Innovative Wax Design to Meet the Challenges Within the Investment Casting Industry

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Introduction

Wax is a critical component of the investment casting process and as the demands on our industry and the complexity of geometries increase the material is required to adapt and respond to these changes. While for many little has changed over the years in the world of wax, there is also the opportunity through innovative thinking and wax design to both increase current productivity and future opportunities. This paper presents some recent work including the methodology used in designing a dimensionally repeatable material, the paper describes the process of designing a gating wax from first principles. New generation and hybrid materials are considered with a view to designing wax materials to meet the challenges of both today and the challenges we expect to face tomorrow. Further research will explain the direction and the focus of the work for the future.

Wax Composition

Wax is the oldest thermoplastic material known to man, beeswax was utilized in the lost wax process by craftsmen in the ancient civilizations of China & Egypt, today the name wax applies to any substance having wax like properties. To make patterns for early molds many types of materials were used, these materials included beeswax, tallow, resin, tar and though suitable for castings at the time, these would be unsuitable for the demands of modern manufacture. The demands of modern manufacture require complex compounds for today's industry, Modern wax is made up of materials such as paraffin wax, microcrystalline wax, hard wax, resins, polymers, fillers. Many variations are formulated to suit differing requirements with key properties such as melting point, hardness, viscosity, expansion and contraction, setting rate which are all influenced by the structure and composition of the wax compound. The complex composition manifests itself in a physical behaviour different to that of other substances and knowledge of the properties of the individual components and how they interact is essential in understanding the behaviour of wax during the investment casting process

Dimensional Control

The control, predictability and repeatability of dimensions is possibly the single most important factor and characteristic required of a pattern making material. Choice of raw materials have profound effects on the overall behaviour of the wax, for example just two possible materials, resin and fillers can affect the overall material dimensions and repeatability, the viscosity and fluidity, the expansion and contraction characteristics, the mechanical properties. With so many variables, wax design is both highly skilled and possibly time consuming. Wax dimensional aspects as we know are also affected by injection parameters, for example the control of temperature and the injection time, but also aspects such as deformation on removal from the die. Post injection creep which is commonly known as wax memory is another theory to be considered.

Gating Wax

When we consider the theory of dewax the perfect scenario would be when the shell and wax work in harmony, the wax is able to melt and flow into the shell before any failure occurs. The alternate scenario sees the brittle shell not having enough strength to withstand the forces exerted by the wax as it expands during the melt process. Shell cracking is a challenge faced with the industry and as with many problems determining the root cause is often difficult. When designing a gating wax there are several factors to consider, first of all it is not possible to reliably engineer a wax for a poor and variable shell system, likewise it not reliable to engineer a wax for poor equipment. When engineering a gating wax from first principles several aspects need to be considered, including wax melting variables, any difference required in melting points, wax expansion, energy demands, DSC criteria, specific heat capacity, flow properties post melting and mechanical aspects. Typical additives to help reduce the melting point of gating wax might be paraffin or microcrystalline wax, however despite having similar raw material feedstock their properties are very different. If we compared a paraffin and microcrystalline wax with similar congealing points the microcrystalline wax would appear to be the best option but would make the runner wax more ductile. Looking at the TMA and DSC analysis of the two materials up to the melting point the rate of expansion and amount of expansion are similar but analysis suggests that the microcrystalline wax begins to expand earlier and set later.

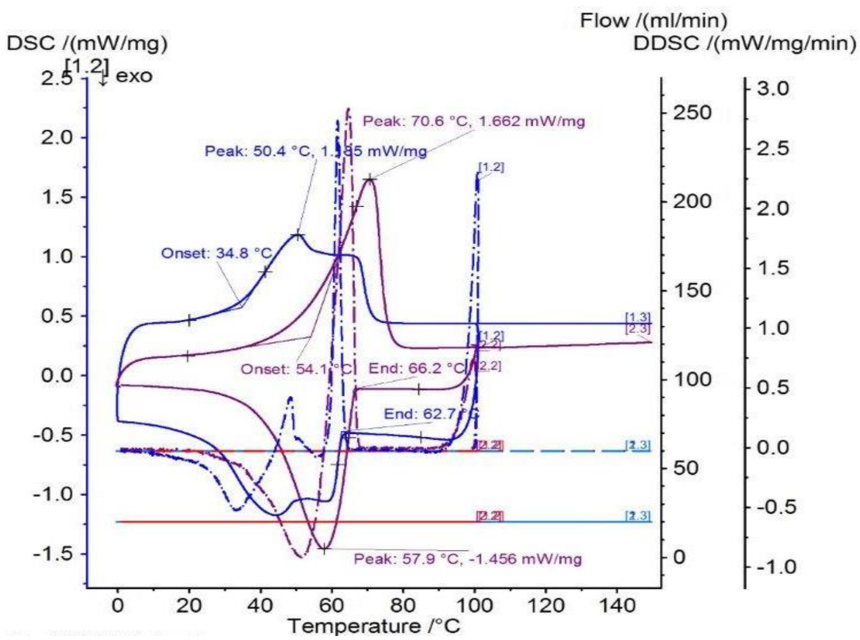

Figure 1

When considering the melt characteristics research suggests that a key variable is the ability of the material to flow through the prime coat post melting. The theory being that the material must flow through the shell material fast enough to reduce any pressure exerted during expansion. TMA and DSC provide an indication of how a material might absorb energy during the melt process and what it might do with that energy.

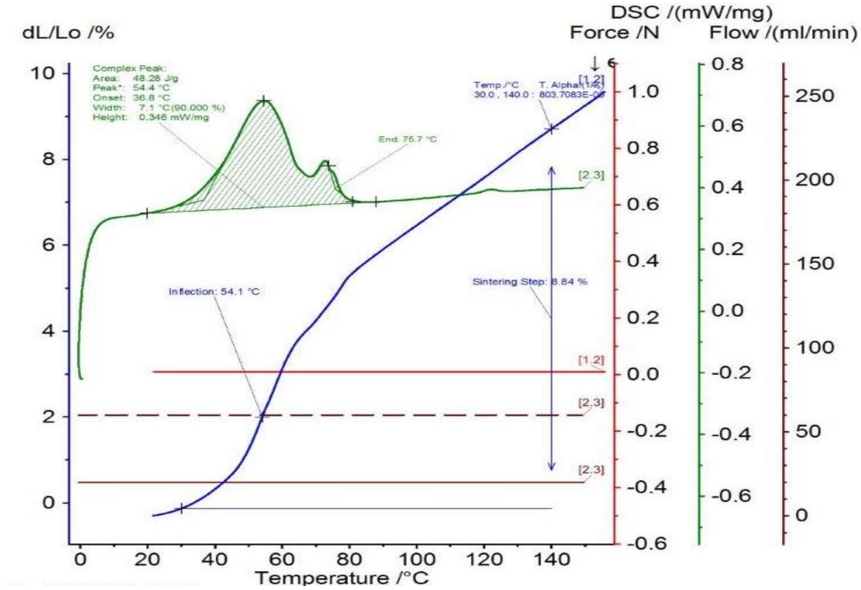

Figure 2

But what about flow? The challenge here is that no test existed to characterise how a wax flowed post melting. Certainly, viscosity would play a part, but the viscosity will change as the material temperature increases Initial trials involved use of a viscosity cup held at a fixed temperature and measuring weight loss versus wax temperature. This simple test gave way to a mechanised version using flow measured with a time lapse camera. Taking this approach further allows us to evaluate how raw materials behave. An understanding of this would allow design improvements. This approach also allows the development of alternative material sources and suppliers. Fillers for example, are supplied to a particle distribution range, the challenge is understanding how this variability might affect areas such as dewax and flow during dewax. Customer trials have shown that filler particle distribution can be used to design materials to help a customer reduce shell cracking.

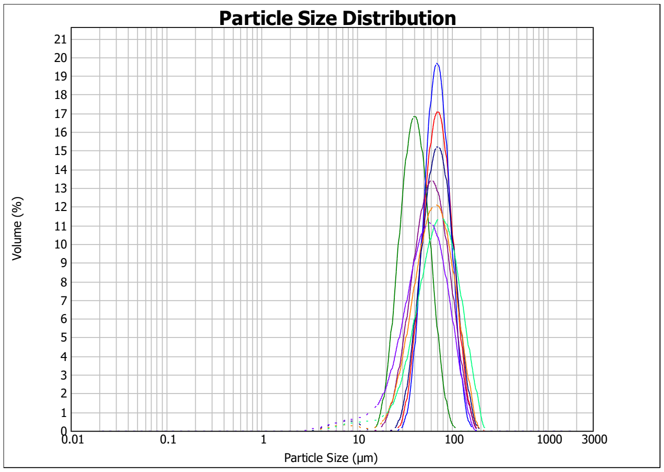

Figure 3

In summary, development of tests to evaluate the full range of wax melting properties is possible and the impact of raw materials on these properties can be analysed. This provides the ability to use this knowledge in the design of virgin wax materials, reconstituted runner wax to virgin repeatability and reclaim runner wax.

New Generation Wax

The initial request from a customer was for a material with improved fluidity characteristics to overcome non-fill issues, more detailed requirements included improved dimensional repeatability, good flow characteristics, fast set rates and the ability to utilise laser measurement of wax dimensions. One challenge is how to measure fluidity, traditional methods rely on viscosity, but this is dependent upon test equipment and conditions, rheology gives a more detailed picture but requires skill to interpret. The introduction of spiral injection test is a simple process-based procedure which provides accurate injection fluidity data. Analysis suggested that by manipulation of type and percentage of filler we could affect both fluidity and dimensional repeatability. Using this approach also allowed us to gain some insight into the effect of filler combinations on other areas of interest for example, mechanical, dewax properties and fluidity aspects. Two challenges faced were how to measure the effects of the action of removing a part from a die and how to give a reflection of wax set rate during injection. The work outlined led to the development of wax materials for turbo wheel and aerospace blade manufacture which are high filled for dimensional repeatability, very fluid and with improved set rates for productivity gains.

Further Research

Further research taking place includes looking at the relationship between forces exerted during the injection process, dimensional repeatability and injection parameters, specifically to understand the forces exerted on cores both during and after injection.

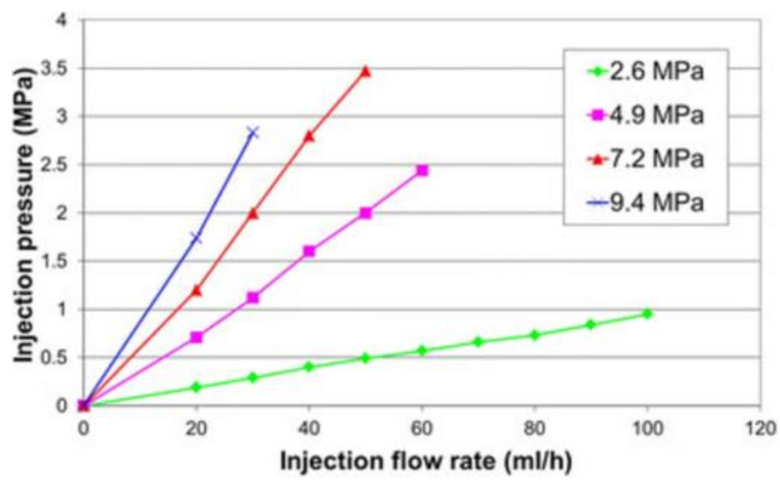

Figure 4

Summary

In design and selection of a wax material there are many competing factors which need to be considered, this paper has attempted to provide a small insight into the challenges and some unique solutions that were adopted to overcome these challenges. The design of any material is a two-way process involving not just the manufacturer but critical feedback from the customer and it is essential that foundries and suppliers work together to ensure the best possible wax performance to overcome both the challenges of today and the challenges that our industry will face tomorrow.