WHITE PAPER

Five Steps to Improving Die Performance

North American Die Casting Association

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Five Steps to Improving Die Performance

One of the myths that still affect some designers' decisions about choosing die casting is that tooling is not reliable or that short die life will impact production. However, research and innovations over the last 10 years have proved that a number of methods are available to extend die life, improve die performance and reduce the overall cost-per-part.

There are five key factors that can extend die life:

1. Die design
2. Die material
3. Heat treatment
4. Coatings
5. Operation/maintenance

Applying specific practices in these areas can improve die performance anywhere from 50 percent to nearly 100 percent. These improvements in performance typically offset any additional costs for producing high-quality, long-lasting tooling, making it a better choice than less expensive, lower-quality tooling from offshore sources.

Evaluating Die Performance

Die performance – or die life – may mean different things to different organizations because of various measurement methods. However, it is generally agreed that improved die performance means more parts at less cost.

Typically, performance can be measured using one input and two outputs:

Input: the total amortized die cost;

- The new die cost plus aggregate repair cost before retirement.

Outputs:

- Uptime; the number of shots between in-machine die-related repairs, and
- Repair/downtime; hours lost during or between casting production runs.

Limitations on die performance are caused primarily by three factors that affect the tooling:

- Soldering and chemical attack between the liquid metal and the die material
- Wear and erosion
- Heat checking or thermal fatigue cracking due to the thermal cycling that takes place with each shot or casting cycle

Eliminating or reducing these factors will increase die life and reduce overall costs. The improvements in die performance that are possible are shown by a long-term study of a die caster tracking aluminum squeeze castings. The caster used a combination of techniques to achieve these results.

Long Term Results: Squeeze Cast only	1990	2005	% Change
Mold Life (shot count) before scraping cavities	45,000	71,000	+58%
SMED changeover time (Shot to shot)	8 hours	2 hours	+75%
Die preheating influence @ startup	2 hours	5 hours	-75%
Recovery from downtime; 30-minute event	1 hour	25 hours	+75%

In a 10-year study of die performance for transmission case castings, a large OEM reported a die life increased from 170,000 to 240,000 shot between die rebuilds.

Performance Improvement Steps

The five key factors for improving die life described in this paper are a starting point for determining what combination of elements will have the greatest impact on performance in a particular situation. Just as there are many nuances within each performance improvement element, the specific steps that will yield the best results will depend upon a variety of factors, such as the type of die casting (hot or cold chamber), the alloy being cast, shot size, or whether it is a thin wall or thick wall casting.

Examining each of the five factors in more detail, however, will provide a foundation for industry "best practices" that can be adapted to each specific situation.

1. Die Design

Tool life improvement begins with product design. In particular, sharp edges and corners on a die casting can directly affect die life and tooling costs. Corresponding sharp corners in the tool act as either stress concentrators or local zones of high heat build-up. Both conditions can cause premature surface and corner cracking in the tool and shorten tool life. Therefore, parts should be designed with round edges or generous radii.

Gate location also is important, since control of the metal flow in the die cavity is a key factor in producing sound die castings. Metal must flow rapidly and uniformly into the die, minimizing sharp direction changes that can contribute to premature tool wear. Flow and solidification software can be used to evaluate and refine the tool design before production begins.

2. Die Material

Premium or Superior Grade H13 tool steel is the starting point for most tool construction. However, many die casters are realizing significant improvements in die life using modified versions of H11 steel, heat treated to a hardness level of 48 HRC. The H11 has higher molybdenum content, with lower silicon and vanadium, providing higher toughness than H13, with good temper resistance that extends die life in demanding applications such as thick-walled castings.

When using H13 steel, it is important to specify either Premium or Superior grades. These grades are typically made by Vacuum Arc Remelting (VAR) or Electro-Slag Remelting (ESR) of the Standard H13. These processes produce superior steel with low sulfur, phosphorous and inclusion content, as well as a tightly controlled carbide size and distribution. The NADCA 207-2006 Specification for Special Quality Die Steel and Heat Treatment provides detailed guidelines and acceptance criteria for these materials. Many die casters also recommend independent testing of the material to ensure it is meeting the minimum Charpy impact toughness values for the specified grade.

3. Heat Treatment

Extensive research has shown that the heat treating process is at least as important as the selection of the proper die steel in determining die life. The thermal fatigue cracking is sharply reduced by using an austenitizing temperature that will place the maximum amount of carbide forming elements in solid solution in the austenite. When combined with a rapid quench rate, toughness is unaffected.

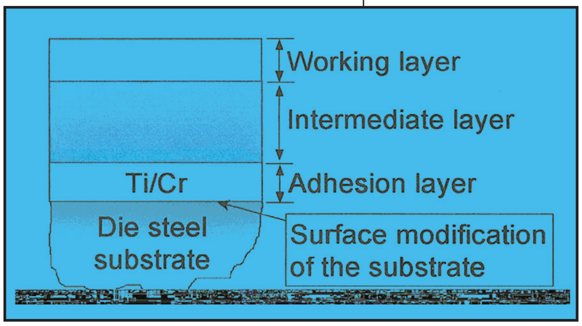
The current NADCA specification requires a minimum cooling rate of 50 Fahrenheit degrees/minute as measured by a thermocouple inserted in the die. Many heat treaters use six or ten-bar nitrogen quench furnaces to attain these high cooling rates. To avoid quench cracks in large dies, it is common practice to perform a step quench in order to limit the difference between the inside and surface temperatures.

Within these general guidelines, however, specific heat treatment techniques have been tested and proven to improve die life. A summary of these methods is included in NADCA's research and development publication "Die Materials & Technologies," which is part of the Turn Research into Action series.

4. Coatings

Coatings and/or surface treatments can be used to extend tool life by preventing soldering and erosion between the tool steel and the liquid alloy being cast. Although surface modification techniques such as ferritic nitrocarburizing and plasma ion nitriding can be used to extend die life, coatings typically provide greater improvement.

There are a number of chemical and physical coating processes available. Researchers at the Colorado School of Mines proposed an optimized multi-layer/ graded coating system, as shown in the drawing at right.



Optimized multi-layered coating system for die casting dies

Additional coating methods and case history examples can be found in another section of NADCA's Turn Research into Action series, titled "Die Surface Engineering."

5. Operations/Maintenance

Just as good design is the starting point for improving die life, correct operation and maintenance contribute to the overall success in improving die performance. Following NADCA's die set up procedures, pre-heating tools and verifying clamping pressures are among the steps that will help enhance die life. If a hard coating is being used, cleaning procedures need to be changed to avoid damaging the coating.

Planning for Tool Life Improvement

Combining the various techniques for die life improvement can produce a significant increase in the number of shots per tool while decreasing downtime. Using the tool life extension process described below, a large squeeze casting facility improved tool life for squeeze cast aluminum parts by 58 percent over a 15-year period.

The process includes these elements:

Die Construction – The company starts by using NADCA specifications for ordering and heat treating Premium Grade H13 steel. Hardness is typically 47 +/-2 pts HRC, depending on the steel thickness. Cooling line location is determined by flow and solidification analysis software. Gating location is also a factor given the potential for erosion. Special attention is also given to other cooling line factors, including:

- Cooling lines and bubblers constructed with ball nosed terminus points
- No spiral grooving on cooling line walls
- The use of Beryllium Copper (BeCu) inserts for cooling leak repair
- If applicable, using specialized steel inserts for cooling

The company is careful to avoid thin steel conditions for parting lines; otherwise auxiliary cooling is needed. They also polish out all EDM white layer areas and apply ferritic nitro carburizing in a fluidized bed process on cavities. Finally, they use PVD or CVD type coatings on troublesome areas exhibiting solder and erosion.

Die Repair – When repairing dies, the casting facility carefully follows NADCA recommendations for pre- and post-heating for welding, and uses proper welding materials. The company peens and cleans each weld pass, and if possible, renews the surface treatment or coatings for the repaired area.

Production – The company vigilantly follows NADCA die setup procedures, paying special attention to the following elements:

- Preheating tools with hot oil to a minimum 250 degrees F measured by internal thermocouples (surface temperature of approximately 300-500 degrees F)
- Pulse cooling water during mold preheat
- Electric heaters used if run downtime is longer than 10 minutes
- Applying mold release spray or cooling spray to appropriate areas to ensure part quality, solder prevention and erosion; gating size and location are a big factor in use of sprays
- Avoiding chippers, chisels or scrappers made of steel; use BeCu where possible
- Verifying all cooling lines and solenoids are functioning properly, and are timed in sequence
- Confirming that clamping pressures are correct and equal among the tie bars

Additional Research

Two sections of NADCA's Turn Research into Action series of research and development reports include detailed information and case histories about techniques that can be used to improve die life.

Pertinent reports about choosing materials and heat treatment in "Die Materials & Technologies" include:

<u>ACCELERATED DIE LIFE CHARACTERIZATION OF DIE MATERIALS</u> *R. Shivpuri, Ohio State University, and J. Conrad, University of Wisconsin*

This project provides the die caster with information on methods to reduce die washout, leading to cost savings through reduced down time and replacement costs.

<u>EXTENDING H13 DIE LIFE THROUGH HEAT TREAT OPTIMIZATION</u> *John Wallace and David Schwam, Case Western Reserve University*

The primary objective of this project was to determine how the heat-treating of H13 die steel can optimize its useful life.

<u>DIE MATERIALS FOR CRITICAL APPLICATIONS AND INCREASED PRODUCTION RATES</u> *J. Wallace, D. Schwam and Q. Zhou, Case Western Reserve University*

A research report with information on the use of die steels with improved thermal fatigue resistance, such as Dievar and QRO-90 that could improve cycle rates compared with H13 die steel.

<u>RESIDUAL STRESS AND SOFTENING EFFECTS ON DIE LIFE</u> *John Wallace and David Schwam, Case Western Reserve University*

Information that shows the die caster the benefits of rapid quenching to improve hardness on the die surface.

Reports about coatings and surface treatments include:

<u>DEVELOPMENT OF SURFACE ENGINEERED COATINGS FOR DIE CASTING DIES</u> *J. Moore, Colorado School of Mines*

The objective of this research was to develop an "optimized coating system" for die casting dies using fundamental scientific principles to minimize the effects of soldering (wetting), erosive wear, thermal fatigue and corrosion and oxidation.

<u>EVALUATION OF COATINGS FOR DIE SURFACES</u> *R. Shivpuri, Ohio State University*

This project provides the die caster with information about the benefits of various coatings – particularly on core pins – which can reduce downtime and provide cost savings ranging up to $25,000 per production run.

<u>COATINGS FOR DIE CASTING DIES</u> *R. Shivpuri, Ohio State University and P. Ried, NADCA Die Surface Engineering Task Force*

This research report has information about die coating technologies to improve die life by reducing soldering and washout problems.

Conclusion

Using the strategies and techniques outlined in this paper, plus the additional research information available from NADCA and other sources, die casters can significantly improve die performance, produce higher quality parts and reduce the overall cost per part.

The five major steps that can improve die performance are:

1. **Die design**
2. **Die material**
3. **Heat treatment**
4. **Coatings**
5. **Operation/maintenance**

Although some of these techniques may increase the initial cost of the die or the operational cost – such as the cost of coatings – the improvements in die performance will greatly reduce the overall cost-per-part. Die casters who use this type of cost-per-part analysis will typically find that a slightly more expensive but longer lasting tool will provide savings and production efficiencies that far outweigh the initial difference in price of cheaper offshore tooling. ■

The following individuals provided information for this report. NADCA gratefully acknowledges their contributions. Additional source material came from the "Ask the Experts" column in Die Casting Engineer, May 2005.

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Based in Wheeling, IL, the North American Die Casting Association represents the world's most effective die casters creating the world's best cast products. The organization serves as the voice of the industry, promoting growth and enhancing its members' ability to compete domestically in the global marketplace.

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