Understanding Investment Casting Wax

Keith Batchelor
Operations Director
Blayson Olefines Ltd

February 2020

Blayson

Advantages of Investment Casting

In the traditional casting process, a pattern is made in the shape of the desired part. Simple designs can be made in a single piece or solid pattern. More complex designs are made in two parts, called split patterns. Where the split pattern separates is called the parting line.

The pattern is made of wood, plastic, or metal. the mould material, normally sand resin mix, is poured around the pattern and compacted. The pattern is removed and in the case of a split mould it is reassembled. If the part has an undercut where there is part of the pattern under the mould material, it is impossible to remove the pattern without damaging the mould.

Advantages of Investment Casting

There are some big advantages of using investment casting to get the piece you desire. One such advantage is that it is possible to make more intricate forms—even forms with undercuts, loops and whorls. Also, the casting that is produced has a very smooth surface, which is created without a parting line—something that would be unavoidable in other processes.

Investment casting achieves this by using a pattern that is a solid to produce the mould but changes its state to either liquid or gas for removal

Choices for Pattern Material

As said earlier the pattern must be made from a solid material which changes to a different state to exit the mould but also leaves no residue afterwards. This leaves us with either something that melts to a liquid or sublimes or burns to a gas. We are therefore looking at organic materials as nearly all inorganic materials cannot fulfil that criteria. The material must also be readily available safe and inexpensive

Common pattern materials used are wax or plastics in various forms

Making Patterns

- Patterns are broadly made in three ways
- **Subtraction** - where the pattern is carved or cut from a solid block
- **Addition** - where the pattern is built up layer by layer. For example, wax printing
- **Moulded** - where a material is poured or injected into a mould or die and then removed
- The patterns can also be made of a combination of these processes

Brief History

- 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

Brief History

- In order to make patterns for early moulds many types of materials were used
- These materials included beeswax, tallow, resin, tar
- Though suitable for castings at the time, these would be unsuitable for the demands of modern manufacture

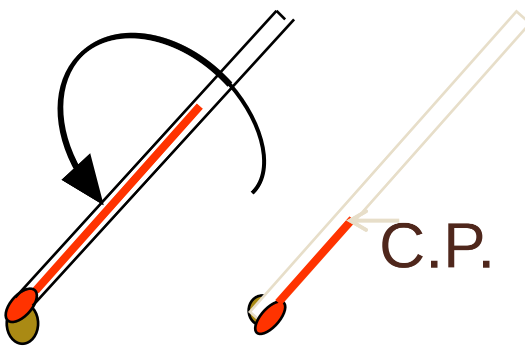
Modern Materials

- 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

Structure of Investment Casting Wax

- Many variations are formulated to suit differing requirements
- Key properties such as melting point, hardness, viscosity, expansion and contraction, setting rate 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
- 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

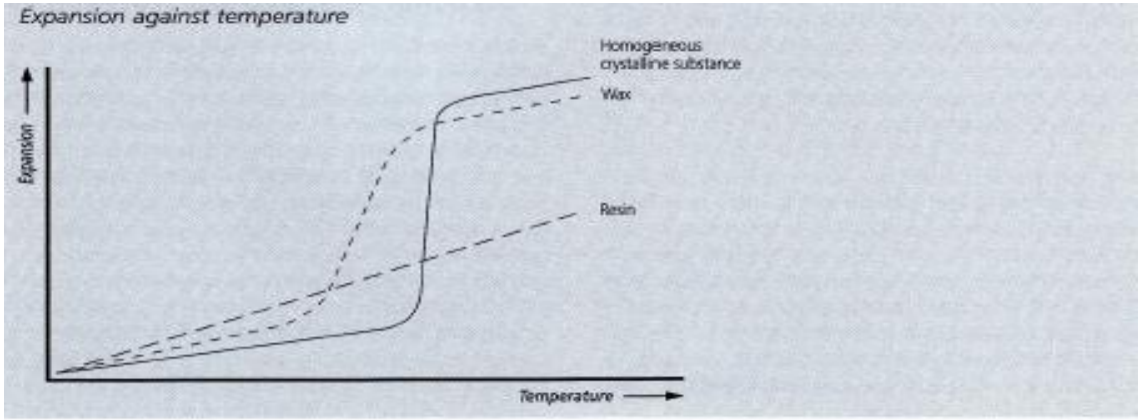
Traditional Wax Testing



- Wax testing has traditionally been based around the Petrochemical industry with tests such as
  - Congealing point
  - Melting point
  - Viscosity
  - Penetration
  - Percentage ash
- Although a place remains for such tests complexity of design and performance demands requires a change in thinking

Expansion & Contraction

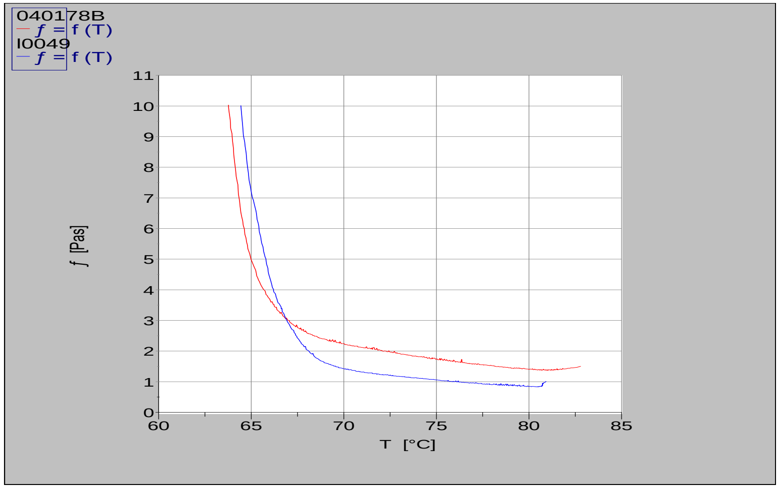
- The structure and components used in an investment casting wax will influence the expansion and contraction
- Like other materials wax expands on heating and contracts on cooling
- In comparison with a metal the expansion is relatively high
- Wax expansion and contraction rates are not uniform but vary with phase and structure changes during heating and cooling



Wax Fluidity

- Fluidity is the ability of a material to flow, in particular through thin sections
- The effects of wax fluidity should not be underestimated
- Too low a fluidity may cause non-fill or flow lines
- Too high a fluidity will lead to turbulence during injection causing flow lines and air entrapment

Wax Fluidity



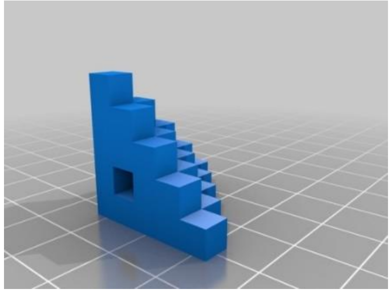
- There is a clear relationship between the viscosity of a wax and its fluidity, the more viscous, generally the less fluid, e.g. water and treacle

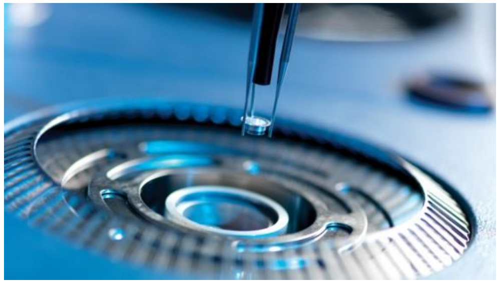
- There is a relationship between temperature and fluidity, the cooler the wax and die temperatures the lower the fluidity

- Experiments show a linear relationship occurs in the liquid and paste regions, but not around the congealing point

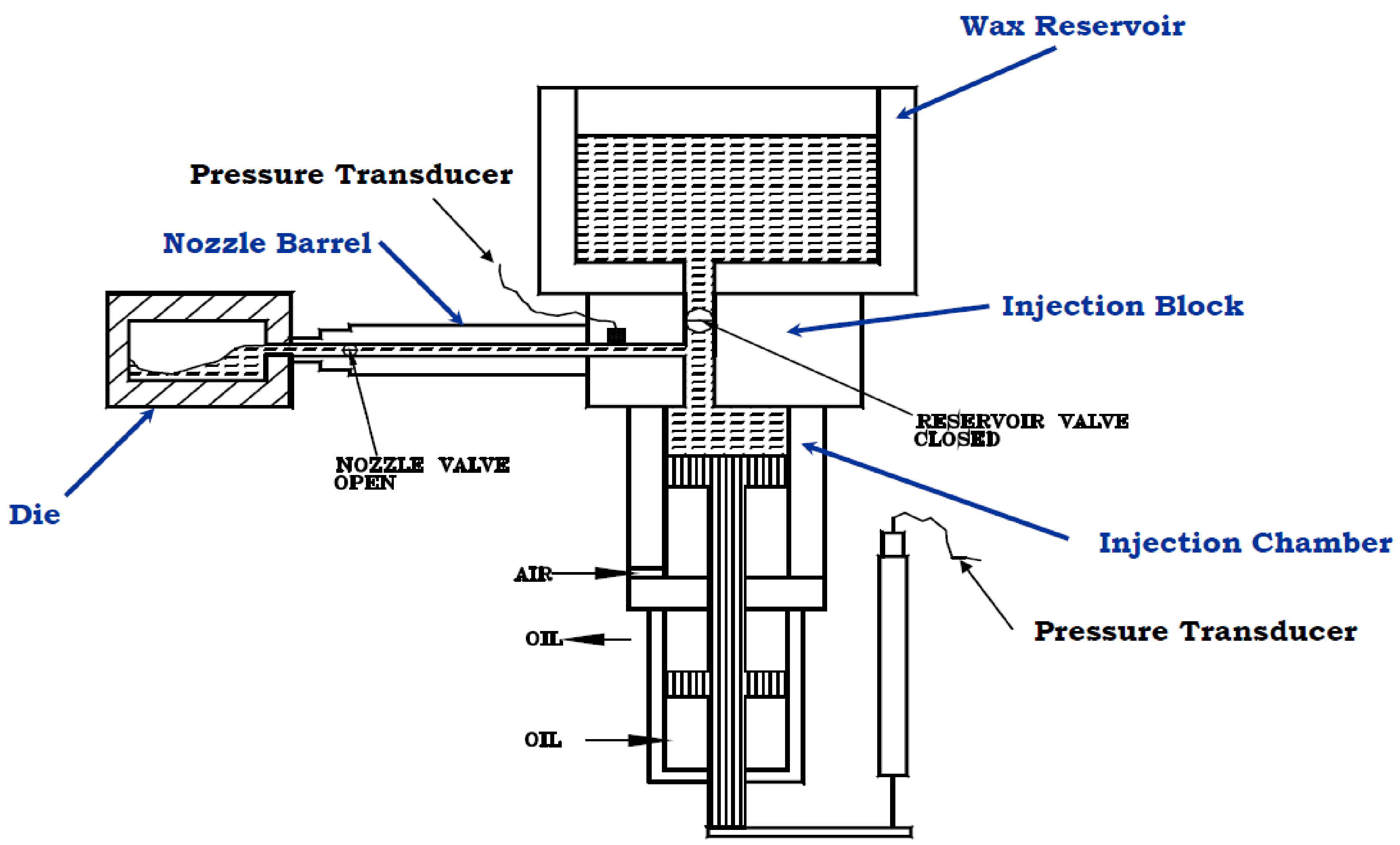
Advanced Wax Testing

- Test methods specifically developed to model how the wax is used in the foundry
- Rheometry
- Infrared analysis (FTIR)
- Differential scanning calorimetry (DSC)
- Thermomechanical Analysis (TMA)
- Wax Strength Analysis
- Injection profiling and fluidity analysis





Simple Wax Injection Schematic



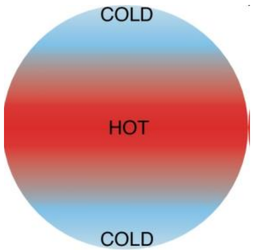
Injection Machine Controls

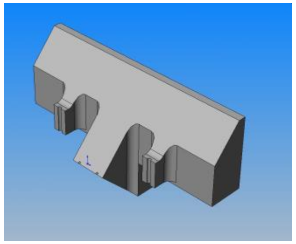
- Clamp pressure
- Wax tank temperature
- Wax injection cylinder temperature
- Wax hose temperature
- Injection nozzle temperature
- Injection speed
- Injection pressure
- Platten temperature

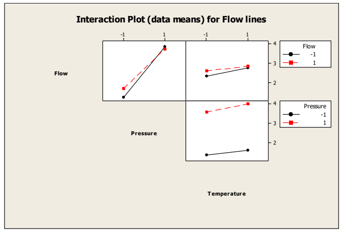
Wax Temperature Control

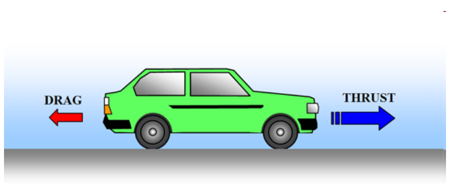
- Wax has a very poor thermal conductivity
- Any temperature changes take hours to achieve
- As a rule 15 minutes per degree Celsius is suggested
- When using automatic wax filling it is important that the liquid level in the holding tank does not fall too low
- Temperature gauges give an indicative reading only and often do not reflect the wax temperature in the centre of the tank
- Die temperature will change with use, this may give rise to changes in wax injection characteristics

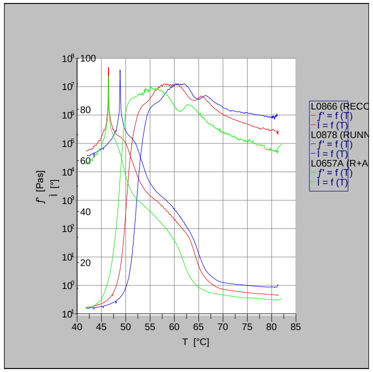
Factors Affecting Fluidity at Injection











- Wax temperature
- Die temperature
- Die thermal conductivity
- Section thickness and changes in section
- Injection pressure and flow
- The ability of the die to evacuate the air (air resistance)
- Finish of the die and release agent (surface tension)
- Set rate of the wax

Advice on Wax Storage

- Whether its inside or outside wax **materials will age prematurely with sunlight** – If stored outside ensure they are covered, if inside ensure they are not located directly below a sky light
- What are the **effects of temperature?**
- Wax pellets stored in cold conditions, for example just above freezing should not be affected unduly if in sealed bags
- Remember wax takes a long time to rewarm
- Pellets stored at elevated temperatures for example above 30°C may soften and stick together

Advice on Wax Storage

- Care should be taken to ensure that wax products are not in direct contact with solvents for long periods as this will “soften” or even dissolve them
- Wax materials have a shelf life, typically 2 years if storage conditions are ideal
- With materials such as water soluble wax it is important to ensure they are sealed from moisture in the atmosphere
- If in doubt get your supplier to retest the product and confirm its suitability

Advice on Wax Storage

- Injected patterns are a very different story !!
- If **too cold** then the wax may embrittle particularly as it contracts around inserts such as cores and crack
- This applies in areas such as wash off tanks where the water including fresh water must be held around **18 - 22°C**
- Other areas of concern might be weld joints which may open up as a results of variation in contraction of components
- In elevated areas, particularly in roof storage for example in uncontrolled shell areas, waxes may soften and distort
- **Ideal storage temperatures 20 - 22°C**

Tips to Minimise
Wax Related Defects

Wax Injection Videos

- Four videos of wax injected at
- 55.5 °C
- 58.8 °C
- 71.1 °C
- 73.8 °C
- Shown in real time and slowed

https://www.youtube.com/watch?v=JMd9aGfZnfU

Flow Lines

- Definition - a negative surface indication seen as a line from above
- Cause - lack of energy within the wax either as a result of cold wax or turbulence
- Problem - can be a source of ceramic inclusions on shelling, weakening of the wax structure
- Possible solutions
  - Increase the injection pressure
  - Increase the temperature
  - Reduce the turbulence by reducing pressure and or flow
  - Use a filled wax
  - Use more viscous wax

Surface Pitting

- Definition - a rough surface finish which visually has a "sandpaper" effect
- Cause - lack of wax fluidity
- Problem - can be a cause of ceramic inclusions on shelling
- Possible solutions
  - Increase wax fluidity by means of increasing the temperature
  - Use a more fluid wax

Cavitation

- Definition - a surface depression, normally in the form of a bowl like shape
- Cause - lack of feed to the area in question
- Problem - a cause of dimensional problems
- Possible solutions
  - Reduce the injection temperature
  - Increase the size of the injection sprue
  - Use a filled wax
  - Use a wax “chill”
  - Reduce die temperature

Incorrect Wax Dimensions

- Definition - final wax dimensions are outside of the required specification
- Cause - wax contraction is incorrect
- Problem - the finished parts are to the wrong size
- Possible solutions
  - Change wax temperature
  - Change wax
  - Change die dimensions (expensive)

Air Defects

- Definition - either surface or just below surface depressions caused by air
- Cause - the air is unable to escape from the wax quickly enough during injection
- Problems - a possible source of ceramic inclusions on shelling
- Possible solutions
  - Reduce wax turbulence
  - Increase wax viscosity
  - Allow air to escape from the die more easily

Non-Fill or Cold Shut

- Definition - the cavity either does not fill completely or the pattern has rounded edges
- Cause - insufficient wax energy to fill the die cavity
- Problem - incorrect dimensions
- Possible solutions
  - Increase injection pressure
  - Increase wax temperature
  - Make wax more fluid
  - Improve wax venting
  - Reduce turbulence

Good Assembly Practices

- Ensure any negative depressions such as flow lines and surface depressions are filled in or polished out
- Parts should be allowed to complete contraction before assembly as failure to do this may put pressure on the joints
- Remember wax has a ‘memory’, and particularly twisted sections will attempt to straighten themselves over time once taken off setters
- Any liquid runs from glue or welding should be trimmed off, as they can be a source of shell inclusions
- Air Defects near to or breaking the surface must be exposed and filled
- Ensure all surfaces are clean and free from release agent, consider use of pattern wash
- Consider automation

Summary

- Investment casting wax compounds are complex
- They consist of many different components
- Consequently they exhibit a range of properties
- Wax properties influence pattern behaviour in the foundry and ultimately the quality of castings produced
- The understanding of wax characteristics and their control is critical to the investment casting foundry

Reference videos created by the ICI

- The Process https://youtu.be/o18cQrCVVNA
- Pattern Making (Including defects) https://youtu.be/gbV9Ih6O0uU
- Pattern Assembly https://youtu.be/XH30RjmlSO0
- Shell and Dewax https://youtu.be/lb-EXdMG6uk

Thank You

Blayson