Breaking Barriers: Light Zinc!

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Introduction

One of the biggest barriers that zinc die casters face when selling zinc die castings is weight. Although the zinc die casting process is more economical (which we will detail below), many applications today simply require parts to be lighter, and therefore zinc is often overlooked – especially in automotive applications.

On the surface it may appear that there are no opportunities for zinc die castings in light weight applications; however, due to new alloy technology and improved process controls in the die casting process, zinc die casters now have the ability to cast zinc lighter!

Why Choose Zinc For Die Castings Anyway?

Before discussing this "Light Zinc" concept, let's first lay the ground work on why zinc is considered more economical than other die casting alloys. Since zinc alloys are heavier than aluminum and magnesium alloys, its price per volume will simply be higher. Zinc alloys will not win this pricing battle. Even if the price per pound is the same, the price per volume will favor aluminum and magnesium every time.

However, price per volume is only one small factor in the overall cost of die cast components. There are many other factors that should be considered when choosing the diecasting alloy. The following are four of many of these potential factors:

Die life: One of the largest up-front costs when buying die castings is the investment in tooling. The dies used in the die casting process are typically heat treated premium grade H13 tool steel. This die material is designed to withstand the aggressive die casting process and is therefore used in high volume casting programs. These dies are a large investment. The current cost of one of these dies can range from 5k to 100k USD depending on the size and complexity of the tooling.

The advantage is that dies used in the zinc die casting process will typically last 10 times longer than those dies used for aluminum die castings and approximately 5 times longer than magnesium. Therefore, when designing high volume components, zinc becomes extremely cost competitive when accounting for tooling costs.

Cycle time: The heat content in aluminum alloys are approximately 4 times greater than the heat content of zinc alloys. (Mangalick, 1992, p. 5) This means that it takes aluminum approximately 4 times longer to solidify than zinc. Since the cycle time is largely dependent on solidification time, we can estimate that the cycle time of zinc is approximately 4 times shorter than aluminum parts of the same weight.

If we compensate for the density difference between zinc and aluminum, a zinc part of the same volume will be heavier, and therefore zinc's cycle time would only be approximately 2 times shorter than aluminum (which is still a big cost savings). However, the point of this article is to support the fact that zinc alloys can be made as light as aluminum and therefore the cycle time for zinc castings of 4 times shorter than aluminum is reasonable.

Mechanical Properties: Standard zinc alloys are stronger and harder than standard aluminum & magnesium alloys at room temperature. This strength is inherent in the alloy and does not require heat treatment processes to improve its strength (and therefore less costly) as is required for achieving higher strength in aluminum alloys.

EZAC® is a zinc die casting alloy that is stronger and harder than any other die casting alloy available. EZAC is approximately 2.5 times stronger (yield) and 1.5 times harder than A380 (see Table 1).

Alloy	Yield Strength (ksi)	Hardness (Brinell)
EZAC ®	57	120
Zamak 3	32	82
Al380	23	80
AZ91D	23	75

***Table 1** - Mechanical Properties of Die Casting Alloys.*

The improvement in strength of EZAC® is simply attributed to its chemistry. The specific combination of zinc, aluminum and copper give EZAC® it's higher mechanical properties, but also improved castability.

Castability: Zinc alloys are the most fluid of all die casting alloys. The published value for the typical minimum wall thickness of zinc alloys is 0.02" (Table 2). This is half of the typical minimum wall thickness that can be cast with aluminum and magnesium die casting alloys (see Table 2).

Alloy	Minimal Wall Thickness (in)
Zinc Alloys	0.02”
Al/Mg Alloys	0.04”

Table 2 *– Typical Minimum Wall Thickness of Die Casting Alloys. (Walkington, 2003)*

Due to zinc’s greater fluidity, die castings can be made thinner, more intricate and complex, eliminating the need for various secondary operations that are often necessary in aluminum and magnesium alloys.

EZAC® is a ternary eutectic alloy. This means that it is even more fluid than the standard zinc die casting alloys. With EZAC®’s improved fluidity and today’s enhanced die casting technology, thinner and more complex castings can now be achieved than what has been previously published.

As an example, DECO products (Decorah, IA) has recently developed a thin wall “business card holder” component cast in EZAC®. A portion of this casting is 0.016 inch (0.4 mm) thick with a flow length of 2.7 inches (Figure 1). In addition, the entire length of the casting is over 3.5” with wall thicknesses ranging from .016 to 0.025 inches (max). This die casting could not be made in any other alloy other than zinc, and with EZAC’s improved mechanical properties there is no strength loss even when casting this thin.

Figure 1 *– Thin Wall Card Holder – EZAC Alloy – 0.016” Thick.*

The Weight Barrier

Automotive is the die castings industry’s biggest market. Zinc and aluminum die castings have been used in automotive applications for many years. Today, due to strict environmental controls requiring automotive companies to reduce weight, we are seeing a decline in automotive zinc die casting components and a rise in aluminum (Figure 2).

Zinc castings are currently being overlooked in the automotive industry. This decline in zinc die casting components is understandable if we don’t take into account the

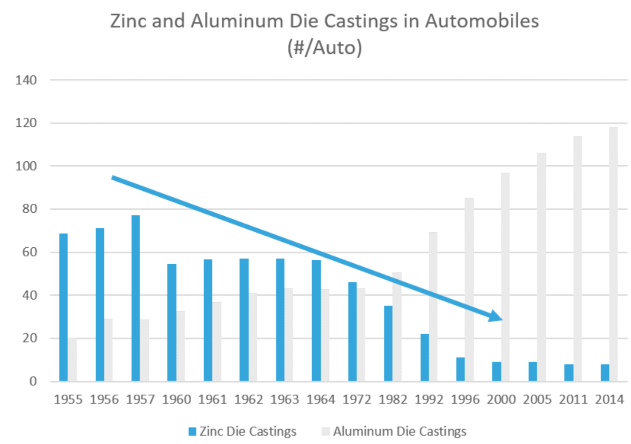

Figure 2 *– Zinc and Aluminum Die Castings in Automotive Applications. (Twarog, 2015)*

current alloy and die casting technology that is available to us today.

The highly fluid, high strength EZAC® alloy cast in combination with today’s improved technologies provide enormous cost savings opportunities to automotive companies who replace aluminum die casting components with extremely thin wall EZAC® components. This “Light Zinc” casting process saves costs without losing strength or increasing component weight.

The “Light Zinc” Process

“Light Zinc” is a combination of using the new highly fluid and high strength EZAC® alloy in combination with today’s improved die casting technology. We cannot decrease zinc’s density without major changes in chemistry that would adversely affect the alloy’s properties. We simply cast thinner and more complex.

For instance, since EZAC® is 2.5 times stronger than A380 and can be cast at least 2.5 times thinner, we now have a component of comparable strength and weight, with the potential cost savings described above.

“Light Zinc” cannot be accomplished without applying today’s die casting technology. The following are die casting methods that should be considered when casting “Light Zinc” components:

Casting conditions & control: In order to properly fill a cavity that is 0.016 in (0.40 mm) thick, the casting conditions must be carefully controlled. The Gate velocity must be above 100 FPS to ensure proper atomization of the alloy passing through the gate, there can also be no plunger “blow by” or hydraulic leaks that cause reduced pressure during cavity fill.

Cavity fill time and die temperature may be the most important parameters to consider. The data in Table 3 are calculated values of solidification time for zinc die castings using the Chvorinov’s rule (Giesserei, 1940, pp. 177-186). This rule calculates how fast molten alloy solidifies in cavities with respect to thickness and die temperature. For instance, a casting with a thickness section of 0.4 mm (0.016”) with a die temperature of 120° C (248° F) will solidify in 3 milliseconds. Therefore the

	Solidification Time in ms		
Thickness in mm	T_F = 120° C	T_F = 160° C	T_F = 200° C
0.4	3	4	5
0.8	12	16	20
1.5	50	64	80
3.0	200	250	320

***Table 3** - Calculated Solidification Time Using Chvorinov's Rule.*

required cavity fill time must be less than 3 milliseconds under these conditions.

It is important for die casting designers and engineers to understand these casting requirements, design the tooling accordingly and have the ability to measure these critical die casting parameters.

Although these conditions seem difficult, they are achievable with today's die casting technology. Tools such as shot monitoring accurately measures the hydraulic pressures and plunger speed during the die casting process. These measurements translate to gate velocity, cavity fill time and metal pressure, which are the parameters needed to ensure quality castings.

Die Heating: Figure 3 shows the dramatic improvement of castability due to die temperature. (Battelle Memorial Institute, 1984)

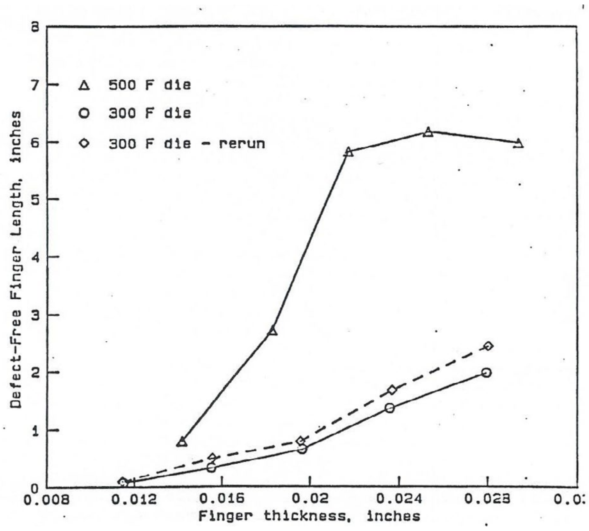

***Figure 3** - Castability Difference in Zamak 3 Die Castings Due to Die Temperature.*

In this research, Zamak 3 die castings were produced in a test tool with 5 channels, ½" wide x 7-5/8" long and ranging from 0.010" to 0.030" thick. Process conditions were varied, and Flow lengths were measured and compared. As shown in this graph a die temperature of 500° F improves castability when compared to castings produced with a die temperature of 300° F. Even at 0.016", castability improves by over 100%. At a wall thickness of 0.024" die temperature appears to have the greatest effect, improving by approximately 300%.

Due to zinc's low melting temperature, it can be difficult getting die temperature high enough to achieve castings free of surface defects, but the technology is available to achieve an optimum die temperature. There are effective methods available to pre-heat dies to quickly get dies to the proper temperature prior to casting. Hot oil unit technology is also available to help keep die temperature at an optimum temperature during the casting process.

There are also many ways to monitor die temperature during the casting process. Thermocouples placed in the die are still a viable process tool to help monitor surface temperature. However, new technology is available including thermal imaging cameras which can measure the entire die surface, not just at single points beneath the die.

Texturing Die Surfaces: Texturing dies adds a cosmetic appearance to the casting's surface; however, research has shown that texturing dies also improves castability.

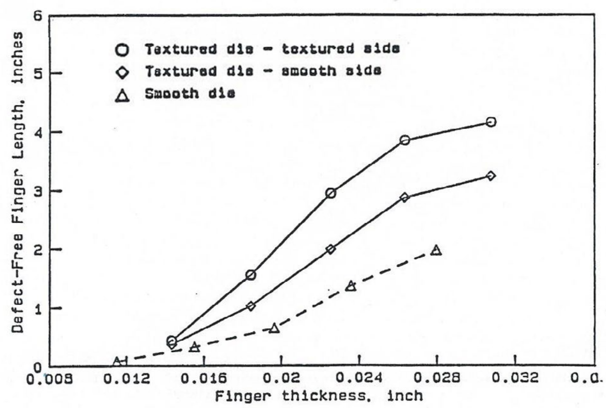

***Figure 4** - Castability Difference in Zamak 3 Die Castings Due to Texturing.*

Figure 4 shows results from further flow work performed at the Battelle Institute regarding texturing (Battelle Memorial Institute, 1984). The results compares a die with texture (400 RMS) on one side, texture on both sides as compared to a smooth die.

As shown, texturing improves castability at all thicknesses tested. Even if only one side of the die is textured, castability can improve by up to 150 to 300%, depending on thickness.

Thinner Walls Increase Strength: Much work has been done on how casting thin wall die castings improves strength. Prior work with Zamak 2, 3, 5, ZA-8, and the HF alloy have been performed. In every case it was found that the strength of castings increase as wall thicknesses decrease.

For example, Figure 5 shows data results from a ILZRO research program (Goodwin, 1991) which compares mechanical properties with respect to casting thickness and other process parameters.

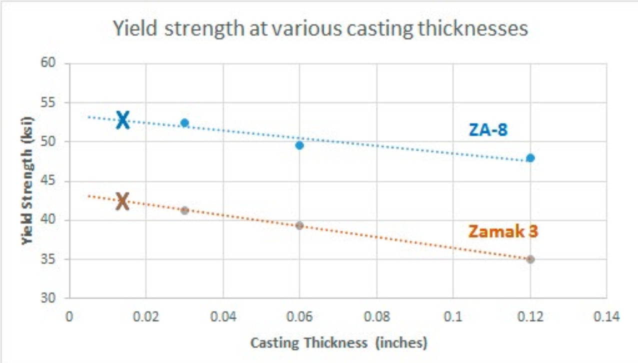

Figure 5 *- Data from ILZRO research program ZM-361 showing the relationship between casting thickness and yield strength (parameters were: water quench, 27 m/s gate velocity & 190° C die temperature).*

As can be seen in Figure 5, Yield strength in both ZA-8 and Zamak 3 increases as casting thickness decreases. This is due to the higher percentage of the fine skin microstructure in thinner castings compared to thicker castings. The "X" points on the graph was not measured but predicted using a linear trend line at a casting thickness of 0.015".

Although testing on extremely thin EZAC® samples was not performed during this research, we can assume that EZAC® will perform similarly resulting in higher yield values with thinner walls.

Using Ribs: Ribs are an important design concept for die castings in general, but even more important in thin wall applications. Two main advantages of using ribs in thin wall applications are:

1.) Adding ribbing in thin wall die castings provides the needed additional strength to the casting. This added strength is beneficial both for the function of the casting, but also to help the thinner castings eject without distorting.

2) Ribs assist filling. As discussed earlier, it is much more difficult to cast thin walls. Proper rib design provides a larger flow path for the molten alloy to travel, and therefore helps improve metal flow in casting areas farthest away from the gate.

Efficient runner design: Proper runner and feed design is fundamental in die castings; however, poorly designed feed systems are regularly found and often the cause of poor filling conditions and associated defects. In some cases poorly designed runner systems can achieve acceptable castings, but for thin wall castings it is essential to have an efficient runner design.

The runner, feed and gating system must have a gradual reducing cross sectional area with the smallest area occurring at the gate. Feed designs must be chosen depending on the design and layout of the casting and gate location. Gates areas should be chosen using gating equations which depend on the size of the part and the size of the die casting machine.

A correctly design runner system will help ensure the most efficient filling conditions in the die casting die.

Conclusion

Although the zinc die casting process is the most economical die casting process available, zinc has been over-looked in many light weight components due to its higher density. Combining today's die casting technology with the new high strength, highly fluid EZAC® zinc die casting alloy, it is now possible to compete in light weight applications. This new "Light Zinc" process allows designers to save cost by using the zinc die casting process without losing strength or increased weight.

References

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