

## **GUIDELINES FOR DIE CASTING DESIGN**

Advice on designing die castings is usually based upon desirable practices or situations to avoid. However, like most rules, there are exceptions. These affect either costs, appearance and/or quality of final products. Listed below are guides which should be considered when designing for die casting:

1. Specify thin sections which can easily be die cast and still provide adequate strength and stiffness. Use ribs wherever possible to attain maximum strength, minimum weight.
2. Keep sections as uniform as possible. Where sections must be varied, make transitions gradual to avoid stress concentration.
3. Keep shapes simple and avoid nonessential projections.
4. A slight crown is more desirable than a large flat surface, especially on plated or highly finished parts.
5. Specify coring for holes or recesses where savings in metal and overall costs outweigh tooling costs.
6. Design cores for easy withdrawal to avoid complicated die construction and operation.
7. Avoid small cores. They can be easily bent or broken necessitating frequent replacement. Drilling or piercing small holes in die castings is often cheaper than the cost of maintaining small cores.
8. Avoid use of undercuts which increase die or operating costs unless savings in metal or other advantages fully warrant these extra costs.
9. Provide sufficient draft on side walls and cores to permit easy removal of the die casting from the die without distortion.
10. Provide fillets at all inside corners and avoid sharp outside corners. Deviation from this practice may be warranted by special considerations
11. Die casting design must provide for location of ejector pins. Take into consideration the effect of resultant ejector marks on appearance and function. The location of ejector pins is largely determined by the location and magnitude of metal shrinkage on die parts as metal cools in the die.
12. Specify die cast threads over cut threads when a net savings will result.

13. Die castings which affect the appearance of a finished product may be designed for aesthetics, and to harmonize with mating parts.
14. Inserts should be designed to be held firmly in place with proper anchorage provided to retain them in the die casting.
15. Design parts to minimize flash removal costs.
16. Never specify dimensional tolerances closer than essential. This increases costs.
17. Design die castings to minimize machining.
18. Where machining is specified, allow sufficient metal for required cuts.
19. Consider contact areas for surfaces which are to be polished or buffed. Avoid deep recesses and sharp edges.

## **DIE CASTING ALLOYS**

Die casting alloys are normally non-ferrous, and there is a large number available with a wide range of physical and mechanical properties covering almost every conceivable application a designer might require.

Aluminum and zinc alloys are the most widely used, and are followed by magnesium, zinc-aluminum (AZ) alloys, copper, tin and lead.

Zinc, lead and tin based alloys are classified as low melting point metals, all melting at less than 725°F (385°C). Zinc-aluminum (ZA) alloys have a slightly higher melting range of 800°F to 900°F (426°C to 482°C). Aluminum and magnesium alloys are considered to be moderate melting point alloys, being cast in the 1150°F to 1300°F (621°C to 704°C) range. Copper alloys are considered to be high melting point, over 1650°F (899°C). Low melting point alloys are cast in hot chamber machines. Intermediate and high melting point alloys are cast in cold chamber machines. In recent years, specially designed hot chamber machines for die casting magnesium alloys have come into use.

---

## **ALUMINUM ALLOYS**

Aluminum die casting alloys (**Table 1**) are lightweight, offer good corrosion resistance, ease of casting, good mechanical properties and dimensional stability.

Although a variety of aluminum alloys made from primary or recycled metal can be die cast, most designers select standard alloys listed below:

**360 --** Selected for best corrosion resistance. Special alloys for special applications are available, but their use usually entails significant cost premiums.

**380 --** An alloy which provides the best combination of utility and cost.

**383 & 384 --** These alloys are a modification of 380. Both provide better die filling, but with a moderate sacrifice in mechanical properties, such as toughness.

**390 --** Selected for special applications where high strength, fluidity and wear-resistance/bearing properties are required.

**413 (A13) --** Used for maximum pressure tightness and fluidity.

---

## ZINC ALLOYS

Zinc base alloys (**Table 2**) are the easiest to die cast. Ductility is high and impact strength is excellent, making these alloys suitable for a wide range of products. Zinc alloys can be cast with thin walls and excellent surface smoothness making preparation for plating and painting relatively easy.

It is essential that only high purity (99.99 + 0/0) zinc metal be used in the formulation of alloys. Low limits on lead, tin and cadmium ensure the long-term integrity of the alloy's strength and dimensional stability.

---

## ZINC-ALUMINUM (ZA) ALLOYS

ZA alloys represent a new family of zinc based die casting materials which contain higher aluminum content than standard zinc alloys. These alloys provide high strength characteristics plus high hardness and good bearing properties (**Table 2**). Thin wall castability characteristics and die life are similar to zinc alloys. ZA-8 is recommended for hot chamber die casting, which ZA-12 and ZA-27 must be cast by the cold chamber die casting process. All ZA alloys offer similar creep properties and are superior to standard zinc alloys.

**ZA-8 --** Provides strength, hardness and creep properties.

**ZA-12 --** Provides excellent bearing properties with strength and hardness characteristics between ZA-8 and ZA-27, plus good dimensional stability properties and somewhat better castability than ZA-27.

**ZA-27 --** Offers the highest mechanical properties of the ZA family and is, therefore, recommended when maximum performance is required.

---

## MAGNESIUM ALLOYS

Magnesium alloys (**Table 3**) are noted for low weight, high strength to weight ratio, exceptional damping capacity, and ease of machining. Casting temperatures are about the same as aluminum, and both hot chamber and cold chamber machines are used to produce castings.

Casting rates for magnesium are high because of its low heat content which produces rapid solidification. For the same reason, less energy is required to heat the metal to casting temperature.

AZ91HP (high purity) alloy has been developed for die casting parts subject to corrosive environments. Because of lower levels of nickel, iron, copper and silicon versus AZ91B, this alloy is finding applications in automobiles, computers and peripheral equipment, and in other applications where paint or coatings are either undesirable or expensive.

Although magnesium die castings are used uncoated, they can be finished in a variety of ways to give increased protection against corrosion, wear and abrasion resistance, and to improve appearance. Common inorganic treatments include chemical dips, anodizing and plating. Organic coatings -- oil, wax, resin or paint -- are usually applied over chemical treatments or anodizing to seal the surface, increase corrosion protection and provide an attractive appearance.

---

### RELATIVE ALLOY WEIGHTS TO MAGNESIUM

|                  |            |
|------------------|------------|
| Aluminum         | 1.6        |
| Zinc             | 3.7        |
| ZA Alloys        | 2.7-3.4    |
| <b>Magnesium</b> | <b>1.0</b> |
| Brass            | 4.7        |
| Tin              | 4.0        |
| Lead             | 6.3        |
| Bronze           | 4.9        |

### Typical Mechanical Properties

|                              | <b>Aluminum</b> | <b>Brass</b> | <b>Magnesium</b> | <b>Zinc</b> |
|------------------------------|-----------------|--------------|------------------|-------------|
| Tensile strength, psi x 1000 | 47              | 55           | 34               | 41          |

|                                                  |      |       |      |      |
|--------------------------------------------------|------|-------|------|------|
| Yield strength, psi x 100 (0.2 pct offset)       | 23   | 30    | 23   | --   |
| Shear strength, psi x 1000                       | 28   | 37    | 20   | 31   |
| Fatigue strength, psi x 1000                     | 20   | 25    | 14   | 7    |
| Elongation, pct in 2 in.                         | 3.50 | 15    | 3.0  | 10   |
| Hardness (Brinell)                               | 80   | 91    | 63   | 82   |
| Specific gravity                                 | 2.71 | 8.30  | 1.80 | 6.60 |
| Weight, lb/cu. in.                               | .098 | 0.305 | .066 | 0.24 |
| Melting point (liquid), °F                       | 1100 | 1670  | 1105 | 728  |
| Thermal conductivity, CGS                        | 0.23 | 0.21  | 0.16 | 0.27 |
| Thermal expansion, in./in./°F x 10 <sup>-6</sup> | 12.1 | 12.0  | 15.0 | 15.2 |
| Electrical conductivity, pct of copper standard  | 27   | 20    | 10   | 27   |
| Modulus of elasticity, psi x 10 <sup>6</sup>     | 10.3 | 15    | 6.5  | --   |
| Impact strength (Charpy), ft/lb                  | 3.0  | 40    | 2.0  | 43.0 |

### Finishing: Decorative

|                                       | <b>Aluminum</b> | <b>Brass</b> | <b>Magnesium</b> | <b>Zinc</b> |
|---------------------------------------|-----------------|--------------|------------------|-------------|
| Chrome plating                        | Fair            | Excellent    | Fair             | Excellent   |
| Black chrome plating                  | Fair            | Excellent    | --               | Excellent   |
| Colored plating                       | Fair            | --           | --               | Excellent   |
| Mechanical-polishing & buffing        | Excellent       | Excellent    | Excellent        | Excellent   |
| Lacquers, enamels, epoxies & acrylics | Excellent       | Excellent    | Excellent        | Excellent   |
| Anodizing                             | Fair            | --           | --               | --          |

| Protective                                                                                                                                 |           |           |           |           |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------|-----------|-----------|-----------|
|                                                                                                                                            |           |           |           |           |
|                                                                                                                                            | Aluminum  | Brass     | Magnesium | Zinc      |
| Anodizing-corrosion & abrasion protection                                                                                                  | Excellent | --        | Good      | Excellent |
| Chromate conversion-corrosion                                                                                                              | Excellent | --        | Excellent | Excellent |
| Heavy paint, wrinkle, matte finishes-abrasion, corrosion protection & to hide imperfections                                                | Excellent | Excellent | Excellent | Excellent |
| NOTE: This chart does not intend to compare metals. Its purpose is to show the most satisfactory methods of finishing each specific metal. |           |           |           |           |

| Processing and Production              |          |        |           |         |
|----------------------------------------|----------|--------|-----------|---------|
| Machine Types:                         | Aluminum | Brass  | Magnesium | Zinc    |
| Hot chamber (Plunger)                  | No       | No     | Yes       | Yes     |
| Cold chamber                           | Yes      | Yes    | Yes       | Yes     |
| Production range, shots/hr             | 40-200   | 40-200 | 75-400    | 200-550 |
| Average tool life, no. of shots x 1000 | 125      | 20     | 200       | 500     |

## Chemical Composition (%)

|           | Aluminum   | Brass      | Magnesium   | Zinc       |
|-----------|------------|------------|-------------|------------|
| Aluminum  | Remainder  | 0.25       | 8.3 to 9.7  | 3.5 to 4.3 |
| Cadmium   | --         | --         | --          | .004 (max) |
| Copper    | 3.0 to 4.0 | 57.0 (min) | 0.35 (max)  | 0.25 (max) |
| Iron      | 1.3        | 0.50       | --          | 0.10 (max) |
| Lead      | --         | 1.50       | --          | .005 (max) |
| Magnesium | 0.10       | --         | Remainder   | .02 to .05 |
| Manganese | 0.50       | 0.25       | 0.13 (min)  | --         |
| Nickel    | 0.50       | --         | .03 (max)   | *          |
| Silicon   | 7.5 to 9.5 | 0.25 (max) | 0.5 (max)   | *          |
| Tin       | 0.35       | 1.50       | --          | .003 (max) |
| Zinc      | 3.0        | Remainder  | 0.35 to 1.0 | Remainder  |
| Other     | 0.50       | 0.50       | 0.3 (max)   | --         |

|  |
|--|
|  |
|--|

### Characteristics of Die Casting Alloys

|                       | Aluminum | Brass     | Magnesium | Zinc      |
|-----------------------|----------|-----------|-----------|-----------|
| Dimensional stability | Good     | Excellent | Excellent | Good      |
| Corrosion resistance  | Good     | Excellent | Fair      | Fair      |
| Casting ease          | Good     | Fair      | Good      | Excellent |
| Part complexity       | Good     | Fair      | Good      | Excellent |
| Dimensional accuracy  | Good     | Fair      | Excellent | Excellent |
| Die cost              | Medium   | High      | Medium    | Low       |

|                |        |        |      |     |
|----------------|--------|--------|------|-----|
| Machining cost | Low    | Medium | Low  | Low |
| Finishing cost | Medium | Low    | High | Low |

## Dimensional and Weight Limits

|                                                                                      | Aluminum | Brass | Magnesium | Zinc |
|--------------------------------------------------------------------------------------|----------|-------|-----------|------|
| Maximum weight, lb.                                                                  | 70       | 10    | 44        | 75   |
| Minimum wall thickness, large castings, in.                                          | .080     | .090  | .100      | .035 |
| Minimum wall thickness, small castings, in.                                          | .040     | .055  | .040      | .015 |
| Minimum variation per in. of diameter or length from drawing dimensions over one in. | .0015    | .009  | .0015     | .001 |
| Cast threads, max. per in. external                                                  | 24       | 10    | 24        | 32   |
| Cored holes, min. diameter in.                                                       | .080     | 0.250 | .080      | .050 |

The values shown herein represent normal production practice at the most economic level. Greater accuracy involving extra close work or care in production should be specified only when and where necessary since additional cost may be involved.

## Comparison of Metals

| MATERIALS                               | SPECIFIC GRAVITY | LBS./CU. IN. |
|-----------------------------------------|------------------|--------------|
| <b>Metals</b>                           |                  |              |
| Magnesium AZ-91B-ingot                  | 1.81             | 0.0653       |
| Aluminum SAE-306<br>(380-1% Zinc)-ingot | 2.77             | 0.100        |
| Aluminum SAE-309 (360)-ingot            | 2.64             | 0.0953       |

|                                   |           |               |
|-----------------------------------|-----------|---------------|
| Zinc SAE-903 ('Zamac' 3)-ingot    | 6.6       | 0.238         |
| Brass-Yellow (#403)-ingot         | 8.5       | 0.307         |
| Brass-85/5/5/5 (#115)-ingot       | 8.75      | 0.316         |
| Steel-CR Alloy-strip              | 7.85      | 0.283         |
| Steel-Dwg. Qual.-sheet            | 7.85      | 0.283         |
| Steel-Stainless 304-bar           | 7.92      | 0.286         |
| Iron-Pig, basic-pig               | 7.1       | 0.256         |
| <b>Plastics</b>                   |           |               |
| Polyester (thermoplastic)         | 1.31      | 0.0473        |
| Polystyrene--General Purpose      | 1.06      | 0.0383        |
| Polypropylene Resin               | 0.905     | 0.0327        |
| Polyvinyl Chloride (rigid)        | 1.20-1.37 | 0.0433-0.0494 |
| Styrene Acrylonitrile (Copolymer) | 1.07      | 0.0386        |
| ABS Resins                        | 1.04-1.06 | 0.0375-0.0383 |
| Modified Acrylic Resin-Rubber     | 1.12-1.18 | 0.0404-0.0426 |
| Cellulose Acetate Butyrate        | 1.19      | 0.0430        |
| Modified Polyphenylene Oxide      | 1.06-1.10 | 0.0383-0.0397 |
| Polycarbonate Resin               | 1.20      | 0.0433        |
| Polysulfane                       | 1.24      | 0.0448        |

## Comparison of Materials

| MATERIALS          | SPECIFIC GRAVITY | LBS./CU. IN. |
|--------------------|------------------|--------------|
| <b>Polystyrene</b> |                  |              |
| 20% Reinforced     | 1.20             | 0.0432       |

|                                       |           |        |
|---------------------------------------|-----------|--------|
| 30% Reinforced                        | 1.28      | 0.0462 |
| <b>Polypropylene</b>                  |           |        |
| 20%                                   | 1.04      | 0.0375 |
| 30%                                   | 1.13      | 0.0407 |
| <b>Styrene Acrylonitrile</b>          |           |        |
| 20%                                   | 1.22      | 0.0440 |
| 30%                                   | 1.31      | 0.0472 |
| <b>ABS</b>                            |           |        |
| 20%                                   | 1.21-1.23 | 0.0439 |
| 30%                                   | 1.28      | 0.0462 |
| <b>Polyester (thermoplastic)</b>      |           |        |
| 30%                                   | 1.52      | 0.0549 |
| <b>Polyphenylene Oxide (modified)</b> |           |        |
| 20%                                   | 1.21      |        |
| 30%                                   | 1.27      | 0.0458 |
| <b>Polycarbonate</b>                  |           |        |
| 20%                                   | 1.34      | 0.0484 |
| 30%                                   | 1.43      | 0.0516 |
| <b>Polysulfane</b>                    |           |        |
| 20%                                   | 1.38      | 0.0498 |
| 30%                                   | 1.45      | 0.0523 |

## Current Industries Served

|                 |                   |                |
|-----------------|-------------------|----------------|
| Appliances      | Electronics       | Timing Devices |
| Automotive      | Government        | Toys, Sports   |
| Computer        | Plumbing, Heating | Personal Goods |
| Office Machines | Hardware          | Transportation |



## 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.

**1. 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.

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

**3. 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.

**4. 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.

**5. 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.

**Q. What is the difference between high-pressure die casting, low-pressure die casting and gravity die casting?**

**A.** High pressure casting and high-pressure die casting are terms used in Europe and countries other than the U.S. for what is referred to in the U.S. simply as the die casting process. The terms low-pressure die casting and gravity die casting are terms used outside the U.S. for what in the U.S. is called low pressure permanent mold and gravity permanent mold casting. Although they each use metal dies, because of the lower pressures involved they are restricted to heavier section parts, often resulting in higher cost because of the less efficient use of the alloys involved and the slower processing time. They also require a sprayed-on protective coating on the die cavities, which means looser tolerances and rougher surface finishes.