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Bees in Business
Engineered Waxes
An investment casting outlook
Case Study (Part 2):
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Interviewed by Ian Wallace
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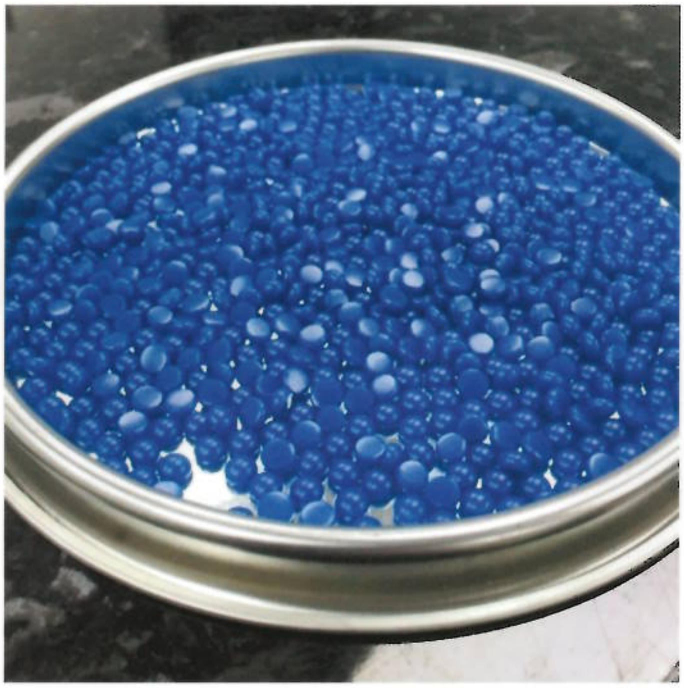
Engineered Waxes

Gavin Dooley PhD, Group Technical Director, Remet UK, with an investment casting outlook



Wax Pastilles ready for wax injection

If you drive a turbocharged diesel car, or fly anywhere in the world today, you are benefiting from investment casting (IC) technology. From engagement rings to medical prostheses, IC has a sizable impact on the world we live in. Based on archaeological evidence, the investment casting process can be dated back to 5000 BC. Traditionally, the IC (or 'lost wax') process was used for the casting of ornamental artefacts. Since World War One, the technology has been developed to cast high-value alloys to near-net shapes which require little machining following casting. The process ensures a superior surface finish that cannot be achieved with other casting processes, along with high metal yield.

The technology is currently used in the aerospace, automotive, energy, commercial, medical and jewellery industries. In 2015, the global market was estimated to be approximately $13 billion.

Photographs and illustrative material supplied by Gavin Dooley, Remet UK

The Precision Investment Casting Process

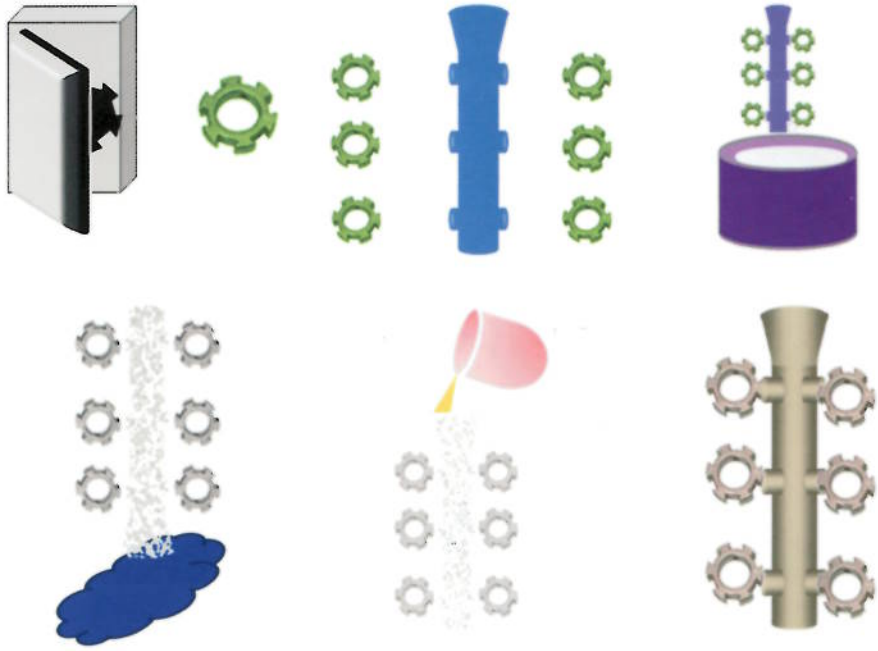
Wax injection is the first stage of the process. Wax pellets are melted in an agitated hopper and then injected into (typically) an aluminium or steel die to create the desired shape. The wax is injected at a temperature of 50–80 °C to produce the pattern. This can be repeated as necessary to produce multiples. When solidified, the wax objects are fixed onto a central wax downsprue using hot plates or glue wax. This wax tree is then 'invested' in a ceramic mould which is built by applying successive layers of ceramic material onto the wax tree and allowing each layer to dry, until the required thickness is met.

Following this, the wax is melted or burnt out to leave a void in its original shape. De-waxing can be achieved using a high-pressure steam autoclave or flash firing. Autoclave de-waxing allows the wax to be collected, reclaimed and reprocessed. Following de-wax, the ceramic shell is fired and sintered in temperatures exceeding 1000 °C. It is then ready for use as a mould. Subsequently, metal is melted, poured into the mould and cooled. Following cooling, the shell is removed and the parts are detached from the metal tree. Further finishing operations include fettling, dimensional and X-ray inspection.

Investment Casting Waxes: An Engineered Material

An investment casting wax blend is made up with paraffins, microcrystalline wax, resins, synthetic and natural waxes. During investment casting processes, dimensions alter as the part proceeds through the process because of wax and metal shrinkage. Therefore, there is a requirement for the wax properties to be defined and replicable. This requirement for high dimensional repeatability has led to fillers being used within the waxes to reduce shrinkage. These fillers are typically made of crosslinked polystyrene (XLPS), acid, water or bisphenol A and typically make up 20–40 per cent of the overall blend. XLPS is most commonly used within the European Union (EU) because of the reduced environmental impact. Fillers are expensive, cannot be recycled and act as a viscosity modifier so, in recent years, work has begun to reduce their use in wax blends.

The precision investment casting process



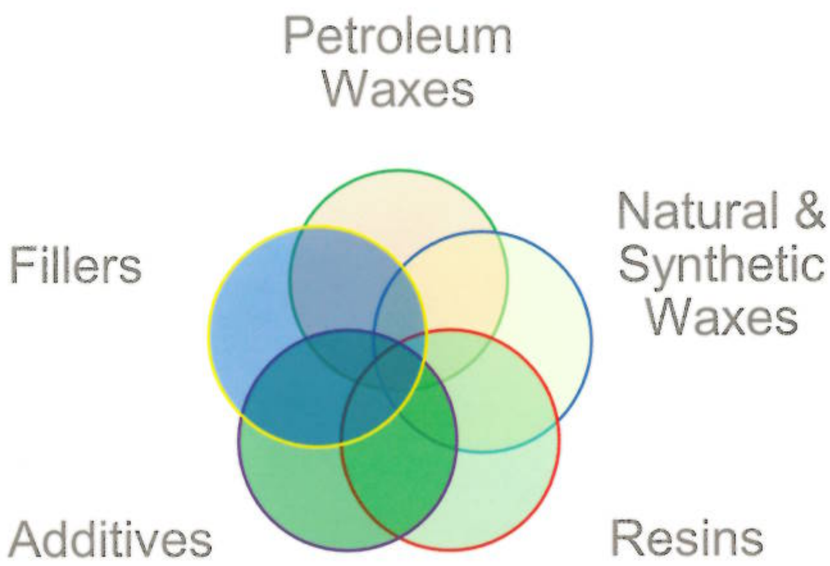
Controlling Wax Properties

The properties of investment casting waxes are tested to ensure the product performs as required. Tests include the following:

- **penetration testing:** these tests drop a needle from a defined height onto the wax and assess its penetration into the wax. This ensures the product has the correct hardness or softness for the required application
- **strength testing:** this test ensures there is sufficient strength, ductility or stiffness within the material to maintain shape during processing
- **congealing and melt point:** these properties are important to understand for the injection and de-waxing process. Knowing when the wax becomes molten or starts to flow is essential to understanding how it will perform within the process
- **viscosity testing:** this assesses how the wax will flow during injection. Out-of-specification viscosity can cause flow lines and defects which result in wax and metal scrap
- **ash content:** the amount of ash within the wax must be kept as low as possible. If ash is present following wax burnout, it will cause metal defects and scrap
- **volumetric expansion:** the expansion of the wax during the solid to liquid phase is essential to understand if the wax may cause issues during de-wax
- **dimensional testing:** understanding the shrinkage of the wax is essential in relation to the dimension tolerances
- **filler content:** in line with dimensional control, knowing the amount of filler present within the wax will ensure better control of dimensions and viscosity within the process.

Customers of precision investment casting (PIC) waxes are constantly striving for more control and stability of wax blends. Given the fact that most wax raw materials are derived from natural sources and crude oil production, control of raw materials is key. Paraffins are by-products of stage one crude oil refining. Improved refining techniques are reducing the availability and stability of paraffins for the IC process. With this in mind, a recipe for an engineered wax is not sufficient to maintain stability. Active control of materials is required in order for the properties of the final product (wax) to be better managed. Keeping the range of properties under control ensures the wax will perform for customers as required.

Typical components of PIC engineered waxes



Reclaimed Wax: Reducing the Environmental Impact

The three major waste products (wax, shell and metal) generated during the PIC process can be reused and recycled. Ceramic shell materials can be re-used in landfill or in the production of ceramic bricks. Metal waste is sent for recycling and is reverted back into the process. Wax can be reclaimed for reuse.

Wax reclamation is important within the IC wax industry. The high-pressure autoclave process melts out the wax from the mould and it is collected in a container. The wax is then shipped back to the manufacturer for reclamation. The wax is then de-watered and filtered to remove foreign material. Reclaimed waxes are cheaper but have more variable properties than virgin waxes.

These waxes are sometimes used within a closed-loop system with customers and can be recycled and returned to the customer for use. Such waxes can be reclaimed many times before they need to be disposed of and are a valuable asset to reduce costs and to reduce environmental impact for the customer.

Future Trends

As previously mentioned, fillers are expensive additives within waxes which increase viscosity and can cause issues with wax removal. In addition, they are not recyclable and, therefore, are a source of waste during reclamation. With this in mind, Remet has developed a series of innovative patented formulations, known as the FastForm® wax series, which maintain dimensional stability and eliminate the need to fill waxes. The formulae can be adjusted for different applications.

Additive manufacturing also has the ability to alter the future of the PIC industry. Complex shapes can be printed using wax and then processed through the PIC process. Many 3D printers on the market today use materials which can be de-waxed or burnt out to produce prototypes or complex shapes not possible through standard injection. This reduces the lead time for samples or can allow low-volume production without the need for expensive tooling. Although the additive manufacturing process has many benefits, it is still only utilised on small and low-volume castings to date.

Summary

The precision investment casting process produces high-value parts for the automotive, aerospace, defence, medical and jewellery markets. PIC waxes with known and carefully controlled properties are vital to the process. □

The Dancing Girl of Mohenjo-Daro (4500 BCE), an example of early investment casting

Further Information

For further information, see: www.remet.com/uk

Gavin Dooley recently joined Remet UK as director of technical operations. Having been senior process engineer for a medical device precision investment casting (PIC) process, Gavin has first-hand experience of engineered waxes and their required properties.

Remet UK is a supplier of wax and ceramic consumables to the PIC industry throughout Europe, Asia and Africa. With extensive knowledge in investment casting, the company specialises in novel technology and offers superior customer support to better serve the PIC market worldwide.