FAQ about Die Casting

Introduction

Die casting is a versatile process for producing engineered metal parts by forcing molten metal under high pressure into reusable steel molds. These molds, called dies, can be designed to produce complex shapes with a high degree of accuracy and repeatability. Parts can be sharply defined, with smooth or textured surfaces, and are suitable for a wide variety of attractive and serviceable finishes.

Die castings are among the highest volume, mass-produced items manufactured by the metalworking industry, and they can be found in thousands of consumer, commercial and industrial products. Die cast parts are important components of products ranging from automobiles to toys. Parts can be as simple as a sink faucet or as complex as a connector housing.

History

The earliest examples of die casting by pressure injection - as opposed to casting by gravity pressure - occurred in the mid-1800s. A patent was awarded to Sturges in 1849 for the first manually operated machine for casting printing type. The process was limited to printer's type for the next 20 years, but development of other shapes...
began to increase toward the end of the century. By 1892, commercial applications included parts for phonographs and cash registers, and mass production of many types of parts began in the early 1900s.

The first die casting alloys were various compositions of tin and lead, but their use declined with the introduction of zinc and aluminum alloys in 1914. Magnesium and copper alloys quickly followed, and by the 1930s, many of the modern alloys still in use today became available.

The die casting process has evolved from the original low-pressure injection method to techniques including high-pressure casting — at forces exceeding 4500 pounds per square inch — squeeze casting and semi-solid die casting. These modern processes are capable of producing high integrity, near net-shape castings with excellent surface finishes.

The Future

Refinements continue in both the alloys used in die casting and the process itself, expanding die casting applications into almost every known market. Once limited to simple lead type, today’s die casters can produce castings in a variety of sizes, shapes and wall thicknesses that are strong, durable and dimensionally precise.

The Advantages of Die Casting

Die casting is an efficient, economical process offering a broader range of shapes and components than any other manufacturing technique. Parts have long service life and may be designed to complement the visual appeal of the surrounding part. Designers
can gain a number of advantages and benefits by specifying die cast parts.

High-speed production - Die casting provides complex shapes within closer tolerances than many other mass production processes. Little or no machining is required and thousands of identical castings can be produced before additional tooling is required.

Dimensional accuracy and stability - Die casting produces parts that are durable and dimensionally stable, while maintaining close tolerances. They are also heat resistant.

Strength and weight - Die cast parts are stronger than plastic injection moldings having the same dimensions. Thin wall castings are stronger and lighter than those possible with other casting methods. Plus, because die castings do not consist of separate parts welded or fastened together, the strength is that of the alloy rather than the joining process.

Multiple finishing techniques - Die cast parts can be produced with smooth or textured surfaces, and they are easily plated or finished with a minimum of surface preparation.

Simplified Assembly - Die castings provide integral fastening elements, such as bosses and studs. Holes can be cored and made to tap drill sizes, or external threads can be cast.

Die Casting Process

The basic die casting process consists of injecting molten metal under high pressure into a steel mold called a die. Die casting machines are typically rated in clamping tons equal to the amount of pressure they can exert on the die. Machine sizes range from 400 tons to 4000 tons. Regardless of their size, the only fundamental difference in die casting machines is the method used to inject molten metal into a die. The two methods are hot chamber or cold chamber. A complete die casting cycle can vary from less than one second for small components weighing less than an ounce, to two-to-three minutes for a casting of several pounds, making die casting the fastest technique available for producing precise non-ferrous metal parts.

Die Casting vs. Other Processes

Die casting vs. plastic molding - Die casting produces stronger parts with closer tolerances that have greater stability and durability. Die cast parts have greater resistance to temperature extremes and superior electrical properties.
Die casting vs. sand casting - Die casting produces parts with thinner walls, closer dimensional limits and smoother surfaces. Production is faster and labor costs per casting are lower. Finishing costs are also less.

Die casting vs. permanent mold - Die casting offers the same advantages versus permanent molding as it does compared with sand casting.

Die casting vs. forging - Die casting produces more complex shapes with closer tolerances, thinner walls and lower finishing costs. Cast coring holes are not available with forging.

Die casting vs. stamping - Die casting produces complex shapes with variations possible in section thickness. One casting may replace several stampings, resulting in reduced assembly time.

Die casting vs. screw machine products - Die casting produces shapes that are difficult or impossible from bar or tubular stock, while maintaining tolerances without tooling adjustments. Die casting requires fewer operations and reduces waste and scrap.

Choosing the Proper Alloy

Each of the metal alloys available for die casting offer particular advantages for the completed part.

Zinc - The easiest alloy to cast, it offers high ductility, high impact strength and is easily plated. Zinc is economical for small parts, has a low melting point and promotes long die life.

Aluminum - This alloy is lightweight, while possessing high dimensional stability for complex shapes and thin walls. Aluminum has good corrosion resistance and mechanical properties, high thermal and electrical conductivity, as well as strength at high temperatures.

Magnesium - The easiest alloy to machine, magnesium has an excellent strength-to-weight ratio and is the lightest alloy commonly die cast.

Copper - This alloy possesses high hardness, high corrosion resistance and the highest mechanical properties of alloys cast. It offers excellent wear resistance and dimensional stability, with strength approaching that of steel parts.

Lead and Tin - These alloys offer high density and are capable of producing parts with extremely close dimensions. They are also used for special forms of corrosion resistance.

Die Construction

Dies, or die casting tooling, are made of alloy tool steels in at least two sections, the fixed die half, or cover half, and the ejector die half, to permit removal of castings. Modern dies also may have moveable slides, cores or other sections to produce holes, threads and other desired shapes in the casting. Sprue holes in the fixed die half allow molten metal to enter the die and fill the cavity. The ejector half usually contains the runners (passageways) and gates (inlets) that route molten metal to the cavity. Dies also include locking pins to secure the two halves, ejector pins to help remove the cast part, and openings for coolant and lubricant.

When the die casting machine closes, the two die halves are locked and held together by the machine’s hydraulic pressure. The surface where the ejector and fixed halves of the die meet and lock is referred to as the "die parting line." The total projected
surface area of the part being cast, measured at the die parting line, and the
pressure required of the machine to inject metal into the die cavity governs the
clamping force of the machine.

**Die Casting Dies Have Four Basic Functions:**

- *Hold molten metal in the shape of the desired casting.*
- *Provide a means for molten metal to get to a space where it will be held to the desired shape.*
- *Remove heat from the molten metal and to allow the metal to solidify.*
- *To provide for the removal of the casting.*

There are four types of dies:

1. Single cavity to produce one component

   ![Single-Cavity Die](image)

2. Multiple cavity to produce a number of identical parts
3. Unit die to produce different parts at one time

4. Combination die to produce several different parts for an assembly.

**Hot Chamber Machines**

Hot chamber machines are used primarily for zinc, copper, magnesium, lead and other low melting point alloys that do not readily attack and erode metal pots, cylinders and plungers. The injection mechanism of a hot chamber machine is immersed in the molten metal bath of a metal holding furnace. The furnace is attached to the machine by a metal feed system called a gooseneck. As the injection cylinder plunger rises, a port in the injection cylinder opens, allowing molten metal to fill the cylinder. As the plunger moves downward it seals the port and forces molten metal through the gooseneck and nozzle into the die cavity. After the metal has solidified in the die cavity, the plunger is withdrawn, the die opens and the casting is ejected.

**Cold Chamber Machines**

Cold chamber machines are used for alloys such as aluminum and other alloys with high melting points. The molten metal is poured into a "cold chamber," or cylindrical sleeve, manually by a hand ladle or by an automatic ladle. A hydraulically operated plunger seals the cold chamber port and forces metal into the locked die at high pressures.
High Integrity Die Casting Methods

There are several variations on the basic process that can be used to produce castings for specific applications. These include:

Squeeze casting - A method by which molten alloy is cast without turbulence and gas entrapment at high pressure to yield high quality, dense, heat treatable components.

Semi-solid molding - A procedure where semi-solid metal billets are cast to provide dense, heat treatable castings with low porosity.

Automation and Quality Control

Modern die casters use a number of sophisticated methods to automate the die casting process and provide continuous quality control. Automated systems can be used to lubricate dies, ladle metal into cold chamber...
machines and integrate other functions, such as quenching and trimming castings. Microprocessors obtain metal velocity, shot rod position, hydraulic pressure and other data that is used to adjust the die casting machine process, assuring consistent castings shot after shot. These process control systems also collect machine performance data for statistical analysis in quality control.

**Die Casting Design**

Die casting is one of the fastest and most cost-effective methods for producing a wide range of components. However, to achieve maximum benefits from this process, it is critical that designers collaborate with the die caster at an early stage of the product design and development. Consulting with the die caster during the design phase will help resolve issues affecting tooling and production, while identifying the various trade-offs that could affect overall costs.

For instance, parts having external undercuts or projections on sidewalls often require dies with slides. Slides increase the cost of the tooling, but may result in reduced metal use, uniform casting wall thickness or other advantages. These savings may offset the cost of tooling, depending upon the production quantities, providing overall economies.

Many sources are available for information on die casting design, including textbooks, technical papers, trade journals and professional associations. While this section is not intended to provide a comprehensive review of all the factors involving die casting design, it will highlight some of the primary considerations. Additional sources of information are listed in the “Resources” section of this brochure.

**Alloy Properties** One of the first steps in designing a die cast component is choosing the proper alloy. Typical properties for the most commonly used alloys are shown on the linked charts.
The cost of materials is another important design consideration. Accurate comparisons require looking beyond the cost per pound or cost per cubic inch to fully analyze the advantages and disadvantages of each competing process. For instance, the relatively greater strength of metals generally allows thinner walls and sections and consequently requires fewer cubic inches of material than plastics for a given application.

**Effective Design** Load example illustrations to help show how design and engineering can affect final production.

**Glossary and Additional Resources**