ALLIED METAL COMPANY
Aluminum Alloys ■ Zinc Alloys ■ Metal Trading

Just as die casting offers advantages over other manufacturing processes, zinc provides advantages over other die casting alloys. Zinc die casting alloys are stronger, tougher and more ductile than die castings in aluminum or magnesium. Zinc alloys can be used to die cast extremely small, complex shapes. They can be cast smoother, easier, more accurately, and at lower cost. Zinc die castings can be readily painted and more easily plated than aluminum or magnesium alloys. Zinc's low melting point prolongs die life, even into the millions of parts.

Miniature zinc die casting provides component designers and users the following benefits:

- low component cost
- tight dimensional tolerances
- fast production cycle times
- thin wall sections
- high mechanical properties
- good physical properties
- ability to design intricate configurations
- excellent surface quality and finishing characteristics

The Casting Process

Zinc casting alloys enable the product engineer and designer to produce components using a wide range of casting processes, and to supply quantities ranging from one to millions per year. In fact, zinc alloys surpass all other ferrous and nonferrous alloys in casting-process flexibility.

The following table provides a general overview of the common zinc casting processes.

Included are die casting, permanent-mold casting, graphite permanent-mold casting, sand casting, shell-mold casting and plaster-mold casting.

Die Casting

The vast majority of zinc alloy castings are produced by pressure die-casting. The Zamak alloys and ZA-8 are cast in hot-chamber die-cast machines. The hot-chamber process uses a metal pump immersed in a molten zinc bath. Metal is pumped from the bath through a nozzle and into the die. After solidification, the die opens, ejecting the finished part.

Hot-chamber die casting produces castings with intricate detail and excellent surface finishes at extremely high production rates. Cycle times of 400-1000 shots-per-hour for larger parts are common.

Extremely small castings (i.e., up to a few ounces) are produced on special hot-chamber machines with very high cycle times (2000-3500 shots-per-hour). These machines are capable of producing flash-free, zero-draft, very-close-tolerance castings that require no secondary trimming or machining operations. One type of miniature die casting machine is the four-slide machine. This machine uses four sliding dies to produce highly-complex and tight-tolerance components.

This component photo is an ideal product for the four-slide process due to its complex shape and tight tolerance (+/-.001") in the shutoff and parting line areas.

Die-Cast Alloy Selection

Zinc alloys fall into two groups. The first group includes the traditional Zamak alloys, Nos. 2, 3, 5 and 7. All contain nominally 4 percent aluminum and a small amount of magnesium. (Magnesium is added to improve strength and hardness and to protect castings from intergranular corrosion).

Alloys 2 and 5 also contain copper, which further strengthens and improves wear resistance of castings but at the expense of stability (dimensional and property), especially when copper content exceeds 1 percent.

The No.7 alloy is a special high-purity alloy, which may be specified for die-castings requiring optimum surface finish (i.e., decorative applications). The high purity and small nickel addition permit the magnesium content to be lowered for maximum fluidity and ductility.

This group of zinc alloys is predominantly pressure die cast with No. 3 being the most widely-used alloy in North America. It offers the best combination of mechanical properties, castability and economics. Other alloys, being slightly more expensive, are used only where their specific properties are required.

In addition to the Zamak alloys, ZA-8 alloy can also be hot-chamber die cast. ZA-8 is a high-strength alloy containing a nominal eight percent aluminum. The alloy also contains copper and magnesium for optimum castability and mechanical properties.

Typical Properties Profile of Zinc Casting Materials

Zinc alloys are not suited for heavy continuous stresses or high-temperature service in the broad engineering sense, but perform well under conditions of moderate continuous loading and of high short-term or impulse load. Their thermal and electrical conductivity properties are favorable for wide-ranging applications. Zinc alloys have impact values comparable with gray cast iron at room temperature and aluminum and magnesium die casting alloys at 40 deg. F.

At elevated temperatures, there is some decrease in tensile strength, an increase in ductility, and an increase in creep. Zinc alloys are not recommended for stressed applications over 200 deg. F. In unstressed applications, zinc castings can normally tolerate continuous exposure to 300 deg. F.

The differences between Zamak alloys 3 and 5 are not significant, so the lower-cost alloy 3 is used for the majority of applications in North America. Zamak 3 is characterized by good impact strength and long-term dimensional stability. Zamak 5 exhibits somewhat higher tensile strength and creep resistance than Zamak 3, but has lower impact strength at elevated temperatures.

ZA-8 can be hot-chamber die cast. It offers excellent machinability, is anti-sparking and has good finishing characteristics for decorative parts.

Summary

Zinc alloys offer a number of design advantages. They exhibit high density and superior heat-transfer capability and electrical conductivity, and they outperform other casting and molding materials in numerous mechanical functions. Zinc alloys also feature excellent damping capacity and machinability, making them attractive for a variety of commercial, industrial and consumer applications.

Miniature and subminiature die-casting provides the ultimate cast-to-size technology for precision high-volume production.

When proper design is combined with effective part processing, zinc die-castings accept a wide variety of surface finishes for enhanced corrosion protection, aesthetic appeal and engineering properties.

Alloy Description

Alloy	Description
#3	No. 3 alloy is usually the first choice when considering zinc for die casting. Its excellent balance of desirable physical and mechanical properties, superb castability and long-term dimensional stability are the reasons why over 70% of all North American zinc die castings are in No. 3 alloy. It is, therefore, the most widely available alloy from die casting sources. ZAMAK No. 3 also offers excellent finishing characteristics for plating, painting and chromate treatments. It is the "standard" by which other zinc alloys are rated in terms of die-casting.
#5	No. 5 alloy castings are marginally stronger and harder than No. 3. However, these improvements are tempered with a reduction in ductility which can affect formability during secondary bending, riveting, swaging or crimping operations. No. 5 contains an addition of 1% copper which accounts for these property changes. The alloy is widely die cast in Europe and does exhibit excellent castability characteristics, as well as, improved creep performance over No. 3. Because of No. 3's wide availability, material specifiers often strengthen components by design modifications instead of using No. 5. However, when an extra measure of tensile performance is needed, No. 5 alloy castings are recommended. The alloy is readily plated, finished and machined, comparable to No. 3 alloy.
#7	No. 7 alloy is a modification of #3 alloy in which lower magnesium content is specified in order to increase the fluidity. To avoid problems with inter-granular corrosion lower levels of impurities are called for and a small quantity of nickel is specified. Alloy #7 has slightly better ductility than #3 with other properties remaining at the same level. The alloy is therefore popular for those special cases where the die caster is making thin walled components requiring a good surface finish. However, research testing has shown that metal

	and die temperatures have a bigger effect than changing alloys. Close attention to control of the die casting process parameters is important so as to eliminate defects and achieve consistent quality.
#2	No. 2 is the only Zamak alloy that is used for gravity casting; mainly for metal forming dies or plastic injection tools. This alloy is sometimes referred to as Kirksite. For die-casting, No. 2 offers the highest strength and hardness of the ZAMAK family. However, its high copper content (3%) results in property changes upon long term aging. These changes include slight dimensional growth (0.0014 in/in/after 20 yrs.), lower elongation and reduced impact performance (to levels similar to aluminum alloys) for die cast products. Although No. 2 alloy exhibits excellent castability, it has seen limited use by die casters in North America. It does, however, provide some interesting characteristics which may assist designers. Its creep performance is rated higher than the other Zamaks and No. 2 maintains higher strength and hardness levels after long term aging. Also, preliminary investigations suggest No. 2 alloy is a good bearing material, and may eliminate bushings and wear inserts in die cast designs.
ZA-8	A good gravity casting alloy, ZA-8 is rapidly growing for pressure die-casting. ZA-8 can be hot chamber die cast, with improved strength, hardness and creep properties over Zamak's, with the exception of a No. 2 alloy which is very similar in performance. ZA-8 is readily plated and finished using standard procedures for Zamak. When the performance of standard No. 3 or No. 5 is in question, ZA-8 is often the die casting choice because of high strength and creep properties and efficient hot chamber castability.
ZA-12	ZA-12 is the most versatile zinc alloy in terms of combining high performance properties and ease of fabrication using either gravity or pressure die casting. ZA-12 is the best gravity casting alloy for sand, permanent mold and the new graphite mold casting process. It is also a good pressure die casting alloy (cold chamber) which provides a sounder structure than ZA-27, as well as higher die cast elongation and impact properties. For these reasons, die cast ZA-12 often competes with ZA-27 for strength application. An excellent bearing alloy, ZA-12 is also platable, although plating adhesion is reduced compared to the Zamak alloys.
ZA-27	ZA-27 is the high strength performer of the zinc alloys whether for gravity or pressure die casting (cold chamber). It is also the lightest alloy and offers excellent bearing and wear resistance properties. ZA-27, however, requires care during melting and casting to assure sound internal structure, particularly for heavy wall sections. It may also need a stabilization heat treatment when tight dimensional tolerances are required. ZA-27 is not

	recommended for plating. However, when brute strength or wear resistant properties are needed, ZA-27 has demonstrated extraordinary performance.

Mechanical Properties

	#3	#5	#7	#2	ZA-8	ZA-12	ZA-27
Ultimate Tensile Strength: psi x 10^3 (MPa)	41 (283)	48 (328)	41 (283)	52 (359)	54 (374)	58 (400)	61 (421)
Yield Strength - 0.2% Offset: psi x 10^3 (MPa)	32 (221)	39 (269)	32 (221)	41 (283)	42 (290)	46 (317)	55 (379)
Elongation: % in 2"	10	7	13	7	6-10	4-7	1-3
Shear Strength: psi x 10^3 (MPa)	31 (214)	38 (262)	31 (214)	46 (317)	40 (275)	43 (296)	47 (325)
Hardness: Brinell	82	91	80	100	95-110	95-115	105-125
Impact Strength: ft-lb (J)	43[2] (58)	48[2] (65)	43[2] (58)	35[2] (48)	31[3] (42)	21[3] (29)	9[3] (5)
Fatigue Strength Rotary Bend - $5x10^8$ cycles: psi x 10^3 (MPa)	6.9 (48)	8.2 (57)	6.8 (47)	8.5 (59)	15 (103)	17 (117)	21 (145)
Compressive Yield Strength 0.1% Offset: psi x 10^3 (MPa)	60[4] (414)	87[4] (600)	60[4] (414)	93[4] (641)	37 (252)	39 (269)	52 (385)
Modulus of Elasticity - psi x 10^6 (MPa x 10^3)	12.4[6] (85.5)	12.4[6] (85.5)	12.4[6] (85.5)	12.4[6] (85.5)	-	-	-
Poisson's Ratio	0.27	0.27	0.27	0.27	0.29	0.30	0.32

Physical Properties

	#3	#5	#7	#2	ZA-8	ZA-12	ZA-27
Density: lb/cu in (g/cm^3)	.24 (6.6)	.24 (6.6)	.24 (6.6)	.24 (6.6)	.227 (6.3)	.218 (6.0)	.181 (5.0)
Melting Range: °F (°C)	718-728 (381-387)	717-727 (380-386)	718-728 (381-387)	715-734 (379-390)	707-759 (375-404)	710-810 (377-432)	708-903 (376-484)
Electrical Conductivity: %IACS	27	26	27	25	27.7	28.3	29.7
Thermal Conductivity: BTU/ft/hr/°F (W/m/hr/°C)	65.3 (113.0)	62.9 (108.9)	65.3 (113.0)	60.5 (104.7)	66.3 (114.7)	67.1 (116.1)	72.5 (125.5)

Coefficient of Thermal Expansion: 68-212°F µin/in/°F (100-200°C µm/mm/°C)	15.2 (27.4)	15.2 (27.4)	15.2 (27.4)	15.4 (27.8)	12.9 (23.3)	13.4 (24.2)	14.4 (26.0)
Specific Heat: BTU/lb/°F (J/kg/°C)	.10 (419)	.10 (419)	.10 (419)	.10 (419)	.104 (435)	.107 (448)	.125 (534)
Pattern of Die Shrinkage: in/in	.007	.007	.007	.007	.007	.0075	.008

Compositions

Chemical Specification (per ASTM) (% by Weight)														
	#3		#5		#7		#2		ZA-8		ZA-12		ZA-27	
	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting	Ingot	Casting
Al	3.9-4.3	3.7-4.3	3.9-4.3	3.7-4.3	3.9-4.3	3.5-4.3	3.9-4.3	3.7-4.3	8.2-8.8	8.0-8.8	10.8-11.5	10.5-11.5	25.5-28.0	25.0-28.0
Mg	.03-.06	.02-.06	.03-.06	.02-.06	.01-.020	.005-.020	.025-.05	.020-.060	.020-.030	.010-.030	.020-.030	.010-.030	.012-.020	.010-.020
Cu	.10 max	.10 max	.70-1.10	.70-1.20	.10 max	.10 max	2.7-3.3	2.6-3.3	0.9-1.3	.8-1.3	0.5-1.2	0.5-1.2	2.0-2.5	2.0-2.5
Fe (max)	.035	.05	.035	.05	.075	.05	.075	.05	.065	.075	.05	.075	.070	.075
Pb (max)	.004	.005	.004	.005	.0030	.003	.004	.005	.005	.006	.005	.006	.005	.006
Cd (max)	.004	.004	.003	.002	.0020	.002	. 003	.003	.005	.003	.005	.003	.005	.003
Sn (max)	.002	.002	.0015	.002	.0010	.001	.001	.002	.002	.003	.002	.003	.002	.003
Ni (other)x[10]	-	-	-	-	.005-.020	.005-.020	-	-	-	-	-	-	-	-
Zn	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.

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