INTRODUCTION TO RTM WORKSTATION

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**Introduction To RTM Workstation**

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See also ADM001700, Advanced Materials Intelligent Processing Center: Phase IV., The original document contains color images.

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**SUPPLEMENTARY NOTES**

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14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:

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Outline

1. Objective / Motivation
2. Previous design concept
3. Current lab scale implementation
4. On-line mixing of resin
5. Extension
Objective

The objective is to build a modular RTM Workstation featuring:
- Modularity in part geometry
- Reduced prototype development costs
- Automated control
- Integrated system
Motivation

There is a need to have better control of the filling stage to ensure part quality and increase yield of production ...

... as well as a desire to reduce tooling costs and turnaround times, which are a major factor in the expense of RTM.
Part-to-Part Operation

The mold system is ready to start with the first part.
Part-to-Part Operation

The preform is loaded into the mold
Part-to-Part Operation

The mold is closed and sealed, the resin is injected and allowed to cure.
Part-to-Part Operation

The mold is open, revealing the filled part.
Part-to-Part Operation

The part is demolded …
Part-to-Part Operation

... and removed from the mold
Part-to-Part Operation

The plate systems are separated, revealing the resin chunks.
Part-to-Part Operation

The resin chunks are demolded …
Part-to-Part Operation

... and removed from the mold
Part-to-Part Operation

Finally, the mold is prepared for the next part by applying release agent.
RTM Workstation

To test the entire system, it was decided to build a mid-scale system. The details are as follows:

- No hydraulics to open and close plates
- Single sided mold, with gates/vents/sensors on bottom only
- Acrylic lid on top for visualization
- 1’ x 2’ working area for parts
- 20 psi limit inside mold
RTM Workstation

- Reinforcing ribs
- Acrylic lid
- Spacer plate
- Plate 1
- Membrane
- Plate 2
- Manifold
- Pistons
- Legs
- Pressure bucket
Control Center

– neatly containing all data acquisition components
Control Center

Shelf 1:
- ER-16 Relay Box
- ER-16 Relay Box
- SMART Sensor card

Shelf 2:
- 5V Power Supply
- 24V Power Supply
- Power Supply Switch

Shelf 3:
- PXI Computer
Sensor Plate

The electric sensors detect the arrival of the flowing fluid. They are mold imbedded to allow for ease of use and minimal effect on the part surface.
Multiplexing allows an array of 23 sensors to be realized with only 10 wires (5 excitation / 5 sensing)
Manufacture of Different Geometries

Once the workstation was built, the ability of the mold to be modular and to produce different geometries was tested.
First Geometry

The first geometry was a simple rectangle, taking advantage of the full 1’ x 2’ area of the mold.
Second and Third Geometry

The second and third geometries were used to demonstrate the ability to manufacture multiple parts at the same time.
The fourth geometry selected was used to demonstrate the controllability of the workstation. A sequential injection was used to ensure that the entire part could be filled quickly.
Sequential Injection Scheme

- Initial Gate IG
- Triggering sensor TS
- Auxiliary gate AG

**Step-1:** Initial gate opens

**Step-2:** Flow reaches TS1, which triggers automatically opening of AG1 and closing IG

**Step-3:** Flow reaches TS2, which triggers automatically opening of AG2

**Step-4:** Flow reaches TS3, which triggers automatically opening of AG3,4,5,6,7,8

**Step-5:** Flow reaches TS4,5, which triggers vent closing.
Sequential Injection Wizard

Simulation

Implementation fully automated
Simulation Results
Sequential Injection Experiment

- Open gate
- Closed gate
- Open vent
- Closed vent
- Untriggered sensor
- Triggered sensor
Resultant Part
The fifth geometry was selected to demonstrate the integration of SLIC with the RTM Workstation for sensing and control of the filling.
SLIC for New Geometry

The potential gate/vent/sensor locations were input into SLIC and the program was run to generate the mode detection and control action files.

Work is ongoing to experimentally validate these results.
On-Line Mixing Studies of Resin and Curing Agents

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
1. Develop an **AUTOMATED SYSTEM** providing a **varying mixing ratio** and hence curing reaction kinetic by progressively increasing hardener concentration during injection.

**Approach:** use a computer controlled Injector pump

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

**Approach:** use by-pass tubing for hardener
Experimental Setup

Varying mixing ratio with injector pump

- Syringe implementation and calibration
- Uniform gel time control
- Resin curing time chart needed
- Can be also used for VARTM

Constant mixing ratio with by-pass tubing

- Validation of diameters calculation
- Monitoring of the mixing ratio during injection
- Characterization of the degree of cure
- Can be also used for RTM

• Validation of diameters calculation
• Monitoring of the mixing ratio during injection
• Characterization of the degree of cure
• Can be also used for RTM
Results

1. Wide range of mixing ratio available.

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

3. According to DSC measures, the degree of cure obtained with this process is comparable to mechanical mixing results.

4. Mixing ratio obtained with by-pass tubing setup remains constant over time.
Extension - RTM

- Reinforcing ribs
- Acrylic lid
- Spacer plate
- Plate 1
- Plate 2
- Membrane
- Manifold
- Pistons
- Legs

On-line hardener injector

Pressure bucket
Extension - VARTM

The modularity of the system as well as the injection system can be applied to manufacturing with VARTM.

Mold surface for preform / distribution media / bagging material
Conclusions

- The modularity of the workstation was validated through manufacturing various part geometries.
- The seamless flow of data between LIMSUI and the workstation as well as experimental automation were demonstrated with a sequential injection.
- The integration between SLIC and the workstation are in the beginning stages.
- On-line mixing of resin components allows for ease of resin handling during manufacturing.