Enhanced Performance of Aluminum Die Castings through Metal Finishing

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Introduction

Injection die casting is one of the most popular and efficient methods used in mass production of aluminum parts. Unfortunately, from a metal finisher's point of view, corrosion protection and aesthetically pleasing finishes can be difficult to achieve on die cast parts. The nature of the die casting process promotes the migration of silicon particles to the surface of aluminum die castings. Since silicon is inert and relatively unaffected by chemical finishing techniques, these silicon particles make it difficult to produce uniform coatings.

Castings in general will also exhibit more potential for porous surfaces. High performance coatings depend upon smooth, non-porous base metals to produce a continuous barrier for protection against corrosive environments. Porous surfaces are more susceptible to corrosion and coating failures.

Over the past several years, Pioneer Metal Finishing's Research and Development Division has created new methods and finishes specifically for aluminum die castings.

Chromate conversion, anodizing, hardcoat anodizing and electroless nickel plating provide a wide range of options to die casters from basic corrosion protection to extreme corrosion protection with cosmetic appeal to wear applications. Each offers certain performance characteristics at different price points; plus, new hybrid finishes are available for maximum protection. It is critical for the die caster (and/or customer) to match the metal finish to the desired performance of the part.

The following information outlines these metal finishing processes for die cast aluminum and the associated capabilities of these coatings.

Methods of Finishing Aluminum Die Castings

Chromate conversion coatings are a basic, relatively low-cost method for preparing parts for additional coatings or as a corrosion protection option. Chromate conversion coatings may also be known as chemical film, yellow chromate, clear chromate, Iridite and Alodine. Traditional yellow chromates are hexavalent chromium based and new formulations are clear in color and free from hexavalent chromium.

Conversion coatings leave no measurable build-up on the part (film thickness is 0.00001" to 0.00003"), and die cast parts typically fail after 48 to 100 hours in salt spray testing. In many paint or adhesive applications, conversion coatings are used as a base for superior bonding. All varieties of conversion coatings are conductive. Hexavalent coatings will be yellow iridescent to clear iridescent in appearance and

***Figure 1** – Hexavalent Chromate Conversion Coating*

non-hexavalent coatings are generally clear. All conversion coatings are amorphous (which permits cold forming without rupture of the film) and non-porous (which aids against corrosion). In spite of the fact that conversion coatings don't have the hardness of an anodized finish, it stands up fairly well against abrasion of a non-cutting nature. An important quality of conversion coatings is its ability to heal scratches in the film. The exposed metal gradually becomes covered by soluble chromate from areas surrounding the scratch.

Conventional Anodize (MIL-A-8625 Type II, Class 1 & 2) and Hardcoat Anodize (MIL-A-8625 Type III, Class 1 & 2) offer minimum corrosion protection on die castings (<48 hours salt spray test), but increased wear protection over chromate. Anodize finishes also provide an excellent base for promoting the adhesion of subsequent organic finishes and adhesives. Proper formation of aluminum oxide coatings provides aluminum with increased resistance to corrosion and abrasion.

On wrought alloys an anodized thickness between 0.0001" to 0.001" lends itself readily to clear and color work, as the coating is more transparent than other types of anodizing. In addition, it serves as a base for color absorption to create decorative finishes. Dyes can be deposited into the pores of the anodized layer and then sealed. Due to the nature of aluminum die cast material, a thinner, non-uniform anodized layer is produced. This results in a naturally gray coating on die casts even at low thicknesses. These factors yield darker, more muted colors on die castings.

A critical consideration for metal finishing die cast parts is the difference in the surface finish between the machined surface (if machined) and the as-cast surface. The machined surface will have a more uniform anodized layer because the underlying aluminum has less un-alloyed silicon than the as-cast surface. The as-cast areas will be higher in silicon and will have a wider range of thickness due to the irregularities in the surface, as well as voids in the anodic coatings that result in potential corrosion sites. In general, a maximum anodic coating thickness of 0.0004" is possible for die cast parts.

Specification Alert:
In 2006, the military specification Mil-C5541 for conversion coatings was updated to address environmental directives and calls out traditional hexavalent chromate and the new non-hexavalent chromate conversion coatings. A producer of parts for the automotive industry, telecommunications, consumer electronics or household appliances that specify conversion coating must request a non-hexavalent chromium conversion coating (Type II). Hexavalent chromium is banned from parts used in these industries per these environmental directives: ELV (End of Life Vehicle); RoHS (Reduction of Hazardous Substance) and WEEE (Waste Electrical and Electronic Equipment). These directives eliminate the use of heavy metals, specifically hexavalent chromium, lead, cadmium and mercury.

The new military specification for conversion coatings reads as follows:

Mil-DTL-5541 Revision F:

- Type I compositions containing hexavalent chromium
- Type II compositions containing no hexavalent chromium

Customers needing traditional chromate need to specify "Type I."

Customers needing a conversion coating to meet the environmental directives need to specify "Type II."

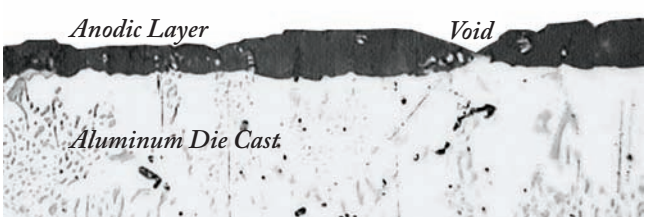

Figure 2 – *Cross-section of an aluminum die cast part reveals the irregularities in the anodic coating layer. Voids, or areas of little or no coating, occur due to the migration of silicon or other non-aluminum particles. These areas are particularly vulnerable to corrosion and coating failures.* Image captured at 500x magnification.

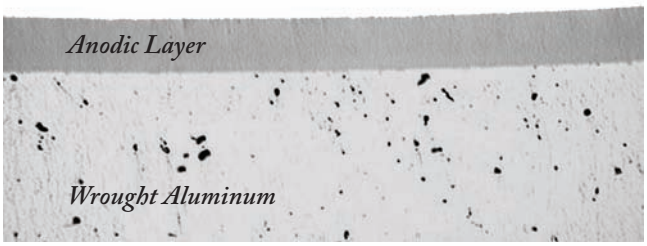

Figure 3 – *Cross-section of a wrought aluminum part reveals an extremely uniform anodic coating. A uniform coating minimizes areas of vulnerability and offers the best protection.*
Image captured at 500x magnification.

All anodize and hard anodize processes are free from heavy metals and are compliant with all environmental directives.

ARP-Acid Etch is used as a pretreatment for processing high silicon aluminum castings resulting in a leveled, fine-grained, activated surface for subsequent chemical treatments like chromate conversion or anodizing. ARP Acid Etch chemically removes the silicon rich surface of the die casting, which helps produce a more uniform chromate or anodized finish. This process also allows a deeper dye color to be achieved with the anodized coating and makes die cast parts more visually appealing.

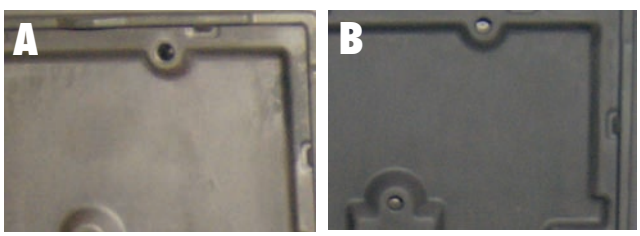

Figure 4 – (a) *Anodize on die casting; (b) Black Anodize + ARP on die casting.*

Electroless Nickel Plating – Offers an extremely uniform coating and provides a variety of performance options for aluminum die cast parts. This versatile plating process enhances corrosion protection, release properties and/or wear resistance depending on the type of electroless nickel utilized. Additionally, electroless nickel has the appearance of stainless steel, is conductive, and unlike anodizing, can be welded or soldered. Tight tolerances of + /- 0.0001" of electroless nickel are possible and typically do not require any post-grinding operations. The electroless nickel coating adhesion is actually more robust on aluminum die castings than any other aluminum alloy.

Traditional electroless nickel baths contain small percentages of cadmium and lead, which is not compliant with environmental directives. Newer electroless nickel baths are

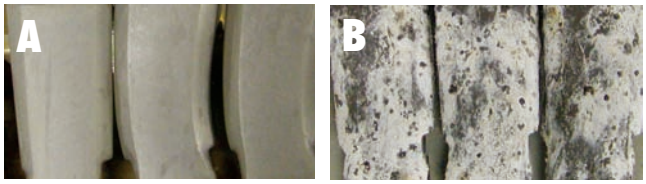

Figure 5 – (a) CastGuard™ after 2,000 salt spray hours; (b) Anodize after 2,000 salt spray hours.

Figure 6 – EnduraGuard™

free from cadmium and lead and are compliant with environmental directives. It is important to communicate with your metal finisher if you require a finish that is compliant to ELV, RoHS and WEEE directives.

Table 1 – Die Cast Aluminum Salt Spray Results

Process	Salt Spray Failure	Aesthetic Rating (1-5)
Yellow Chromate (Type I)	100 Hours	1
Pioneer ELV Conversion Coating (Type II)	100 Hours	1
Type II Anodize	48 Hours	2
Type III Hard Anodize + ARP	48 Hours	3
Pioneer CastGuard™	>2,000 Hours	2
Pioneer EnduraGuard™	>3,500 Hours	5
High Phosphorous Electroless Nickel 0.001"	100 Hours	3

Note: Testing performed as per ASTM B-117. Failure based on first signs of white corrosion. Actual parts may exhibit higher or lower values based on the integrity of the casting and finishing processes performed.

Hybrid finishes – Over the past several years, Pioneer Metal Finishing's Research and Development Division created new finishes specifically designed for protecting die cast aluminum. These finishes typically combine the Type II anodize process with a unique seal to offer supreme corrosion protection and cosmetic appeal. CastGuard™ is a functional coating that offers over 2,000 hours of salt spray protection and provides an excellent base for promoting the adhesion of subsequent organic finishes and adhesives. EnduraGuard™ was developed for corrosion protection in extreme marine environments plus has a rich, shiny black cosmetic finish. EnduraGuard™ is a premium finish that offers the best corrosion protection and the cosmetic appearance. CastGuard™ and EnduraGuard™ are free from heavy metals and meet all environmental directives.

Conclusion

In summary, when utilizing die cast aluminum, there will be a trade off in coating performance vs. manufacturing costs when compared to making products from wrought aluminum alloys. It is possible to minimize these concerns when there is an understanding of the performance characteristics various finishes can provide in relation to protection from harsh environments while enhancing the appearance of this metal. It is critical to communicate to the metal finisher what is needed from a performance and appearance standpoint. By working together with your metal finisher, you will maximize the performance of your die cast parts.

About the Author

Steve Goodsett is the corporate product manager for Pioneer Metal Finishing and has 28 years of experience in the metal finishing and plating industry with the last 23 years at Pioneer. Goodsett has held positions as chief chemist, quality assurance manager and production manager. Currently as the corporate product manger, he oversees the process controls for Pioneer's four metal finishing facilities and manages the development and implementation of new processes. Please send any questions or comments to sgoodsett@pioneermetal.com. For more information, visit www.pioneermetal.com.