ON-LINE MIXING STUDIES OF RESIN AND CURING AGENTS FOR LIQUID TRANSFER MOLDING

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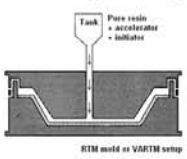
MOTIVATION

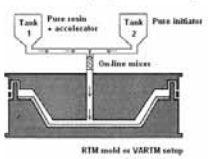
In the last decades the composites manufacturing industry has come under the pressure to be cost effective and develop automation for LCM processes. In order to avoid storage of large amounts of polymerizing resin and to automate the process, an on-line mixing process is often desired. The idea is to mix the curing agent with the resin as the resin enters the mold through a separate system featuring two feed-lines.

Standard injection setup



- Mixture has a short time life
- Unused resin is waste
- Discontinuous process

On-line mixing injection setup



- Both components are stable when apart
- Appropriate system for process automation
- No degasification required
- Cost effective
- Continuous process possibility

ACKNOWLEDGEMENTS

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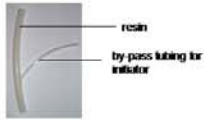
GOALS

1. Develop a **SIMPLE AND LOW COST SETUP** providing a **constant mixing ratio** during injection.

Approach: use by-pass tubing for hardener



2. Develop an **AUTOMATED SYSTEM** able to provide a **varying mixing ratio**

Approach: use a computer controlled injector pump

3. Check the **ON-LINE MIXING INFLUENCE ON RESIN PROPERTIES**

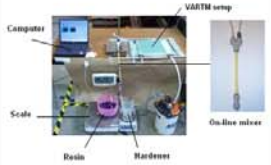
Approach: use DSC and DMA to compare mechanical properties and degree of cure between regular and on-line mixing processes.

BY-PASS TUBING SYSTEM

Poiseuille's law allows us to calculate the by-pass tubing radius required for the desired mixing ratio. We assume that both tubes have the same length.

$$V = \frac{\pi r^4 \Delta P}{8\eta L} \quad \Rightarrow \quad \frac{V_2}{V_1} = \left(\frac{x}{100-x}\right) = \left(\frac{\eta_1}{\eta_2}\right)\left(\frac{r_2}{r_1}\right)^4$$

Experimental setup



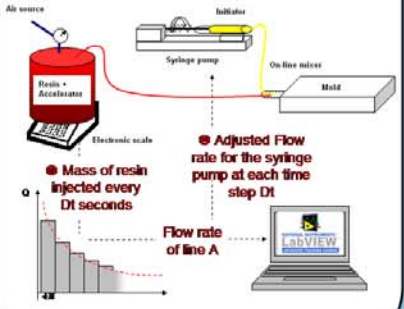
- Validation of diameters calculation
- Observe cure quality of composites parts
- Constant mixing ratio ?
- Can be also used for RTM

Labview application

In order to monitor:

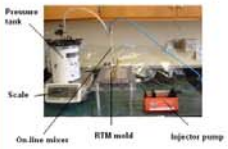
- mixing ratio during injection
- components flow rate
- average components consumption

AUTOMATED SYSTEM



AUTOMATED SYSTEM

Experimental setup



- Observe cure quality of composites parts
- Constant mixing ratio ?
- Can be also used for VARTM

Labview application

- Input parameters :
  - density
  - ratio
  - DAQ frequency
  - syringe size
- Monitor Components flow rate
- Control syringe injection speed

In the case of Vinyl ester resin, this system can be used in order to enhance cure reaction by varying the mixing ratio of the resin and the catalyst during injection.

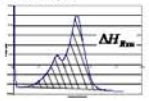
DEGREE OF CURE CHARACTERIZATION

When only a single curing reaction and no other enthalpic events occur, heat flow is proportional to the reaction rate:

$$\frac{d\alpha}{dt} = \frac{dH/dt}{\Delta H_{Rm}} \quad \Rightarrow \quad \alpha_t = \frac{\Delta H_{Rm} - \Delta H_t}{\Delta H_{Rm}} = \frac{\Delta H_t}{\Delta H_{Rm}}$$

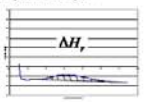
By using DSC we can calculate the degree of conversion:

Uncured sample:



Total amount of energy needed to reach the maximum extent of conversion.

Partially cured sample:



Residual heat for completion of cross-linking

Results with Epoxy resin samples:

	Mixed by hand	Mixed mechanically	On-line mixer
Degree of cure	66.50%	66.50%	63%

CONCLUSIONS

1. Several successful experiments were run using different types of resins and fibers for both RTM and VARTM processes

2. Degree of cure obtained with this process is comparable to mechanical mixing results.
3. Mixing ratio obtained with both setups remains constant over time during injection:

WHAT NEXT ?

- Carry out the degree of cure characterization with vinyl ester resin.
- Determine influence of dual injection on mechanical properties with DMA measures.
- Use a peristaltic pump in order to avoid syringe limits.