WHITE PAPER

Comparing Magnesium Die Castings and Plastic Components

NORTH AMERICAN DIE CASTING ASSOCIATION

Die casting is one of the most mature manufacturing processes available. The most common materials die cast are alloys of aluminum, magnesium, and zinc. In recent years, significantly improved technology has enabled the die casting industry to remain very competitive in many market segments. The use of computerized product and process design tools, as well as significant new equipment technologies, have further enhanced the rapid cycle times and low cost of die castings.

One area of the die casting industry that is seeing rapid growth is the die casting of magnesium alloys. In the automotive industry, magnesium use has grown by 10-15 % annually over the past 15 years. Automotive companies are continuing to direct significant research and development resources into accelerating this increase in the use of magnesium in vehicles because of the advantages of magnesium components. These advantages include excellent dimensional stability, resistance to temperature extremes, and superior electrical and thermal conductivity.

While many new applications for magnesium die castings in the auto industry are being realized by conversions from aluminum components and steel fabrications, the purpose of this white paper is to compare magnesium die castings to injection molded plastic components, which are also being converted to magnesium die castings in many applications. Magnesium components are also being widely utilized by manufacturers of personal electronics, computers, and office equipment. These industries have discovered the many advantages of magnesium components and have moved quickly to design their products with magnesium in mind. Of course, the continuing volatility of the price of oil is affecting the price of plastic material used in producing plastic parts, providing additional incentive for manufacturers to look at magnesium die castings.

Comparing Magnesium versus Plastics

Die casting and plastic injection molding are both high-speed production processes which inject the material into a die under high pressure. The dies, which are made of steel, are capable of producing a large quantity of complex thin-walled parts with high levels of reproducibility. There are several areas, however, in which magnesium die castings have significant advantages. These include material availability and recycling, material properties, design tolerances, and material cost.

Material Availability and Recycling

Magnesium is the 8th most common element found on earth. It is the 6th most abundant metal, composing 2.5% of the surface of the earth. Magnesium is naturally found in Carnallite, Magnesite, Dolomite, and in brines and sea water. It is considered an unlimited resource since 100 gallons of sea water yields 1 pound of magnesium and 1 cubic mile of sea water yields 1 billion pounds of magnesium. Industrial production of magnesium alloys began in the 1920's and the material is 100% recyclable. At the end of their useful life, magnesium components can be reclaimed, re-melted, and reused to produce completely new magnesium products.

On the other hand, plastic feedstock is produced primarily from oil, which is a limited global resource. In addition, mechanical and physical properties of plastics can change or are compromised each time they are "re-ground" and re-molded. Plastic components are often land-filled at the end of their useful life and add significant social cost to the environment. Figure 1 shows the energy needed to recycle both magnesium and several plastic materials. As much as two times the energy is needed to recycle plastic materials as that required for recycling magnesium.

Material	Secondary Energy Required (kJ/kg)
Magnesium	27,200
Nylon	32,100
Fiberglass Reinforced Plastic	40,000
Polycarbonate	48,100
Polyester	50,400
Sheet-Molded Compound	50,400
ABS	51,400
Polyethylene	56,000
Phenolic	N/A

***Figure 1** – Life Cycle Energy Needed to Recycle Material.*

Material Properties

The design of complex components often requires the designer to make a series of trade-offs between the properties of several potential materials. There are often critical properties that lead the designer to the selection of a particular material. When considering magnesium die castings and plastic components the critical properties that impact the material selection often include strength and stiffness, energy absorption, corrosion, heat tolerance, and electromagnetic compatibility.

Figure 2 shows the specific stiffness and specific strength of three common magnesium die casting alloys (AZ91D, AM60B, and AM50A) and those of several plastic materials. Since magnesium is a metal, it has excellent stiffness. Some of the reinforced plastic materials have excellent strength. However, the designer is usually looking for a combination of

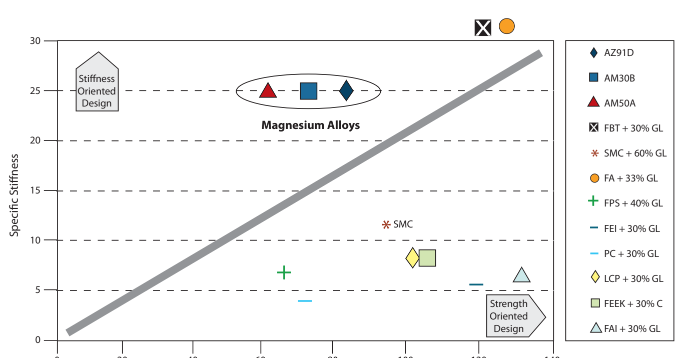

***Figure 2** – Specific Properties.*

these two properties in order to meet the needs of the product and the magnesium alloys offer the best combination of both stiffness and strength.

Energy absorption is a critical property for structural components and safety applications. These applications include automotive components such as seat frames, instrument panel structures, and steering wheels, or where possible cold forming applications are needed. The energy absorption index for several magnesium alloys and plastic materials is shown in Figure 3. The energy absorption capability of all of the magnesium alloys is very good.

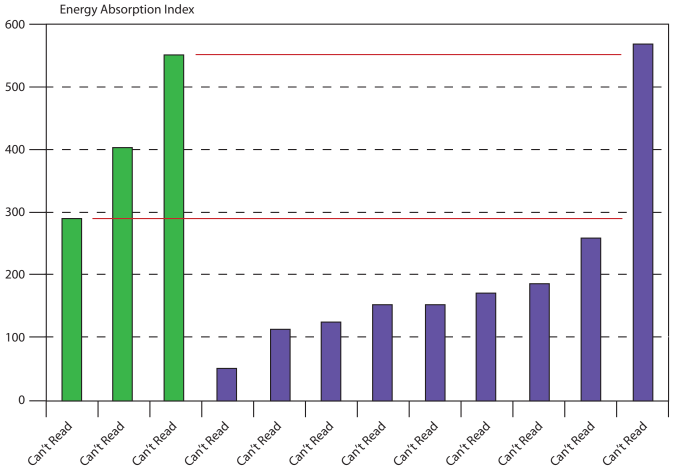

Figure 3 – Energy Absorption.

There is sometimes concern by designers when considering magnesium because of galvanic corrosion issues which are not a concern with plastics. Galvanic corrosion occurs when there are two dissimilar metals in contact with each other and there is an electrolyte present (such as salt water). There should be no concern about galvanic corrosion for components that are not exterior components. If there is a likelihood of galvanic corrosion (due to use in wet applications), techniques have been developed to mitigate this issue. One approach would be to coat one of the materials. Another way to eliminate galvanic corrosion is to use an isolating material (such as a washer). With proper design considerations and the use of proven mitigation techniques galvanic corrosion protection should be achievable.

The ability of a component to withstand high temperatures without deforming or degrading is often a key design parameter. This is called heat tolerance. Magnesium die castings have a much higher heat tolerance than plastics. The melting temperature of magnesium die casting alloys of about 600°C is 2-3 times the melting temperature of typical ABS and Nylon-6 plastics. In addition, many plastic components require the design and use of heat shielding. These heat shields can often be eliminated completely by using magnesium components, reducing both weight and manufacturing costs.

Electromagnetic compatibility is a material property which has become increasingly important in recent years due to the proliferation of personal electronic devices. Both Electromagnetic Interference (EMI), which is the electronic noise created by other electronic components having a processor, and Radio Frequency Interference (RFI), which is the electronic noise created by nearby sources of radio waves, are often of great concern. Since magnesium die castings are millions or even billions of times more conductive than plastics, they do an excellent job of shielding components from external electrical noise. Computer and office equipment manufacturers have gradually moved to more and more magnesium components to meet new, more stringent RFI emission requirements from the Federal Communications Commission (FCC). Plastic components must often be coated with expensive insulating materials to meet these requirements.

Design Tolerances

The typical design tolerances for magnesium die castings and plastic components are shown in Figure 4. Magnesium die castings require lower dimensional tolerances, lower minimum draft angles, and smaller wall thickness requirements than plastic components. These tolerances permit magnesium die castings to have less volume than plastic components for a similar product. This results in reduced material cost and weight. In addition, magnesium offers a lower coefficient of thermal expansion and a greater resistance to "creep" over time and temperature.

	Magnesium	Plastics
Dimensional	± 0.050mm	± 0.120mm
Draft Angle	0° to 2°	1° to 5°
Wall Thickness	1-2mm	2-5mm

Figure 4 – Typical Design Tolerance of Materials.

Since both magnesium die casting and plastic injection molding are high speed, high pressure processes, the tooling used is very complex. Many times, multiple components are produced from a single cycle of the equipment, further increasing the production rate of components. A common misconception is that the tooling for plastic injection molding is less expensive, which is not the case. In fact, tooling cost and lead time are nearly the same for both processes and some glass reinforced plastics may actually be harder to process and create more tool wear than the magnesium die casting alloys.

Material Cost

The cost of a pound of one material compared to another is not very useful for designed components. It is the cost of the amount of material required to meet the product requirements that is more useful. Magnesium die castings often require less material than plastic components for the same application. When comparing magnesium and plastic material costs, the material price and price stability as well as the strength of the material per unit cost are both important.

The price and price stability of magnesium alloys have been stable since the 1920's. Most major automotive OEM's have magnesium alloy prices under long-term contracts. In fact, prices for magnesium dropped during the 1990's due to excess capacity by smelters to produce magnesium. On the other hand, most plastics are derived from petroleum, which is traded as a commodity and priced primarily based on supply quotas by the OPEC nations. Resin prices are based on both the supply/demand of raw material and the market price swings of oil. Also, prices for plastic materials tend to increase after the market introduction of each new resin. Additives for plastic materials are "options" to the base resin and these can also drive up material prices.

The strength per unit cost for magnesium is much better than that of plastic materials, as shown in Figure 5 which graphs specific strength versus the material cost per cubic inch. The magnesium alloys are generally much less expensive for the strength provided. There are some reinforced plastics that have been developed that are very strong, but to achieve that strength the cost is very high. As shown on the graph, plastic materials that are stronger than the magnesium alloys have material costs that are at least 4 times more than magnesium.

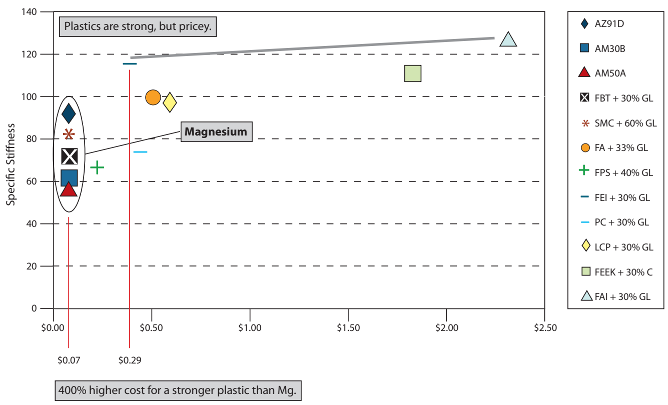

Figure 5 –Specific Strength & Price of Materials.

Magnesium Product Examples

Magnesium die casting offers great versatility in design and offers excellent material properties. It is suitable for a wide variety of products, including those weighing less than an ounce to those weighing 15-20 pounds or more. In addition, when special finishing is required, magnesium die castings can be powder painted, e-coated, and even plated if necessary.

Shown in Figure 6 is a 0.2 pound bezel display for a laptop computer. This high precision AZ91D casting with wall thicknesses between 0.03 inches and 0.08 inches is machined, deburred, coated with NH-35, and painted. The finished casting contributes to a 30% smaller and 50% lighter laptop computer. This is just one example of the growing demand for magnesium die castings in the computer and office equipment industry.

The casting in Figure 7 is an 18-pound magnesium automotive frame. It is an example of the large products that can be produced by magnesium die casting. The ductility of magnesium

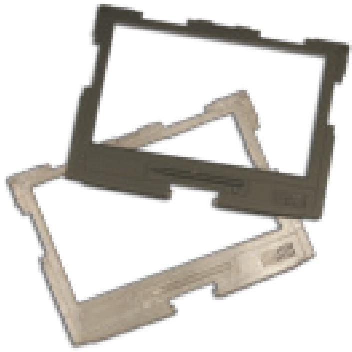

Figure 6 – Magnesium Laptop Computer Bezel Casting.

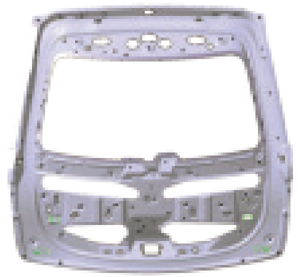

Figure 7 – Magnesium Automotive Frame.

alloys makes them excellent candidates for safety and structural applications. Automotive companies worldwide are vigorously developing new applications for magnesium die castings.

Conclusion

Magnesium die casting and plastic injection molding are very similar processes. They both inject material into a steel die very rapidly and at high pressure and produce a high volume of parts consistently. However, magnesium die castings have several significant advantages. These include:

- Abundant material supply.
- 100% recyclable.
- High strength to weight ratio.
- Excellent energy absorption.
- Good heat tolerance.
- Good electromagnetic shielding properties.
- Smaller design tolerances.
- Good strength per unit cost.

Magnesium die castings offer many advantages over plastic components when these advantages can be utilized to produce a more effective product. The large selection of magnesium alloys, when coupled with their light weight and strength, make them an excellent choice for many products. The North American Die Casting Association (NADCA) provides on-site seminars to help OEM designers capitalize on the advanced magnesium die casting capabilities that are available today. The "Creating Value with Die Casting" seminars analyze current processes to determine where die casting can help reduce costs and improve the final product.

About NADCA

Headquartered in Wheeling, Illinois, The North American Die Casting Association (NADCA) acts as the voice of the die casting industry, representing more than 3,100 individual and 300 corporate members in the United States, Canada, and Mexico. NADCA serves the industry by providing industry news, technical information, networking opportunities, publications and trade events. NADCA is committed to promoting industry awareness, domestic growth in the global marketplace and member exposure.