Blayson

Waxes for Investment Casting-A view from England

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Blayson Olefines Ltd
Investment Casting Wax

WAXES FOR INVESTMENT CASTING – A VIEW FROM ENGLAND

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By R.B.Williams, Blayson Olefines Ltd

In my opinion wax and it's properties are regarded with some mystique by a number of foundrymen, and whilst I do not plan to unravel the secrecy of formulae etc, I do hope my lecture can give a clear view of investment casting waxes in England, some of their associated technology and the industry in which they are used. In doing this I plan to divide the lecture into the following sections and emphasise that in each case I am referring to the situation in Britain.

1. Resume of the British Investment Casting Trade Association
2. Brief Outline of the Investment Casting Industry in Britain
3. Rough Categorisation of Investment Casting Waxes
4. Reclamation of Investment Casting Waxes
5. Quality Control of Investment Casting Waxes
6. The Choice of Wax and Changing Wax
7. Wax Pattern Production and the Monitoring of Faults

1. Resume of The British Investment Casting Trade Association (BICTA)

The British Investment Casting Trade Association (BICTA) was formed in 1958 by the coming together of a small nucleus of investment casting foundries interested in the development of the industry and its technology. There has been continued growth of membership so that BICTA has over sixty foundry members throughout the World.

Early membership was restricted to only producers of investment castings but the benefits of close liaison with materials and equipment suppliers were soon realised and such companies were accepted into the Association. Total membership now approaches 100 companies and as a wax manufacturing company, and hence supplier to the industry, we are graded as an Associate member of BICTA.

Originally conceived as a Technical Association, BICTA gained a high reputation through a number of its committee projects and publications. After re-location to its new Birmingham, England premises, the Association was able to extend its scope to include important aspects of trade and promotional activities on behalf of the industry.

The Association has steadily added to its collection of Conference proceedings and technical papers throughout the world, so that it can now offer a comprehensive library service to members and non-members alike. Most of BICTA's publications come from the work of its technical committees and working groups, although more recently the proceedings of seminars have provided valuable information.

With further seminars, conferences and meetings etc together with collaborative research projects between BICTA, its member companies and other research and trade bodies, it aims to keep abreast of all developments within the industry.

2. Brief Outline of The Investment Casting Industry in Britain

Within Britain there are somewhere over 60 investment casting foundries and these obviously slot into various categories in size. As in the USA, there is a wide range of metals cast and the nature of the castings produced transcends a broad range of industries. The British Investment Casting Industry has much the same broad base as the industry in the USA, i.e. from sophisticated aerospace parts and turbine blades etc right through to many commercial castings. This broad base also highlights the variety of metals that are cast.

Owing to the fact there is not a total membership of British foundries within BICTA, it is difficult to give an accurate figure for turnover of castings. However, as a guide, it could be currently estimated at £200,000,000/year (or U.S $330,000,000/year).

3. Rough Categorisation of Investment Casting Waxes

Before categorising investment casting waxes, it is worth considering some basic questions: -

What is a wax?

Why do we use wax?

Why are there so many different types of wax?

Wax is the oldest thermoplastic material known to man and because it can be cast or formed while in a liquid, semi-liquid or plastic state, its history has been closely linked with the development of arts and craft and the growth of the industry. In early times the craftsmen of China and Egypt used the lost wax process but the name wax referred only to beeswax. However, today the name, especially in the investment casting industry, is applied to any substance having a wax-like property. Hence modern blends of pattern waxes are compounds containing numerous components such as natural hydrocarbon waxes, natural ester waxes, synthetic waxes, natural synthetic resins, organic filler materials and water. Many variations of such compounds have been formulated to suit various requirements.

We can now move on to examine the pattern waxes currently used in Britain more closely and these can be divided into 3 rough categories: -

1. Straight or unfilled pattern waxes
2. Emulsified pattern waxes
3. Filled pattern waxes

Straight or unfilled pattern waxes

These waxes are in effect complex compounds of many waxes and many resins. When using a straight wax however, cavitation can occur on solid sections whatever the specification of the grade used and chills are sometimes used in a number of patterns to overcome this cavitation. However, having said this, straight waxes are used by numerous foundries.

Emulsified pattern waxes

A number of foundries prefer emulsified waxes. These have similar base materials to the straight waxes, but are emulsified with water. The surface finish is extremely smooth and because the water acts partially as a filler, less cavitation takes place.

Some foundries use emulsified wax for all their work and have found this type of material suitable for producing numerous parts, ranging from small blades ½ inch in length to solid impellers some 20 inches in diameter, with satisfaction.

Handling of emulsified wax is quite simple providing the user keeps to the following guidelines laid down by the supplier: -

a) Critical temperature control of the wax at melting and holding to avoid water loss. The melting temperature should not exceed 85°C and the holding temperature must be controlled below 80°C. Should the temperature exceed these limits, the water will gradually evaporate and the properties of the wax will change.

b) Condensation on cold surfaces such as the covers on melters and machine reservoirs should be avoided to stop water dripping back onto the wax surface.

c) Use of a straight wax for the runner system is necessary to avoid spitting of wax particles during the mounting stage.

Filled pattern waxes

These are also preferred by some foundries. Here again the base materials are similar to those of the other two categories, but into the compound is blended a powdered filler material insoluble in the base wax. It is essential 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 that of the wax base to ensure that minimum separation takes place when the wax is liquid.

The advantage of filled waxes is that little or no cavitation should take place even on heavy sections and such waxes will give greater stability to large, especially thin walled patterns. Again, handling is quite simple providing the user keeps to the guidelines for avoiding filler powder separation.

Having briefly outlined the categories of pattern waxes used in Britain today, it is just worth mentioning the other grades of waxes that are used in the industry. They are: - Water Soluble, Runner, Dipping, Patching and Adhesive (Sticky) Waxes and their applications are self explanatory. A further category of casting wax in Britain is reclaim wax. This important area concerns the majority of foundries and to emphasise this importance it is highlighted separately in the next section.

4. Reclamation of Investment Casting Waxes

For a considerable period of time, the reclamation of autoclaved wax has been an important area of consideration for British Investment Casting foundries, not only from an ecological point of view but also from an economical one. The majority of investment casting foundries in Britain today would be either reclaiming wax 'in house' or a wax manufacturing company would be carrying this out for them. The greater tendency is for the material to be returned to the supplier for reclaiming.

The method of reclamation used would be similar for the three major categories of pattern waxes mentioned previously with some variations, but the most important aspect for the foundries to consider, regarding reclaiming, is what they decide to use the reclaim wax for – runner bars or both runner bars and patterns. The majority of foundries have autoclave dewaxing facilities so we can base our thoughts on this.

For foundries using straight or unfilled waxes, reclaiming to eliminate water and filter out extraneous particles is a straightforward process. The resultant reclaimed wax should make an ideal runner wax, although sometimes it may be necessary to make additives to increase strength, increase fluidity and decrease melting point. However, if a foundry were to consider using this for pattern production, recommendations on additives are preferably blending with virgin wax would be made by the supplier.

For foundries using emulsified waxes, again the process is similar to that mentioned previously. The resultant reclaimed wax free from water should make an ideal runner wax with any additions necessary, but again if a foundry were to consider using this for pattern production, consultation with the supplier must take place so that correct re-emulsification, additives and blending with new material can be made.

Where foundries are using a filled wax, the autoclaved wax is again reclaimed in a similar way, although the separation of a filler material does lengthen the process and in the case of highly filled waxes, results in a lower yield. The reclaimed wax is again ideal for runner wax but rarely would this be considered suitable for pattern production again.

As indicated it is possible to reclaim all three categories of wax but strict quality control over the process is recommended. One major example is to check the ash content of the reclaimed material and to look at ways on how this can be reduced further.

It is advisable to ensure that only one grade of wax, pattern and reclaimed runner, is run out of the autoclave to avoid unnecessary contamination. It is also important to minimise contact with metal oxides (corroded parts), which cause metal to combine in solution with the wax, giving high ash value. It is important to test the penetration (hardness) of the reclaimed wax. Autoclaving and hence heating of wax causes breakdown in the structure of the compound, often giving a change in property. For example, the reclaim wax could become more brittle and more susceptible to dimensional variation.

It is because of these points along with others that control of reclaim wax is so important for both runners and patterns. To summarize the situation, some foundries have their reclaim wax reconstituted for pattern production but it would normally be those producing commercial parts. The majority use reclaim for runner systems only.

5. Quality Control of Investment Casting Waxes

The quality control of pattern waxes is extremely important to both customer and manufacturer. For the customer it ensures that the material purchased is within the specification issued by the manufacturer and therefore will produce patterns equally as good as those produced from the previous batch of material supplied. For the manufacturer, it will ensure that the material is within specification

If problems are encountered by the customer, then they are more likely to be due to other reasons and a discussion between the two parties should help solve these.

When a foundry produces wax patterns it will usually do so against set machine and die parameters for specific patterns.

E.g. Wax temperature in injection machine
Nozzle temperature
Die and/or platen temperature
Injection pressure
Flow control
Injection and hold time etc

If there is a variation in material specification, such as congealing point, penetration or viscosity and the customer has not been informed, then a considerable amount of time can be wasted producing reject patterns before the machine variables are adjusted satisfactorily.

Most associations/institutes would issue their own recommended test methods. They are sometimes varies by individual manufacturing companies, but as long as customer and manufacturer are looking at the same test methods, this is not critical.

The tests laid down by BICTA are: -

1. Melting Point (Drop Point)

2. Congealing Point

3. Ash Content

4. Penetration

5. Viscosity

Melting Point (Drop Point) and Congealing Point

The definition of the melting point is: -

“ The melting point is the temperature at which a drop of the sample detaches itself from the main bulk.”

As the melting point is closely allied to the congealing point test we can deal with them together, but first the definition: -

“ Congealing point is that temperature at which molten wax, when allowed to cool under prescribed conditions, ceases to flow.”

The results give a variation of temperature but for practical purposes they give a picture of what is happening to the compound. Most important is that for the customer it gives a guide to temperatures required in the injection machine tank and the injection temperature itself, whereas for the manufacturer it is a further check on materials used.

Ash Content

No definition is required for ash content as this is self explanatory. It represents the percentage of non combustible solids contained in the compound, and providing the figure is below the required limit, it is accepted by customer and manufacturer.

Penetration

Penetration is defined as: -

“ The penetration of a wax compound is the distance in tenths of a millimetre that a standard needle penetrates vertically into a sample of the material under fixed condition of loading, time and temperature.”

Penetration of course gives the customer a guide to the hardness of the wax. If the penetration figure has increased but is still within the limit, then the compound is slightly softer, and it may be necessary to increase the hold time in the die to maintain dimensions. If penetration has decreased then the converse applies. For the manufacturer the test is again a further check on materials used.

Viscosity (Kinematic and Dynamic)

The definitions of kinematic and dynamic Viscosity are given as follows: -

“ Kinematic viscosity is a measure of the time for a fixed volume of liquid to flow through a capillary. The unit of KV is the Stokes, which has the dimension centimetres squared per second. In the petroleum industry, kinematic viscosity is usually expressed in Centistoke (cSt) so that 1 St = 100 cSt.”

“ Dynamic viscosity is numerically the product of kinematic viscosity and the density of the liquid,
both at the same temperature. The unit of dynamic viscosity is the Poise – P, which has dimension
grams (1) per centimetre per second.”

For Newtonian fluids, the absolute (dynamic) viscosity is defined as: -
“ A quantitative measure of the tendency of a fluid to resist sheer.”

The results of these tests give the customer a guide to the flowability of the wax, the pressure required to transfer wax from machine to die and the size of the injection channel required to maintain pressure applied. Again for the manufacturer they are a further check on materials used.

Finally, there are a number of other tests sometimes applied to a wax. These include dimensional, volumetric contraction/expansion, linear contraction/expansion, strength, specific gravity etc.

In conclusion and as stressed throughout this section, the testing and quality control of wax compounds is of paramount importance to successful wax pattern production.

6. The Choice of Wax and Changing Wax

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. This was to avoid running the risk of dimensional variation of patterns coupled with just a basic fear of changing. Pattern waxes have been chosen by foundries for numerous different reasons e.g. historical, the only suitable compound at the time, recommendation or copy of another foundry etc.

I am not advocating that a foundry changes its wax for the sake of changing. There are many foundries happy with their wax. 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. These are just a few of the reasons as certainly the list must be longer.

As mentioned previously it has always been a difficult decision for a foundry to change wax, but now with a better understanding of materials and a close liaison between foundry and supplier, the process is easier. It is possible for the supplier to develop wax compounds with a foundry’s specific requirements in mind and the majority of cases submit a wax that meets these requirements providing such requirements are not regarded as too demanding.

For example, a particular foundry purchased a new automatic wax injection machine. In the remainder of their plant they used a heavily neutral filled wax on hydraulic injection machines very successfully. However, this wax would not operate successfully on the automatic machine. The pattern would not release easily from the die, it showed signs of pattern cracking and the wax tended to clog the machine. Their requirement was for a wax that would give the correct dimensions, would release easily and quickly from the die, be tough enough to avoid pattern cracking and not 'clog up' the machine. A particular filled and emulsified wax was adapted for their use on the automatic machine and patterns are now produced successfully.

A further example is another foundry that uses emulsified wax to produce a vast range of patterns for aluminium castings. The wax produced all patterns successfully until they obtained a particular new casting job and hence pattern for production. This was a box 300mm x 80mm x 250mm. The wall thickness was approximately 6mm, whereas the six vertical plates were 2mm and 3mm thick. On making the pattern with the original pattern wax, the contraction rate caused slight deformation on the plates. When the foundry used a filled wax with a lower contraction rate this solved the problem and fortunately the larger sized pattern produced was still within their dimensional limits.

A further example is a foundry that used Montan based filled wax. The two major reasons for wanting to change were firstly the high ash content of the wax and its detrimental effect on the mould, secondly they wanted to reclaim wax easily 'in house' for patterns and runner systems. For this they required an unfilled straight wax and a compound was developed that gave the same contraction conditions as the original wax, had a low ash content and could be reclaimed 'in house' for runners and with suitable additions for pattern production.

These examples, whilst not being major revelations, are put forward to help show the reasons why foundries have considered changing a wax and how this is possible by working closely with the wax supplier. Naturally, there are more, but as indicated before, I am not advocating change for the sake of changing and it is also important to consider the numerous faults that can occur during wax pattern production before a foundry contemplates a change.

7. Wax Pattern Production and the Monitoring of Faults

In the previous section the changing from one wax to another was discussed. As indicated, the reasons for changing must be fundamentally sound and if problems with wax pattern production are being encountered, it is very important to consider with the wax supplier a number of fault guidelines before deciding to change wax.

The most common faults encountered during wax injection are as follows: -

1) Flow lines
2) Trapped air
3) Lubricant marks

4) Chill breakthrough

5) Incomplete coverage of chill

6) Surface finish (orange peel effect)

7) Misrun

8) Cavitation

(1) Flow lines are usually associated with

a. Cold die

b. Cold Wax

c. Incorrect injection pressure

d. Incorrect flow rate setting

e. Injecting a thick section through a thin section

(2) Trapped air is usually associated with: -

a. Wax too hot – causing turbulence during injection

b. Flow rate too high – the wax flowing into the die faster than the air escaping through the joints, thus becoming trapped.

c. Air entrapped in the wax in the machine, causing air bubbles to be injected with the wax.

d. Air entrapped in the patching wax when filling in slots in ceramic cores.

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