FINISHING AND ELECTROPLATING DIE CAST AND WROUGHT ZINC

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by W. H. Safranek and E. W. Brooman

BATTELLE-COLUMBUS
Columbus, Ohio

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PREFACE

The International Lead Zinc Research Organization, Inc. (ILZRO) has continuously supported research on new finishes for zinc die castings and wrought zinc alloys since its inception in 1957. Several new processes have been developed and/or evaluated during research programs conducted for ILZRO. Some of these new procedures have been adopted by industry and others promise to become so. This Handbook combines descriptions of prior-art practices with accounts of ILZRO research developments and attempts to explain the advantages of the new processes.

As for any viable business serving mankind, the die casting and finishing industry must continue to seek better and lower-cost procedures. ILZRO has and will continue to dedicate its resources to this task. Feedback from industry is important, however, to insure that research is appropriately guided in fruitful directions. The authors hope that this Handbook will provide industrial engineers with up-to-date information on finishing and plating procedures and that industrial experience with the new processes discussed in the Handbook will, in turn, provide research engineers with the guidance they need for seeking further practical improvements.

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Chapter 1
INTRODUCTION

The die casting process is one of the most important fabrication processes for producing complex shapes with accurate dimensions. Zinc alloy die castings can be finished and plated inexpensively and are lower in costs than castings of other metals and alloys. Hence, the yearly consumption of zinc alloy for making castings now exceeds 5 x 10^8 kg (500,000 tons) in the United States and Canada. This rate of consumption is about 35 percent higher than that for zinc alloys converted to castings in 1962. Increases in consumption in several other countries have ranged from 100 to 300 percent during the same 10-year period.

Zinc die castings are electroplated with copper, nickel and chromium to perpetuate a decorative appearance. Thus, corrosion resistance is an important criterion, which is dependent partly on good surface quality and partly on good plating practice. Die-cast surfaces with fissures caused by cold shut or other forms of porosity tend to corrode prematurely, even when good cleaning and plating procedures are adopted to prevent corrosion. Some, but not all, surface defects can be removed by abrasive polishing, but preplate finishing costs are increased in proportion to the amount of polishing required to remove the defects.

Costs for finishing and plating are usually higher than costs for die casting. Preplate finishing costs range from 20 to 30 percent of the total cost for die casting and plating, when castings are polished and buffed to prepare them for plating. New practices have been adopted in the past two or three years to reduce the high costs of finishing and plating. For example, some castings are now being made in super-finished dies with a surface roughness of <0.25 μm (<10 microinches) to eliminate the cost of buffing. In other cases, vibratory finishing with resin-bonded abrasive has been adopted to reduce preplate finishing costs.

Design precepts have been identified to make die castings easier and less costly to plate. Inspection procedures have been improved in some cases to eliminate costly rejects after plating that are caused by defects in the original casting. These and other cost-reduction procedures are described in detail in this handbook.

Plating practices that provide durable nickel and chromium coatings also are described in this handbook. For example, procedures have been adopted in the past 5 or 6 years for plating microporous and microcracked chromium, which improve corrosion endurance considerably while minimizing the cost of nickel plating. Data detailed in the chapters on nickel and chromium plating demonstrate the improved performance obtained with the new chromium plating processes.

Chapter 2
DESIGN FOR ELECTROPLATING

Finishing and electroplating costs are influenced by design, which has a greater effect on costs and quality than process variables. Design precepts have been established for minimizing finishing and plating costs and insuring good corrosion performance. Departures from these precepts frequently impose cost penalties, or reduce corrosion performance.

Both surface smoothing prior to plating and the electroplating process are facilitated and simplified when sharp edges and deep recesses are avoided. Good thickness uniformity is obtained only on gently curving, convex surfaces. Corners, edges, fins, ribs and other protuberances "steal" more than an equal share of electrodeposited metal. Conversely, grooves, serrations, holes, concavities and deep recesses are "starved" of their share. The area that receives the thinnest electroplate is commonly the area of first failure for any die casting produced by sound die casting procedures. Specifications for exterior automotive parts recognize this fact by requiring a minimum thickness of electroplate on any area exposed to view during service.

Specific design features that influence the distribution of the electroplate are discussed in Table 1, reproduced from a Zinc Institute publication.[1] The improved designs given are somewhat exaggerated to emphasize the recommended design precepts. Designing articles for finishing by polishing and buffing or electroplating is often a compromise between what is functional, what is preferred by the plater, and the need to allow the designer some latitude in artistic interpretation. With these limitations in mind, the following precepts[2–7] should be considered in the design of die castings:

(1) Convex surfaces should be adopted in preference to flat surfaces. A minimum crown of 0.015 cm per cm (0.015 in. per in.) is recommended to improve metal distribution, and hide substrate imperfections such as may arise from uneven buffing. If flat surfaces are considered essential to the design, a satin chromium finish rather than a bright chromium finish may hide surface waviness.

TABLE 1. DESIGN FEATURES THAT INFLUENCE THE ELECTROPLATABILITY OF ZINC DIE CASTINGS

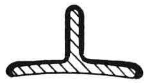
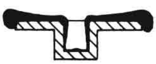
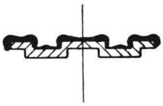
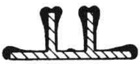
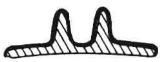
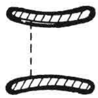
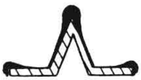
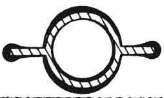
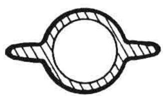
Design Feature	*Platability*	*Improved Design*
	**Convex Surfaces** Ideal shape. Easy to plate uniformly, especially where edges are rounded.	
	**Flat Surfaces** Not as desirable as crowned surfaces. Use a 0.015-inch/inch crown to hide undulations caused by uneven buffing.	
	**Sharply Angled Edges** Undesirable. Reduces thickness at center areas and requires increased plating time for depositing a minimum thickness of durable electroplate. All edges should be rounded. (Edges that will contact painted surfaces should have a minimum radius of 1/32 inch.)	
	**Flanges** Large flanges with sharp inside angles should be avoided to minimize plating costs. Use a generous radius on inside angles and taper the abutment, if an unsupported, narrow flange like this is necessary.	
	**Slots** Narrow, closely spaced slots and holes reduce electroplatability and cannot be properly plated with corrosion-protective nickel and chromium unless corners are rounded.	
	**Blind Holes** Blind holes must usually be exempted from minimum thickness requirements.	
	**Sharply Angled Indentations** Sharp angles increase plating time and costs for a specified minimum thickness and reduce the durability of the plated part.	

TABLE 1. (Continued)

Design Feature	*Platability*	*Improved Design*
	**Flat-Bottom Grooves** Inside and outside angles should be rounded generously to minimize plating costs. Plating thickness distribution will tend to restore the crisp design concept that is usually desired for styling grooves.	
	**V-shaped Grooves** Deep, V-shaped grooves cannot be satisfactorily plated with corrosion-protective nickel and chromium and should be avoided. Shallow, rounded grooves are better.	
	**Fins** Fins increase plating time and costs for a specified minimum thickness and reduce the durability of the plated part.	
	**Ribs** Narrow ribs with sharp angles usually reduce electroplatability; wide ribs with rounded edges impose no problem. Taper each rib from its center to both sides and round off edges. Increase spacing if possible.	
	**Concave Recesses** Electroplatability is dependent upon dimensions.	
	**Deep Scoops** Scoops increase plating time and costs for a specified minimum thickness.	
	**Spearlike Juts** Buildup on jut will rob corners from their share of electroplate. Crown the base and round off all corners.	
	**Rings** Electroplatability is dependent upon dimensions. Round off corners and crown from center line, sloping towards both sides.	

(2) All edges should be chamfered or rounded off to a radius of at least 0.4 mm (1/64 in.), but preferably 0.8 mm (1/32 in.). Such radii will be reduced appreciably by the electrodeposited metal, and distribution effects will tend to restore crisp lines. Sharp edges should be avoided for several reasons. First, they will become beaded during electroplating, which may destroy the design concept. Second, sharp edges in contact with painted auto bodies or other steel surfaces may rupture the paint film and lead to rusting. Third, apart from complicating casting and electroplating, polishing and buffing costs are increased because the sharp edges dislodge compound from the rotating wheels.

(3) The depth of concave recesses should be reduced as much as possible. Deep scoops with a depth greater than 50 percent of the width should be avoided. Otherwise, the plating time is prolonged for a minimum thickness of electroplate. Even when sidewalls are sloped, and the inside and outside angles are rounded, plating time will be increased. The uniformity of electroplate thickness in apertures and deep recesses with a minimum diameter of 5.0 cm (2 in.) can be improved considerably by employing current shields to mask high-current-density areas or special auxiliary anodes to focus supplemental current at the bottom and sidewalls of the recesses. An increase in the plating time sometimes can be avoided with such devices. Use of shields and special anodes will increase plating costs, but cost premiums generally will be less than that imposed by an increase in the plating time. Many plating plants are skilled in the use of special anodes and shields. Shields are less costly than special anodes, as a rule. Additional information on special anodes and shields is discussed later in this handbook.

(4) Flat-bottom indentations should be rounded off and their depth limited to 50 percent of their width. Deep indentations generally increase plating costs, depending on the width and the radius of the angles between perpendicular planes. The radii suggested for specific indentations are indicated in Table 2. The inside and outside angles of indentations may, of course, be chamfered or beveled instead

of being rounded. In such cases, the minimum angle defined by the chamfer should be 110 degrees.

(5) When sharply angled grooves are desired for specific decorative effects, an organic finish is recommended for protecting the bottom of the grooves. Applied after plating, such a finish contrasts sharply with the mirrorlike areas of the plated surfaces between grooves. The painted finish usually costs less than the necessary premium in cost for plating the bottom of the grooves if a minimum specified thickness of copper plus nickel is required.

(6) Slots and holes should be widened to at least two times their depth, and slots should be spaced out to make distances between centers at least four times their width. The complications imposed by slots and holes can be minimized by chamfering or beveling the edges. Circular or elliptical contours between slots are preferred to square or rectangular shapes.

(7) The number of blind holes should be minimized. Blind holes should be limited in depth to one half of their width. Diameters less than 5.6 mm (7/32 in.) should be avoided or the electroplate thickness within the holes will be inadequate. Blind holes on opposite sides of a part must be avoided or drag-out losses will be excessive.

(8) Threaded holes should be countersunk to minimize the effect of electroplate build-up at their peripheries, and thus

TABLE 2. MINIMUM RADII FOR ANGLES DEFINED BY INDENTATIONS

Depth of Indentation		Minimum Radius of Angle Between Perpendicular Planes	
mm	inch	mm	inch
1.6	1/16	0.4	1/64
3.2	1/8	0.8	1/32
6.4	1/4	1.6	1/16
9.5	3/8	2.4	3/32
12.7	1/2	3.2	1/8
25.4	1	6.4	1/4
38.1	1-1/2	9.5	3/8

expedite the insertion of fasteners after plating. The electroplate distribution in threaded, ribbed or fluted holes will be uneven, and this must be taken into consideration for surfaces which mate upon subsequent assembly. Threaded, ribbed, or fluted holes may also entrap cleaning materials and/or plating solutions which is detrimental to maintaining consistent quality.

(9) The height of fins or ribs, if required, should be reduced as much as possible. A generous radius greater than 1.6 mm (1/16 in.) is suggested at each base. Pointed tips should also have radii of at least 1.6 mm. Parallel fins should be spread out to make the distance between centers at least four times the fin width so that the lands between the fins will receive an adequate thickness of electroplate. In general, broad hollow ribs or fins are preferred to slender, solid ones.

(10) Flanges perpendicular to, and shielding, face areas, reduce metal thickness uniformity and prolong the plating time. Short flanges of 6.4 mm (1/4 in.) or less may be acceptable if the inside angles are rounded with a radius of 2.4 mm (3/32 in.) or more. Sides should be sloped with a 3° taper, and protruding edges should be rounded generously.

(11) Recessed rather than raised letters are recommended for insignia, but edges should be rounded with gentle contours. A decorative paint in shallow recessed symbols provides excellent contrast with chromium electroplate. If raised letters are necessary, those with a height 50 percent or less of the width are easier to plate than higher letters. A maximum height of 4.8 mm (3/16 in.) is specified by some designers. Corners and edges should be rounded, or surfaces adjacent to small apertures will be deficient in electroplate thickness. Tapered sides to the lettering are recommended.

(12) Peripheral contours with a circular or elliptical form favor uniform electroplate thickness, but spars, fingers and other peripheral projections reduce uniformity and prolong the plating time. Irregular peripheral projections combined with flat perpendicular sides "steal" an excessive amount of current during plating.

(13) Integrated studs for fasteners should have as low a profile as possible, and inside angles at each base should be rounded generously. Tips must be similarly rounded, or the inevitable thick deposit at the tips will increase dimensions beyond acceptability. If studs are threaded before plating, thickness is limited on significant surfaces to only 5μm or 7.6μm mm (0.0002 or 0.0003 in.). References (6) and (7) give recommendations for plating threaded parts. In general an allowance of five times the average electroplate thickness should be made. Special threads must be adopted if thicker coatings are required.

(14) Studs or bosses with hollow centers should be shortened as much as possible and angled 90° from the major plane of the casting. All bosses should face the same direction to facilitate racking and electroplating.

(15) Drain holes must be provided in cup-like contours to avoid the costly supplementary hand rinsing that otherwise would be required between cleaning and plating operations. Tubular articles should also have provision for complete drainage to prevent dragout. Alternatively, tubes should be completely sealed.

When considering die castings for plating, designers should keep in mind that complex shapes may result in the trapping of air bubbles during the plating process and cause some areas to be plated badly, or not to be plated at all. Small, deep blind holes may also entrap air and not be plated properly. Design engineers should take into account the need for suspension points giving good electrical contact between the part and the rack during electroplating. Such a point may be a hole, thread, or a lug, preferably located where surface appearance is unimportant.

The increase in costs associated with increasing complexity of shape is lower for some finishing processes than for others. The difference in the costs of electroplating simple and complex shapes in barrels is relatively small, once the feasibility of barrel plating is established, and provided drag-out losses and plating time are minimized. Barrel plating is low in cost for simple or complex shapes that can be tumbled freely with no intermeshing, and have sufficient strength to withstand the tumbling action. Small rounded protrusions or raised edges are useful on flat surfaces to prevent lodging and sticking during electroplating.

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[5] H. K. Barton, "Plating Requirements and the Design of Zinc Alloy Die Castings", Machinery, December 1963, p. 1457.
[6] A.W. Wallbank and D.N. Layton, "Plating of Screw Threads", Trans. Inst. Metal Finishing, *32*, 308 (1955).
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Chapter 3
QUALITY OF ZINC DIE CASTINGS

Good quality zinc die castings are the result of good die design and good die casting practice. Sound castings with defect-free surfaces will be obtained from:

(1) Properly designed and constructed dies
(2) Smoothly working, run-in casting machines
(3) Correct alloy composition
(4) Good melting and delivery practice, proper die lubrication
(5) Correct ejection and trimming procedures.

Marks left on the casting surface by ejector pins may interfere with appearance or performance. Anticipating the necessity of placing ejector pins on certain areas of the casting will enable the designer to plan ahead so that the marks are either on insignificant areas which do not require their removal prior to finishing, or are on accessible areas which facilitate subsequent polishing. Similarly, the designer should locate the parting line at nonsignificant or accessible areas where it can be removed easily.

Die gating must introduce metal smoothly with a minimum of turbulence. Thick sections should be filled before thin sections to promote progressive cooling. Adequate venting reduces the chances of porosity, and permits complete filling of the die cavity. The molten alloy should reach the vents and overflows last to prevent premature plugging and avoid air entrapment in the casting. If vents are placed at parting lines, flash can readily be removed with the casting to insure that vents remain unobstructed. High pressure at the end of the injection stroke can help counter shrinkage and porosity by forcing still liquid alloy between the metal which has already begun to solidify.

Surfaces which have to slide on the die cavity during ejection should be tapered to reduce binding and drag and promote a better surface finish. Inner casting walls which exert higher shrinkage forces on the die need more allowance than outer walls. A generous taper should always be given to surfaces which require the best surface finish.

The quality standard for a die casting depends on the application and the efficacy and limitations of the finishing processes. For functional applications, internal soundness is vital because it affects mechanical properties. Imperfections in surface smoothness may be acceptable if these castings are painted or protected with chromate films in place of electroplated coatings.

For decorative parts that receive an electrodeposited finish, a high quality with few or no surface defects is important. Internal soundness is usually of secondary importance in typical cases. Three quality grades may be described for castings that are electroplated: (1) good castings that offer no plating problems; (2) salvageable castings with defects that can be removed economically by polishing, buffing, or vibratory milling; and (3) castings with defects that are still visible after finishing and plating. Detailed comments on each grade are as follows.

Good Die Castings

Modern casting procedures produce good quality castings suitable for direct plating, apart from trimming and parting line polishing. With the best casting technology which includes the use of superfinished die cavities, laborious and expensive polishing and buffing are circumvented. Some of the factors which have led to this improved die casting quality include (1) a dedicated attitude on the part of die casters to improve product quality and minimize costs; (2) a better understanding of the casting parameters which control the quality of the product; and (3) increased use of the proven advantageous process of coating die cavity surfaces with electroless nickel alloy deposits to preserve good surface finishes. Electroless nickel coatings about 25 μm (1.0 mil) thick have been effective for preventing wear and erosion for die runs of more than 200,000 shots. Prospects are good that smooth cavity surfaces may be preserved for even longer runs. Proper cleaning and plating procedures are important, as discussed in the section on "Preparation for Electroplating", to insure such long runs.

Leveling copper and nickel electroplates smooth or hide minor surface defects difficult to eliminate in some complex