Applied process monitoring and control for liquid composites moulding

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Presentation Overview

• The basic monitoring technology used
• The iREMO project and the new technologies
• First results from the application to an automotive RTM production
• The industrial experience and perspective
Consortium

CEMCAT (Research Centre, Co-ordinator)
Sotira (Automotive industry)
Atoutveille (Consulting)
Synthesites (Process monitoring and control)
NTUA (Process monitoring, modeling & control)
BIBA (Wireless communications and logistics)
Newcastle University (Artificial Intelligence)
Inasmet (Material and process modelling)
Acciona (Constructions Industry)
Karnic (Boat industry)

iREMO project is partially funded by the European Commission
Process monitoring advantages

• Detect resin ageing or mixing deviations before injection
• Detect resin arrival
• Detect resin movements
• Detect viscosity changes
• Identify critical processing milestones in the cycle
  - minimum viscosity
  - gelation
  - vitrification
• Identify the ‘end of cure’
• Detect unexpected events
• Automate the production
Process Control Advantages

- Production automation
- Continuous temperature optimisation for injection and curing
- Quality control
- Scrap reduction
- Improve productivity
- Increase process know-how and decrease dependency from craftsmanship
The DC-based Sensing System from Synthesites

Advantages

– Non-intrusive
– Durable
– Repeatable
– Fast
– Compact
– Wireless
– Quality control capabilities
– Process control potential
Process Sensing

Several sensor models have been manufactured and tested to match a range of composite materials processing sensing requirements.

**process monitoring sensor** = resistance sensor + RTD sensor

<table>
<thead>
<tr>
<th>In-mould durable sensor</th>
<th>Flexible sensor</th>
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**High Temp RTM**
- Resin arrival
- Viscosity rise
- Gelation
- end-of-cure

**For VI / RT**
- Resin arrival
- Viscosity rise
- Gelation
- end-of-cure

- Avoid pipe cleaning
- injection window
- mixing ratio checking

- Resin Quality
- Addition of fresh resin or rejection
- Injection window
Lab-scale trials (Dielectric vs. Electrical)

Dielectrics is more suited for labs while electrical is the optimal solution for monitoring thermoset curing at industrial level.
Intelligent sensorised automation in composites production
What’s new

• Introduction of artificial intelligence in process monitoring, modelling and control

• Wide range of applications from RTM to pultrusion and from 0°C to 200°C

• Application and trials in four real industrial environments for fast RTM, Light RTM, vacuum infusion and pultrusion.
Viscosity is directly related to resistance.

Repetitive (4) tests of resistance and viscosity monitoring of Bakelite’s neat L20 epoxy resin at various temperatures.
Resistance vs mixing ratio of fresh and aged monocomponent resin
Effect of mixing ratio in curing time

±3% hardener variation

Exact ratio

-3% hardener

+3% hardener

Remaining Cure Factor

Cure Monitoring Index

Curing time [min]

30% time variation
Mixing ratio check before injection

Resistance (MOhm) vs hardener percentage (nominal mixing ratio 100:34)
Glass/UP in composite tool without temperature control (Karnic case). Temperature provides valuable information for the reaction.
1st Industrial Application

Cure control of carbon-glass/epoxy RTM production of automotive parts

Monitoring targets

• Monitoring viscosity, gelation and end-of-cure in the cavity (in-mould sensor)
• Monitoring viscosity rise and mixing ratio in feeding line (in-line sensor)

Control targets

• Opening of mould exactly when part is cured
• Optimise moulding temperature during set-up or production
• Avoid cleaning the feeding line between mouldings
• Check mixing ratio deviations before injection
Injection time vs mould temperature
Industrial Set-up

- Press
- Injection machine
- Punch
- Die
- Wifi
- In-line sensor
- 2 Monitoring systems
- In-mould sensor
In-mould sensor installed

No direct contact with the part is necessary
In-line sensor installed
In-mould sensor at hot tool

Significant parameter is that in-mould sensor is installed in the punch (hotter) and not in the die (colder) as previous case.
Monitoring serial production
Towards Automatic Control

Monitoring and control’s computer environment

Graphical Display

Real-time info based on measurements and models

Process Milestones
Control capabilities

25% decrease of cycle time is possible (to be confirmed at serial production)
IREMO project
SOTIRA targets

• RTM for high performance automotive parts:

  – process monitoring and traceability in accordance with automotive quality standards (ex: Tg and polymérisation rate),
  – avoid failures costly in time, ie detect problems before injections,
  – improve productivity by reducing press closing time,
  – decrease VOC by controlling resin state between the mixing head and the injection head to suppress cleaning after injection,
  – Reduce development time and cost of the new parts,
  – Improve knowledge of parameters in connection with parts quality and productivity.
Process monitoring: demonstrate with live measures the matrix quality (curing rate and Tg).

• During the moulding of a RTM epoxy part we have to:
  – inject two components in good quantities (check with flowmeters),
  – Mix the two components,
  – Cure the matrix (parameters: mould temperatures and press closing time, today this time is define during development of the moulding process).

So, it is not possible to control the quality of the matrix before moulding as it is possible with prepreg.

• It is not possible to make a DSC for each part.
  Today we mould 2 parts/hour and we have the target to increase this quantity to 4 or 5 parts/hour.
  For one car we have a lot of parts to mould (around 20 for a set of body panels and more for a platform)

• In case of problem, it is necessary to be reactive.
Process monitoring: prove with live measurement the process stability.

- We detect with the sensor when the resin is coming under it.
- Analyse of times between beginning of injection and arrival of the resin under the sensor gives an idea of the resin flow in the cavity.
- Those values help us to detect if we have some flow troubles coming from tightness, vents, preforms etc....
avoid failures costly in time, ie detect problems before injections

- Resin is prepared between mixing head (injection of two components in good quantities and mixing in a static mixer) and injection head.
- A sensor in line should detect problems in the liquid resin and stops the moulding before injection.
Improve productivity by reducing press closing time.

• Today closing time is define during part development. To define this value, it is clear that we have to take into account moulds temperatures or resin reactivity variations.
• Sensor in the mould has to pilot the press and open it when Tg and percentage of curing are at the right values.
• We can also imagine to pilot heating system of light moulds.
Decrease VOC by controlling resin state between the mixing head and the injection head to suppress cleaning after injection,

• Today, to avoid gelification, we clean, after each injection, injection circuit between mixing head and injection head (acetone and high pressure air).

• Measurement of the curing state of the resin, with the sensor in line, could avoid this systematic cleaning and help us to pilot the cooling to block the curing or, the heating to decrease the viscosity before injection.
Improve the process knowledge.
Reduce development time and cost of the new parts.

- We have three objectives:

1. Analyse the behavior of resin during injection and curing for better understanding of quality and productivity parameters (ex: surface quality, fibers wetting…),
2. Easier optimisation of parameters and drastic limitation of DSC.
3. Resin flow control to check the robustness of the process.
• For information contact us or visit our website

www.iremo.eu