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Tim Cowell
President
Cowell Chemical, Inc.

Title: Die Lubricants: Science or Black Art?

Introduction

Early on in the Die Cast Industry, die lubricants were usually a concoction of various compounds that the die caster had available to him.¹ He would create different mixtures and whatever yielded the best results for his specific application was what he used. Although much was learned from this trial and error type of evaluation, this method of die lubricant development was considered more of a “Black Art” than a science. Several decades later, there are some who still believe it.

Over the years, die lubricant manufacturers and others have gone to great lengths to develop laboratory methods aimed at correlating a product’s performance in the lab with how it will perform in production, and yet there are still no standardized scientific methods within the industry for evaluating die lubricants. The only true test to determine the functionality of a new die lubricant is by its introduction to the production environment.² Even then, there are issues that are not clearly explainable. For instance, it is not uncommon for a trial die lubricant to work well on one casting and yet create problems on a similar casting running on the machine next to it. This causes many to ask the inevitable question, “Why?”

There are no simple answers to this question. In spite of the fact that die lubricant manufacturers know more now about the physical and chemical properties of their products and their potential performance in the die casting environment, there are still intangibles within the die casting process that are often overlooked during product selection. Some of these intangibles are variations in types of castings, cycle times, die design, water quality, machine equipment etc..... Because each of these variables has an effect on the thermal balance of the process, they impact the performance of the die lubricant, which in turn impacts the quality of the casting, the scrap rate, downtime and finally the profitability of the company.

The purpose of this paper is to look at areas where the die caster and die lubricant manufacturer can work together to improve the development and functionality of a die lubricant specific to their process, resulting in a superior casting, reduced scrap and downtime, and ultimately increasing the bottom line.

There are four areas that need to be focused on:

- Understanding the Needs of the Customer
- Product Selection
- Product Evaluation
- Practicing “CANI”

Understanding of the Needs of the Customer

If a person went to a doctor and described his/ her problem, and the doctor gave that person a prescription without further examination, you would think the doctor was either incompetent or negligent and would be guilty of malpractice.

While many die lubricant manufacturers are knowledgeable about the performance of their products, they would be as guilty as the doctor if they recommended a product without performing a thorough examination of the customer’s process to determine which product best suits the customer’s needs. For example, a cold die can cause a soldering condition as much as a hot die. The symptom would be the same, but the solution would be very different.

It is imperative that the die lubricant manufacturer know as much about the die caster and their process as possible. The following areas are important items that the die lubricant manufacturer must understand about his customer in order to make the best recommendation.

The Customer's Philosophy of Die Casting

Although every die caster strives to manufacture a quality casting for the least amount of expense, there are different ideological ways of accomplishing this.

One die caster who manufactures transmission housings will run their dies hot with short cycle times, while another die caster manufacturing a similar transmission housing run their dies much cooler with longer cycle times. The die caster who runs their dies hot with short cycle times, places a high emphasis on number of castings run per day. He/She might have a slightly higher scrap rate, but more than make up for it by producing a large quantity of acceptable castings for their customer. The die caster who runs their dies cooler with longer cycle times, are placing an emphasis on lower scrap rates, hoping that their scrap rate will be low enough to produce enough quality castings that will satisfy their customer. Neither die caster is right or wrong, it is simply their philosophy of operation.

Another example of philosophical differences amongst die casters is in the area of recycling the die lubricant. Some die casters who do not have waste treatment facilities have chosen to recycle their die lubricants because the cost to have it hauled away is excessive, while others choose to have it hauled off or treat it onsite.

In both of the examples mentioned above, the die casters, regardless of the similarity of the product that they are casting, could not run the same die lubricant successfully without compromising productivity due to their philosophical differences.

Casting Products

Too often, a die lubricant is recommended to resolve one specific problem on one casting without looking at the potential problems that the new lubricant might cause on another casting. The die lubricant manufacturer should pay close attention to the following:

- **Types of Castings** – Are the castings thick or thin walled? Do they have multiple inserts or cores that might create a problem? What is the alloy or alloys used to manufacture these castings?
- **Die Designs** - What are the thermals associated with this die? Where are the coolant lines run? Are there Infrared pictures associated with it? What is the die lubricant spray pattern?
- **Defects** – What are the primary defects associated with each casting?
- **Finish** – What are the finish requirements associated with the casting, will it be powder coated or chrome plated?

A thorough knowledge of the products and their various lubrication needs allows the die lubricant manufacturer to develop or select a die lubricant that will best accommodate those needs.

Die Cast Machine Systems

Although the die lubricant manufacturer should be familiar with all aspects of the customer's die cast machine, there are a few key systems that directly affect the performance of the die lubricant.

- **Die Heating /Cooling Systems**

While die heating / cooling systems are a science within themselves, it is vital that the die lubricant manufacturer knows which type of system that the customer has and its thermal impact on the operating temperatures of the die. Does the die's cooling system use a synthetic glycol, a petroleum oil or water for its cooling system? What is the preventative maintenance program? These questions are critical to understanding the thermals of a die and how they might change during the production process.

In spite of what many manufacture's claim, all materials will undergo a thermal decomposition when exposed to very high temperatures. Some of the glycol's decomposition by-products are acidic in nature and can cause corrosion. The oils oxidize and form a thick sludge which tends to build up on the sides of the coolant lines. This reduces the amount of flow through the lines and in extreme situations, clogs the line completely. The reduction in flow reduces the amount of Btu's that can be removed from the die.

In regard to those die casters who use water, some will use deionized(DI); however, most (because of the expense of using DI) will use city or well water. City or well water, even if treated, will contain minerals which plate out on the sides of the walls and reduce the thermal transfer out of the die as well.

- **The Spray Equipment**

There are three basic methods of applying the die lubricant to the die, **manual spray** with a gun or wand, **recipicators**, and **robotic**.

Manual Spray application relies on the familiarity of the operator of both the casting he/she is running and the equipment being used.

Recipicators are perhaps the most common in the industry. They contain a series of spray heads directed at different locations on the die.

Robotic sprayers are becoming more common. This is the most accurate method of applying die lubricants. However due to the high capital cost, many die caster's don't utilize them.

It is also important to pay particular attention to the **air / die lubricant pressure** as well as the differential between the two, which is responsible for proper atomization of the lubricant onto the die surface.

- **Die Lubricant Mixing Units (Central / Individual)**

There are two types of mixing systems. Each die casting machine will be supplied die lubricant with either **Central Unit Systems** which supplies several other machines at the same ratio, or an **Individual Systems** which supplies the die lubricant to one machine.

The primary advantage to the central system is that it requires less maintenance than the individual units, while the disadvantage is that the machines which it supplies may be running castings with different die lubricant needs.

The primary advantage to the individual systems is that they allow the die lubricant ratio to be customized based on the need of the individual casting. The disadvantage is that it is more labor intensive.

Product Selection

Once the die lubricant manufacturer and die caster have reviewed and discussed the die caster's operations objectives (operation philosophy), the casting product line and the equipment, it is time to begin selecting or developing a product. There are several steps involved with this process. The first is:

Establishing the Critical Operating Criteria for the Die Lubricant

Primary Objectives of the Customer

This is fundamental to the success of this program. It is important that the die caster clearly states what objectives hope to be obtained by changing die lubricants. Are buildup, solder, heat check on the dies, bent or cracked parts, porosity, adhesion problems, primary concerns? It is also important that the die lubricant manufacturer makes the die caster aware of potential conflicts. For instance, the die caster may have buildup on one casting and soldering due to excessive heat on another and he/she may list that the resolution of this problem needs to part of the Critical Operating Criteria for the new die lubricant. The die lubricant manufacturer needs to make the die caster aware of the limitations of the chemistry and assist them in finding resolution.

Operating Temperature Ranges

After identifying the primary objectives, the die lubricant manufacturer needs to know what die temperature range the product needs to perform at, which can be determined by an infrared camera. Pictures can be taken before the die is closed and immediately after it is opened to determine the high and low temperatures and their location on the die cavity.

Surface Finish Requirements

Finally, the manufacturer needs to know the surface finish requirements. Is the part going to be painted or decorative or is it part of an engine where cosmetics are not an issue?

Each one of these areas is important in determining the chemical composition of the die lubricant.

Chemical Composition (Formulation)

The next step is to select the chemical composition of the die lubricant

There are six basic groups of functional additives used in formulating die lubricants. These are:

- **Anti Solder Additives**
- **Metal Flow Additives**
- **Hydrodynamic and Extreme Pressure Additives**
- **Surfactants**
- **Rust Preventatives**
- **Preservatives**

Within each group, there are several different chemical compounds that perform these functions. Some of them are multifunctional. The key is to determine which combination of these compounds formulated into a die release agent will allow the die caster to achieve his/her objectives.

Often a die lubricant manufacturer will use his / her knowledge gained from previous experiences (i.e. die lubricant trials) along with the Critical Operating Criteria, to formulate the initial product, and then make modifications to the lubricant based on empirical data from lab evaluations.

Laboratory Evaluations

There are two types of laboratory evaluations for the product being developed, ***Chemical*** and ***Thermal***.

Chemical

Chemical evaluations are to determine the Emulsion Stability, the Corrosion and Residue characteristics of the die lubricant.

- **Emulsion Stability**

Emulsion Stability is critical to the performance of the die lubricant. Unlike most emulsions, a die release emulsion must remain stable even when it is diluted at a 100:1 ratio. The emulsion stability is evaluated by diluting it with the die caster's water, dyeing it with a water based dye (allows the cream layer to be seen easier) and let sit in a Babcock bottle for 24 hrs, then visually checking it for creaming.

- **Corrosion**

The corrosion evaluation is performed on the die lubricant concentrate with cast iron chips. This evaluation is not to measure the die lubricant's corrosion inhibition properties, but rather its corrosivity. It is important the die lubricant does not attack the metallic parts of the die or die casting machine.

- **Residue**

Since die lubricants are applied by an atomized spray, they tend to coat everything around it, including moving mechanical parts of the machine. The residue left after the water is evaporated needs to be soft and fluid, preventing it from seizing up the equipment.

Thermal

Although most die lubricant suppliers have a general understanding of how these compounds work together, there is still a lot of mystery as to how they work within the frame work of a high temperature thermodynamic environment.

In an effort to better understand the thermodynamic characteristics of a specific die lubricant, many die lubricant manufacturers are using the following technologies.

- **Hot Plate and Surface Wetting Evaluations**

Hot plates are perhaps the oldest test method in evaluating the wetting characteristics of a die lubricant. Although there are different variations of this test, the primary parameter that is being evaluated is at what temperature does the die lubricant begins to wet and when does it stop wetting.

- **Thermal Gravimetric Analysis Evaluations**

Thermal Gravimetric Analysis (TGA) analyzes the rate of thermal decomposition of an organic material from 100° C – 540°C. For die lubricants, this analysis provides key important information about the thermal characteristics of the product (See Figure 1).

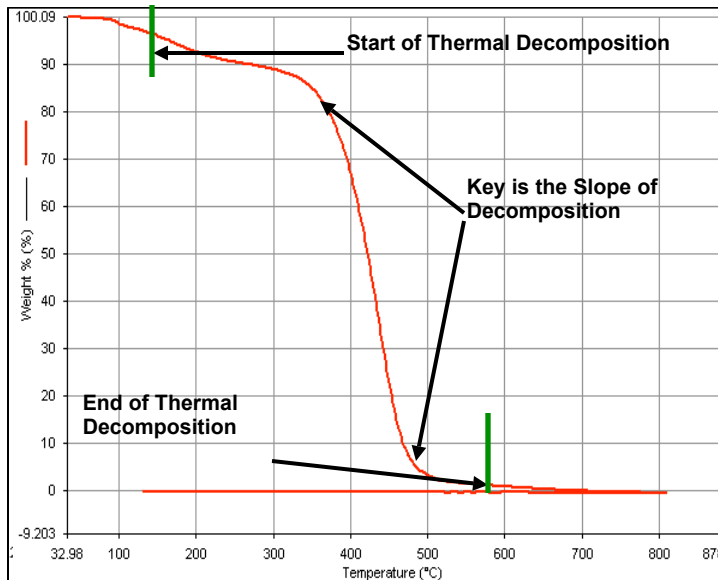


Figure 1. Die Lubricant undergoing TGA Analysis

Water is removed from the die lubricant before being analyzed. The initial weight loss (from 100 °C to 140°C) is residual moisture.

The *initial thermal decomposition* starts after 140 ° C and is an indication as to when energy (heat) starts being absorbed by the lubricant.

The *slope of decomposition* reveals the temperature range of the die lubricant, how quickly it decomposes and the solids remaining at any given temperature.

The *end of thermal decomposition* indicates the amount of material remaining after the die lubricant has been subjected to the temperature of the metal alloy. If there is excessive material remaining after 500 °C, then there will an excessive build up on the die.

- **Other Testing**

The capability of being able measure a die lubricant's ability to remove heat under die cast temperature conditions within a controlled laboratory environment has been studied in depth. Perhaps the most well known studies were performed using a piece of equipment labeled the Lubricant Testing Apparatus (LTA).

The Lubricant Testing Apparatus was designed by Arthur Schmidt. It has been used by Ohio State University's Dr. Jerald Brevick and others, to measure the *heat fluxes* associated with different die lubricants.³

Heat flux is often associated with the die lubricant's ability to remove heat from the die surface.⁴

Although this has not been a common piece of lab equipment, many die lubricant manufacturers are incorporating similar equipment designed to measure this characteristic.

Product Evaluation

Once a product has been selected, it is ready for trial on the casting that had been predetermined by the die caster. When evaluating a die lubricant, the following items are crucial.

- **Good Baseline Data** - without this, any trial would be subjective at best
- **Properly Maintained Machine** - it is important that the die cast machine be in good working order to properly evaluate the die lubricant performance. A machine that is up and down several times per day, changes the thermal of a die and impacts the performance of the die lubricant
- **Proper technical support** – when evaluating a die lubricant, it is imperative that a technical support person from the die lubricant manufacturer be onsite. The die lubricant manufacturer needs to know how the product is performing. Is it releasing ok? Are the mechanical parts being lubricated? Is there buildup on the die? Etc.....
- **Detailed Documentation of Evaluation** – When a product either succeeds or fails, it is crucial to have detailed documentation as to why. Otherwise, both the die caster and the die lubricant manufacturer are destined to repeat the failure. This also shows any adjustments that need to be made to the formulation.

After the die lubricant has run several days producing quality castings and meeting the die casters objectives, the lubricant then needs to be trialed on a casting that represents the opposite thermal conditions than the first trialed casting. For example, if the first trialed casting ran fast cycle times and high die temperatures, then the next casting trialed should represent the lower temperatures. This is to make sure that the die caster did not trade one problem for another.

Practicing “CANI”

"CANI" stands for **Constant and Never-ending Improvement**. It's an acronym that motivational speaker Mr. Tony Robbins developed more than a decade ago as a result of being influenced by Dr. W. Edwards Deming.

Dr. Deming, who was an American, is credited as one of the leaders who brought one of the first quality movements to the Japanese. He is credited as one of the major forces that allowed the Japanese to achieve world power and economic success so quickly after WWII. His basic premise was that **every person and organization** needs to **commit** to a **mindset and action of continuous improvement**.

It is this same premise that both die casters and their suppliers need to adopt as their own. Today, more than ever, the die casting industry in North America is feeling the impact of global competition. Although there are several internal programs that die casters are using to improve their productivity, there needs to be a concentrated effort by suppliers to do the same, especially in the area of lubricants and release agents.

Conclusion

Although there is still much to be learned about die lubricants and exactly how they function within the die casting process, it is clear that it has made the transition from a Black Art to a Science. Today, die lubricant formulations are based more on scientific data rather than the traditional trial and error method.

However, in spite of the fact that there have been several improvements in the area of die lubricants, die casters and lubricant manufacturers **must realize** that there is still much to be learned and that they **must work together** in order to **realize** the benefits. There can be no resting on today's technologies without a plan for tomorrow!

¹ E. F. Van Winkle, “Die Casting Release and Lubrication Technology for Water and Solvent – Carried Compound Systems” Technical Paper presented at the Die Casting Exposition and Congress in Cleveland, OH November 14-17, 1966. p. 1

² Dr. Jerald Brevick, David Leff & Medhavin Potdar “Characterization of Die Casting Spray Lubricants” Technical Paper T01-054, 2001. p. 1

³ Mark Osborne, Dr. Jerald Brevick, “Laboratory Characterization of Die Lubricant Performance” Minneapolis Technical Paper T97-05\

⁴ Dr. James L. Graff; Dr. Lothar H. Kallien “The Effect of Die Lubricant Spray on the Thermal Balances of Dies” Cleveland “Technical Paper T3-083