PREDICTING DIE LUBRICANT PERFORMANCE IN PRODUCTION WITH FOUR STANDARD LABORATORY TESTS

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ABSTRACT

Die lubricant production trials can be a costly endeavor. Die casting production trials typically require casting loss, equipment and resources to properly evaluate a lubricant. Many attempts have been made to evaluate performance in the laboratory before attempting a production trial. Most known methods provide some useful information with regard to a specific property of a lubricant, but are very poor at judging overall performance. In this communication, G.W. Smith and Sons, will present a four test laboratory methods that accurately predict die lubricant performance in the field.

INTRODUCTION

This communication is intended to determine if a lubricant is a valid candidate in a direct comparison amongst other lubricants considered for a production trial at a die casting facility. Many of the testing methods mentioned are capable of providing significantly more information than what is covered. Numerous attempts to use laboratory methods to determine the effectiveness of a die lubricant in a production environment have been conducted1-3. These methods include monitoring the cooling efficiency, coefficient of friction, pull force testing, determining liedenfrost effect and others. While these tests provide useful insight into specific properties of a lubricant and are excellent tools for die lubricant development, they only provide cursory information with regard to overall performance in the field.

With over 80 years of die lubricant formulation experience in the high pressure die casting market, we have observed the major lubricant characteristics that determine die lubricant performance in a production environment. The main lubricant characteristics are, solids content, thermodynamic stability, composition and decomposition cleanliness. Based on these lubricant characteristics, we can accurately predict lubricant performance in the field and have developed four laboratory tests to evaluate these properties.

Solids content determines the percentage of water and active material in the lubricant. Active components include petroleum derived oils, synthetic and natural esters, waxes, polymeric materials, parting agents, surfactants and others. The blend of these materials define the physical properties of a lubricant. The solids percentage of water based commercial die lubricants can range from as low as 6% to a high of 40% active material.

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Thermogravimetric analysis (TGA) is used to determine the thermodynamic stability of the active material used. Thermodynamic stability is a measurement of how much heat a lubricant can tolerate before decomposition. The ability of a die cast lubricant to release a part and protect the die from solder is directly related to the die lubricant thermodynamic stability. The convention in the industry is to measure die temperatures before and after application of lubricant and use these temperatures as guidelines for product selection. The average die temperatures typically range from (200-600 oF, 93-315 oC). However the die lubricant must provide protection to the die surface when exposed to molten alloy temperatures. In the instance of aluminum alloy the typical temperature range is (1240-1270 oF; 671-687 oC). Depending on the flow of alloy through the dye and cycle time the heat exposure can vary significantly. The thermogravimetric analyzer measures the die lubricants ability to withstand thermodynamic decomposition and provide a protective layer on the die surface. The ideal die lubricant will provide this protective layer and leave minimal residue on the die surface.

FTIR analysis is utilized to determine the approximate composition of a die lubricant. A trained operator can utilize FTIR data to determine a lubricants general components. The component blend of a lubricant used in a particular die casting operation determines what properties the material possesses. While the major desirable properties of a die lubricant, i.e., release and solder resistance can be determined by TGA and solids content. Properties such as, ejector pin lubrication, wetting and wicking characteristics are based on component selection and can be better understood by FTIR analysis.

Visual inspection of the lubricant once water is removed from the sample provides useful information. Combined with FTIR data and TGA visual inspection helps determine wax content of a die lubricant. Visual inspection also provides insight into a lubricants tendency to build on overspray and stain castings. Overspray tendency can be determined by viscosity and tendency to stain by the darkness of the residue. While the visual inspection is subject to human error and tester variation, in general, it is an effective method.

**THERMOGRAVIMETRIC ANALYSIS (TGA)**

TGA analysis is conducted with a PerkinElmer TGA 7 under standard atmosphere from 25 oC to 800 oC at a rate of 20 oC/min. Data is recorded as a function of weight % vs. temperature and all samples are dehydrated before testing. Figure 1 displays two TGA curves of die lubricants. Assuming both products before dehydration are the same solids content, for example 30%, lubricant 1 will outperform lubricant 2 by providing greater solder resistance and release characteristics under the equivalent production environment. Lubricant 1 has overall superior thermodynamic stability and therefore will resist thermal decomposition of the protective layer on the die, this property provides better solder resistance and release.
The FTIR comparison illustrated in Figure 2 depicts two lubricants with very similar formulations. The components selected to make these products are all from very similar chemical families. Typically when conducting an initial production trial it is advantageous to air on the side of caution and choose a formulation with similar chemistries to avoid unforeseen production issues.
SOLIDS CONTENT
Solids content is obtained on a Sartorius Mark 3 Moisture Analyzer MA-Mark-3 at 140°C. A 2.0g sample of a water based die lubricant is run on an aluminum pan equipped with dry filter paper. Solids content reports the amount of active material as a percentage, all non-solids are water. Solids content is necessary to determine the amount of lubricant applied to a die surface at a particular dilution ratio. This information can be used in conjunction with TGA data to determine the starting dilution ratio for a production trial. For example a 30% solids lubricant applied at a dilution ratio of 100:1 with water delivers 0.297% lubricant to the die surface. A 40% solids product diluted to a ratio of 134:1 will deliver equivalent lubricant to the die surface. Assuming the TGA analysis of the materials are equivalent the 40% solids product will be capable of running at a higher dilution ratio and offer the same performance.

VISUAL COMPARISON
A 15g sample of lubricant concentrate is placed on a 3 inch aluminum pan and the water is removed at 140°C. The visual inspection of the dehydrated lubricant provides a general indication of the lubricants tendency to stain castings in a production environment. Visual inspection also provides insight into overspray build on the die surface. If the material is solid and tacky at room temperature the overspray build on the die and machine will be greater compared to a lubricant that is liquid at room temperature. Additionally the uniformity of a multiple component lubricant can be observed with this test. Sample A in Figure 3 illustrates a lubricant with poor component solubility. Sample B in Figure 3 depicts a lubricant where components are soluble due to optimization of surfactant selection and formulation. Uniform coatings allow the lubricant to form a consistent protective layer on the die surface where the components in the formulation share properties. Non uniform coatings components act independently as the components are insoluble with one another.

Figure 3- Photo of two die lubricants.
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COMPARISON OF TWO LUBRICANTS

Below we will compare two die lubricants offered for a production trial to a die caster lubricant A and Lubricant B. The solids content of lubricant A was determined to be 25% active material and 75% water. The solids content of lubricant B was determined to be 35% active material and 65% water. The TGA data from lubricant A and B are depicted below in Figure 4.

For simplicity let’s assume the FTIR analysis and visual comparison are virtually identical. Based on the above testing information it is safe to conclude that lubricant B with 10% higher active content and greater thermodynamic stability will outperform lubricant A by a considerable margin.

Figure 4- Photo of two die lubricants.

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