Understanding Investment Casting Wax

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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

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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

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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

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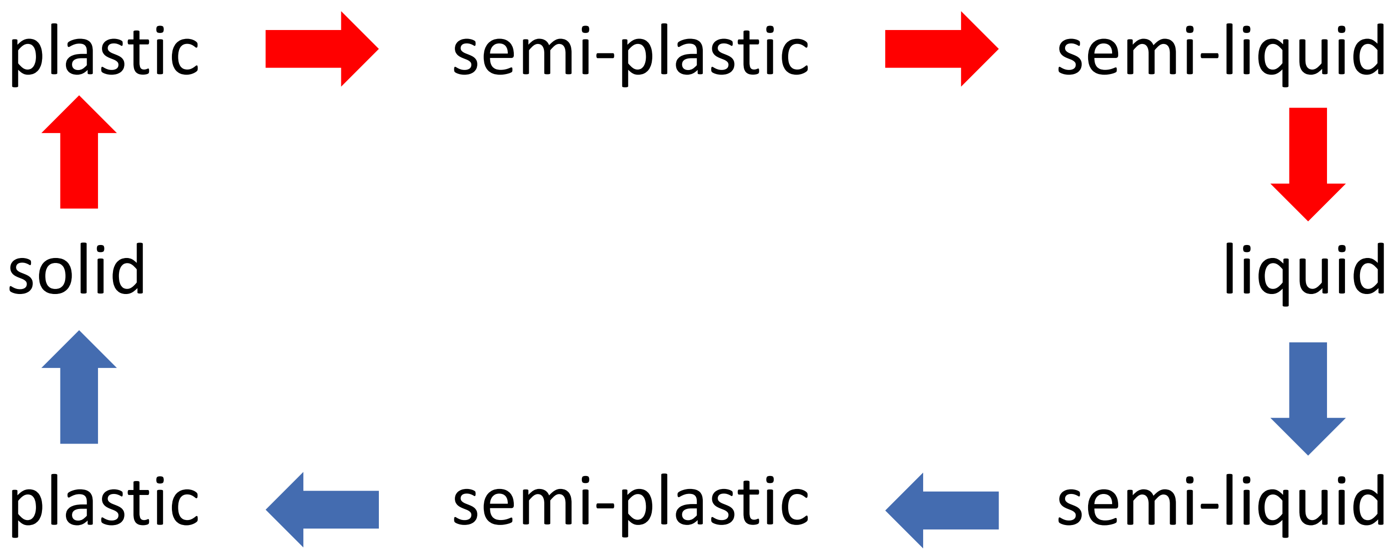
Structure of Investment Casting Wax

- 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

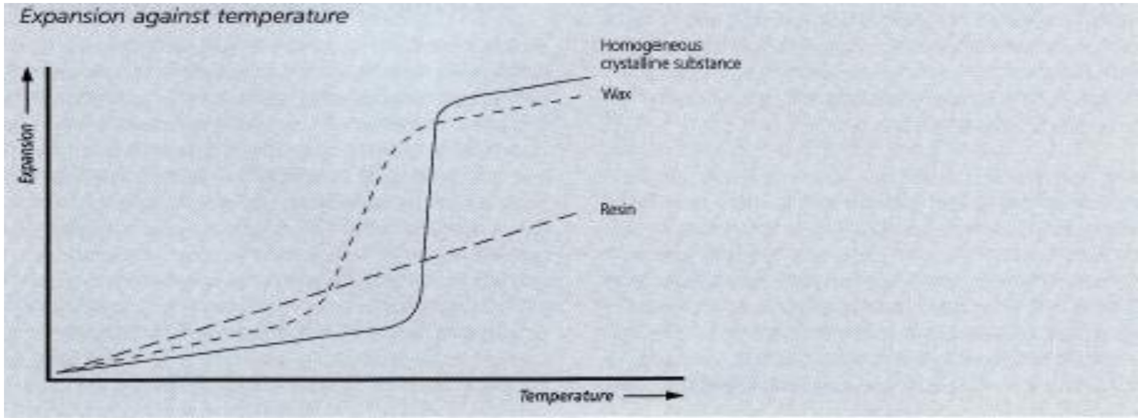
Phase Changes

- Unlike other homogeneous chemical compounds wax does not melt immediately on heating but passes through several intermediate states
- The cycle is reversed in the cooling phase



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



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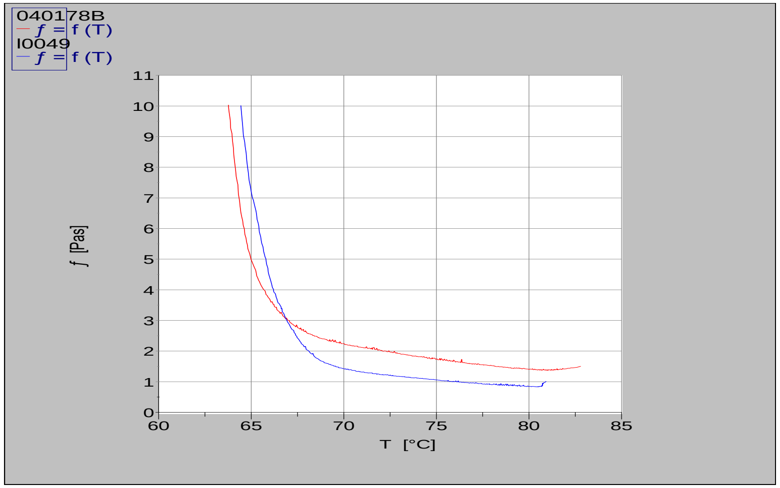
Wax Temperature Control

- Wax has a very poor thermal conductivity
- Any temperature changes take hours to achieve
- As a general 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

Wax Fluidity

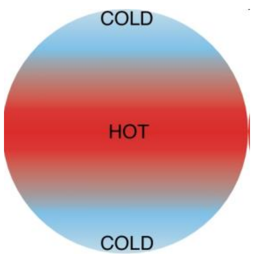
- Fluidity is the ability of a material to flow, in particular through thin sections
- The effects of wax fluidity should not be underestimated
- Too low a fluidity may cause non-fill or flow lines
- Too high a fluidity will lead to turbulence during injection causing flow lines and air entrapment

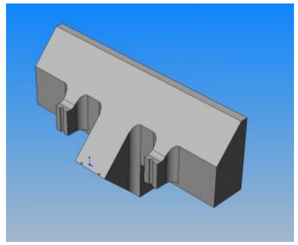
Wax Fluidity

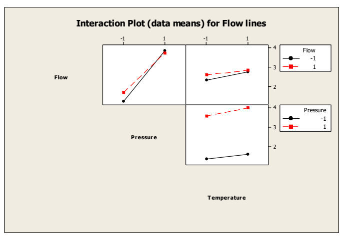


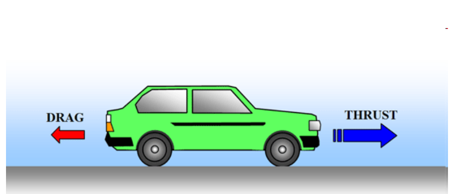
- There is a clear relationship between the viscosity of a wax and its fluidity, the more viscous, generally the less fluid, e.g. water and treacle
- There is a relationship between temperature and fluidity, the cooler the wax and die temperatures the lower the fluidity
- Experiments show a linear relationship occurs in the liquid and paste regions, but not around the congealing point

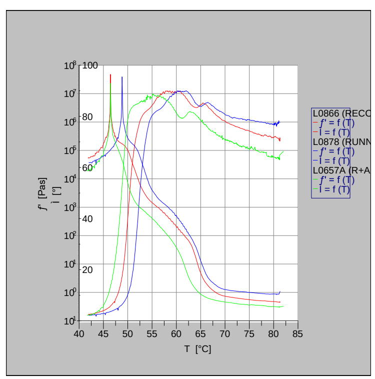
Factors Affecting Fluidity At Injection











- 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 as long as 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

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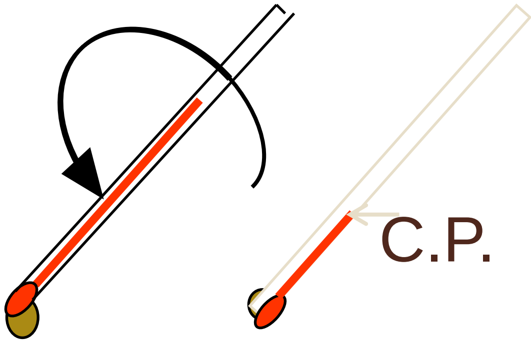
Advice on Wax Storage

- 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**

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

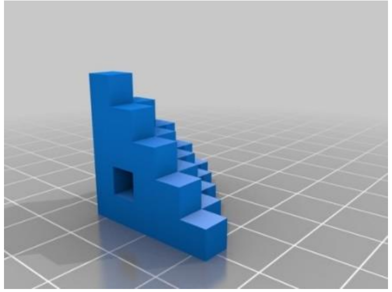
Traditional Wax Testing

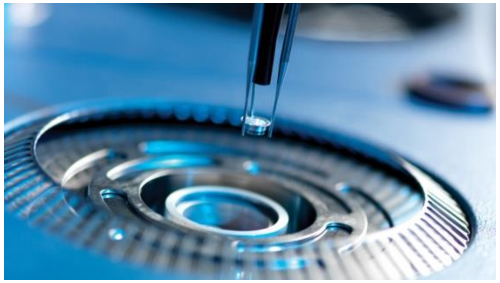


- Wax testing has traditionally been based around the Petrochemical industry with tests such as
  - Congealing point
  - Melting point
  - Viscosity
  - Penetration
  - Percentage ash
- Although a place remains for such tests complexity of design and performance demands requires a change in thinking

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





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Tips to Minimise Wax Related Defects

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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

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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

Thank You

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