COPING WITH TEMPERATURE VARIATION ON THE SURFACE OF DIES - SMART POLYMER CHEMISTRY

By Matt Lococo Ph.D, Global Technical Director

Abstract

Overcoming variations in die temperature to provide an evenly distributed protective coating has been a long standing and challenging problem in high pressure die casting. Traditionally the ability of a die casting lubricant to form a protective die coating when exposed to hot areas of the die and not build in cooler less demanding areas could only be achieved with a modified spray application system. The inert nature of die casting lubricant components requires the materials to respond the same regardless of their environment. A lubricant must be chemically reactive to adapt to thermal variations on the die surface. To this end, Quaker Houghton has formulated Smart Polymer technology. Smart Polymer technology is based on thermodynamically reactive (heat activated) polymers. Smart Polymers when exposed to high heat areas of the die polymerize through a crosslinking mechanism. The degree of reactivity is dependent on temperature of the die surface and exposure time. This allows Smart Polymers to offer excellent protection on high temperature challenging areas of the die without excess coating on less demanding low temperature areas.

Introduction

High pressure die casting is a process of forcing molten alloy at high pressure into a die. Common alloys are aluminum, zinc and magnesium. The dies can be very complex and the variation of parts produced is extensive. Due to the wide variation in die design, size and complexity, the flow of alloy through the die and the thermodynamic profile of each system is unique. This leads to temperature variation, hot areas and cold areas on the die surface. Two of the major roles of a die casting lubricant are, protect the die from the molten alloy and provide release of the casting. Therefore the need for a lubricant to be effective in a broad temperature range is preferred.

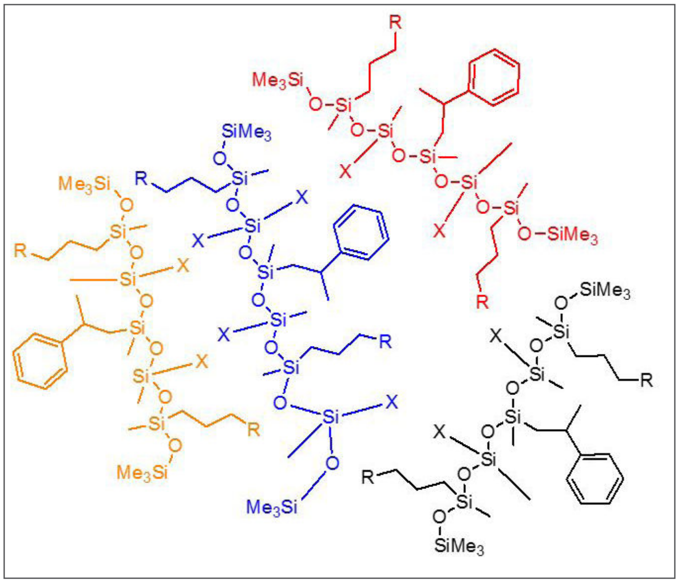
Traditionally die lubricants that are good at protecting hot areas on the die are also likely to build residue in cooler areas. The results are more maintenance and lost production time. This property is a direct result of the lubricants inability to adapt to die temperature variations. Inert blends of wax, oil and silicone polymers can provide an effective coating of the die surface but apply equal protection regardless of temperature variation. The ability of a die lubricant to offer superior protection on high temperature areas of the die while not building excess residue on low temperatures of the die is desired. To accomplish this goal, the lubricant must contain a thermodynamically reactive component.

The reactive sites on the polymer are the key to the function of Smart Polymer chemistry. These reactive functional groups allow for the formation of chemical bonds when exposed to high heat areas of the die surface. When exposed to a low temperature area of the die surface Smart Polymer will remain unreacted and offer standard protection from molten alloys (110-220°C). At medium temperature ranges the polymer will begin to chemically react forming a stronger more heat resistant coating (220-330°C). At die temperatures above 330°C Smart Polymer will react quickly and adhere to the die surface more effectively, providing the best protection and strongest coating (Figure 1).

Figure 1 - Illustration of Crosslinking at low, medium and high heat

X = active site

I = newly formed chemical bond



Low Heat 110-220°C

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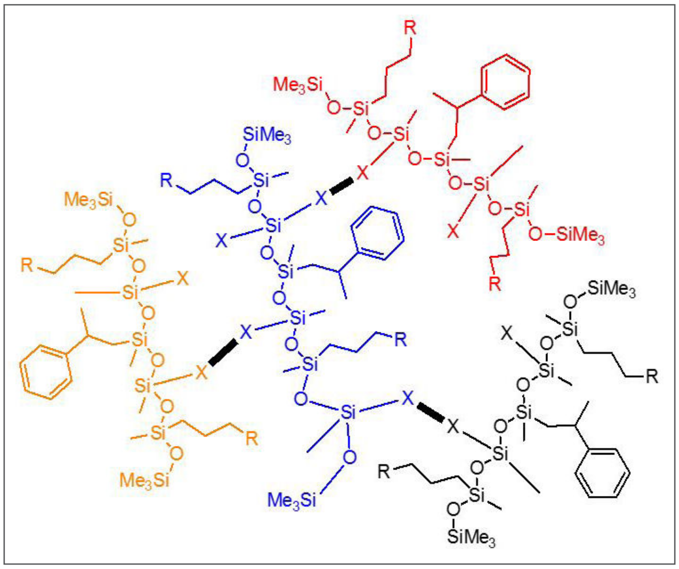
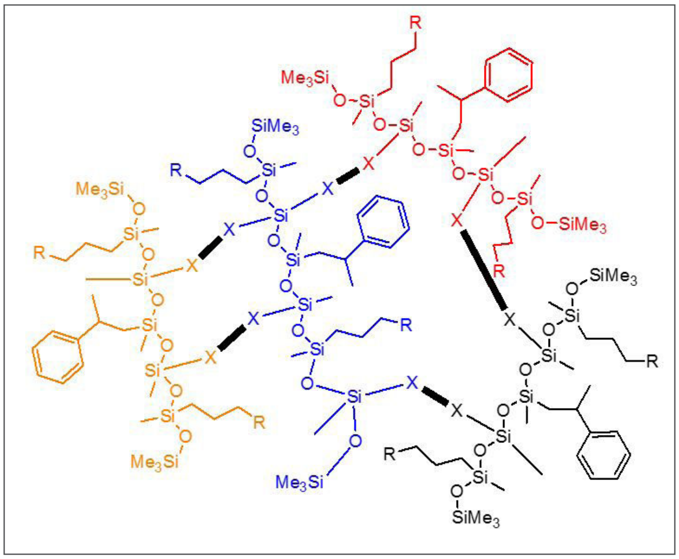


Medium Heat 220-330°C



High Heat > 330°C

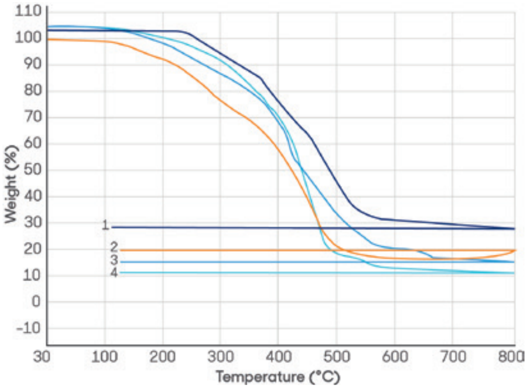
Thermogravimetric Analysis of Siloxane Polymers With Varying Degrees of Reactive Sites

Thermogravimetric analysis (TGA) is a known testing method to determine the thermodynamic stability of materials. A sample is heated at a predetermined rate, starting temperature, end temperature and atmosphere. Laboratory testing illustrated in Figure 2 was conducted on a Perkin Elmer TGA 4000 starting temperature 30°C, rate 20°C/min to 800°C under normal atmosphere. The graph reports weight percentage of neat anhydrous samples vs. temperature, i.e. (Sample 1, Figure 2) retains 100% of starting weight at 200°C and 25% at 800°C.

TGA analysis of modified siloxane polymers with varying numbers of reactive sites is illustrated below. Each siloxane polymer tested is equivalent with the exception of available reactive sites. Reducing the amount of free reactive sites reduces the overall thermodynamic stability above 600°C (Samples 1-4, Figure 2). Polymer 1 with the largest number of reactive sites illustrates the overall improved thermodynamic performance through the entire temperature range.

Polymer 4 shows increased thermal stability vs. polymers 2 and 3 from 30-400°C and then drops rapidly. This observation is unexpected when correlated to number of reactive sites. Polymers 2-3 show similar initial decomposition rates from 30-500°C and then differentiate above 650°C. The differences in thermal stability are attributed to accessibility of active sites and macrostructure of the oligomerized polymers.

Figure 2: TGA Curve



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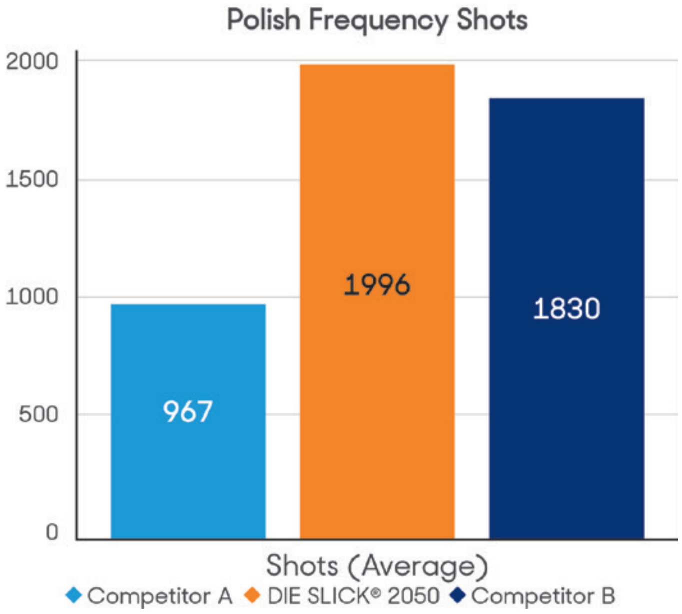
Siloxane polymers with decreasing number of reactive sites 1>2>3>4

The detailed mechanism and availability of access to reactive sites due to steric hindrance and oligomerization of the polymers once crosslinking occurs is not well understood. The variation in TGA performance of polymers (2-4, Figure 2) are associated with this mechanism. Efforts to optimize performance based on greater understanding of the chemical mechanism and active site control is ongoing.

Production Trial with Smart Polymer Technology

A tier 1 automotive supplier was looking for solutions to reduce soldering on castings and die maintenance interval due to excess soldering on the die surface. Castings were a variety of automotive parts some powder coated made from 383 aluminum manufactured on 600-2500 ton Toshiba die casting machines. The customer was running the current production at a lubricant dilution ratio of 60:1 with Competitor A. Competitor B from a second supplier was also undergoing trials at the same customer location at a dilution ratio of 70:1. DIE SLICK® 2050 die lubricant with Smart Polymer technology was recommended and trialed as a replacement lubricant.

Trials were conducted over a six month period using DIE SLICK® 2050 die lubricant at a dilution ratio of 75:1. Customer reported longer interval of uninterrupted casting, increased casting quality and cosmetic appearance (Figure 3). Dies accumulated minimal soldering during the extended cycle using DIE SLICK® 2050 and were easier to maintain (shorter maintenance time). DIE SLICK® 2050 is currently in use at the customer location at an initial cost savings of 20%. Cost savings due to reduced production maintenance and improved casting quality are not yet determined.



Summary

Smart Polymer technology with reactive heat active polymerization has been shown to reduce cycle times, maintenance intervals, soldering and improve overall part quality. The benefits of this new technology have been illustrated in numerous die casting locations globally. As high pressure die casting evolves with new technologies in lubrication application and control, the benefits of Smart Polymer technology will become more evident.