Process and Material Selection for Product Recyclability

Frequently Asked Questions (FAQ)

1) Are die cast materials recyclable?
   See page 1-2, Raw Material and page 1-4, Recycling
2) How much energy is saved using recycled material versus virgin material?
   See page 1-2, Raw Material and Table 1-1 Comparison of Recycled vs Virgin Aluminum
3) Can die castings reduce the environmental impact of the manufacturing process?
   See page 1-3, Manufacturing Process
4) How do metal components effect automotive recycling?
   See page 1-4, Recycling

Introduction

Product design is a complex process that attempts to optimize functionality, cost, and aesthetics. This alone is enough to make designing products challenging, but as the environmental impact of products become more well-known designers must address environmental concerns. This means a designer needs to take into account how production and material selection will impact the environment. This could vary greatly depending on the product being designed.

Although there are other factors that will determine if die casting is the manufacturing process of choice for a product, die casting offers advantages for environmental concerns. In the past die castings were often used to contain components of an assembly, but did not have any mechanical function. As technology and processes have advanced, the role of die castings has expanded. Die castings can be utilized as connectors, brackets, or risers that need to withstand a load or safety critical components that absorb the force of a crash. The expanded role of die castings provides further opportunities and choices for a product design.

1 Product Life Cycle

When designing a product with environmental concerns in mind it is important to consider the product life cycle as a whole. Some questions to keep in mind are:

- *Where does the material come from? (Virgin versus recycled material)*
- *How environmentally friendly is the component manufacturing process? (Energy usage, environmental contamination, etc.)*
- *What environmental benefit does the product receive from the component? (Weight savings, hazardous material reduction, etc.)*
- *Is there a developed infrastructure to recycle the material?*
- *Can the recycled material be used to manufacture high quality products?*

There are tools available to assist designers with assessing the environmental friendliness of a product, such as environmental vulnerability assessments and life-cycle assessments.

2 Raw Material

All components for a product start as a raw materials taken from the earth. This material needs to be extracted through mining, drilling or other removal process. Removing resources from the earth has an impact on the environment. To design an environmentally friendly product it is important to understand the environmental impact of the extraction process.

- *Energy use from extraction equipment*
- *Vegetation and habitat loss from clearing of land*
- *Gases and dust affecting air quality*

- *Chemical contamination of the land and water*
- *Availability of elements – aluminum (8.1%) and silicon (27.7%) make up two of the top 3 elements found in the Earth's crust*[6]

Because of these issues it is important to consider the recyclability of a material. Recycled material reduces the amount of material that needs to be extracted from the ground, which reduces the environmental impact. All die casting metals have the ability to be recycled an infinite number of times. Die casting parts are typically used automotive and housing applications. Over 90% of the aluminum used in housing and automotive parts are recycled[6].

Recycling can also reduce the energy required to processes material into a usable form. When metal is extracted from the ground it needs to be smelted into a useable form. Similarly, oils need to be distilled to make plastic. Recycling aluminum and magnesium requires only 5%[1],[2] of the energy required to smelt virgin material. Zinc, which has lower energy requirements for virgin material, requires 40%[3].

Table 1-1: Comparison of Recycled vs. Virgin Aluminum

Energy Savings	95% Energy Savings
Environmental Impact	92% Pollution Reduction
Natural Resource Savings	4 pounds of bauxite saved for every pound of aluminum
Miscellaneous Information	In the US, enough aluminum is thrown in the trash to rebuild the commercial air fleet 4 times every year. Leaving potential for sustainable recycling of more aluminum.

3 Manufacturing Process

Many factors determine the manufacturing method for a component. The most environmentally friendly manufacturing process is useless if it cannot make a part that meets the design needs. Die casting offers unique advantages, in terms of both design and environment.

Die castings can be produced with thin walls compared to plastic parts or other metal casting processes. The die casting process is designed to form high mechanical properties in the thin walls through rapid cooling. This leads to better properties, lighter weight products, and less material used.

Net-shapes or near net-shapes of complex geometries can be formed with die casting. This reduces or even eliminates the number of machining operations required later, leading to a reduction in lead time. The complex geometries of a casting can replace multiple components in an assembly, which has the benefit of fewer components, reduced assembly time, decreased weight, and possibly lower cost. It is also easier to disassemble and recycle.

Every year NADCA hosts an international die casting competition to highlight die castings that push the boundaries of die casting. Previous winners of the die casting competition can be found at *bit.ly/NADCACastingWinners.*

The following examples highlight some of the casting competition winners that show the benefits of the die casting process.

- *An axial vane stator was die cast with aluminum for an HVAC unit. This die cast axial vane stator replaced an assembly consisting of over 22 components.*
- *A guide was die cast with zinc for a seat belt assembly. The guide used steel shutoffs to create "two" castings joined by a small amount of metal. During assembly the "two" castings could be assembled via the cast in dovetail that is already aligned, saving time and cost during assembly.*
- *An inner liftgate was die cast with magnesium for an automobile. The inner liftgate replaced 7 steel stampings and 2 plastic pieces. It was able to reduce the weight of the assembly by 40% and number of joining technologies from 84 to 10.*

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4 Product Use

Through material selection and the die casting process the product can be made more environmentally friendly. Thin walled components made from aluminum die casting can replace steel components to make the product lighter. Durable metal die castings can replace plastic components to extend product life or allow the product to be serviced or rebuilt.

To illustrate this a comparison of mechanical properties for aluminum A380 and ABS plastic is provided in Table 1-2.

Table 1-2: Mechanical property comparison between aluminum A380 and ABS plastic

	A380 Aluminum		ABS Plastic*	
Ultimate Strength	47 ksi	324 MPa	11 ksi	76 MPa
Yield Strength	23 ksi	159 MPa	6.7 ksi	46 Mpa
Modulus of Elasticity	10.3 x 10^6 ksi	71 GPa	0.3 x 10^6 ksi	2 GPa
Elongation	3.5%		39.1%	

** Properties are the average ABS properties from matweb.com*

Advances in the die casting process have expanded the uses for die casting. Modern die castings can utilize vacuum, squeeze, or semi-solid technologies to improve the strength and elongation. Die castings can be produced that meet safety critical requirements in vehicles. These advanced process die castings are called high integrity or structural die castings and make up roughly 10% of the die castings in the average vehicle.

5 Recycling

Aluminum die casting alloy recycling has been in place almost from the beginning of custom die casting production. Specifications for aluminum alloys have been developed that provide for a full range of compositions that can utilize recycled metal. A wide variety of aluminum scrap can be reprocessed to produce all of the most widely specified die casting alloys.

Scrap can be categorized into either production or end of life scrap. Production scrap is the material used in the process that does not get shipped to the customer. This could be from scrap castings, overflows, and runners. This material, if chemistry limits allow, is often recycled internally at a die caster by remelting the metal and recasting it. It can also be sent out to a smelter to remelt and clean the material (which is often done with dross). End of life scrap is when the component is no longer useful (ie. a car stops running or a tool gets discarded).

Over 95% of the aluminum die castings produced in North America are made of post-consumer recycled aluminum[4]. Since the production of recycled aluminum alloy requires approximately 5% as much energy as primary aluminum production[1], there is a dramatic conservation of non-renewable energy resources. In fact, we still use nearly 75% of all aluminum produced in the US[6].

Die casting alloys tend to have a wider range for elemental chemistries than alloys used in other production methods. Table 1-3 shows a comparison of the chemistries between A380, A356, and 6061; the most common alloy used for die casting, sand casting, and forging respectively. The wider range for allows recycled material to be more easily incorporated.

The typical life cycle for die cast components is shown in Fig. 1-1. While the recycling circle for aluminum, copper, magnesium and zinc die cast parts is very similar, each will differ in the extent to which internally reclaimed alloy at the die casting plant will be reused directly or will move to a secondary smelter or primary producer for remelting and reprocessing.

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When a die cast product is reclaimed at the end of its useful life, it enters the nonferrous alloy reclamation stream. Nonferrous alloy parts can be readily separated from ferrous components by long-established magnetic means.

Large assemblies with a high proportion of metal parts, such as automotive vehicles, are the easiest scrap to be recycled and a well-established infrastructure exists. High-value components are usually dismantled from vehicles and enter the used parts or remanufactured parts distribution channel. The remaining automobiles are then shredded, with 80% of the weight of a typical car yielding recycled material, virtually all metal[5].

Unlike plastic, there is no necessity to segregate various types of aluminum scrap for remelting and reprocessing. Reclaimed aluminum from siding, trailers, major appliances, and automobiles — produced by a variety of metal forming processes in a range of alloy types — can be recovered by the aluminum smelter using selective thermal processing. Carefully engineered and analytically controlled chemical composition result in precise specification ingot for each of the commonly used die casting alloys.

As product engineers seek to design their new products for optimum servicing, reuse and recycling, aluminum, copper, magnesium and zinc die castings are available to meet their needs.

With an infrastructure in place for reclaimed die casting alloys, and a proven ability to capitalize on parts consolidation principles, die castings can be respecified for a wide variety of parts originally conceived as molded plastic.

Table 1-3: Chemistry comparison between A380, A356, and 6061

	A380*	A356**	6061**
Cr			.04 - .35
Cu	3.0-4.0	<= .2	.15 - .4
Fe	<= 1.3	<= .2	<= .7
Mg	<= .3	.25 - .45	.8 – 1.2
Mn	<= .5	<= .1	<= .15
Ni	<= .5		
Si	7.5-9.5	6.5 – 7.5	.4 - .8
Sn	<= .35		
Ti		<= .2	<= .15
Zn	<= 3.0	<= .1	<= .25
Other (each)		<= .05	<= .05
Other (total)	<= .5	<= .1	<= .15

Note: *Alloys chosen based on most common aluminum alloys used for die casting, sand casting and forging*
** Information from NADCA Product Specification Standards Chapter 3*
*** Information from matweb.com*

6 Conclusion

Where lightest weight is an important product criteria, selected die casting alloys can offer excellent strength-to-weight ratios, with total part weight virtually identical to the plastic component being replaced. In selecting materials and manufacturing processes which meet environmental concerns, the product designer should ask these questions:

- *Does the material allow for efficient and economical maintenance, repair, refurbishing or remanufacturing of the product to extend its life, where this is a design benefit?*
- *Is the material readily recyclable at the end of its useful life?*
- *Can the material be recovered and reused in high performance applications?*
- *Is the necessary infrastructure in place to make recycling of the reclaimed material a practical reality?*

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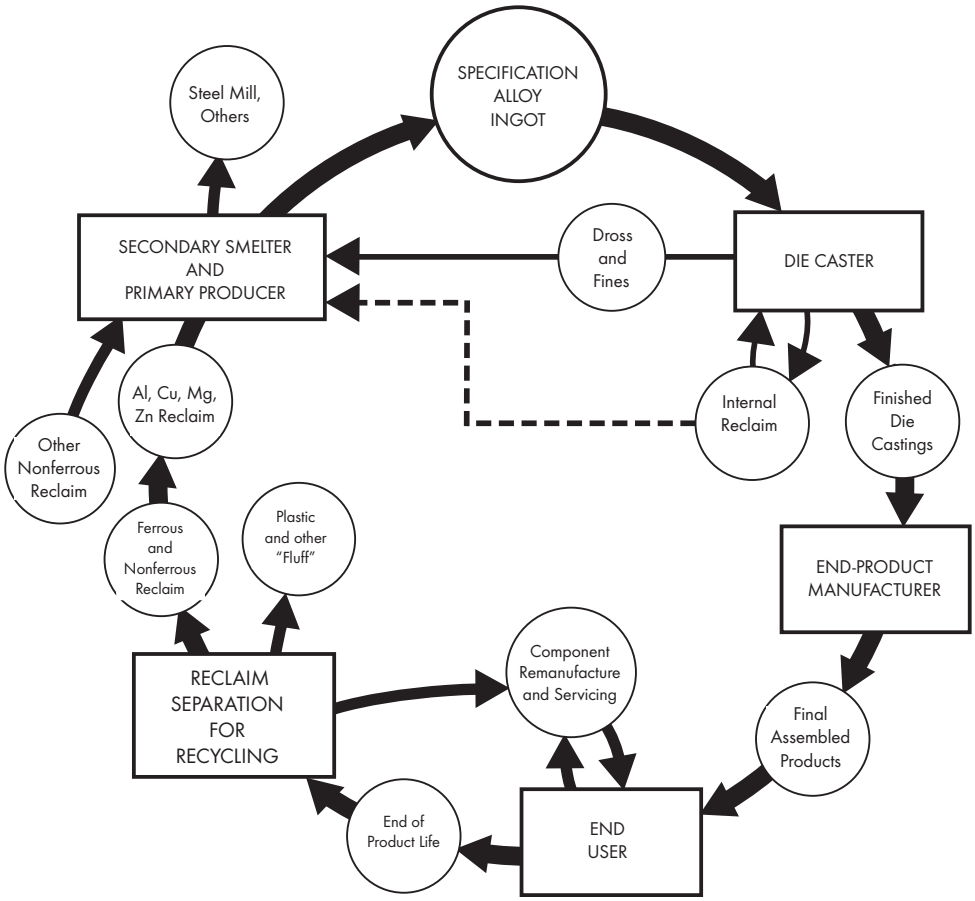

Figure 1-1 The Die Casting Recycling Circle – The die casting alloy recycling stream, illustrated above, is based on an existing worldwide metal reclamation infrastructure that has been operative for more than 40 years. This basic recycling pattern, with variations based on the amount of reclaimed alloy going to secondary and primary producers, applies to the majority of die castings being currently specified.

References:

1. Aluminum: The Element of Sustainability A North American Aluminum Industry Sustainability Report. The Aluminum Association. September 2011
2. Recycling Magnesium. International Magnesium Association. *www.intlmag.org/page/sustain_recycle_ima*
3. How Much Energy Does Recycling Metal Save. Moffatt Scrap Iron & Metal Inc. April 7, 2017 *https://moffattscrapiron.ca/scrap-iron-blog/much-energy-recycling-metal-save/*
4. The "Carbon Footprint" of Aluminum and Magnesium Die Casting Compared to Injection Molded Components. William A. Butler. 2008.
5. Auto or Car Recycling Facts and Figures: Facts About Car or Automobile Recycling. Rick LeBlanc. September 9, 2016. *https://www.thebalance.com/auto-recycling-facts-and-figures-2877933*
6. Recycling. The Aluminum Association. *aluminum.org/industries/production/recycling*