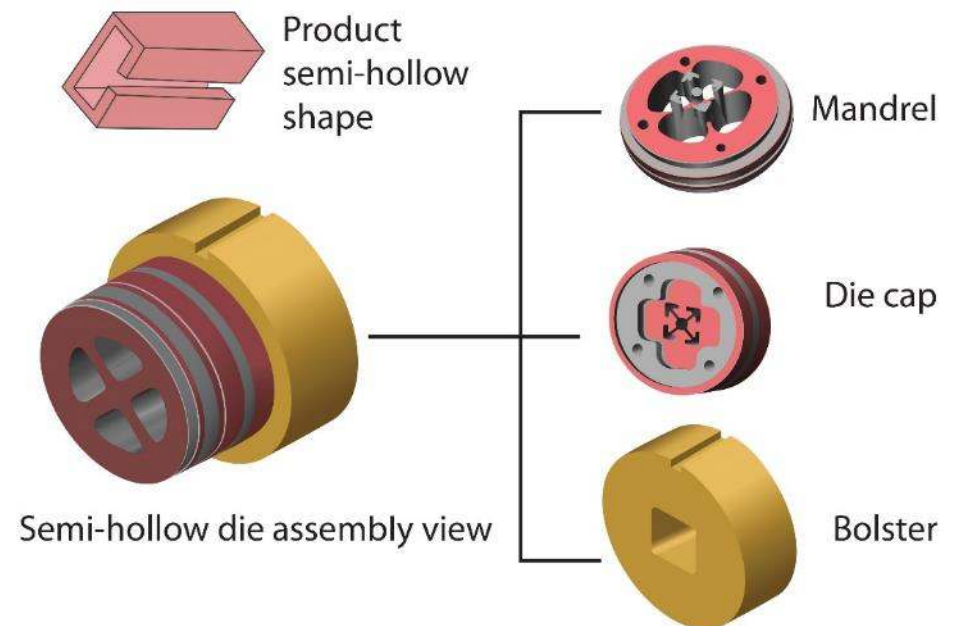
from the die cap and mandrel.



Semi-Hollow Dies

A semi-hollow die extrudes a shape that is nearly hollow, partially enclosing a void. Similar to a hollow die, a semi-hollow die set includes a mandrel with port holes, but without cores to make a complete void, as well as a die cap and bolster.

While a solid die may also partially enclose a void, the difference is the ratio of the area of the void to the size of the gap where the tongue is connected to the main body of the die. This ratio is called the tongue ratio. For semi-hollow dies, the tongue ratio is larger than in a solid die, which creates more complexity when manufactured, and in turn, more cost.



Efficiency & Die Tooling Costs

The efficiency of the die creation process has improved greatly in the past few decades. Thirty years ago, 75% of the aluminum extruded on a new die was produced to specifications, and 25% was waste. Today, the industry-wide rate is 92% to 95%. These improvements can largely be attributed to advances in computer-aided design and extrusion technology, which enable manufacturers to meet higher tolerance requirements from customers. Yet, even with these advancements, there are still several factors that influence the cost of producing a die. These factors include:

1. Use of standard versus custom die
2. Die size
3. Profile shape
4. Wall thickness
5. Tongue ratio
6. Tolerance requirements
7. Aluminum alloy used



1. Standard Versus Custom Die

A standard die is a common shape. Standard dies can be solid, such as a rod, bar, angle, or channel, or hollow, such as a square or rectangular tube with a single void.

A standard solid die costs between \$1,500 and \$3,000, while a standard hollow die costs \$2,000 or more.

Variation within that range is due to the die's size and shape and the size of the press required to manufacture it.

A custom die is made to a specific shape and for a specific purpose. In general, custom dies come with a higher price tag, with actual cost varying greatly based on the complexity of the design. Due to this complexity and the higher dimensional tolerance requirements, not all aluminum extruders offer custom extrusion manufacturing. MMG Engineered Extrusions has built a reputation for working closely with designers in need of custom extrusions and having the capabilities to manufacture custom dies to meet demanding specifications.

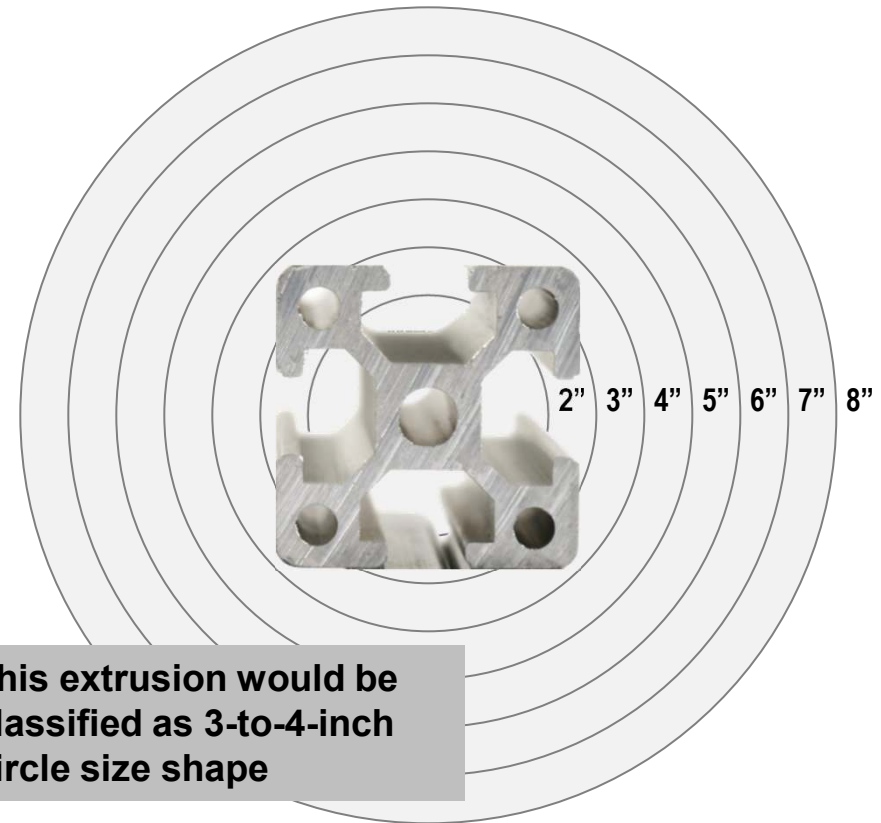


2. Die Size

A common measurement of an extrusion profile is its circumscribing circle diameter (CCD)—the diameter of the smallest circle that entirely encloses an extrusion cross-section. The circumscribed circle of the profile will determine the size of the press it can be extruded on. Most common profiles are less than 8" in diameter, but a few extruders can produce extrusions with a larger CCD, some as large as 18".

However, depending on how the die must be designed to produce the desired shape, a larger die, and hence a larger press, may be required. There is a significant force generated when pushing a billet through a die, so if a profile requires multiple voids, it may be necessary to create more openings within the die. Thus, the diameter of the container will need to be slightly larger than the shape so it extrudes accurately. This enables the aluminum to flow through the die without too much negative pressure. As you might guess, large custom

dies cost more and take longer to produce. For example, a die over 11" will typically require an additional 4-5 days to produce and, on average, cost \$1,000 or more than a 9" die.

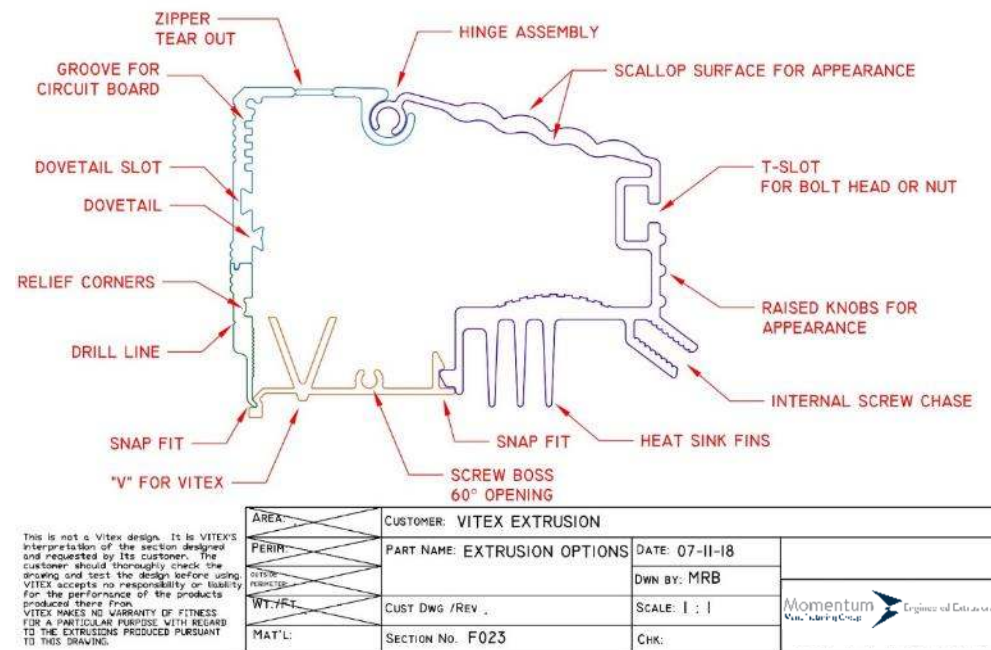


3. Profile Shape

When designing for aluminum extrusions, the more unsymmetrical or unbalanced a shape, the less likely it is to remain straight or hold angles and general dimensions. While non-symmetrical shapes can be produced, metal flows less readily into narrow and irregular die sections, making distortion and other quality problems more likely. If an extrusion manufacturer determines it can extrude a non-symmetrical shape, it should not come as a surprise that both the die tooling cost and the production estimate are higher due to a slower extrusion rate (the need to push the metal through the die at a slower rate to avoid breakage).

Additionally, the number of sides and channels in a die, the more expensive the extrusion, and achieving shape accuracy is reduced. This often happens when designers try to incorporate too many features into the profile. While a unique benefit of aluminum extrusions

is the ability to incorporate holes, slots, or screw bosses into the shape, it can result in highly complex designs that are very costly to produce (or not extrudable at all).



Sometimes, small changes in a profile's shape or size can dramatically decrease tooling costs. Some designs (example below) with multiple voids can be redesigned to a single void, resulting in a 10% cost reduction and a reduced risk of die breakage.



Initial Design



Redesign After Extruder Feedback

For example, one customer's initial drawing called for a 6" x 3" hollow die with three voids. Die tooling cost was \$5,000. After discussing the design with our die team, the designer returned with a revised drawing, which called for a 3" x 4" hollow die with the same number of voids, which cut the die tooling cost in half.

Die Longevity & Replacement

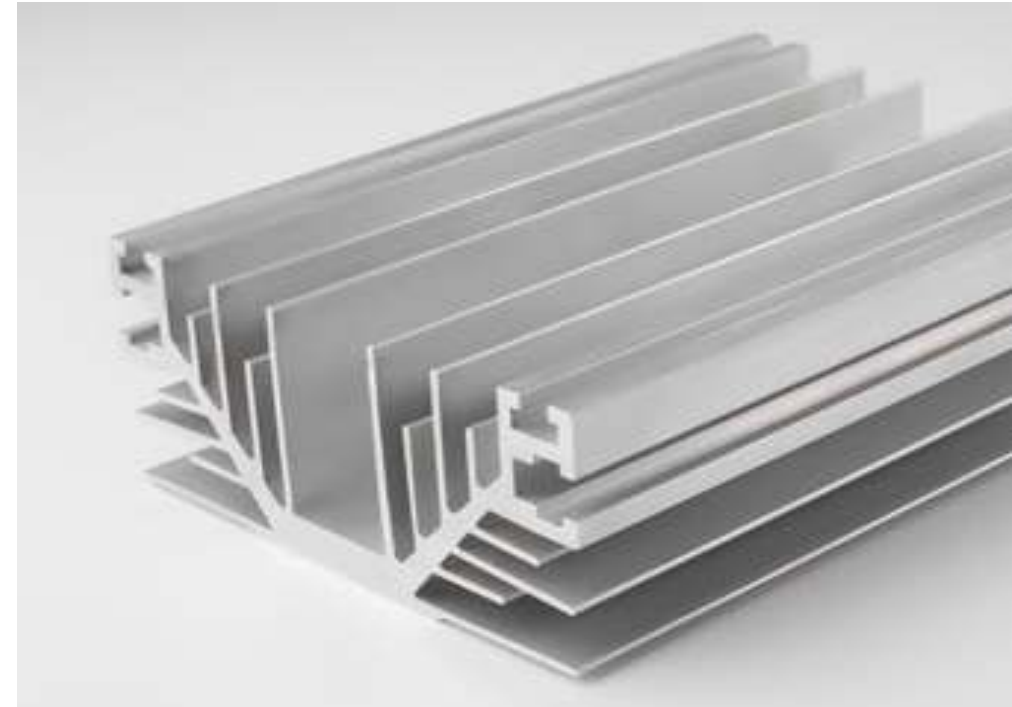
Heat buildup and uneven pressure caused by a profile's design—use of thin walls, unbalanced shapes, and protruding legs—are the biggest killers of the longevity of an extrusion die. An experienced extruder will design the die to control heat and uneven pressure and to slow the extrusion rate to extend the life of the die, but eventually, dies must be replaced. Fortunately for designers, most extruders absorb the cost of die replacements.

4. Wall Thickness

To ensure the integrity of the profile shape and avoid distortion, the extruded material should exit the die at a uniform velocity. As with non-symmetrical shapes, dies with unequal wall thickness can be difficult to produce because hot aluminum is forced through the widest sections the fastest, while moving slowly through the thinner areas. If the thinner sections do not fill properly, the entire profile could become compromised and twist during extrusion. Thus, adjustments and proper testing of the die before production are needed, which adds costs.

While simpler designs with soft lines, symmetrical shapes, and a lack of deep channels are less costly to produce, there are certain advantages to having a variety of thicknesses, such as increasing the strength of a product by concentrating the thickness away from

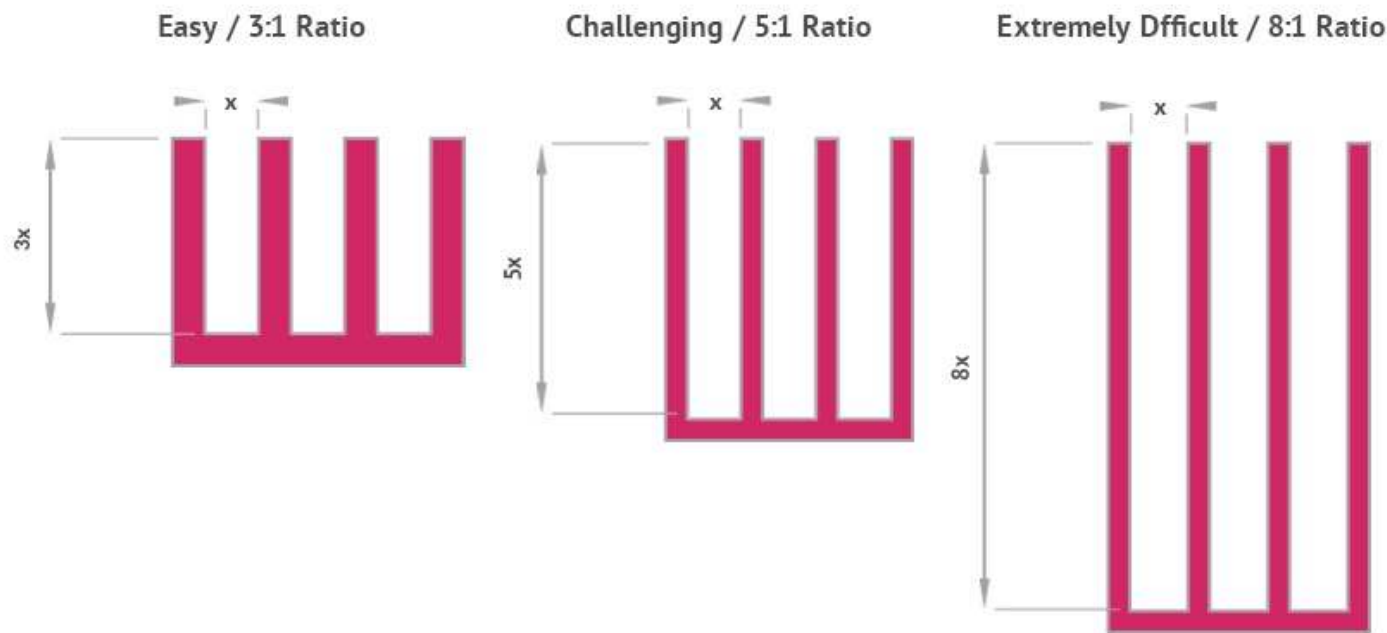
the center of gravity and moving it toward the outside of the profile. So if your product requires these unique shapes, they are extrudable, just costlier to produce.



5. Tongue Ratio

Another factor in a profile's complexity is its tongue ratio. Tongue ratio of an extrusion is calculated as Area/Gap^2 , whereas the total area of the shape is divided by the square of the smallest opening to the void (Gap). The higher the ratio, the more difficult the part will be to extrude. Once your calculations go past the 4:1 ratio, the tongue become considerably more

difficult to extrude because the pressure required to push the metal through the gaps is too great for the steel strength of the die. This usually causes the die to bend or break sooner, causing an out-of-tolerance condition or complete failure of the die. This results in longer lead times and unscheduled downtime.



For example, this heat sink, which has a high tongue-to-die ratio, created the following issues when extruded:

- Material began to bow and flex because the bottom of the extrusion was filling faster than the fins. This caused the surface to become wavy.
- Design would not hold dimensional tolerances.
- Added pressure against the die plate caused the die to break.
- To reduce die breakage, production had to run too slow, causing cost and production time to increase.

Use of Zero Bearing Dies

An alternative approach is to use a “zero bearing” die to provide greater support for the tongue condition. A zero-bearing design uses multi-stage flow chambers to control metal flow around all extrusion positions at the same bearing height and includes a small outside cone angle to reduce metal deformation and minimize friction, thereby greatly improving extrusion speed. Given the additional tooling and testing required for production, a zero-bearing die is considerably more expensive than a standard extrusion die.



High tongue ratio makes this profile challenging to produce.

6. Tolerance Requirements

When working with aluminum extrusions, it is important to understand the standard levels of acceptable tolerance for characteristics such as straightness, flatness, and twist, as well as cross-sectional dimensions as thickness, angles, contours, and corner or fillet radii. These tolerances are published in the Aluminum Association's Aluminum Standards & Data guide.

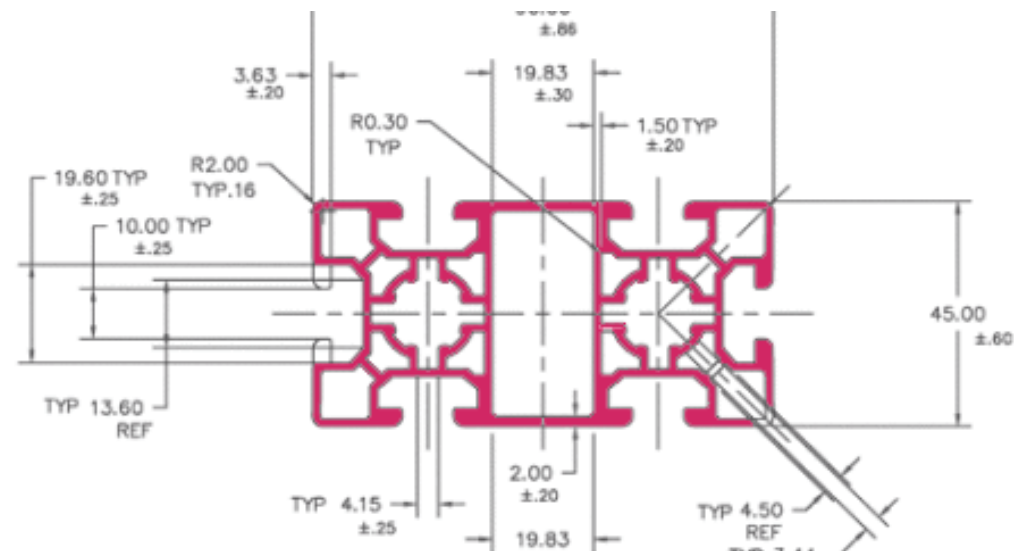
While standard industry tolerances usually provide adequate precision for most applications, more complex components may call for greater geometric dimensioning and tolerancing in order to achieve the shape-related intricacies. When requested, very precise tolerances of 1/2 or 1/3 of the specified tolerance may be feasible. For example, if the tolerance calls for + or - .010, a tighter tolerance of perhaps + or - .005 could be held, when requested and deemed feasible.



However, to achieve these tighter tolerances may require more involved die corrections, slower extrusion rates, and sometimes a higher rejection rate. All that special care adds up to higher costs. Therefore, carefully consider the application of your part or product when setting tolerances. For example, in assembly, if dimensions do not fall within a specified range, the parts will not fit together. Replacement parts must also be a duplicate of the original part within certain limits of deviation. So always check the part tolerance of the item you are mating with the aluminum extrusion.

Also, be aware of tolerance stack up when designing your profile. Tolerance stack-up calculations represent the cumulative effect of part tolerance with respect to an assembly requirement. By adding tolerances to determine the total part tolerance, then comparing it to the available gap or performance limits, you can determine whether the design will work properly.

A good rule of thumb is to NOT TOLERANCE ANYTHING that doesn't absolutely have to have a tolerance. In rare instances when a desired tolerance may not be achievable, the die design team may suggest a change that solves the problem while still meeting the profile's functional requirements.

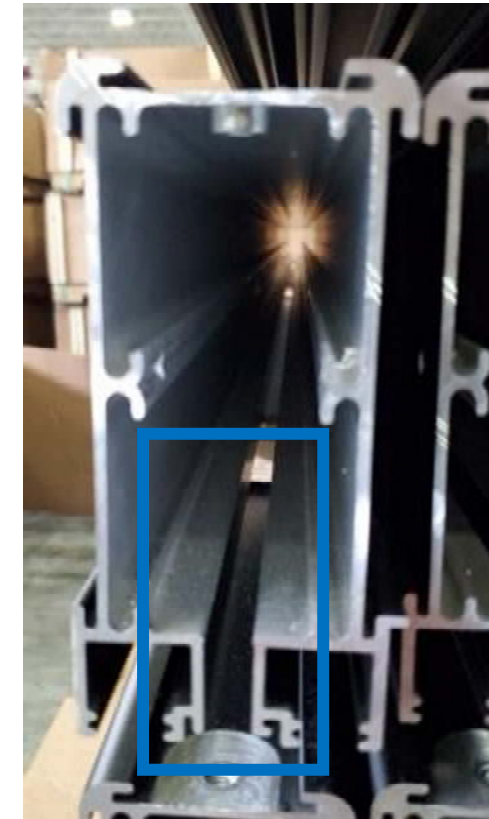


Unique Technique to Achieve Tighter Tolerances

To improve the chances of holding tighter tolerances between gap openings in a semi-hollow die, a fine wire, called a “zip strip,” can be inserted into the die during manufacturing. It is then removed after the profile has been extruded and artificially aged. Where the wire connects to the die, the metal is so thin that the manufacturer can “zip” the wire off the die, leaving the required channel in the shape. This method offers greater flexibility when working with designs that are not easily extruded, but requires more human intervention, which increases cost.



Zip Strip In Place



Zip Strip Removed

7. Aluminum Alloy Used

The aluminum alloy used will also influence the cost of the extrusion die. Some dies must be replaced after 20-30,000 pounds of aluminum have been extruded, while others can last to 100,000 pounds or more. This is largely dependent on the alloy used. Some alloys, due to the alloying elements such as copper, magnesium, manganese, and zinc, are rougher than others, causing faster wear and erosion to the die. In addition, stronger alloys require slower extrusion rates, which increase costs.

While some applications demand the use of specific alloys to meet set industry requirements, you should avoid choosing an alloy that is stronger than required. It is sometimes more cost-effective to increase dimensions and extrude the profile in a slightly softer, but more easily extruded alloy.

| ALLOY SERIES | ALLOY | PROPERTIES | APPLICATIONS |
|--------------|--------|---|--|
| 1XXX | Pure | Low strength, excellent thermal/electrical conduction and corrosion resistance, highly reflective | Fuel filters, electrical conductors, radiator tubing, lighting reflectors, decorative components |
| 2XXX | Cu | High strength, relatively low corrosion resistance, good elevated temperature strength | Aircraft skin, aircraft fittings and wheels, ballistic armor, forged and machined components |
| 3XXX | Mn | Medium strength, good formability, good corrosion resistance | Storage tanks, beverage cans, home appliances, heat exchangers, pressure vessels, siding, gutters |
| 4XXX | Si | High castability, high machinability, high fluidity, low ductility | Variety of castings, including large casting, filler metal (2xxx, 3xxx, 5xxx and 7xxx used for castings) |
| 5XXX | Mg | Medium strength, good formability, excellent marine corrosion resistance | Interior automotive, appliance trim, pressure vessels, armor plate, marine and cryogenic components |
| 6XXX | Mg, Si | Med-high strength, good corrosion resistance, easily extruded | Exterior automotive, automotive profiles, railcars, piping, marine, screw stock, doors and windows |
| 7XXX | Zn | Very high strength, prone to stress corrosion, poor corrosion resistance | Aircraft construction, truck trailers, railcars, armor plate, ski poles, tennis rackets |
| 8XXX | Li | Very high strength, low density | Aircraft and aerospace structures, foil, heat exchanger fin stock |

The Impact of Tariffs on Lead Times and Sourcing

Following tariff increases on imported aluminum in 2025, the availability of specialty alloys has tightened considerably in the U.S. market. Lead times for structural extrusions in 7xx and 2xx series alloys have reached 25–30 weeks, and drawn porthole tubing now requires 12–14 weeks in many cases.

To protect project timelines and cost forecasts, designers should work with extrusion partners who source aluminum domestically – where tariff exposure is avoided and material availability is more predictable – and engage that partner early enough in the project schedule to account for current lead time realities.



Bottom Line

While the upfront investment in an aluminum extrusion die may seem expensive, shorter lead times and lower overall production costs make it a clear winner for many product applications. Understanding which design decisions have the most dramatic impact on your upfront tooling costs—before you send your design to an aluminum extruder—can save you time and money. Changes, where possible, to a profile's design, tolerance settings, and alloy could save you thousands of dollars in tooling costs.

Whether you're new to aluminum extrusions or a seasoned extrusion designer, your aluminum extrusion manufacturer is your best resource for expert guidance on what is and is not extrudable. By engaging your extruder early in the design process, you can save yourself time and frustration when determining appropriate tolerances and tongue ratios. If your die design quote comes back higher than you expected,

just ask your aluminum extrusion manufacturing partner, "What can I do differently?"

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