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
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
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.
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
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
Tips to Minimise Wax Related Defects
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
Thank You