Dr. Die Cast

Design of Experiments (D.O.E.) and Black Belt Projects (Searching for the Red X)

Every good die caster knows that there is a lot of sweat involved in developing a strong reliable process. In short, there are few "shortcuts" to success whether in management, operations or engineering. Most of us have heard the terms "Design of Experiments (D.O.E.)", "Experimental Design", and "Black Belt", but are they valuable in our industry? You may have even referred to a D.O.E. as a "Taguchi" experiment after one of the teachers of the methodology, Dr. Genichi Taguchi. Dr. Taguchi defines quality as follows:

"Quality is the loss imparted to society from the time a product is shipped. Loss is the waste, the expense, the lost potential and savings that occur due to a product not being perfect. It is variation from the ideal or the target. The loss is that to society as a whole, and not just that of the manufacturer at the time of production."

First let's start by defining what we mean when we say "Design of Experiments". The following is quoted from the American Society for Quality.

"This branch of applied statistics deals with planning, conducting, analyzing and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters."

Most of us know by experience that the fast shot velocity is important in producing a quality casting. But what is the impact of the other parameters and their "interactions" on the final quality? The results of a D.O.E. can sometimes indicate a set of parameters that were never used in combination.

The procedure is systematic in both the parameters that are being tested and in the evaluation of the test results. The attributes tested must be measurable and quantitative. Even Aesthetics can be "scored" by using instruments such as profilometers or gloss meters. In order to be effective, the results must be reproducible and practical. When properly documented the results are "portable" in that they can be used as a starting point on similar equipment and families of castings.

Let's look at an example of a typical die casting. Initial samples from a new die produced a reasonable surface finish but the casting had internal porosity. In addition, a key dimensional attribute was flatness. If we could produce a casting with improved flatness we could reduce machining stock and speed up the milling process. Thus, a D.O.E. was conducted. The goal of the experiment was to identify the parameters that produced the least variation (lowest sigma value) for the key attributes.

Typical die casting test parameters:

- Cold chamber diameters (in or mm): A and B
- Calculated Critical Slow Shot Velocity for each cold chamber size used (IPS or M/S): Nominal, + 5%, - 5%
- Fast Shot Velocity (IPS or M/S): Nominal, + 5%, - 5%
- Slow to Fast transition point: Nominal (metal at the gate), Sleeve full, and X% Pre-fill
- Intensifier Pressure (Calculated for each cold chamber diameter): 9,000, 10,000 and 11,000 PSI (620, 689 and 758 BAR)
- Solidification (Dwell time): Nominal, +/- X seconds
- Furnace (metal) temperature (Fahrenheit or Celsius): Nominal, +/- 30 degrees Fh (Nominal, +/- 16 Celsius)
- Quench Method: Water or Fan cooled

Base-line parameters:

There may be parameters that, while they may not be considered "variables", must be documented as they could have a profound influence when it is time to run a confirmation test or when starting up a few weeks or months later. These are referred to as "fixed variables".

Who's Dr. Die Cast?
Robert P. McClintic
Die Casting Consultant

Bob McClintic & Associates
2544 Almar Street
Jenison, MI 49428-9108

rmcclintic@ameritech.net
www.drdiecast.com
616.669.2932

Examples of "Fixed variables" could include:

- Die lube type and ratio
- Die lube central system pressure
- Die spray application, # of spray heads, type
- Process cooling water pressure and temperature
- Alloy certification especially when dealing with some of the "special" alloys like 390 or Silafont 36.
- Locking tonnage
- Tip lubricant type and volume
- Biscuit thickness
- PQ^2 data on the machine
- Intensifier "Rise time"
- Shot and intensifier accumulator nitrogen charge
- Die temperature (be specific on the location)

Test Day:

Verify and record each of the "Steady state" parameters.

Number each casting during the test so each can be tracked throughout the inspection process and correlated to a particular set of parameters.

When testing furnace or die temperatures or solidification times, it is critical to allow time for the die to reach steady state before saving the castings.

Failures/unstable/unusable combinations? Some combinations may be beyond the capability of the machine. Examples include high furnace temperatures combined with high injection speeds and high intensifier settings. It is important to record the results and move on to the next test. Even these results are useful.

Inspection:

This may be the most labor intensive part of the experiment. The castings may be graded and scored on multiple criteria as listed above, dimensional, visual and X-ray.

Interpreting the results:

When the inspections are completed, it is up to the engineer to enter the data into a spreadsheet to calculate and interpret the results. (Calculations and interpretation information may be found in the NADCA Problem Solving text and is taught in the problem solving course). Many times the results are intuitive but counterintuitive results can also be discovered. These may be groundbreaking especially when dealing with difficult and high volume products. It could be the difference between profit and loss on a product.

Affirmations and surprises:

Many of the "nominal" parameters selected in the above example were affirmed. That is, the inspection data demonstrated that the calculations for some of the "classical" die casting parameters such as "critical slow shot", "gate velocity" and "cavity fill time" were not just valid but produced better quality castings.

One of the surprises was the effect of dwell time and cooling method on the casting flatness. Typically the biscuit is the controlling factor in dwell time. In this case by increasing "dwell time/die closed time" by 2 seconds the flatness was significantly improved. The final surprising factor was the cooling method. We found that by "air cooling" the casting instead of water quench, the flatness stabilized. This was the "icing on the cake".

Confirming the conclusions:

- The final step is to perform a "confirmation test".
- Verify and record each of the "Steady state" parameters.
- Set the machine parameters to the "New settings" indicated by the interpretation.
- "Is it within the capabilities of the machine"? Is it stable? Do the parts meet or exceed acceptance criteria?
- Now you are ready to go in to production!
- Congratulate your team!

Additional resources are available from:

Die Cast Problem Solving Book - This text is designed for solving difficult die casting problems that can't be resolved though conventional process engineering methods. The book will assist in improved, data-driven process decision making, promote statistical thinking in regard to process variation; develop an objective defect ranking system for a subjective defect and correlate the process to the defect without preconception. This publication can be purchased in the NADCA Marketplace at: www.diecasting.org/store/detail.aspx?id=PUB-413

Design of Experiments Tutorial and Template can be found at: http://asq.org/learn-about-quality/data-collection-analysis-tools/overview/design-of-experiments.html