

# Manufacturing **Process** Selection Guide



Narrow down the design process



Shorten the time of the product to market



Design the product right the first time

Provided by Chaparral Technologies



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**This selection guide from Chaparral will help you **narrow down the manufacturing options** that are available to you when designing your project.**

Use the information in the following pages for designing. After, you will have the information you need to contact a supplier and get your project moving forward.

If you use this selection guide the right way, it will help you:

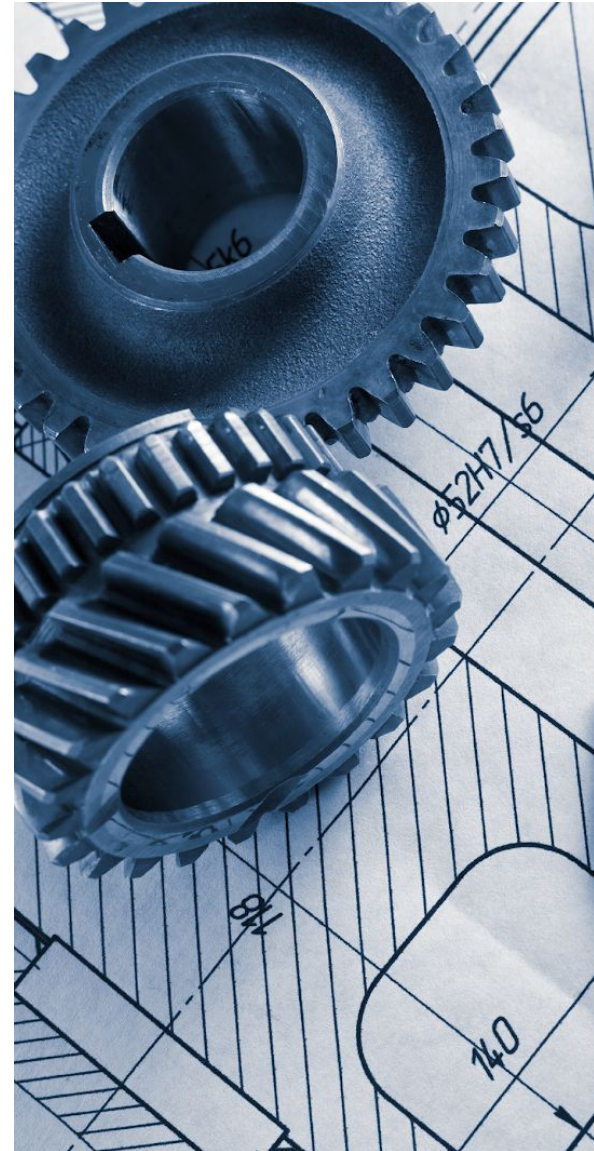
- ✓ Shorten the time of your product to market
- ✓ Help you design the product right the first time
- ✓ Narrow down the design process
- ✓ Save you time & money

We hope you find this guide helpful! If you have any questions, please email us at [sales@chaparraltech.net](mailto:sales@chaparraltech.net) or call us at 972-988-0067. We are always here to help.



**Ashwin Kalia**

President - Chaparral Technologies



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## How to Use This Guide:

The table should be read from left to right. Here's how to start:

1. Sort by the manufacturing type
2. Identify the metals used within that type
3. View the size range associated with the type
4. See the tolerances & dimensions used
5. Continue down the rows for more information about the specific manufacturing type

### Annotation Key (A.S.A., \*, \*\*, +, ++, +++)

A.S.A. After Sample Approval

\* These are for critical dimensions and should not be specified where not necessary.

\*\* Draft requirements inversely affected by depth of draw.

+ 1 Most. 5 Least.

++ Size and surface area influence this considerably.

+++ This will vary widely depending on business conditions and foundry load.

Manufacturing Type	Metals	Size Range	Tolerances *	Tooling Costs +	Part Price +	Design Freedom +	Surface Finish	Minimum Draft **	Minimum Wall Thickness ++	Ordering Quantities	Normal Lead Time +++
<b>Die Casting</b>	Aluminum, Zinc, Magnesium and limited Brass.	Ounces to 15 pounds. Not normally over 2 feet square. Some foundries capable of larger sizes.	Al & Mg +/- .002"/inch. Zinc +/- .0015"/inch. Brass +/- .005"/inch. Add +/- .001" to +/- .015" across the parting line, depending on size.	1  \$10,000 to \$100,000	5	4	32-63 RMS	Al & Mg: 1-3 deg Zinc: 1/2-2 deg Brass: 2-5 deg	Alum: .030"-.060" Mag: .030"-.045" Zinc: .025"-.040"	Usually 2,500 and up.	<b>Samples:</b> 12-22 weeks. <b>Production:</b> 8-14 weeks A.S.A.
<b>Description</b>	Molten metal is injected, under pressure, into hardened steel dies, often water cooled. Dies open and castings ejected.										

Manufacturing Type	Metals	Size Range	Tolerances *	Tooling Costs †	Part Price †	Design Freedom †	Surface Finish	Minimum Draft **	Minimum Wall Thickness ††	Ordering Quantities	Normal Lead Time †††
<b>Permanent Mold</b>	Aluminum, Zinc, Brass, H.C. Copper, Lead & Gray Iron.	Limitation mainly foundry capabilities. Aluminum & Copper base: Ounces to 100 lbs. Ferrous: 60 lbs. Max.	Alum.: Up to 1" +/- .015"/inch. Add +/- .002" for each add'l inch. Add +/- .010" to +/- .030" for across parting line, depending on size. Copper Base: Similar to Investment. Iron: +/- .030" Basic.	2  \$5,000 to \$25,000	Non-Ferrous: 3 Ferrous: 4	Non-Ferrous: 3 Ferrous: 5	Alum: 150-250 RMS. Copper base: 125-200 RMS. Ferrous: 200-350 RMS.	<b>Non-Ferrous:</b> External: 3 degrees. Internal: 4 degrees. <b>Ferrous:</b> External: 1 degree. Internal: 5 degrees.	<b>Alum:</b> .100" for small areas, 3/16" for large areas. <b>Copper Base:</b> .060" <b>Ferrous:</b> 3/16" for small areas, 1/4" normal.	Minimum One Day's Run: 100-1,000, depending on size.	<b>Samples:</b> 8-20 weeks. <b>Production:</b> 4-8 weeks A.S.A.
<b>Description</b>	Molten metal is gravity poured into cast iron molds, coated with ceramic mold wash. Cores can be metal, sand, sand shell or other. Molds open and castings ejected. New L.P.P.M. method pressure pours with up to 15 PSI. <b>Data supplied by Bodine Alum.</b>										
<b>Investment (lost wax)</b>	Most all castable metals.	Fraction of an ounce to 150 lbs.	+/- .003" to 1/4". +/- .004" to 1/2". +/- .005" per inch to 3". +/- .003" for each additional inch.	3  \$3,000 to \$20,000	1	1	63-125 RMS	None.	.030" small areas. .060" larger areas.	Usually under 1,000.	<b>Samples:</b> 5-16 weeks (depending on complexity) <b>Production:</b> 4-12 weeks A.S.A. (depending on subsequent operations)
<b>Description</b>	Metal mold makes wax or plastic replica. These are sprued, and then surrounded with investment material, baked out, metal poured in resultant cavity. Molds broken to remove castings.										

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Manufacturing Type	Metals	Size Range	Tolerances *	Tooling Costs +	Part Price +	Design Freedom +	Surface Finish	Minimum Draft **	Minimum Wall Thickness ++	Ordering Quantities	Normal Lead Time +++
<b>Plaster Mold</b>	Aluminum , Brass, Bronze, Zinc, Beryllium Copper.	Normally up to 500 square inch area. Some foundries capable of much larger. Ounces to 50 pounds.	One side of parting line +/- .005" up to 2". Over 2" add +/- .002"/inch. Across parting line add +/- .010".	4 \$3,000 to \$15,000	1	2	63-125 RMS	External: 0-1/2 deg. Internal: ½-2 deg.	.070"	Usually low. <b>Often used to prototype for die castings.</b> 50-250 pieces.	<b>Samples:</b> 2-6 weeks. <b>Production:</b> 2-4 weeks A.S.A.
<b>Description</b>	Plaster slurry is poured onto pattern halves, allowed to set, then mold is removed from pattern, baked, assembled, and metal is poured into resultant cavity. Molds broken to remove castings.										
<b>Ceramic Mold</b>	Most all castable metals.	5 lbs. to 350 lbs.	One side of parting line +/- .005" up to 2". Over 2" add +/- .004"/inch. Across parting line add +/- .010" (Assumes epoxy or metal patterns).	5 wood 4 epoxy or metal	1	3	80-125 RMS	0-1/2 degree	.125"	Low to medium. <b>Often used for tooling for other casting methods, plastic injection molds.</b> Special machine parts.	<b>Samples:</b> 3-8 weeks (depending on complexity). <b>Production:</b> 2-8 weeks A.S.A. (depending on metal and quantity).
<b>Description</b>	Ceramic slurry poured over cope and drag patterns, allowed to set, then molds removed from pattern, baked at 1800 deg F, producing hard, stable molds. Molds assembled with or without cores and metal poured into resultant cavity. Molds broken to remove castings.										
<b>Graphite Mold</b>	Presently limited to Zinc alloys ZA12, ZA27	One ounce to 10 lbs. Currently 12" to 14" with a depth of 7".	Up to first inch +/- .005". Add +/- .002" for each add'l inch. Across parting line add +/- .005".	4	3	4	63-125 RMS	External: ½ degrees Internal: 1 degree	.100" (can go to .060" for very small areas)	Usually 300 and up	<b>Samples:</b> 6-10 weeks. <b>Production:</b> 4 weeks A.S.A.
<b>Description</b>	Same as permanent mold, except no ceramic mold wash is needed since Graphite molds are used. Core pins are usually steel.										

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Manufacturing Type	Metals	Size Range	Tolerances *	Tooling Costs +	Part Price +	Design Freedom +	Surface Finish	Minimum Draft **	Minimum Wall Thickness ++	Ordering Quantities	Normal Lead Time +++
<b>Resin Shell Mold</b>	Most all castable metals.	Normal maximum 550 square inches usable. mold area. Depends on equip at each foundry	<b>Non-Ferrous:</b> +/- .008"/inch. <b>Ferrous:</b> +/- .010"/inch. Add +/- .005" to +/- .010" across the parting lines.	2	2	2	<b>Non-Ferrous:</b> 125-200 RMS <b>Ferrous:</b> 200-350 RMS	External: ½-1 degree. Internal: ½-2 degrees.	<b>Non-Ferrous:</b> .093" <b>Ferrous:</b> .125"	<b>Non-Ferrous:</b> Usually 100 and up. <b>Ferrous:</b> Usually 1,000 and up.	<b>Samples:</b> 12-16 weeks. <b>Production:</b> 6-10 weeks A.S.A.
<b>Description</b>	Resin-coated sand is poured onto hot metal patterns, curing into shell-like mold halves. These are removed from pattern, assembled with or without cores. Molds broken to remove castings.										
<b>Sand Casting</b>	Most all castable metals.	Limitation mainly foundry capabilities. Ounces to many tons.	<b>Non-Ferrous:</b> +/- 1/32" to 6". Add +/- .003" for each additional inch. <b>Ferrous:</b> +/- 1/32", +/- 3/64" from 3" to 6". Add +/- .020" to +/- .090" across parting line, depending on size (assumes metal patterns).	5 wood 4 alum. 2 iron  \$800 to \$4,000	3-4	3	<b>Non-Ferrous:</b> 150-350 RMS <b>Ferrous:</b> 300-700 RMS	1-5 degrees Cores: 1-1.5 degrees	<b>Non-Ferrous:</b> .125"-.250" <b>Ferrous:</b> .250"-.375"	All Quantities.	<b>Samples:</b> 2-10 weeks. <b>Production:</b> 2-4 weeks A.S.A.
<b>Description</b>	Tempered sand is packed onto wood or metal pattern halves, removed from pattern, assembled with or without cores. Metal is poured into resultant cavities. Molds broken to remove castings. Specialized binders now in use can improve tolerances and surface finish. <b>Data supplied by Bodine Aluminum.</b>										

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Manufacturing Type	Metals	Size Range	Tolerances *	Tooling Costs +	Part Price +	Design Freedom +	Surface Finish	Minimum Draft **	Minimum Wall Thickness ++	Ordering Quantities	Normal Lead Time +++
<b>Metal Injection Molding</b>	Primarily ferrous alloys with limited copper base.	.0005 lbs. to .22 lbs.	+/- .004" per inch.	3	2	1	65 RMS	¼ degree per inch	.015" (small areas).	Usually 10,000 and up.	<b>Samples:</b> 10-16 weeks. <b>Production:</b> 4-6 weeks A.S.A.
<b>Description</b>	Very fine metal powder combined with binder material is injected into die. Part is ejected, the binder melted or dissolved, and vacuum sintered, resulting in 94-99% of theoretical density.										
<b>Powder Metal</b>	Iron and Iron alloys, Carbides, Tool Steels, Copper, Bronzes, Brass, Stainless Steel, Aluminum	Limitation on surface area – up to 20 square inches <b>Ferrous</b> , larger for <b>Non-Ferrous</b> .	If sized; +/- .0005"/inch. Unsize: +/- .002"/inch.  Direction of pressing: +/- .005"/inch.	3  \$5,000 to \$40,000	4-5	4	Equivalent to 32-62 RMS in solid metals.	None on outer periphery, 10-15 degrees on punches.	.030"-.090", depending on density and length ratio. 8 to 1 wall thickness to length ratio max.	Usually 10,000 and up. Larger parts as low as 1,000.	<b>Samples:</b> 6-14 weeks. (depending on complexity). <b>Production:</b> 3-8 weeks A.S.A.
<b>Description</b>	Metal powder is compressed in die barrel between moving upper and lower punches. Lower punch ejects part which is sintered and sized if close tolerance is required. <b>Data supplied by Ceromet.</b>										
<b>Thixomold</b>	Magnesium (AZ91D, AM50, AM60) Zinc Alloys (ZA12)	Depends on press size. Current U.S. limit: 180 square inches max.	Typically, one half of die casting tolerance.	1	5	3	20 RMS	¼ degree per inch. (.002" per linear inch).	.020" in small areas.	Usually 2,000 and up.	<b>Samples:</b> 18 weeks (includes trim die). <b>Production:</b> 4 weeks A.S.A.

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<b>Description</b>	Chipped alloy is converted into a thixotropic slurry in an injection molding barrel/screw assembly and injected into a temperature controlled precision mold. Die opens and castings ejected. <b>Data supplied by AFT.</b>										
<b>Type</b>	<b>Metals</b>	<b>Size Range</b>	<b>Tolerances *</b>	<b>Tooling Costs +</b>	<b>Part Price +</b>	<b>Design Freedom +</b>	<b>Surface Finish</b>	<b>Minimum Draft **</b>	<b>Minimum Wall Thickness ++</b>	<b>Ordering Quantities</b>	<b>Normal Lead Time +++</b>
<b>Semi-Solid Metal (SSM)</b>	Aluminum Alloys	Same as die casting.	Same as die casting.	1	4-5 for SST/Gibb 3-4 for thixocast.	4	32-63 RMS	1-3 degrees.	Approximately .080".	Usually 2500 and up. 50,000 per year min.	<b>Samples:</b> 12-20 weeks. <b>Production:</b> 10 weeks A.S.A.
<b>Description</b>	Metal is held in a partially solidified and agitated state until it is injected under pressure into steel dies. <b>Data supplied by Semi-Solid Technologies.</b>										
<b>V-Casting (vacuum)</b>	Most castable metals	.25 pounds (3-4" cube) up to "limited only by flask size of foundry" (150 pounds).	One side of P/L: +/- .010" first inch, add +/- .002" per add'l inch. Across P/L: add +/- .020" Cored areas may require add'l Tol.	3 \$3,000 to \$14,000	2	2	125 to 150 RMS	None Required.	<b>Non-Ferrous:</b> .090"-.125" <b>Ferrous:</b> .100"-.125"	Prototypes to medium production. 5 to 3,000, depending on flask size.	<b>Samples:</b> 6-8 weeks. <b>Production:</b> 4-6 weeks.
<b>Description</b>	Unbounded sand is held in place in the mold by a vacuum. Pattern is covered by tightly conforming thin sheet of plastic. Metal is poured, solidifies, vacuum is turned off, sand runs out freely, casting is released. <b>Data supplied by Taylor-Pohlman.</b>										

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Manufacturing Type	Metals	Size Range	Tolerances *	Tooling Costs +	Part Price +	Design Freedom +	Surface Finish	Minimum Draft **	Minimum Wall Thickness ++	Ordering Quantities	Normal Lead Time +++
<b>Forging</b>	Aluminum 6061, 2014, 7075. Brass 3770	Aluminum – a few ounces to 10 lbs. Brass – a few ounces to 60 lbs.	+/- .010" between die halves. +/- .005" within each die half. (note: run quantities affect die wear and can impact these tolerances)	3  \$5,000 to \$30,000.	4	5	64-125 RMS	1 degree for shallow dies (1" or less). 3 deg recommended.	.125" (thinner is possible).	500 pieces to 250,000 pieces annually.	<b>Samples:</b> 4-6 weeks. <b>Production:</b> 2-4 weeks.
<b>Description</b>	Forgings consist of a controlled plastic deformation of a piece of metal into a useful shape, usually at an elevated temperature. Pressure or repeated press strokes may be used. <b>Data supplied by Anchor Harvey.</b>										
<b>Miniature Zinc Die Casting</b>	All Zamak Alloys, ZA8 and ACuZinc 5	Fractions of an ounce to 6 ounces Lengths to 4 inches, up to 1.5 inches across parting line	+/- .001" per inch.	1 \$12,000 to \$40,000	5	2	32-64 RMS	Ext. 0- 1 degree Int. ¼ - 2 degree	.020"	Usually 10,000 and up.	<b>Samples:</b> 10 – 16 weeks <b>Production:</b> 2 –4 weeks ASA.
<b>Description</b>	Molten zinc is injected, under pressure at high speed, into hardened steel dies. Casting and parting lines are maintained flash free. See Fishercast.com <b>Data supplied by Fishercast.</b>										

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Manufacturing Type	Metals	Size Range	Tolerances *	Tooling Costs +	Part Price +	Design Freedom +	Surface Finish	Minimum Draft **	Minimum Wall Thickness ++	Ordering Quantities	Normal Lead Time +++
<b>Spin Casting</b>	Zinc Alloys	Fractions of an ounce to 1 pound.	+/- .005" per inch.	5	3	1	125 RMS	No draft necessary.	.040"	1 to 3,000 castings.	<b>Samples:</b> 1-2 weeks. <b>Production:</b> 2-3 weeks.
<b>Description</b>	Vulcanized silicone rubber molds are used with centrifugal forces to produce detailed, low porosity, medium density castings. Molten materials are introduced into center of round mold while it is spinning. <b>Data supplied by Seybert Castings.</b>										
<b>Lost Foam Casting</b>	Aluminum , Copper alloys, Steels, Irons.	Fraction of a pound to thousands of pounds.	Up to ½" .....+/- .003" Up to 1" .....+/- .005" Up to 2" .....+/- .008" Up to 3" .....+/- .010" Up to 4" .....+/- .012" Add .001" for each add'l inch.	2			60-250 RMS	0-2 degrees.		Protos to production. From 500 per year up to several hundred thousand per year (automotive engines).	<b>Samples:</b> 3-7 weeks. <b>Production:</b> 1-3 weeks ASA.
<b>Description</b>	Polystyrene (foam) pattern is produced using aluminum molds. Patterns are attached to runner system and coated with refractory material, placed in flask and sand is vibrated/compacted around assembly. Metal is poured, casting solidifies and is removed.										
<b>Screw Machine</b>	All machinable metals and plastics that come in bar form 3-12 feet long.	Diameters of .004" to 1.25" max with length of 11 feet max.	Standard tol: +/- .002" on diameter. Precision tol: +/- .0001" on diameter if required.	Usually none. Collets are \$80-\$300.	4-5	4	32-63 RMS on all surfaces. 63-125 RMS on drilled hole. 4-6 RMS on	Not Applicable	Not Applicable	1 to 100,000  1,000 to 5,000 is an average run.	<b>Samples:</b> 1 week. Same day if required. <b>Production:</b> 4 weeks ASA.

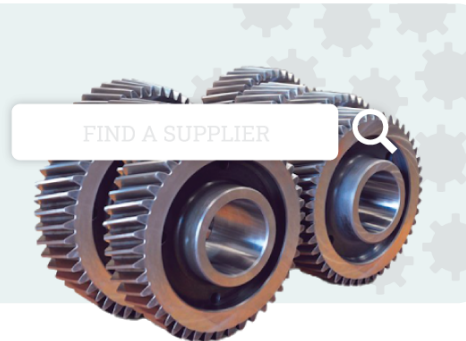
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Type	Metals	Size Range	Tolerances *	Tooling Costs +	Part Price +	Design Freedom +	Surface Finish	Minimum Draft **	Minimum Wall Thickness ++	Ordering Quantities	Normal Lead Time +++
<b>Description</b>	Parts are turned from bar stock. Machines are equipped with live tools and sub spindles. Live tools allow for milling and drilling crossholes. Sub spindles allow for simultaneous machining which reduces cycle times. <b>Data supplied by Intrex.</b>										
<b>Cold Form</b>	Steels, Copper, Brass, Bronze, Aluminum, Stainless Steel	Diameters: .05" to 1.50" Lengths: Up to 14".	Diameters: +/- .001" to +/- .005" Lengths: +/- .002" to +/- .020"				63 RMS	Not Applicable	.050" shank diameter	Minimum range: 10,000 – 25,000.	
<b>Description</b>	Force applied by one or more blows of a tool displaces metal in a portion or all of a slug, wire or rod blank. This plastic flow produces a section of different contour, larger in cross section than the original material.										

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