Tool Vibrations for the advancement of the Vacuum Infusion process

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Liquid Composite Moulding is a “static” process with limited means for process manipulation.

Consequently the existence of fibres may generate:
- Dry spots or high void content and/or
- Resin reach areas

We are looking for more ‘dynamic’ solutions to force the resin:
- to flow more homogenius
- to help bubbles to move towards the vents faster
- But also to improve compaction
Pressure vibrations during injection
Baig & Gibson (1995)
Song & Ayorinde (1995)

Vibration Assisted RTM
R. Meier et al.

Low frequency vibrations at curing
Muric-Nesic et al.

Local compression vibrations
Gangloff et al

Vibration-assisted compaction
Gutiérrez et al (2012)
Kruckenberg et al. (2010)

Vibration Assisted RTM (VIARTM)
Pantelelis et al. (2002)
INVESTIGATION OF INFLUENCING PARAMETERS WITH RESPECT TO FILLING TIME IN VIBRATION ASSISTED RTM PROCESSES,
R. Meier, J. Heim, A. Nieratschker, S. Zaremba, K. Drechsler
Effect of low frequency vibrations on void content in composite materials,
J. Muric-Nesic, P. Compston, N. Noble, Z.H. Stachurski

Fig. 3. Void content of laminates for 30 min of vibrations.

Fig. 3. Measured void content for samples cured at a range of frequencies applied at two different times.
Exploring the behavior of glass fiber reinforcements under vibration-assisted compaction,


<table>
<thead>
<tr>
<th>Experimental Set</th>
<th>Average Fiber Volume (%)</th>
<th>Average Resin Volume (%)</th>
<th>Average Void Volume (%)</th>
<th>Average Infusion Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Bag VARTM Control</td>
<td>50.1</td>
<td>49.0</td>
<td>0.9</td>
<td>30</td>
</tr>
<tr>
<td>Compaction Only 241 kPa (35 psi)</td>
<td>52.4</td>
<td>46.2</td>
<td>1.4</td>
<td>56</td>
</tr>
<tr>
<td>Heated Preform 48.9 ºC (120 ºF) and Compaction 241 kPa (35 psi)</td>
<td>56.6</td>
<td>42.5</td>
<td>0.9</td>
<td>49</td>
</tr>
<tr>
<td>Heated Resin 48.9 ºC (120 ºF), Heated Preform 48.9 ºC (120 ºF), and Compaction 241 kPa (35 psi)</td>
<td>60.4</td>
<td>38.4</td>
<td>1.2</td>
<td>32</td>
</tr>
</tbody>
</table>

Table 5. Fiber volume content of multilayer samples subjected to static and vibration-assisted compaction at 370 Hz with a force ratio of 0.8.
Static and vibration compaction and microstructure analysis on plain-woven textile fabrics,

Teresa Kruckenberg, Lin Ye, Rowan Paton

Fig. 3. Vibration compaction using a roller.

Fig. 6. Effect of vibration frequency on thickness for 4-ply RC200P: (a) 0–100 cycles, (b) 0–3000 cycles.
OptiMold system for monitoring resin cure, resin viscosity, mixing ratio quality and resin quality

OptiFlow system for optimising mould filling, process automation and simple process control

OptiSensors (durable/ disposable, flexible, outlet, custom)

Real-time calculation of Tg/ degree of cure/ viscosity/ resin quality

Simulations, Automation, Design and Prototyping solutions

FPCM’ 12, 14-16 July 2014, Enschede, The Netherlands
Vacuum Infusion Vibration Assisted (VIVA) for aerospace applications

Issues to address

- Oven for the specific tool
- Reinforced tooling
- Vibration mechanism @180°C
- Vibrations possible during cure
- Monitoring systems
Pros & Cons

**Advantages**
- Eliminate dry spots
- Reduce void content
- Decrease required injection pressure
- Acceleration of filling phase
- Possible acceleration of curing
- Allows the combination of other techniques (Vacuum, multiple gates, process monitoring, heating etc.)

**Drawbacks**
- Design and construction of the vibration mechanism
- Difficult for large and heavy tools
Issues to be studied

- Frequency dependence
  - The higher the better: 100 Hz was used.
- Magnitude dependence
  - Two vibration magnitudes were tested: 3mm and 0.3mm
- Volume fraction dependence
- Preform
- Time schedule
  - Vibrations are applied after the end of filling up to gelation
- Effect on curing
- Vibrations’ direction wrsp to the mould
- Extension to other Liquid Composite Moulding techniques (RTM etc.)
- Ideal for vibration effect studies
- First studies with thick Plain Weave GF showed some improvement in compaction
Small-scale VIVA heated system

**VI Characteristics**
- Double vacuum-bag
- Aerospace-grade CF
- RTM6 resin

**Studies**
- vibrations direction
- vibrations frequency
- vibrations magnitude
- Preform type
- wet/dry, hot/cold etc.
Small scale system trials
Carbon-fibre/RTM6 with VI at 120/180°C temperature cycle

<table>
<thead>
<tr>
<th>Vibrations type</th>
<th>@Vacuum port</th>
<th>@injection port</th>
</tr>
</thead>
<tbody>
<tr>
<td>w/o Vibrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$V_f$ %</td>
<td>$V_f$ %</td>
</tr>
<tr>
<td></td>
<td>$V_C$ %</td>
<td>$V_C$ %</td>
</tr>
<tr>
<td></td>
<td>53,1</td>
<td>52,2</td>
</tr>
<tr>
<td></td>
<td>0,564</td>
<td>0,571</td>
</tr>
<tr>
<td>Vibrations with large amplitude (~3 mm)</td>
<td>59,8</td>
<td>57,1</td>
</tr>
<tr>
<td></td>
<td>1,021</td>
<td>1,292</td>
</tr>
<tr>
<td>Vibrations with small amplitude (~0.3 mm)</td>
<td>58,3</td>
<td>57,2</td>
</tr>
<tr>
<td></td>
<td>0,834</td>
<td>0,872</td>
</tr>
</tbody>
</table>
Resin Flow sensing

**New wire sensors**

- Thin wires (0.2 mm)

Optimold and Optiflow combined

FPCM’ 12, 14-16 July 2014, Enschede, The Netherlands
Comparison of resistivity history between a vibrating and a still case for RTM6 resin
Scaling-up to a flat tool of 1.5m x 1m for aerospace applications

- Vibration mechanism should operate at 200°C environment (probably into a special cooling chamber)
- Oven should be custom-made in order to incorporate the vibration mechanism and the supporting table
- Tool should be light to reduce vibrations’ loads
- Everything (including sensors, pipes etc.) attached to the tool should be well supported and should be able to withstand 100Hz vibration
- Extra care should be taken to avoid any preform movement/distortion due to the vibrations.
Scale-up

Tool

Vibration mechanism

Industrial Vibrator
A small-scale vibration assisted vacuum infusion prototype has been developed and used for preliminary trials.

Results have shown that there is a significant improvement in the structural properties of the part even in the small scale.

The process monitoring system still works quite well under the vibrations and provides significant input for the VIVA studies.

A mid-scale Vibration-Assisted Vacuum Infusion system has been developed, constructed and it is ready for trials at Anadolu University.

Following those results and performance a larger system for a much larger part will be decided.