ALUMACAST
PROTOTYPE AND LOW VOLUME CASTINGS

The Designers Guide

For the Procurement of Prototype Aluminum and Zinc Castings

Newly revised edition

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Dear Design Engineer,

This guide has been created to share wisdom gleaned from years of hands-on experience as a metallurgical engineer working in the prototype casting business. For the young designer, I hope this guide will serve to keep you from making a Career Limiting Error. The seasoned design engineer may not necessarily learn anything new here, but hopefully it will serve to remind you of pointers commonly neglected or easily forgotten. In either case, you will find this a useful quick reference. Finally, since we are all colleagues of this complex industry, I would welcome any thoughts, ideas, and experiences you might want to share in future editions of this guide.

Sincerely,

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The Value of Prototyping

We live in a world of ever decreasing product cycle time. In order to compete in today's marketplace, manufacturers must protect their market share by continually improving their products and being quick to market with a proven product. The need for speed is critical, but so also is the importance of getting it right the first time around.

A prototype-proven design can significantly shorten "time to market" by eliminating "false starts" and costly design changes. As a designer, you are best served by obtaining the "design insurance" available through the use of prototypes. You never want to be the designer of a component that "looked good on paper" but did not function as required.

Imagine the nightmare: your part is now the pacing item; your design is being questioned; you are being second-guessed; numerous design changes continue to delay production. All this can be avoided through the proper use of a viable prototype, and I stress "viable" because, as you will see, not all prototypes are alike.

Successful rapid tool and prototype programs are much more likely if you approach this venture with a clear understanding of the advantages and disadvantages of different process options and their effect on the viability of your prototypes. You will need to understand all criteria pertinent to this prototype.

Some of the options available to you include but are not limited to Machined Hog-outs, Sand Casting, Investment Casting, 3-D Printing, Die Inserts or "Soft Die" Processes, Plaster Mold Casting, "Quick-Dies", Direct Shell Casting, among others. Now add to this mix of possibilities the attachment of one of the rapid tool options and you get a feel for how challenging a prototype casting program can get.

How will the finished product be used?

This is one of the most important questions to ask before beginning the prototyping process. The answer to this question may determine your choice of prototyping options as well as your Rapid Tooling options. Below are some real-life situations where neglecting to ask this all-important question unfortunately resulted in a Career Limiting Decision (CLD).

WHERE DO YOU START TO ENSURE A SUCCESSFUL OUTCOME OF YOUR PROTOTYPE PROJECT?

The most important thing to keep in mind in procuring cast prototypes is—accurate simulation. You can waste time, money and possibly your career if the cast prototypes you clear for the final go/no-go decisions are not based on reality. Let me relate some actual situations that transpired as a result of prototypes that did not match the actual performance of the production die casting.

EXAMPLE NO. 1

A small engine manufacturer produces prototypes of a cylinder head. The prototypes performed within established guidelines for heat dissipation. Die was constructed, production castings made and engines sold. After production, the manufacturer discovered that the production engines were running hot. They later discovered that the production engines were produced in an alloy whose heat dissipation characteristics were 150% more efficient than the production alloy.

EXAMPLE NO. 2

The initial prototypes failed in mechanical testing. A subsequent redesign yielded parts that performed well. The designer, however, had prototyped the initial parts in an alloy and process that was not representative of the eventual production process. Without knowing the real cause of the part failure, the company decided to redesign the part to make it stronger. As a result of over-designing the part, the real expense revealed itself later when the unnecessary redesign added $3.00 to the production cost of each part. With an annual production rate of 500,000 parts, such an added cost is certainly an issue.

EXAMPLE NO. 3

The size of the prototype may exceed the build envelope of a particular rapid prototype machine. Parts to be used as patterns would be constructed in pieces and assembled manually. The sacrifice of dimensional integrity alone might make this process suspect before you even factored in the additional time and labor. Apparently, the desire to utilize this "new" technology enticed people to ignore existing processes that would have worked more effectively.

EXAMPLE NO. 4

The part geometry suits one type of technology, but instead another type is used. Thin-walled parts may be better suited to a particular type of rapid prototyping equipment, but some people are still attempting to use technologies better suited for thicker-walled components.

EXAMPLE NO. 5

The CAD data is not available or is so incomplete that considerable programming time can be added to processing time, increasing the lead time for the entire prototype process. In a case such as this, you may be at a time and cost advantage to use other more conventional methods which can be still classified as "rapid".

EXAMPLE NO. 6

Simulation modeling tools can be quickly and easily constructed for computer analysis to generate virtual performance results, thus attempting to bypass the need for cast prototypes. However, if the simulation models are not constructed with the absolutely right parameters they will generate results that do not reflect the real-life performance of the cast part.

All of these have happened, and unfortunately continue to happen today. These cases exemplify why it is so important for you to understand and communicate to the prototype supplier the special requirements of each prototype. You need to make sure the supplier understands all available options in order to render prototypes that most accurately simulate the eventual die cast part. That said, let us now explore what options may be available in prototyping aluminum or zinc die casting designs.

Rapid Prototyping/Rapid Tooling Reminders

It is surprising how many people use the wrong process for rapid prototyping, but unfortunately, it is easy to fall into this type of trap. In many cases, it's simply a matter of using available equipment. This was particularly true early on in the world of Rapid Prototyping. Over the years, I have witnessed many people attempting to shorten their prototype lead-time through the use of what I would term the wrong technology.The economics are often driven by part configuration and quantity requirements. Here are some questions you may want to ask yourself as you venture into the Rapid Prototyping/Tooling process:

PART GEOMETRY

• What is the configuration of the part to be produced?

• Is it best produced by additive or subtractive type of Rapid Tooling process?

• Which features will be cast and which feature will require secondary operations?

• Can your choice of Rapid Tooling process support all features?

• Can your choice of casting processes support these features?

QUANTITY

• How many parts will be produced?

• Will your choice of rapid tooling options support the quantity needed?

• Is this tooling option cost-and time-effective for the quantity you need?

CASTING PROCESS

• Keeping in mind all the parameters of your prototype, what is your best casting option? Which Rapid Tooling options are compatible?

• Is casting this part your best option? Do part configuration or quantity issues make a machined hog-out a more viable solution? A "quick die"?

• Does your casting supplier truly understand your needs?

CHANGES

• What is the likelihood of changes after initial parts are produced?

• Will your choice of process support changes or will the simplest of changes to the part configuration force you to start over?

Once you have taken all of the above factors into consideration, you can consider the variety of prototyping options available to you and choose that which will be most effective for your project. The following are some of the most common options and their respective advantages and disadvantages.

Prototyping Options

HOG-OUTS
"Hogging out" a prototype can be a viable option. Advantages include cost effectiveness in low quantities, precision, and time efficiency. Disadvantages can be higher cost in higher volumes, possible distortion of mechanical testing results from differences between wrought and cast materials, and difficulty in simulating the effects of draft, fillets, and radii.

Using this method, part configuration will be the major cost driver after the initial programming expenses. Minimizing material removal helps to limit costs.

Extra caution must be exercised when considering this method for prototyping structural components due to the aforementioned mechanical property differences.

Examples of part components prototyped via this method include electronic enclosures and low temperature heat sinks.

SAND CASTING
Sand casting continues to be utilized for die cast prototypes. Advantages of this method include cost, timeliness and ease of design changes. A disadvantage is dimensional integrity (as compared to production die castings). Most configurations can be cast effectively, and new advances in precision fine grain sand casting processes can accommodate almost all die cast wall thicknesses and draft angles.

The sand casting process has proven to be significantly effective in structural designs. Together with appropriate alloy and heat treatment choices, the prototype can provide close approximations of die cast mechanical properties. It has also been considerably effective for heavy-walled castings, and much thicker sections than are customary in conventional die casting. The heavy section castings are often conversions from grey or ductile iron into aluminum for production in the advancing "squeeze casting" processes.

INVESTMENT CASTING
Although primarily a production process, die cast designs are occasionally prototyped through the investment casting process. Advantages can include cost effectiveness on longer runs of smaller parts. The primary disadvantage is longer lead-time. The exception to this is when an SLA wax pattern can be used for casting of a single part through investment casting. Part configurations produced via this method include hinges, valves, and switch enclosures.

3D PRINTING
Currently 3D printing is an evolving process with new applications and materials being discovered almost daily. It produces a three-dimensional part from a CAD file or 3D model by adding layer upon layer of material, which is why the process is also referred to as "additive manufacturing." 3D printing can be used to prototype eventual die castings. In many cases the 3D process is used to produce a master pattern in combination with available casting processes. Advantages include shorter lead time and lower cost (particularly in low quantities). Disadvantages include the requirement for a "watertight" or complete design prior to beginning work, some size restrictions, material restrictions, and the need to produce a master in 3D printing technology that best suits a part's geometry. 3D printing of sand molds has provided added opportunities for cast prototypes. This can be cost effective in low quantities since no tooling is involved. It can be cost prohibitive in larger quantities, and still is developing in respect to surface finish and wall thickness considerations.

DIE INSERT OR "SOFT DIE" PROCESSES
These processes are occasionally used for production under certain conditions. A distinct advantage of these processes is that prototypes are truly representative of the actual production. Disadvantages include longer lead-time and higher tooling costs as compared to other prototyping methods. These processes can be effective for larger quantity prototype runs of 1,000 + parts.

PLASTER MOLD PROCESS
The plaster mold process is a viable method of prototyping eventual die cast parts. Advantages include inexpensive tooling, ease of design changes, smooth surface finish, and the ability to cast thin walls. Disadvantages can include increased part cost. Recent advances in sand casting technology appear to be relegating the plaster mold process to special appearance applications and production of ultra-thin-walled parts.

Whatever prototyping process you choose, be sure to fully understand its limitations. Your final selection should be based on which process offers the best simulation of the production cast part. Be sure to have a detailed discussion of all the critical measurements and tests your prototype part must undergo before it is approved for production.

Factors That Will Determine Your Success

UNDERSTANDING SIMULATION

It is important to remember that the prototyping process is often being used to simulate a production die casting. Although this seems rudimentary and obvious to any designer of cast metal components, it does merit mention here. Mechanical and physical properties can vary significantly from the prototyping process to the production process. These variances are often due to different solidification rates of the cast material in dissimilar processes. As an example, 380 aluminum cast in a production die will have different mechanical properties than 380 cast in a prototyping process. Thus an alloy switch and subsequent heat treatment can mimic the desired performance properties of the production alloy. This will ensure that the prototype part you will be testing accurately reflects the performance characteristics of the final production cast part. Also, please note that some common prototyping alloys can have different heat transfer characteristics than the production alloys. Again, an alloy switch may be appropriate if your casting operates in a heat sensitive environment.

TIME

Time is a very precious commodity. The big question confronting designers when it is time to create a prototype of the part design: How much time should you allow for the prototype phase? The time available for prototyping can slip away very quickly. Allow enough time for proper testing of your part. Rushing through the prototyping process is not a formula for success. Ask yourself and your team:

- What are you testing for?
- Are you creating this prototype simply for appearance to have at a show?
- Does this part have to meet the stringent measurements of a tight fit?
- Will this part be subjected to mechanical testing?
- Is testing for RF leakage a serious concern?
- Does corrosion resistance seem an issue?
- Are weight and strength a linked issue?

Any testing requires preparation, coordination and time. Are you allowing for the part to be thoroughly tested or is the testing simply a formality? Are you testing for part failure? Any one of these steps in testing can throw the best of schedules into turmoil. So the question is how much time is enough? If the testing phase comes off without a hitch, then all is well. But what happens if any one test shows negative results, or even questionable results? Results might require a closer investigation of the possible cause of failure in the design. Revising the design and going back for another prototype and subsequent test is not what any designer wants to face with time constraints. Yet, no designer wants to release a part for production without a resounding success in the prototype testing phase. You do not want to be in a situation where you are pressed to release the part for production but you haven't had sufficient time to test it properly, or be forced to to review the design and make changes because the part failed during "thorough" testing.

SELECTING THE PROTOTYPING PROCESS RIGHT FOR YOUR PART

There are a variety of ways to create prototypes for your part design slated for eventual die cast production. Choose the process right for your part.

- Part Geometry helps establish the most appropriate process given the part configuration.
- Complexity of the part design
- Size of the casting

There is no single prototyping process that is right for every application. But for every application there is a prototyping process that is the most optimum solution. The critical question to ask yourself: "What is the primary purpose or use of my prototype castings?"

If you simply need a three-dimensional part in your hand, display at a trade show or serve as the centerpiece for an early-stage engineering design and production meeting, then there are several options available to you. But if the prototype is to be used for testing and analysis of critical performance characteristics then your choices are headed in a different direction.

QUANTITY OF CASTINGS NEEDED

How many cast prototypes will you need? On average it takes between 10 and 20 prototypes to satisfy all the testing requirements. You are far better off having too many castings than not enough.

- Will the selected tooling option support this quantity?
- Can the quantity needed be produced cost-effectively in the time available?

THE REASONS FOR CREATING THE PROTOTYPE

Let us assume that the decision has been made that a prototype castings will be needed before releasing a part for production. So the next question is what type of prototype will you need? Or to phrase the question another way: What is the primary reason for creating prototype castings?

If you are working as a member of a design team, you may have one specific reason for wanting prototypes. Another member of the team may have a completely different reason. Be sure that everyone is in agreement on what needs the prototypes will have to satisfy. Do not assume. Assumption is the mother of many failures.

It is important to understand all criteria pertinent to each particular prototype. You may ask yourself:

• Are we creating this prototype simply for appearance or for "fit" only?

• Will this part be subjected to mechanical testing?

• Will we be testing for RF leakage?

Is corrosion resistance an issue?

• Is weight and strength a linked issue?

The answers to these and other related questions will guide you in the direction of the most suitable prototyping process and subsequently the success or failure of your project.

Add to this mix of possibilities the attachment of one of the Rapid Tool options and you get a feel for how confusing a prototyping program can be. New processes, materials and technologies have only served to add to the options and the pitfalls.

WHAT IS THE CRITICAL TESTING REQUIREMENT?

Having your part fail in prototype testing may seem like a minor catastrophe, but in reality it is a blessing in disguise. It is better to discover part weaknesses in the prototype process than in the production process, with hundreds, if not thousands of parts out in the marketplace. After all, prototyping is done to test the design. Let us assume for a moment that heat dissipation is critical to your part's performance. What if your part overheats in prototype testing? The problem could be in the design, but it could also be in how the prototype is cast and how the test is conducted. Before you rush back to the design computer, take a close look at the prototype itself. In what metal was the prototype cast? Does the casting accurately reflect the characteristics of a production casting? Remember, the prototype casting is only a simulation of the production casting. Take the time to examine the details of the prototype process that is being applied to ensure an accurate simulation. To modify the design without thoroughly analyzing all the issues relating to your prototype may cause you to over-design the part, which may lead to other complications in the production process.

ESSENTIAL SECONDARY OPERATIONS

To save time and money, it may be necessary to machine some features on the prototype casting even though they will be cast as part of the production casting. Also note that secondary operations such as painting or coating provided by your prototype supplier in a turnkey operation can save time and money and give you a more finished looking part.

Know what features need to be cast

• Which features can be cast and which will require secondary operations?

• Should a certain feature be cast?

• Can your choice of prototyping process support all features?

• Can your choice of production processes support these features?

Changes

• What is the likelihood of changes after initial parts are produced?

• Will the prototyping process you have chosen support changes?

• Will simple changes to the part configuration force you to start over?

• How long will it take to make a change? Change is inevitable.

• What will changes cost you?

• What if, after you have placed your order and have your part, you then decide really need more parts? How many castings will you need? What will those additional parts cost in time and money?

WHAT FACTORS DETERMINE YOUR PROTOTYPE COST?

Cost is relative. Something is either expensive, cheap or a good buy depending upon the value received. And so it goes with prototyping. Obviously every buyer, no matter what, wants to make sure that he gets the best value for the money invested. So in the prototyping process, how do you quantify value received?

Since no two prototypes are exactly the same, it is difficult to compare the cost of one to another. Well, you can compare the estimate from one prototype supplier to that from another and compare the price differential. But that will not tell you which one has more value.

So, as an informed and savvy buyer you must take into account past experience. You ask yourself:

• How good do the castings look?

• What kind of advice did I get from the prototype supplier?

• Did the prototype supplier's advice make a difference in the final outcome?

• Can I lean on his expertise to ensure a successful prototype?

• Did he deliver on his promises?

• Does he truly understand what I am trying to do or does he just want a sale?

• Does he ask probing questions?

• Does he offer recommendations?

• Do you hear only "yes," or is he qualified enough to say "no" once in a while and support it with wisdom?

Only after having sorted through this array of assessments are you ready to quantify the real value of your prototype sources and decide whether the lower dollar figure is indeed the better value.

The cost of your prototype is also influenced by:

• Complexity of the design - cores, etc.

• Size of the casting

• Need for secondary operations

• Time available for creating the prototype

• Thoroughness of your briefing

• Quantity needed

• Type testing the part must undergo

• Prototypes for trade show display only

It is not uncommon to have a customer request the prototype be cast in more than one alloy. We can and do cast prototypes in zinc or more than one aluminum alloy to satisfy customer's curiosity.

PICK THE RIGHT PROCESS AND SUPPLIER

What may appear as the right process initially can, upon closer reflection and insight, prove to be the less desirable choice for any number of reasons. If you are not certain which process is the best for your specific application, do not hesitate to ask. It is far better to invest in the expertise of others instead of making mistakes yourself when you don't need to. If you need expert prototyping services, Aluma Cast is able to assure a successful outcome for your project. Contact us at (920) 596-1988, or visit our website at www.alumacast.com.We look forward to helping you get the very best results with your casting design.

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