WHITE PAPER

Collaborative Engineering Reduces Costs, Improves Production Efficiency

North American Die Casting Association

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Collaborative Engineering Reduces Costs, Improves Production Efficiency

Manufacturers in many industries are increasingly using the knowledge of their die casters to help design parts that have a lower overall cost, while improving quality and production efficiency. The terms used to describe the process may vary depending upon the die caster, but whether it is called cooperative engineering, collaborative engineering or concurrent engineering, the results are the same – the potential for saving anywhere from 30 per cent to 55 per cent in the cost of a given part.

Many designers are already aware they can gain a number of advantages and benefits by specifying die cast parts. Die casting is an efficient, economical process offering a broader range of shapes and components than any other manufacturing technique. Parts have long service life and may be designed to complement the visual appeal of the surrounding part.

In addition to these general benefits, however, designers are finding that they can achieve further cost savings and product improvements by engineering products in conjunction with their die caster. Consulting with the die caster during the design phase will help resolve issues affecting tooling and production, while identifying the various trade-offs that could affect overall costs. For instance:

- Casting drill spots may be preferred to casting a cored through hole. Even though an extra step is required, drilling after the casting operation may be simpler and less expensive than creating and maintaining a die with the necessary cores.
- Parts having external undercuts or projections on sidewalls often require dies with slides. Slides increase the cost of the tooling, but may result in reduced metal use, uniform casting wall thickness or other advantages. These savings may offset the cost of tooling, depending upon the production quantities, providing overall economies.
- Switching from castings made on a small machine with a single cavity die to casting in a four cavity die in a larger machine. Production benefits must be weighed against the ability to maintain dimensional tolerances, or tolerances might have to be changed even though they conform to the NADCA standards. Some of the standards are based on the projected area of the casting, and it is the projected area of all the castings in the die that must be used to determine the correct tolerance to use.

Reasons for cooperative engineering

Market forces and effective use of internal resources are among the reasons companies are implementing cooperative engineering. Die casters that effectively use the process find that it gives them a point of competitive differentiation that will help them win business. Often, cooperative engineering provides advantages in keeping business from being sent offshore, since the cost reductions available from more effective designs offset the price advantages of offshore competitors.

Manufacturers, both die casters and their customers, should embrace cooperative engineering because it provides an additional source of knowledge and expertise to supplement their existing engineering staff. Many industries, such as telecommunications, may be particularly open to cooperative ventures because the size of their own engineering staff has been severely reduced in recent years.

Some industries such as aerospace, military or government contracts, as well as the automotive industry have historically been less receptive of cooperative engineering. Often in these situations, the number of layers of approval required to implement changes make the process cumbersome and may appear to outweigh any benefits that would result from engineering changes. Even though a cooperative engineering relationship might be more difficult to establish with those industries, the benefits could be very significant.

Possible Opportunities

Exceptions in military applications may occur for re-engineering parts for older weapons systems. Often, the supply chain for equipment such as the A10 Warthog aircraft is gone, but increased use of the plane during changing world conditions has increased the need for replacement parts. Cooperative engineering can help develop new ways to produce older parts, especially as die casters take advantage of new methods to simulate fatigue life, reducing the need for extensive data and testing before parts are put into service.

The other end of the spectrum for aerospace and military opportunity exists in using cooperative engineering for entirely new parts. A key success factor is getting involved at the very start of the process to ensure that the first part to be tested is a cast part. The ability to conduct high-level simulation that simulate solidification, mold flow and stress analysis are critical elements when dealing with aerospace engineering.

Driving forces for change

To achieve the best results, cooperative engineering should begin as early as possible in the design process. Typically, there are three primary events – tooling changes, engineering changes and process/materials changes – that may spur manufacturers and die casters to embark on a cooperative engineering project. These events occur late in the product development process, but offer opportunities to show the die caster's customer the value of cooperative engineering.

Tooling changes – The need for new tooling to replace old or worn dies provides an opportunity to reexamine the casting process for a given part and look for changes that could reduce costs and improve quality.

Engineering changes – In today's market, the majority of parts are an evolution of a previous design. These design changes may provide opportunities for overall improvements in the casting process.

Process/materials changes – Manufacturers seeking to replace stamped metal or plastic parts will often turn to die casters to develop new solutions. These might include one-piece castings to replace multi-piece stamped parts that require additional assembly, or die cast parts that are stronger than plastic injection moldings having the same dimensions.

Maximum effectiveness is achieved when the OEM engineers engage in cooperative engineering with the die caster as early as possible in order to identify the best die cast for the job based on quality and cost factors. The best time is before the design of the die casting has started, but the need (or possible need if other materials or processes are being considered) and the requirements have been established. Not all die casters are the same. Some can hold closer tolerances, while others may not hold the same tolerances or ensure pressure tightness, but have a lower cost base. So, it is important to fit the job to the die caster or conversely, select the die caster who best fits the job.

Design opportunities

There are a number of interrelated elements that affect the saving that can be achieved through the cooperative design process. However, the two greatest opportunities for savings typically occur from engineering changes that reduce the amount of material in a casting or reduce the amount of machining and other post-casting processing.

Naturally, the larger the part, the greater the savings will be from reducing the amount of material in the casting. However, creating lighter, thinner-walled castings has benefits beyond just the material reduction. Using less material may allow for a faster cycle time, so that more parts can be produced with a given machine. Faster cycle times may free up capacity to allow the machine to be used for other projects, generating more revenue.

Reducing the material and weight of the casting may also permit the part to be cast in a smaller machine, which further saves on operating costs and improves efficiency. However, production volume can sometimes have the opposite effect. Small incremental increases in production volumes from customer orders could force the die caster to buy another machine, which he will not fully utilize, or have to subcontract work at a high cost. Therefore, unless the proper planning and cooperative engineering is done in advance, the incremental cost of those extra parts might not be what the customer is expecting or what the die caster can afford to do.

The total potential savings per pound/per part by removing one pound of aluminum from a casting are shown by the following chart.

Element	Cost-Savings
Metal costs	$ .90/pound
Process efficiency	$ .32/pound/part
Machine efficiency	$ .10/pound/part
Total	$1.32/pound/part

Savings on machining can be achieved in two primary ways. The first is to design parts that can be cast to near-net shape in order to eliminate as many machining operations as possible. The other way is to design the tooling so that any required machining is on one plane of the part, enabling a single set up for the finishing process.

Additional economies can be realized by having the machining operations process engineered to accommodate the natural variation of the casting.

A common practice is to clamp the casting into a set of "master" locators and perform all machining with fixed spindles from those locators. That practice is a carry over from the best practice for machining from a solid block of material, yet it often results in more machining stock removal than actually required simply to accommodate the variation in size from one casting to another. The absolute position of the machined surface in space does not need to be established so precisely. Suppose, for example, that a pressure transducer must be attached to a die casting into a threaded hole, and the unthreaded hole is formed by a moving slide in the die casting die. The absolute position between the cast features of the hole and the threading spindle for any given casting will depend on how many parting lines are between the 3-2-1 locators and the hole and also on how far the locators are from the hole. That variation in absolute location has no bearing on the function of the transducer. However, if the thread (and any necessary seating for the transducer) is machined with a fixed spindle, the casting must have enough machining stock to accommodate all of the accumulated variation. Unfortunately, the probability of machining into porosity increased exponentially with the amount of material removed.

So, one must always try to minimize the amount of material removal when machining a die casting. The 3-2-1 locators must be planned to result in a minimum variation of the absolute position in space of the cast features that are to be machined, or a floating position spindle must be used.

Case Study Example

A good example of how cooperative engineering can improve products is illustrated by the design of an elbow housing for spotlights used on public safety vehicles.

The spotlight has a number of functional, strength, durability and appearance requirements.

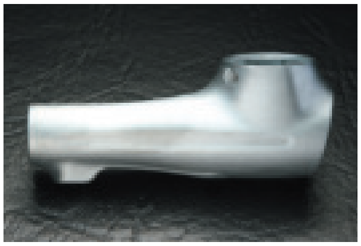
- The assembly has to withstand applied loads from both wind resistance and normal wear and tear.
- The spotlight must retain mechanical motion, electrical function, and an untarnished, professional appearance across a wide range of temperatures and weather exposures.
- Functionally, the housings must block penetration of moisture, dirt, and dust into the gear mechanisms and electrical system.
- The housings must have a smooth, reflective chrome-plated finish for appearance and resist denting, pitting, corrosion, and abrasion.
- The spotlight support shaft and the spotlight head must both fit into the outer housing precisely and securely for load transfer, smooth mechanical motion, electrical grounding, and sealing against moisture.

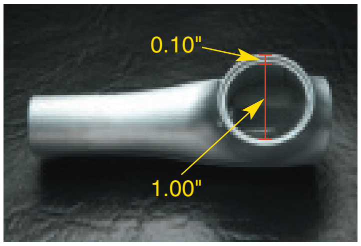
The elbow housing is cast in a single cavity precision steel die in a 50 ton hot chamber die casting machine, with high volume production runs of 10,000 plus parts.

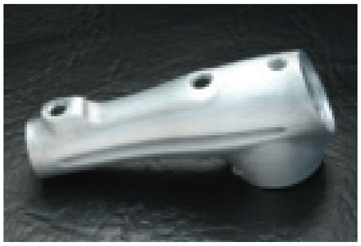
The outer housing is a hollow tapered elbow with a variety of internal and external features. Weighing about six ounces, the elbow is 4 inches long, 1.5 inches high, and 1.2 inches at its widest diameter and 0.8 inches at the smaller outer diameter. The thickest wall sections are 120 mils; the thinnest wall sections are 40 mils. The housing needs to have controlled wall thickness and uniform metal fill for structural integrity and rigidity.

Production requirements include:

- Three access holes
- Internal rib and cylinder stiffeners
- An internal key and keyway
- A stiffening boss on the screw hole
- Two holes and three drill points for three screws and one shaft







The as cast elbow housing

Surface flaws and internal porosity in the housing are not permitted, because they would reduce the strength and stiffness and lead to imperfections on the chrome-plated exterior. The dimensional tolerances on mating surfaces are +/- 1.5 mils; general tolerances are +/- 2 mils.

The casting engineers at the NADCA custom die caster and the OEM manufacturer had three design imperatives — performance, castability, and cost. Compared to an earlier design, the new design has the following performance and production benefits:

- Tighter dimensional tolerances for better weather tightness and a more reliable electrical circuit with less shorting and open circuits.
- A superior surface finish, requiring less polishing which results in reduce production time and expense.
- A lower scrap rate, as compared to the prior design, enhances productivity with significant cost savings.

Five design issues played a major role in meeting the three design imperatives for the elbow housing. The design issues were: choice of the metal alloy; die design; gating and accommodating overflows; placement of the ejector pins; and thermal management.

These issues are interconnected; the information that follows will show the impact each element had on achieving the design objectives.

Metal Alloy - Each of the metal alloys available for die casting – zinc, aluminum, magnesium, copper, and lead and tin – offers particular advantages for a completed part. The NADCA website (www.diecasting.org) provides detailed discussions on material selection. For this particular project die casting with zinc was chosen because the alloy met the requirements for complex shape, close tolerances, superior appearance, and low cost production.

Die Design – The goal for the spotlight housing was to optimize the die design to produce near-net shape parts to reduce machining costs. The designers evaluated two options:

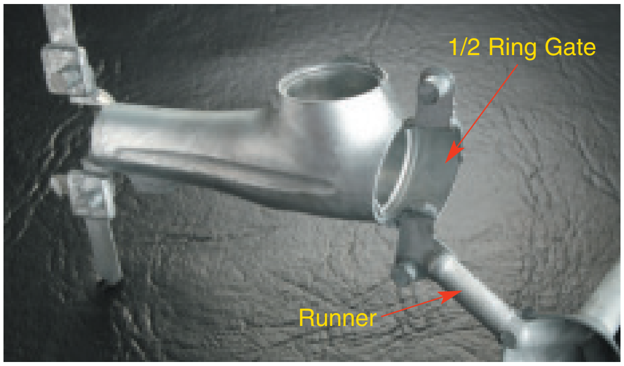
- The cost of a second set of machining steps with added handling and variability
- The cost of a more complex tool with slides

The cost of a fourth (3-feature) slide in the die for this large a production run had lower per-part cost than the alternative of added rough machining steps for the three features. The slide block with the three features will also provided tighter tolerances on the position and diameter of the two holes and drill point, compared to rough machining.

Gating and Overflows – Another consideration in the die design is the positioning of the runners and gates to optimize metal flow and produce a pore-free casting. Two gating designs were considered for feed into the elbow housing:

- A 1/2 ring gate into the heavy end of the housing
- A fan gate at the thinner top center section of the housing

Using the first option, with the gate positioned at the heavier section of the elbow through a 1/2 ring feature, provided two benefits. The metal feed into the heavier section provides a straight flow of metal into the full length of the elbow, minimizing turbulence, directional changes, and porosity caused by pressure drops. Feeding into the end lip puts the trimming operation on an inconspicuous section of the elbow and prevents trim marks on the main body. This produces a clean and smooth surface finish on the main body without blemishes.

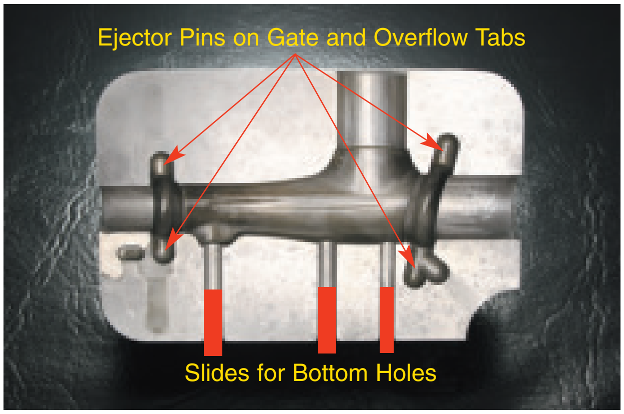


The overflows are positioned on the thin section end of the elbow furthest from the inlet gating. They also use a 1/2 ring geometry (with side tabs) on the thin end to avoid trim blemishes on the visible body of the elbow.

Ejector Pins – Another factor affecting the surface finish is the placement of ejector pins. Two ejector pin designs were considered for the elbow:

- Two ejector pins on the body of the elbow
- Four ejector pins on the gating and overflow half rings

The second option was used because the ejectors act on the half rings, which are trimmed off after casting. Therefore, the main body of the elbow will be free of ejector marks, guaranteeing a smooth, flaw-free finish when chrome-plated.



Ejector pin placement

Thermal Management – Thermal management of the tooling and dies is a critical production factor in quality die casting. If the die faces overheat during a casting run, "heat checking" can occur. This results in the formation very fine surface cracks on the die faces, which will transfer to the die casting as raised veins on the surface.

To eliminate this problem with the spotlight elbows, the engineers used active thermal control to manage die face temperature during the production run. The die blocks have cooling channels in which temperature-controlled oil circulates to keep die faces at the desired temperature. This ensures complete fill and rapid solidification while preventing heat checking and die cracking.

The decisions made during the design process for the spotlight elbow housing illustrate how cooperative engineering can help reduce costs while producing high integrity parts with flaw-free surface finishes and low scrap rates.

For additional detail about this case study and other examples of the die casting design process, visit **http://www.diecasting.org/design/**.

Conclusion

Cooperative engineering has proven to be an effective method for reducing costs, improving quality and increasing production efficiency for die cast parts. The process benefits both die casters and OEM engineers. It allows die casters to help differentiate themselves in the marketplace and provides a competitive advantage, while OEM engineers benefit from the technology transfer and exposure to new ideas for producing better parts. Starting the process as early as possible in the design cycle is a critical factor in the success of the cooperative engineering process in order to effectively plan, evaluate and understand the tradeoffs and options that may be possible for each project.

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Based in Wheeling, IL, the North American Die Casting Association (NADCA) represents the world's most effective die casters creating the world's best cast products. Working with a North American die caster guarantees innovation, integrity, accessibility, and reliability.

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