



ZINC

MOLYBDE

Engineering In Zinc,
Today's Answer

The Advantages of zinc casting alloys

TODAY'S ZINC CASTING ALLOYS are strong, durable and cost effective engineering materials. Their mechanical properties compete with and often exceed those of cast aluminum, magnesium, bronze, plastics and most cast irons. These characteristics, together with their superior finishing capabilities, and choice of casting processes make zinc alloys the unquestioned material choice for the 1990's, because they'll save you time and money:

- ◆ **Assembly operations are reduced.** Entire assemblies can be cast as a single unit, eliminating the need for expensive manual assembly operations.
- ◆ **Less material is required.** Zinc's superior casting fluidity, strength and stiffness permits the design of thin wall sections for reduced weight and material cost savings.
- ◆ **Machining operations are reduced.** Due to the superior net-shape casting capability of zinc alloys, machining can be eliminated or drastically reduced.
- ◆ **Faster production and extended tool life.** Die casting production rates for zinc are much faster than for aluminum, or magnesium. Coupled with a tool life often exceeding 1 million parts, tooling and machine usage charges are dramatically reduced.
- ◆ **Eliminate bearings and bushings.** Zinc's excellent bearing and wear properties allow greater design flexibility and reduce secondary fabrication costs by eliminating small bushings and wear inserts.
- ◆ **Choice of low, medium and high production.** A variety of casting processes are available to economically manufacture any size and quantity required.



Alloys Tailored to meet your needs: General Purpose and Special High Strength Alloys.

ZAMAK alloys are the standard general purpose die casting alloys, exhibiting an excellent combination of cost, strength, ductility, impact strength and finishing characteristics. They are the designers first choice when considering die casting.

ZA alloys are a family of new high strength zinc-aluminum engineering materials. They exhibit the highest yield strengths of all conventionally die cast materials and have superior high temperature performance compared to the ZAMAK alloys. They also offer bearing and wear characteristics superior to conventional bronze bearings.

While the ZAMAK alloys are mainly die casting alloys, the entire ZA family can be used for sand, permanent mold and die casting, as well as in centrifugal, investment, plaster, and continuous casting.

The ZA alloys differ from the ZAMAK alloys mainly in terms of their higher aluminum content. The numerical digits (8, 12 and 27) represent their respective approximate weight percentages of aluminum.

ZA alloys are specialty materials and therefore are not as universally available as the ZAMAK alloys. When die cast, only ZA-8 can be "hot-chamber" cast which is the most cost efficient and flexible die casting process. ZA-12 and ZA-27 must be "cold-chamber" die cast similar to aluminum alloys.

Major Alloy Characteristics

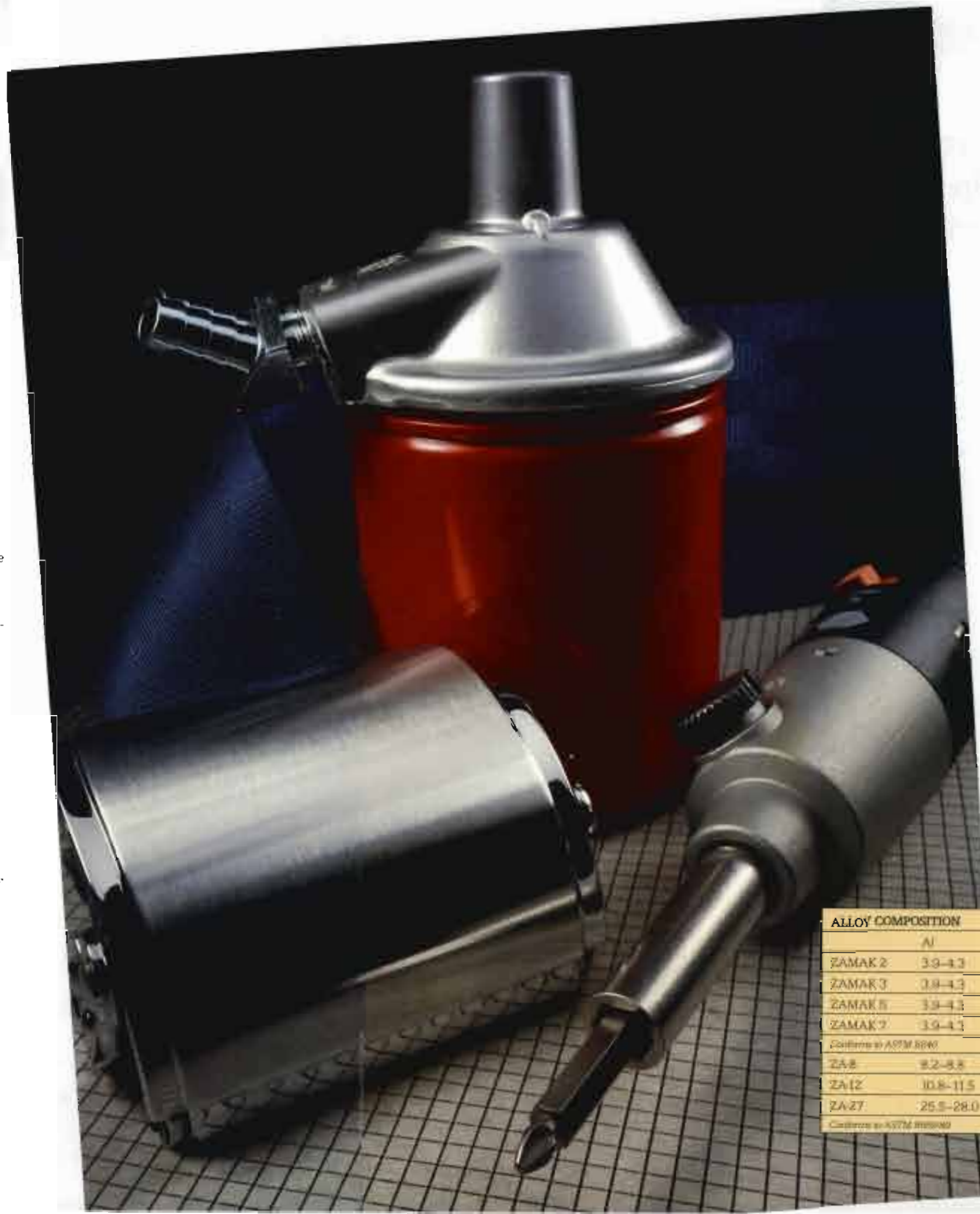
ZAMAK 2: This is the strongest and hardest ZAMAK alloy. Generally die cast, it is occasionally employed for gravity casting. ZAMAK 2 is not widely used.

ZAMAK 3: This is the most used general purpose zinc die casting alloy, providing an excellent combination of strength, ductility, and impact strength. It also provides excellent plating and finishing characteristics. This alloy is the designers first choice for die casting applications.

ZAMAK 5: ZAMAK 5 should be considered when moderately greater hardness, strength and creep resistance is required over ZAMAK 3.

ZAMAK 7: This is a high purity form of ZAMAK 3 with similar mechanical properties. However, ZAMAK 7 has higher ductility (for forming and bending operations) and the highest casting fluidity of the ZAMAK family.

ZA-8: This should be the first choice when considering die casting the ZA family, due to its cost effective hot chamber castability. ZA-8 provides improved performance characteristics over the ZAMAK alloys. Plating and finishing characteristics are similar. ZA-8 can also be sand or permanent mold cast.



ZA-12: This is the preferred alloy for permanent mold applications although it can also be cold-chamber die-cast with excellent results. It combines low temperature melting efficiency and this with capabilities with premium mechanical properties. ZA-12 should be used when switching from cast iron or permanent-molded aluminum. ZA-12 can usually be poured directly into molds designed for aluminum and brass.

ZA-27: Components requiring optimum strength, hardness and light weight should be specified using ZA-27. With over double the yield strength of die cast A380 aluminum and 25% lighter than ZAMAK 3, this is definitely the high performance member of the group. ZA-27 also offers excellent bearing properties, comparable to those of aluminum-bronze.

Figure ZA-27, die cast. Motorcycle oil filter adaptor. ZAMAK 3, die cast. Cordless screwdriver utilizes unit to drive, save draft angle gear housing. ZAMAK 3, die cast. Chrome plated cast iron truck offers good looks and high strength.

ALLOY COMPOSITION	% Weight of Major Alloying Elements			
	Al	Cu	Mg	Zn
ZAMAK 2	3.9-4.3	2.6	.025-.05	balance
ZAMAK 3	3.9-4.3	1 max.	.025-.05	balance
ZAMAK 5	3.9-4.3	.75-1.25	.03-.05	balance
ZAMAK 7	3.9-4.3	1 max.	.01-.02	balance
<i>Conforms to ASTM B240</i>				
ZA-8	8.2-8.8	8-13	.02-.03	balance
ZA-12	10.8-11.5	5-12	.02-.03	balance
ZA-27	25.5-28.0	2.0-2.5	.012-.02	balance
<i>Conforms to ASTM B240</i>				

Material properties that help solve today's engineering problems.

Strength

ZA alloys deliver the highest tensile strength among the most widely used non-ferrous alloys and match or exceed that of most cast irons.

Yield strength is a major ZA alloy attribute reaching 55,000 psi for ZA-27, that's more than twice that of A380 die cast aluminum, and significantly higher than the strongest plastics. Even ZAMAK 3, the most common alloy has a significant yield strength advantage over A380 aluminum, showing 2 times greater elongation, while maintaining greater hardness and higher stiffness.

Rigidity

Zinc alloys are rigid engineering materials. Their elastic moduli are greater than those of aluminum and magnesium alloys and an order of magnitude greater than those of engineering plastics. This, combined with their high strength allows the volume of individual castings to be markedly reduced, saving space and weight.

Toughness and Ductility

High impact strength and good ductility are qualities of zinc alloys that are rarely found in most other casting alloys. Ductility is important for bending and crimping in post-casting assembly operations, while impact strength provides performance in rough environments. Fracture toughness is also greater than for most aluminum alloys and cast irons.

Hardness

ZAMAK alloys provide high hardness and abrasion and wear resistance. Optimum hardness is provided by the ZA family whose Brinell Hardness ranges from 95 to 122 when die cast. These

values are much higher than the 70 to 85 HB displayed by aluminum alloys and much higher than the hardness values of engineered plastics. Along with high hardness, ZA alloys also exhibit excellent abrasion and wear resistance.

Conductivity

As zinc alloys conduct both heat and electricity, they can be used for heat dissipating devices such as heat sinks. Zinc's excellent casting fluidity permits thinner fin and cooling pin design to better dissipate heat. Zinc's excellent electrical conductivity also provides good EMI, RFI and ESD shielding.

Non-sparking and non-magnetic

Aluminum alloys can generate a spark when struck with a rusty iron component. All zinc alloys except ZA-27 are classified as "non-sparking" and are the perfect low-cost alternative to bronze in potentially explosive environments.

Zinc's non-magnetic properties are ideal for use in electronics and other applications where delicate moving parts are subject to magnetic disturbances.

Fatigue Strength

This measure of a material's ability to withstand cyclic loading is an important design criterion. Both the ZAMAK and ZA alloys have high fatigue strengths.

Design (Creep) Stress

The allowable design stress, or resistance to creep, at room temperature of ZA alloys is far better than for all but the most isotropic engineering plastics. The room temperature design stress of die cast ZA-27, for example, is 30,000 psi (stress required for creep of 1% in 100,000 hours). This property allows ZA



alloys to be used in applications subject to significant static loading. However, permissible design stress drops with increasing temperature and a careful review of all constant load applications at temperature is required to determine the suitability of zinc alloys.

Pressure Tightness

Soundness of castings is largely related to product design, molding layout and process control. The case ZAMAKs ZA-8 and ZA-12 are often used for pressure tight applications. For sand and permanent mold casting ZA-12 is the preferred material. All zinc alloys solidify into a dense casting matrix with excellent pressure tightness.

Damping Capacity

All of the ZAMAK and ZA alloys have excellent damping capacity. At 20°C, ZA-27, the highest damping zinc alloy, has nearly ten times greater damping capacity than A380 aluminum or mild steel. At 100°C damping capacity increases and all of the zinc alloys become "HIDAMETS" (high damping metals) and have a damping capacity greater than that of gray cast iron. This property makes zinc alloys the perfect choice for housings where vibration absorption is required.

Corrosion Resistance

Zinc has excellent corrosion resistance under normal atmospheric conditions, and in many aqueous, industrial and petroleum environments. Corrosion resistance can be enhanced by such treatments as plating, chromating, painting and zinc anodizing.

Photo: ZAMAK die cast. First axle tube for VW truck provides high strength and excellent ductility.

Engineering characteristics that answer your most critical needs.

Accuracy

Generally zinc die casting tolerances are superior to those of aluminum and magnesium die castings. Zinc die casting can produce repeatability of less than $\pm 0.001"$ for small components, often resulting machining tolerances. Few other processes can easily achieve the same net shape performance. Many components are die cast to net shape and require no further machining.

Machinability

In general zinc alloys machine rapidly, with minimal tool wear. Machining rates often rival those of free machining brass, and can be three times faster than for cast iron. Ease of machining and elimination of tool breakage problems often influences the selection of ZAMAK and ZA alloys over competitive materials.

Thin Wall Capability

Exceptional casting fluidity is displayed by all ZAMAK and ZA alloys, which provides superior thin-wall castability, regardless of the casting process employed. Wall thicknesses of .025 inches (.635mm) for die casting and .010 inches (.254mm) for permanent mold casting are being produced. This thin-wall capability results in smaller, lighter, low cost components.

Zero Draft Angle Castability

Draft angle is the taper on the surface of a die, required to facilitate removal of the cast part from the die cavity. In general zinc alloys can be die cast with less draft angle than competitive materials. In

fact, zinc components can sometimes be cast with zero draft angles. This is usually not possible with aluminum or magnesium alloys. Zero internal draft permits net shape manufacturing resulting in lower cost production.

Dimensional Stability

The ZAMAK alloys, ZA-8 and ZA-12, have excellent dimensional stability characteristics. ZA-27, however, may require a stabilization heat treatment to minimize aging effects where exceptional tolerances are required.

Joining

Zinc alloys can be welded using MIG and TIG welding methods and brazed using special zinc filler rods. Welding is normally not an economical joining method for zinc die castings due to the high production volumes involved. Normally, mechanical devices are used for joining; however, flaring, riveting and crimping techniques are common low cost joining methods.

Temperature Limitations

The low melting temperatures of zinc alloys are an energy-saving advantage for foundrymen, however this also causes some loss of strength and hardness at moderately elevated temperatures. Plastic deformation or creep can occur with these alloys when they are stressed at less than their yield stress for extended time periods at elevated temperatures. In general, applications which are above 250 degrees F or under high creature stress should be avoided. Moderately stressed parts at ambient temperatures up to 150 degrees F are best suited for ZAMAK and ZA alloys (see design stress).



Item photo ZAMAK 3 diecast. Thin walls, high accuracy, and dimensional stability make zinc alloy the perfect choice for this 4 bore cartridge.

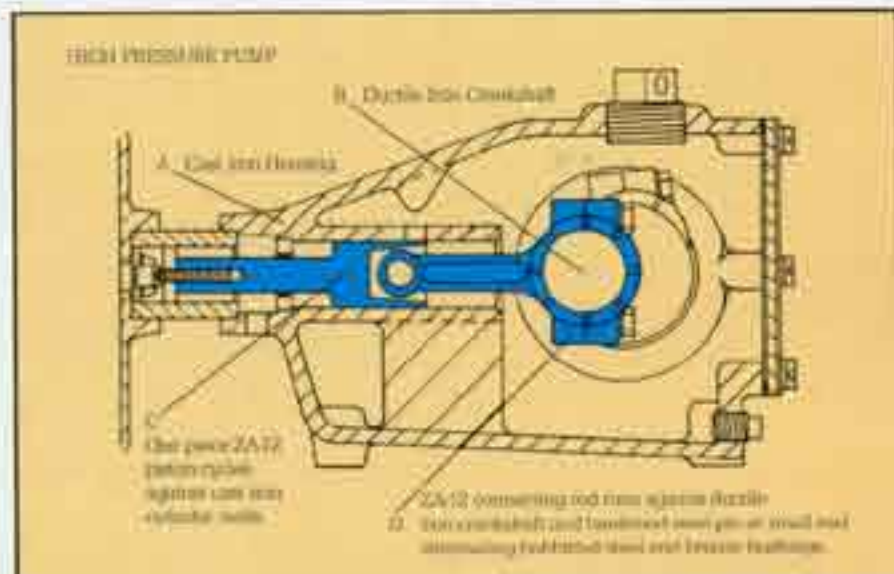
Inset photo ZA-12, graphite permanent mold cast. Method suitable for competition.

Superior bearing properties ensure built-in reliability.

All zinc alloys, particularly ZA-12 and ZA-27 demonstrate excellent bearing and wear resistance qualities thanks to their high hardness and natural lubricity characteristics. ZA alloy bearings should be considered whenever bronze bearings are currently being specified. They generally operate best in lubricated, high load, low speed applications under moderate temperature conditions, however they have also been successfully used in high speed, low load applications.

ZA alloys are increasingly being used as direct substitutes for larger bronze industrial bushings and bearings since they cost less and are up to 43% lighter.

For smaller components, zinc's natural lubricity may contribute to lower secondary fabrication costs by eliminating small bushings and wear inserts, thus allowing greater design flexibility.



Schematic of components shown in main photo

Main photo: ZA-12, well-lubed, large journal bearing uses advantages of zinc cast steel casting method and provides superior performance.
 Inset photo: ZA-12, flexible performance steel case. Low-friction rod end pin for high pressure pump utilizes ZA-27 excellent bearing and wear properties as well as high strength.

A variety of high quality surface finishes is another major advantage.

Electro-Plating

Zinc die castings offer excellent plating characteristics. Electro plating is generally a multi-layered coating consisting of one or two copper layers, one or two layers of nickel, and a final layer of chromium, brass, gold, or any other platable metal. Chromium plating is the most popular decorative finish when corrosion and high abrasion resistance are required.

Chromium plating adheres best to the ZAMAK alloys and ZA-8 followed by ZA-12. Chrome plating of ZA-27 is possible but more difficult due to the need to treat ZA-27 like an aluminum casting. Processes which provide a smooth, dense outer skin such as pressure die casting and permanent mold casting are preferred when plating is being considered.

Chromates

Chromating is a low-cost chemical treatment that provides additional corrosion protection against "white rust." This form of zinc corrosion is caused by prolonged exposure to damp conditions. Chromate finishes are produced by simple dip methods which deposit a thin chromate coating. Chromate coatings are often applied to instrument, military and automotive components where low-cost resistance to moisture is required. These coatings normally have a bronze tone or metallic luster depending on the process used.

Phosphates

Phosphate coatings are primarily used to provide a good base for painting or powder coating.

Anodizing

A special zinc anodizing treatment is available for zinc castings. This coating is completely different than that for aluminum alloys. Zinc anodizing is a functional coating providing maximum corrosion resistance in atmospheric and marine environments.

Since the process uniformly coats deep recesses and threaded areas, anodized zinc alloy castings can serve as an economical alternative when replacing traditional brass, beryllium and stainless steel components.

Polishing and Brushing

Conventional high luster polishing or brush finishing techniques can produce appearances similar to chrome plating or stainless steel. When lacquered, these finishes are suitable for decorative interior applications.



Painting

All zinc alloys form an excellent base for paints. To aid paint adhesion, phosphate or chromate treatments are often employed. Zinc alloys can also be electrostatically painted.

Powder Coatings

Powder coating involves electrostatic spraying of the zinc castings with an epoxy or polyester powder. The parts are then immediately oven cured for a hard durable finish. The result is an even, inexpensive, corrosion resistant plastic coating. Powder coatings are available in a wide range of colors.

Main photo: ZA-27, die-cast. Plated and lacquered for interior applications.

ZAMAK 3, die-cast. Chrome plated finish provides a beautiful, quality finish and excellent corrosion resistance.

Zinc phosphate, for ZAMAK 3, die-cast. Chromated green.

Exposed ZAMAK 3, die-cast. Powder coating provides the best looking with a tough and durable finish, available in a wide range of colors.

Casting versatility leads to further savings.

Die Casting

This is the most efficient process for high volume precision casting, producing the best tolerances and rapid production rates, but having high initial tooling costs.

Die casting should be considered for components requiring a production run of at least 10,000 pieces. All tolerances depend on part size and complexity, however tolerances of $\pm 0.001"$ are common. Hot chamber die casting cycle rates range from roughly 150 parts per hour for large components to over 2000 per hour for small ones.

The ZAMAK alloys and ZA-8 can be used in a "hot chamber" die casting machine, while ZA-12 and ZA-27 must be "cold chamber" die cast like the aluminum alloys. The hot chamber process offers faster cycle times, resulting in lower production costs.

Due to the low melting temperatures of zinc alloys, dies for zinc parts last longer, often 3-4 times longer than the same dies when used for casting aluminum alloys.

Permanent Mold Casting

ZA-8 and ZA-12 are generally considered for permanent mold applications. Permanent mold casting has traditionally been done using steel or cast iron molds, but is now also performed in graphite molds. Permanent mold casting often competes with sand casting by providing tighter tolerances and a smoother surface finish which can reduce machining operations.

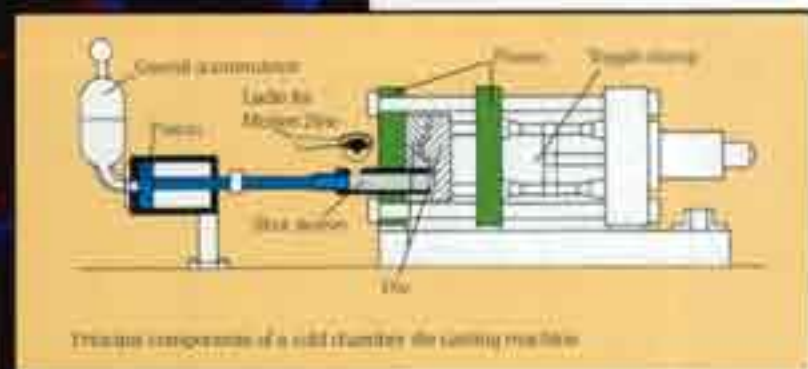
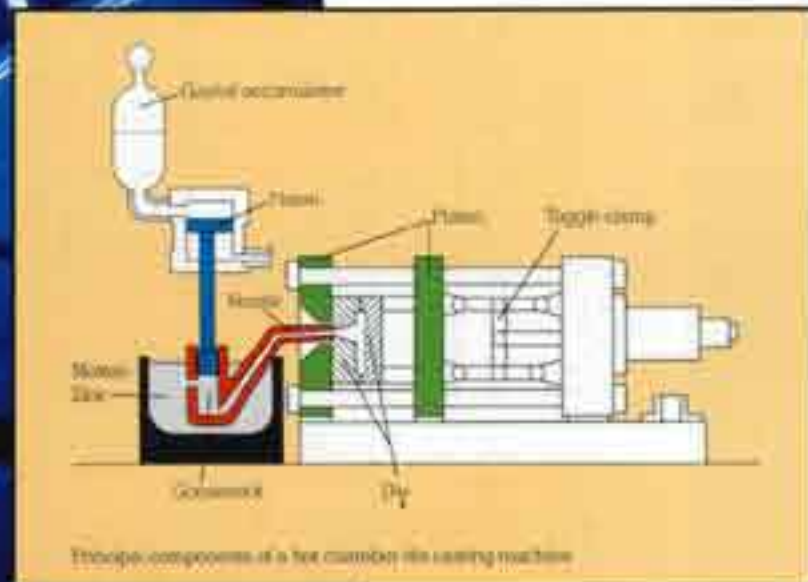
Ferrous permanent molds designed for aluminum alloys are generally suitable for casting zinc alloys. However, due to the superior casting fluidity of zinc, thinner sections can be cast. This process is well suited for medium production runs of 500-10,000 pieces. Ferrous permanent mold casting has great flexibility in terms of part size, ranging from ounces up to 100 lbs.

Graphite permanent mold casting offers some distinct advantages over metal tooling. Improved tolerances, lower tooling costs, and a superior surface finish are all benefits of the graphite mold process. Drawbacks are, limited component size, complexity and coring.

Sand Casting

All the ZA alloys are suitable for sand casting, however, ZA-12 is the most popular. Sand casting offers the greatest design flexibility in terms of size, complexity and quantity requirements. Tooling costs are generally low, therefore facilitating low volume production. However, surface smoothness and tolerance capabilities are limited, usually requiring machining.

Photo: ZA-27 die cast. Automatic gate die casting. Casting for 10000.



COMPETITIVE PERFORMANCE CHART ZINC ALLOY CASTINGS MEASURE UP.

ALLOY PROPERTY	UNITS	ZINC														ALUMINUM			MAGNESIUM		NICKEL-BRONZE		BRASS	
		ZK101				ZK102				ZK103				ZK104		ZK105	ZK106	ZK107	ZK108	ZK109	ZK110			
		1/2"	3/4"	1"	1 1/2"	1/2"	3/4"	1"	1 1/2"	1/2"	3/4"	1"	1 1/2"	1/2"	3/4"	1"	1 1/2"	1/2"	3/4"	1"	1 1/2"	1/2"	3/4"	1"
Ultimate Tensile Strength	psi x 10 ³ MPa	52 359	41 293	45 321	41 293	38 263	35 249	54 374	43 299	48 328	59 404	51 321	46 318	64 441	62 426	47 324	27 186	33 228	34 234	31 241	37 255	31 214	50 345	
Yield Strength 0.2% Offset	psi x 10 ³ MPa	NA	32 221	33 228	NA	29 198	30 208	42 290	31 211	39 268	46 320	54 371	37 257	55 376	54 371	24 166	18 124	24 165	23 159	18 ¹ 124	17 ¹ 117	18 124	32 221	
Elongation (% in 2")		7	10	7	11	17	13	8	15	22	6	4.8	6.4	2.5	2.5	3.0	2	2.5	3	20	30	nil	10	
Young's Modulus	psi x 10 ⁷ MPa x 10 ³	≥ 12.4 ≥ 85.5	≥ 12.4 ≥ 85.5	≥ 12.4 ≥ 85.5	≥ 12.4 ≥ 85.5	12.4 85.5	12.4 85.5	12.4 85.5	12.0 82.7	12.0 82.7	12.0 82.7	11.3 77.5	11.3 77.5	11.3 77.5	11.3 77.5	10.3 71.0	10.7 73.8	10.5 72.4	6.5 44.8	14.5 100	12.0 82.7	13.18 89.9	25 172.4	
Tensural Modulus	psi x 10 ⁷ MPa x 10 ³	NA	NA	NA	NA	1.8 12.1	1.8 12.1	1.8 12.1	1.8 12.1	1.8 12.1	1.8 12.1	1.3 9.0	1.3 9.0	1.3 9.0	1.3 9.0	1.3 9.0	1.3 9.0	1.3 9.0	1.3 9.0	2.4 16.5	NA	NA	NA	5.3 36.1
Show Strength	psi x 10 ³ MPa	40 277	31 214	38 262	31 214	NA	35 241	40 275	37 253	≥ 35 241	43 291	43 292	33 225	NA	47 325	27 186	22 152	20 139	20 138	NA	NA	43 296	45 310	
Hardness (Brinell)		100	85	91	80	85	87	103	94	99	106	111	94	114	119	81	71	71	63	65	66	170-200	110-155	
Impact Strength	ft-lb J	35 ¹ 47	43 ¹ 58	48 ¹ 65	43 ¹ 58	15 ¹ 20	NA	31 ¹ 42	39 25	NA	21 ¹ 29	35 ¹ 48	53 58	NA	8 ¹ 12	3 ¹ 4	4 ¹ 5	5 ¹ 11	2.7 ¹ 3.7	6 ¹ 8	11 ¹ 15	nil	40.65 ¹ 54.88	
Fatigue Strength Rotary Bend (5 x 10 ⁷ cycles)	psi x 10 ³ MPa	8.5 58.6	6.9 47.5	8.2 58.5	6.8 46.9	NA	7.5 51.7	10 68	10 68	NA	17 117	25 172	15 102	NA	21 145	20 138	20 138	8.5 58.5	14 97	16 110	11 76	11 76	28 193	
Compressive Yield Strength 0.1% Offset	psi x 10 ³ MPa	93 ¹ 641	60 ¹ 414	67 ¹ 460	60 ¹ 414	69 479	71 491	37 252	33 230	34 239	39 269	48 330	37 252	NA	52 359	NA	38 261	25 172	23 159	46 ¹ 317	37.5 ¹ 258	100 ¹ 682	NA	

PHYSICAL

Density	lb/in ³ g/cm ³	0.34 6.00	0.29 5.00	0.34 6.00	0.29 5.00	0.27 4.80		0.218 4.02		0.161 3.00		0.168 3.12	0.161 3.00	0.09 ¹ 1.58	0.094 1.62	0.122 2.12	0.108 1.90	0.109 1.91	0.102 1.80	0.108 1.90	0.105 1.86	0.105 1.86	0.28 4.90	
Melting Range	°F °C	719 379	714 379	727 387	714 379	707-708 375-404		710-810 377-430		708-803 386-461		1000 ¹ 538	880 518	1025 ¹ 557	875 ¹ 518	1070 578	1073 579	1073 579	1073 579	1073 579	1073 579	1073 579	> 2110 > 1177	> 2250 > 1232
Electrical Dissipation (% IACS)		25	37	26	27	27.7		28.1		29.7		27	27	31	NA	12	15	15	15	15	15	15	15	
Thermal Conductivity	Btu-ft/hr-°F W/m-K	83.5 144.7	85.3 151.0	101.9 180.9	85.3 151.0	90.3 164.7		87.7 154.7		77.8 137.5		65.8 116.2	85.3 151.0	87 151	41.8 72.3	74 131	41.8 72.3	74 131	74 131	74 131	74 131	74 131	28-30 48-52	NA
Coef. of Thermal Expansion (10 ⁻⁶ /°F)	10 ⁻⁶ x 10 ³ 10 ⁻⁶ x 10 ³	10.4 27.7	10.2 27.4	10.2 27.4	10.2 27.4	10.8 23.2		10.8 23.2		11.4 25.0		11.8 26.0	11.8 26.0	11.8 26.0	11 24.3	11.8 26.0	11.8 26.0	11.8 26.0	11 24.3	11 24.3	11 24.3	11 24.3	11 24.3	11 24.3
Wetted Surfaces Min. of corrosion		0.006	0.006	0.006	0.006	0.008		0.007		0.007		0.007	0.007	0.006	0.006	0.006	NA	NA	NA	0.008	0.006	0.006	0.006	0.006

¹ 3 lbs at 610°F and furnace cooled; ² 10mm unnotched Charpy; ³ 1/4 in unnotched Charpy; ⁴ at 1.2% elong; ⁵ 1ozd; ⁶ notched Charpy; ⁷ compressive strength; ⁸ at 10% permanent set; NA - Not Available.
 * * *Complies with ASTM specification B86
 * * *Complies with ASTM specification B888