

DESIGNING FOR PERFORMANCE

Delivering the best with
investment casting



DELIVERING THE BEST WITH INVESTMENT CASTING

Today's design engineers know they have to extract every ounce of innovation and performance from their components if they're to compete effectively in their markets. Success means taking a more complete view of the entire design process from how the component fits into the overall product, the precise form it needs to take, and the functional efficiency it must deliver.

For many engineers, investment casting has become the go-to process for its ability to deliver higher performance across a wide range of alloys. More than this, it enables designers to consolidate parts to deliver greater functionality and reduce demands on weight and space. And there's virtually no level of complexity it can't handle.

In this mini-guide, we'll give you a core overview of the key elements to designing higher performing precision components with investment casting.

It begins with the tool

Perhaps you're used to a less sophisticated process such as sand casting or forging. Or maybe you currently machine your components from solid. If so, you may not be used to the need for high quality production tooling. But, for investment casting, this is a core ingredient for delivering higher performance and consistently excellent results.

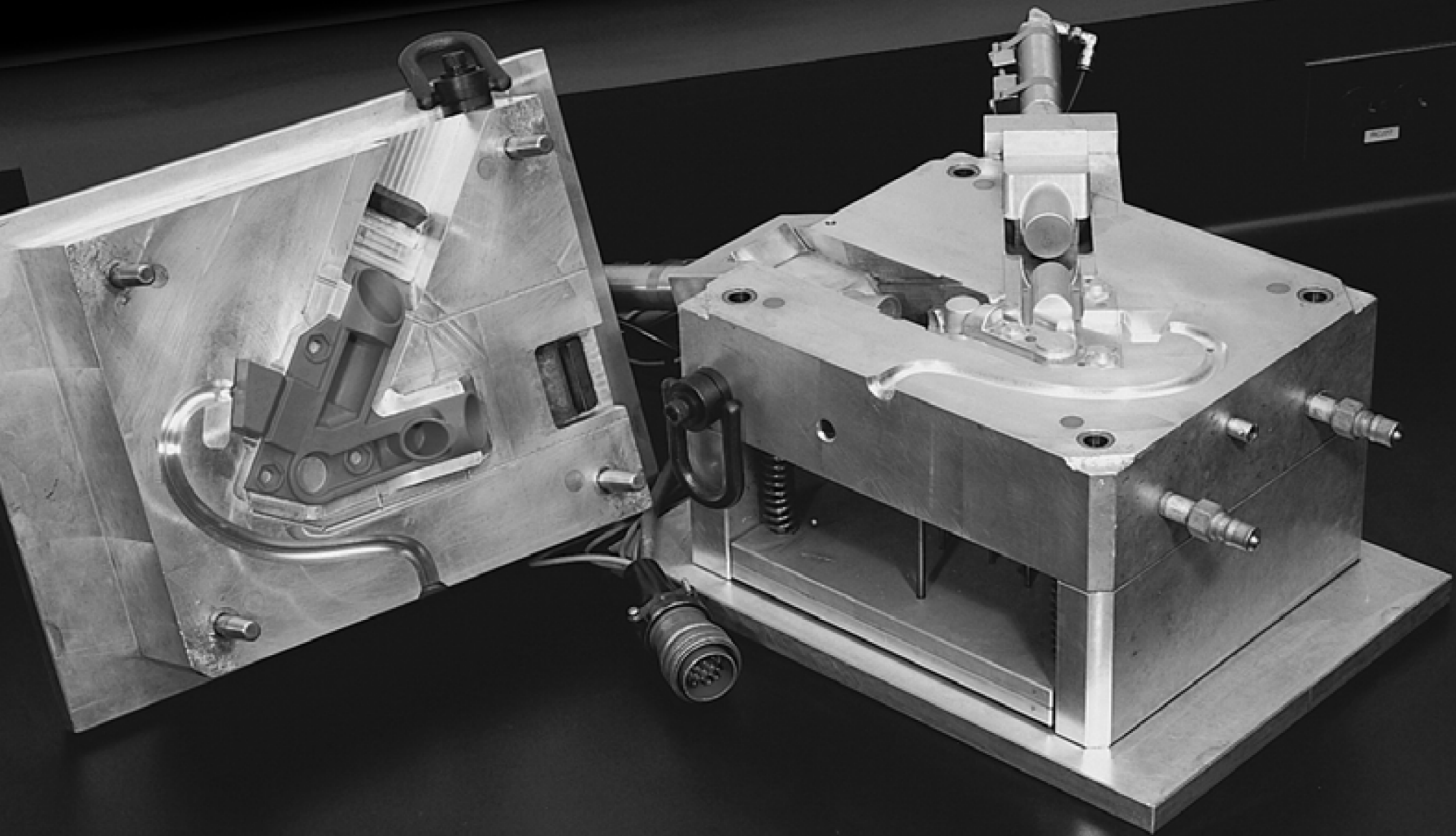
The high-precision tool provides the mold for the wax injection. This delivers the capability to reliably produce net-shape or near-net shape components across the entire production run (no matter how many parts you produce or how complex they are).

At Signicast, all tooling is constructed of 7075 T6 aluminum using CAD/CAM-driven CNC milling and EDM machines. It means we can consistently deliver the precision today's engineers demand. We offer manual tooling for low volume production and prototypes, semi-automatic for large and/or fragile components, and fully automatic for high volume production. Where a part has more complex internal shapes, we can produce tools with collapsible cores, loose inserts, multi-piece wax assemblies, soluble wax cores, and preformed ceramic cores.

Ultimately, this means we can produce virtually any type of component to any volume, no matter how complex—all with ultra-precise geometry inside and out. And we can do so in a fraction of the time of traditional approaches.

Investment Casting offers the freedom to work with virtually any alloy. **For more details, visit: www.signicast.com/material-options**

INVESTMENT CASTING



Tightening tolerances and ensuring repeatability

The investment casting process is capable of excellent repeatability. As-cast process capability of $\pm$ three standard deviations when a single point location is repeatedly measured is typically $\pm .003"$ to $\pm .004"$ per inch ($\pm 0.08\text{mm}$ to $\pm 0.10\text{mm}$ per 25.4mm).

ENGLISH (inches)		METRIC (millimeters)	
DIMENSION	TOLERANCE	DIMENSION	TOLERANCE
Up to .500"	$\pm .007$	Up to 15mm	± 0.20
Up to 1.000"	$\pm .010$	Up to 25mm	± 0.25
Up to 2.000"	$\pm .013$	Up to 50mm	± 0.35
Up to 3.000"	$\pm .016$	Up to 75mm	± 0.40
Up to 4.000"	$\pm .019$	Up to 100mm	± 0.50
Up to 5.000"	$\pm .022$	Up to 125mm	± 0.55
Up to 6.000"	$\pm .025$	Up to 150mm	± 0.65
Up to 7.000"	$\pm .028$	Up to 175mm	± 0.70
Up to 8.000"	$\pm .031$	Up to 200mm	± 0.80
Up to 9.000"	$\pm .034$	Up to 225mm	± 0.85
Up to 10.000"	$\pm .037$	Up to 250mm	± 0.95
Allow $\pm .003"$ for each additional inch.		Allow $\pm 0.1\text{mm}$ for each additional 25mm.	

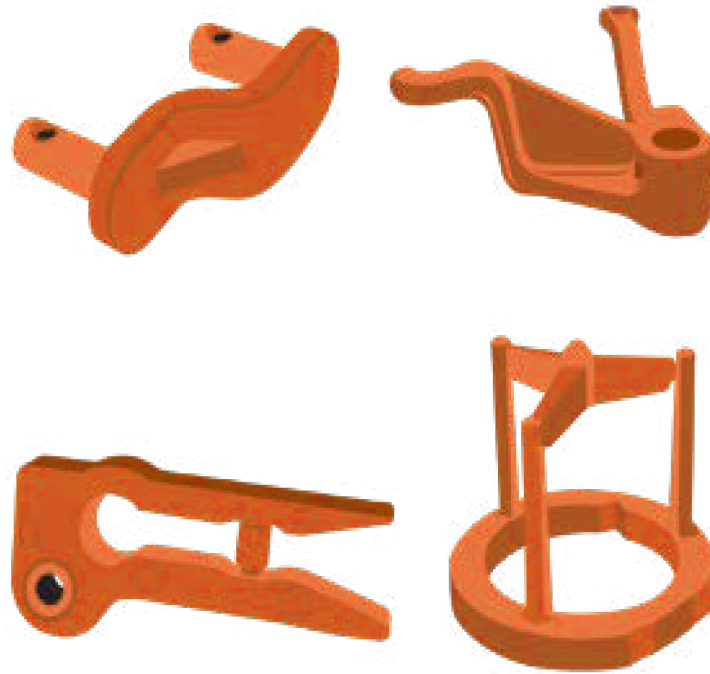
However, tolerance capability is largely influenced by part configuration. Symmetrical shapes with uniform wall sections will solidify with much less variation and distortion than non-symmetrical, non-uniform shapes.

There are three main sources of variation for linear tolerances across normal dimensions:

- Prediction of part and shrinkage factors (20% of linear tolerance)
- Diemaker and tooling (10% of linear tolerance)
- Process variation (70% of linear tolerance)

This variation is due to a combination of part geometry and process variation in producing a wax pattern, ceramic mold, and the casting itself. There are a number of ways all three can be reduced:

- Part redesign, including the addition of tie bars, ribs, and gussets
- Tuning wax injection tooling after the first sample to meet nominal dimensions
- Straightening/coining
- Additional inspection/gaging
- Machining



Premium tolerance capability can be achieved but must be considered on a part-by-part, dimension-by-dimension basis.

Signicast is capable of holding $\pm 0.002"$ ($\pm 0.05\text{mm}$) in some features, although $\pm 0.004"$ per inch ($\pm 0.10\text{mm}$ per 25.4mm) is more typical. It is important to specify tight tolerances which are core to part function, leaving the rest open to normal linear tolerances.

Achieving flatness and straightness

Parts will be held flat and/or straight to .005" per inch (0.13mm per 25.4mm) of length. Heavy part sections may be dished—up to an additional .010" (.25mm). We use feeler gauge and surface plate (or straight edge) methods to inspect flatness and straightness.

It is sometimes impossible to avoid straightening, which can add to costs. So, it's important not to specify tighter flatness, straightness, or roundness requirements than you actually require. Actual straightening costs are often dependent on the specified tolerance. We generally straighten parts using die sets that will be included in your tooling price.

Dealing with curves

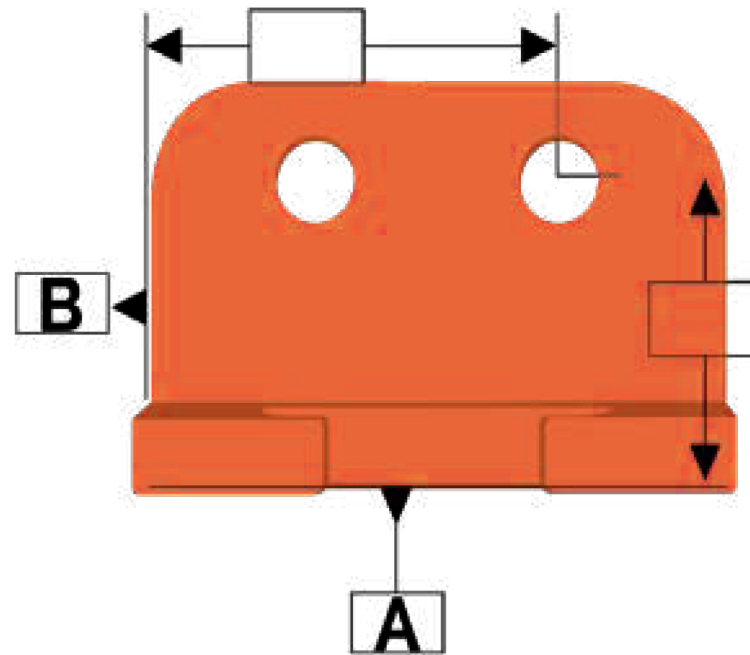
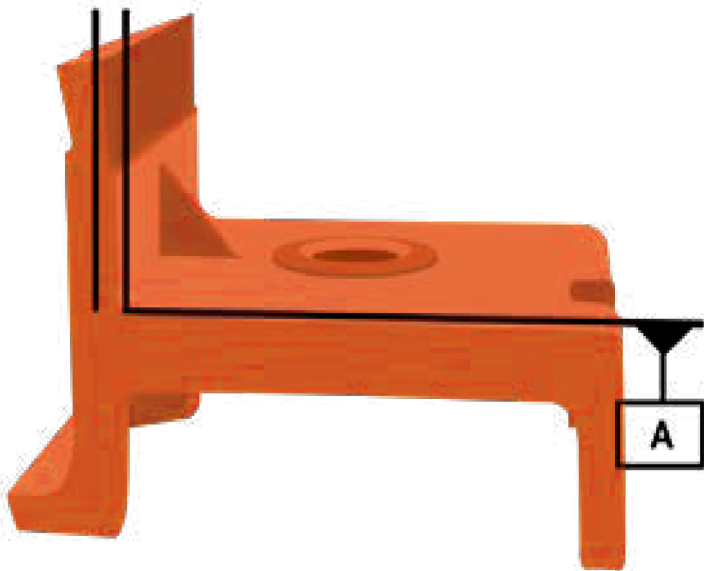
When it comes to curved surfaces, the profile holds the same tolerances and basic principles as flatness and straightness.

The importance of position

Develop linear tolerance based on the longest basic dimension. Concentricity is not a simple characteristic to measure. Consider changing the control to a runout or position notation.

Achieving the right orientation

When it comes to orientation, a good production tolerance is ± 0.5 degree or $\pm .008$ " per inch (± 0.20 mm per 25.4mm) of length. This figure may vary, however, depending upon the shape of the piece.



Getting the optimum surface texture

Roughness (Ra) will be approximately 125 microinch (3.2 micro-meters) maximum for parts of small sections weighing 0.5 pounds (0.2 kg) or less (larger parts may be rougher). Should you need a smoother surface texture, we can use secondary finishing operations to achieve the optimum result.

Adding radii

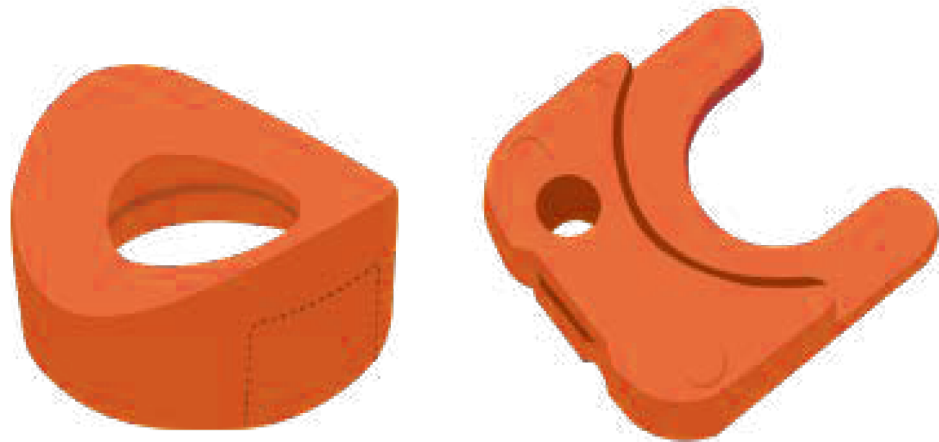
Normally, large fillet and corner radii reduce part stress and improve appearance. You should design with the largest fillet radii that are practical. Where possible, allow .030" R (0.75mm R) minimum outside corner radii. Sometimes outside corners must be tooled sharp, but we'll avoid this whenever possible.



Gate witness

This is a key area of difference between investment casting and other processes. With investment casting, parts are generally gated into one or more of the thickest sections. Allowing a 0.060" to 0.120" (1.52mm to 3.05mm) unground gate witness eliminates the need for secondary gate removal.

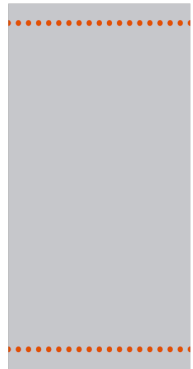
Gates can be removed flush to the adjacent surface or ground to a specific dimension if needed, but this often results in a higher manufacturing cost.



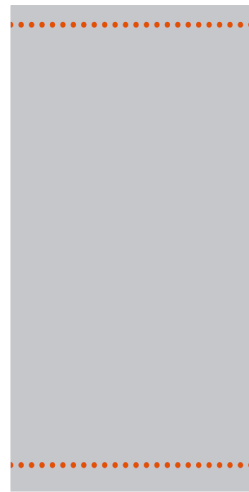
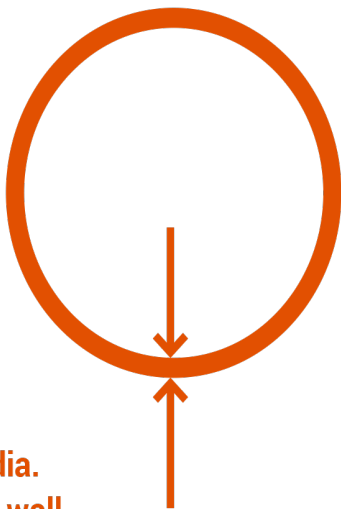
For accuracy, repeatability, and reduced piece cost, Signicast builds a gate grind fixture for all parts aiming to control the removal process to avoid hand belting. When possible, you should design your part so the gate can be placed on a flat—rather than curved—surface for economical gate witness removal.

Minimizing wall thickness

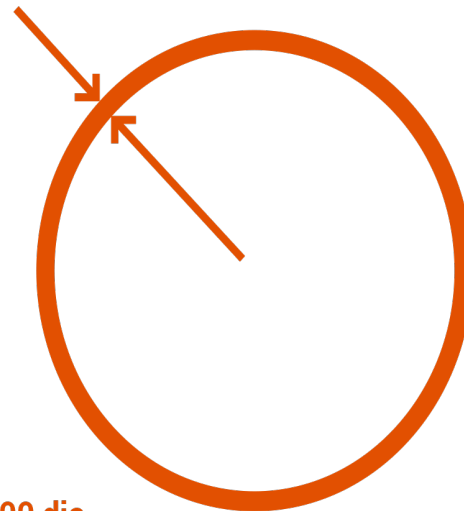
Minimizing wall thickness and corner radii depends upon part configuration and size. Small investment castings may have walls cast to .030" thickness while medium to large castings require .060"-.100" walls, depending on part geometry.



.50 dia.
.030 wall



3.00 dia.
.100 wall



Designing specific cast features

The investment casting process is capable of delivering a wide range of features. Gear and thread profiles can be produced with accuracies of $\pm.004"$ per $.5"$ ($\pm.10\text{mm}$ per 12.7mm) of pitch. And longer lengths or larger diameters can be held to normal or premium linear tolerances as necessary.



Let us help you deliver the performance you need

We hope this mini-guide has given you an overview of some of the key areas you should consider to get the very best out of the investment casting process.

Of course, nothing beats talking to an expert who understands the approach inside and out. Our in-house engineers have decades of experience helping professionals like you drive higher performance and greater precision in their components.

The earlier you can get us involved, the greater value we can add. Wherever you are in your design process, we should talk. Contact us and we'd love to help.

