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Update on Investment Casting Wax

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Blayson Olefines Ltd
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UPDATE ON INVESTMENT CASTING WAX

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Introduction

What I shall endeavour to do in the paper is to have a look at how investment casting wax has developed, with a brief update on structure, properties and categories of casting wax available. Then I would like to express a view on the direction wax may follow in the future.

Brief history and structure of investment casting wax

Wax is the oldest thermoplastic material known to man and because it can be cast or formed while in liquid, semi-liquid or plastic state, its history has been closely linked with the arts and crafts and the growth of the investment casting industry. In early times craftsmen of China and Egypt used the lost wax process but the name wax referred only to beeswax. However, today in the investment casting industry, the name applies to any substance having a wax-like property.

Modern blends of investment casting waxes are complex compounds containing numerous components such as natural hydrocarbon waxes, natural ester waxes, synthetic waxes, natural and synthetic resins, organic filler materials and water. Many variations of such compounds have been formulated to suit various requirements; properties such as melting point, hardness, viscosity, expansion/contraction, setting rate etc. are of course all influenced by the structure and composition of any wax compound. When we are dealing with hydrocarbon waxes, natural ester waxes, many of the synthetic waxes and some of the resins used we are usually dealing with compounds of straight chained carbon atoms. However, some of the resins and filler materials used could also be ring structured carbon atoms.

Generally the shorter these chains are the lower the melting point of the waxes and the less their hardness is. With increasing chain length, both hardness and melting point or congealing point rise. The chain length will also influence viscosity and solubility of the wax.

This condition that casting waxes are a mixture of a large number of components of different chain length results in waxes manifesting a physical behaviour different from other substances. They do not melt immediately on heating like homogeneous chemical components but pass through an intermediate state. This is illustrated in Figure 1.

As seen from the shape of the curve, with gradual heating of waxes of an initially solid consistency become softer than plastic and with further heating semi plastic. At higher temperature they acquire the consistency of a thick liquid (semi liquid) finally passing on complete melting to a Newtonian liquid. It is worth mentioning here that filled waxes are not true Newtonian liquids but would usually still show a behaviour similar to the one depicted by the curve. This gradual change in the overall state occurs since short chain fractions melt first while longer chains remain solid. With further increase in temperature the latter melt progressively until the liquid state is reached. The actual shape of the curve and the temperature range of each phase is naturally a reflection of the specific make up of the blend.

Figure 1. Hardness of a typical wax against temperature

Figure 2. Expansion against temperature

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Of course in cooling the reverse takes place and will occur, again according to the make up of the blend, over a longer or shorter temperature range giving rise to a range of setting rates.

Structure or components of a casting wax will also affect expansion/contraction. Waxes expand like other materials under the influence of heat and when they cool they contract. In comparison with a metal the expansion of a wax is relatively high. In waxes the expansion and contraction rates over a rough range between 20°C and melting point are not uniform per degree centigrade but change in the temperature range as a function of their structure.

It may be useful to demonstrate this briefly by showing some basic (typical) expansion curves for the following three types of materials: a homogeneous crystalline organic substance, a wax and an uncrystalline resin (see Figure 2).

The crystalline substance behaves like any solid and undergoes relatively little expansion. At its melting point, the crystalline structure suddenly breaks down and a sudden transition into the liquid state occurs which is characterised by a sudden increase in expansion. In the liquid state the expansion is again small.

In wax the short chain fractions become soft even at low temperature, giving a gradual rise in the expansion curve. In the case of the higher molecular weight, crystalline fractions, the curve assumes a steeper increase and then rises slowly again on the transition to the liquid state.

The uncrystalline resin behaves differently. It has a uniform pattern of expansion from start of heating to the liquid state. No sharp increase in expansion occurs since no crystalline elements are present. Hence the addition of certain resins to waxes can reduce the crystalline structure and help to reduce this expansion/contraction capacity.

In this brief look at structure we have a simplified view of how or why numerous components are added to a blend and the properties that result. We can now move on to consider the investment casting waxes available and how these are categorised.

UUURough categorisation of casting wax

For ease of reference, casting waxes can be divided into the following categories:

- Pattern waxes
- Runner waxes
- Water soluble waxes
- Other special waxes – including dipping, patching and adhesive (sticky waxes). Mention should also be made of reclaim waxes.

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Pattern waxes can be further divided into the following three main areas: -

- Straight or unfilled pattern waxes
- Emulsified pattern waxes
- Filled pattern waxes

Straight or unfilled pattern waxes. These are in effect complex compounds of many waxes and resins. When using a straight wax there is sometimes a greater tendency for cavitations to occur. However with the use of chills to overcome this cavitation on any heavy sections they are used by numerous foundries. The surface finish of straight waxes would normally be shiny and of course reclaiming is straightforward for runners or patterns.

Emulsified pattern waxes. These have similar base materials to the straight waxes but are emulsified with water normally between 7-12%. The surface finish is extremely smooth and because the water acts partially as a filler, less cavitation take place. Handling of emulsified waxes is quite simple providing the foundry keeps to the guidelines laid down by the supplier. They have become extensively used due to their versatility and ease of reclaiming for runners or patterns.

Filled pattern waxes. Here again the base materials are similar to those of the other two categories but into the compound is blended a powdered, inert filler material, insoluble in the base wax, to give the compound greater stability and less cavitation. It is essential that the filler used is organic to ensure complete burnout leaving no ash and there are a number of different filler materials used. It is also critical to use a fine particle sized filler so that surface finish is not impaired and to have the specific gravity of the filler as near as possible to the base wax to ensure minimum separation takes place when the wax is liquid. Here again they are widely used and can be reclaimed for runners and patterns.

Having briefly considered structure and categorisation now let’s move on to consider general properties of investment casting wax.

General properties that influence the quality of investment casting wax

As explained before, the majority of investment casting waxes are complex compounds of numerous components. Each component has been included to influence the final properties of the compound in some way. These properties of the wax are obviously of critical importance to the foundry in the production of good castings. Once a specification for a casting wax has been agreed between the wax manufacturer and foundry it is essential that the material is manufactured, tested and supplied within these limits. In looking at general properties of casting waxes it may be useful for both foundry and wax manufacturer to consider a series of points that affect the quality of a casting wax and hence pattern production. As the industry moves forward so even more emphasis will be placed on understanding the control of these points or properties.

These points may be listed as

1) Contraction and cavitation

2) Congealing point or melting point
3) Ash content
4) Hardness and elasticity
5) Viscosity
6) Good surface finish
7) Setting rate
8) Oxidation stability
9) Reclaimability
10) Any others

Stable results on contraction and cavitation of a casting wax are of course extremely important to the foundry. Once a foundry has decided on a particular wax compound it is essential that the contraction/cavitation rate is maintained.

We have considered how structure influences the congealing point or melting point of a casting wax. In turn they have a major influence on the required injection temperature of the wax. With the knowledge of either temperature the correct wax conditioning and injection machine temperatures can be set.

Most foundries would be aware of the importance of using and maintaining a wax with low ash content and of the detrimental effect of ash. The limit recommended by BICTA is 0.05% maximum.

We have discussed how structure can affect hardness of a wax. It is necessary that the wax has sufficient hardness and elasticity to help reduce the possibility of rejects due to breakages, bending or other undesirable phenomena during the subsequent processing of the wax pattern.

A knowledge of the viscosity of a casting wax compound is critical to a successful pattern production. Where large fine sections need to be produced then often a low viscosity wax is required to enable the wax to penetrate into the finest spaces in the die. For heavier sections a less fluid wax may be preferred. If a wax with the incorrect viscosity was used for a particular application then the flowability of the wax into the die will be wrong.

Again good surface finish is an important property for successful pattern production. It almost goes without saying that a poor quality wax pattern surface will give the same poor quality to the resultant casting.

The foundry must have a knowledge of the setting rate of a wax in order to successfully produce wax patterns and we discussed how different structures or components give different setting rates. On one extreme foundries are producing parts where they require a very fast set and release from the die, whereas on the other extreme a slower setting wax is an advantage.

Stability of the wax compound is a property worth consideration. Here one is thinking in terms of the ability of the compound to resist oxidation or breakdown of certain of its components due to the action of heat or simply ageing. Some components have a greater tendency to oxidise than others and it is necessary for the manufacturer to use antioxidant materials where this could occur.

The reclaimability of a wax should be considered important from both an ecological and economical standpoint. The method of reclamation used would be similar for all three major categories of pattern waxes mentioned previously with some slight variations, but the most important aspect for foundries to consider regarding reclaiming, is what they decide to use the reclaim wax for – runner bars or both runner bars and patterns. While stating it is possible to reclaim all three categories of wax, strict quality control over the process is recommended. If this is carried out then reclaim material can be widely used.

No doubt there are other properties that could be considered. For example the fact that such compounds should be non-toxic is obvious. We have not discussed water-soluble waxes where properties are somewhat different. However the items considered should cover the majority of general properties required of an investment casting wax and how these can affect quality of the wax and wax pattern production. They complete the updated situation. It is the emphasis that foundries and wax manufacturers place on these properties linked with quality control and commercial considerations that will determine how compounds develop in the future.

A look at possible future trends

It is generally accepted that in the future the industry will become more sophisticated and therefore wax and its quality control will increase in its sophistication also. The balancing factor will be cost as there is obviously a limit to what foundries will pay for a wax depending on its application. I am sure it would be inevitable that if we asked a question of what a foundry wants from a wax in the future, the majority would reply, a low price, high quality material that can be reclaimed. In other words no real change from the past or present. In a competitive world it would be good to think wax manufacturers could to achieve this. However I believe the reality of the situation is that with increased emphasis on understanding properties, quality and quality control a compromise must be made on cost, depending largely on the nature of the casting to be produced, the process used and the market the foundry is operating in. Let us list some of the major points that could develop in the future. There are no doubt more but listing these at least highlights to the industry the need for foundries and suppliers to continuously discuss such areas to enable the industry to move forward.

Points that could influence casting wax in the future: -

1) Quality control of investment casting wax
2) The choice of wax and how to change wax
3) Materials for the future
4) Reclamation of wax
5) Cost

1)
As the industry has developed so the importance of quality control of all materials has grown. With further future development it would seem essential even greater emphasis is placed on quality control of wax. We have discussed how important general properties of a wax are to wax pattern production and therefore we can say it is equally important for both manufacturer and foundry to monitor these properties by a strict quality control procedure.

2)
In the past it was invariably the case that once a foundry had chosen to use a particular grade of pattern wax they would tend to always use that wax. No one should advocate that a foundry changes its wax for the sake of changing. There must be fundamentally sound reasons for wanting to change e.g. superior quality and quality control, increased production from a quicker setting wax, less cavitation, lower price, service of supplier, new injection machines with different injection criteria etc. It has always been a difficult decision to change wax, but now with a better understanding of materials and a close liaison between supplier and foundry, it is possible for the supplier to develop wax compounds to a foundry’s specific requirements and in the majority of cases submit a wax that meets these requirements providing they are not too demanding.

3)
There are from time to time discussions about alternative materials to wax. Polystyrene and expanded polystyrene are used as pattern materials, urea is used and there is the process of the totally injected shell. As discussed earlier in the paper, casting waxes are complex compounds of many different components. Wax is a loose definition of their form as they are basically chemical compounds and it would be difficult to see other materials totally replacing these, as again they would only be chemicals or blends of chemicals themselves. It would seem more logical to suggest that as the industry moves forward so wax manufacturers will continue to work with foundries and continue to expand on their existing knowledge to produce further wax type-materials to suit specific requirements.

4)
We have already discussed how important reclaiming is at present. And undoubtedly this will continue into the future. With improved technology and greater quality control over the total wax system many materials can be reclaimed and reconstituted for both runner wax and pattern wax. However it is important for the foundry to work closely with the wax supplier in order to be certain that the reclaimed or reconstituted wax they receive back is their own material and is not contaminated in any way with other materials. They should expect the material to be batched, tested and returned with an adequate test report. With such close liaison between manufacturer and foundry coupled with a greater understanding of reclaim technology, the concept of greater wax reclamation and reconstitution should become increasingly important as the industry moves forward.

5)
Cost or price of a wax is of course important to any foundry. It must be an area to consider in conjunction with all technical requirements of the wax and something that supplier and foundry will always monitor in the future.

Conclusion

I hope this paper has achieved the aim of giving an updated view of the situation regarding investment casting wax. I also hope it provides some thought on factors that could influence wax within the industry in the future.

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