Advanced Manufacturing Processes in the Marine Industry

Stephen Leonard-Williams
• Introduction to Composite Integration
• Current ‘Closed Mould’ techniques
• Resin Transfer Moulding (RTM) in the marine industry
• Resin Infusion (RI) in the marine industry
• Future developments........
COMPOSITE INTEGRATION ltd

- Founded in 2002 in South West UK
- Specialist in ‘closed mould’ technology
- Manufacturer of award winning Ciject range of equipment
- Supplying Marine, Wind, Aerospace, Automotive, civil and Defence Sectors
- World wide distribution in more than 20 countries
- ISO 9001 accredited
- Driving process and technology development.
Equipment for Resin Transfer Moulding (RTM)
Equipment for Resin Infusion (RI)

Atech Composites Co., Ltd.
Horizon Group, Taiwan

110ft Hull-Infuse with all Structural Members in a Single Shot
Equipment for Aerospace Applications
Ancillary Equipment and Materials
Commercial R&D
Why consider a ‘closed mould’ process?
Which ‘Closed Mould’ process?
• RTM  Resin Transfer Moulding (rigid tooling mechanically clamped)
• VRTM  Vacuum RTM (Semi-rigid tooling- vacuum clamped)
• VARI  Vacuum Assisted Resin Injection System
• VARIM  Vacuum Assisted Resin Injection Moulding
• V(A)RTM  Vacuum (Assisted) Resin Transfer Moulding
• RTM Light  Semi-rigid tooling- vacuum clamped
• CIRTM  Co-Injection RTM
• VI  Vacuum Infusion
• DRDF  Double RIFT Diaphragm Forming
• LRI  Liquid Resin Infusion
• MVI  Modified Vacuum Infusion
• Quickstep  Use of liquids for enhanced heat transfer in infusion
• RI  Resin Infusion
• VIP  Vacuum Infusion Process
• RVBM  Reusable Vacuum Bag Moulding
• RIM  Reaction Injection Moulding
• RFI  Resin Film Infusion
• RIFT  Resin Infusion Under Flexible Tooling
• RIRM  Resin Injection Recirculation Moulding
• HPRTM  High pressure Resin Transfer Moulding
• C-HPRTM  Compression High Pressure resin transfer Moulding
• RTMS  RTM variant with integrated Thermoplastic surface
• SCRIMP  Seeman Composites Resin Infusion Moulding Process
• Flex Moulding  Reusable vacuum bag moulding
• VAIM  Vacuum-Assisted Injection Moulding
• VAP  Vacuum Assisted Processing
• VIM  Vacuum Infusion Moulding.
• VIMP  Vacuum Infusion Moulding Process
• Infujection  Direct mechanical Injection of resin into infusion process

Which ‘Closed Mould’ process?
<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTM</td>
<td>Resin Transfer Moulding (rigid tooling mechanically clamped)</td>
</tr>
<tr>
<td>VRTM</td>
<td>Vacuum RTM (Semi-rigid tooling - vacuum clamped)</td>
</tr>
<tr>
<td>VARI</td>
<td>Vacuum Assisted Resin Injection System</td>
</tr>
<tr>
<td>VARIM</td>
<td>Vacuum Assisted Resin Injection Moulding</td>
</tr>
<tr>
<td>V(A)RTM</td>
<td>Vacuum (Assisted) Resin Transfer Moulding</td>
</tr>
<tr>
<td>RTM Light</td>
<td>Semi-rigid tooling - vacuum clamped</td>
</tr>
<tr>
<td>CIRTM</td>
<td>Co-Injection RTM</td>
</tr>
<tr>
<td>VI</td>
<td>Vacuum Infusion</td>
</tr>
<tr>
<td>DRDF</td>
<td>Double RIFT Diaphragm Forming</td>
</tr>
<tr>
<td>LRI</td>
<td>Liquid Resin Infusion</td>
</tr>
<tr>
<td>MVI</td>
<td>Modified Vacuum Infusion</td>
</tr>
<tr>
<td>Quickstep</td>
<td>Use of liquids for enhanced heat transfer in infusion</td>
</tr>
<tr>
<td>RI</td>
<td>Resin Infusion</td>
</tr>
<tr>
<td>VIP</td>
<td>Vacuum Infusion Process</td>
</tr>
<tr>
<td>RVBM</td>
<td>Reusable Vacuum Bag Moulding</td>
</tr>
<tr>
<td>RIM</td>
<td>Reaction Injection Moulding</td>
</tr>
<tr>
<td>RFI</td>
<td>Resin Film Infusion</td>
</tr>
<tr>
<td>RIFT</td>
<td>Resin Infusion Under Flexible Tooling</td>
</tr>
<tr>
<td>RIRM</td>
<td>Resin Injection Recirculation Moulding</td>
</tr>
<tr>
<td>HPRTM</td>
<td>High pressure Resin Transfer Moulding</td>
</tr>
<tr>
<td>C-HPRTM</td>
<td>Compression High Pressure resin transfer Moulding</td>
</tr>
<tr>
<td>RTMS</td>
<td>RTM variant with integrated Thermoplastic surface</td>
</tr>
<tr>
<td>SCRIMP</td>
<td>Seeman Composites Resin Infusion Moulding Process</td>
</tr>
<tr>
<td>Flex Moulding</td>
<td>Reusable vacuum bag moulding</td>
</tr>
<tr>
<td>VAIM</td>
<td>Vacuum-Assisted Injection Moulding</td>
</tr>
<tr>
<td>VAP</td>
<td>Vacuum Assisted Processing</td>
</tr>
<tr>
<td>VIM</td>
<td>Vacuum Infusion Moulding</td>
</tr>
<tr>
<td>VIMP</td>
<td>Vacuum Infusion Moulding Process</td>
</tr>
<tr>
<td>Infujection</td>
<td>Direct mechanical Injection of resin into infusion process</td>
</tr>
</tbody>
</table>

**Which ‘Closed Mould’ process?**
VRTM (RTM Light)

• Improved laminate quality
• Moulded A and B surfaces (i.e. double sided mouldings)
• Reduced exposure to VOCs
• Cleaner and more efficient process
• Reduced reliance on skilled laminators

Why consider the VRTM process?
A well developed industrial technology
VRTM used to manufacture marine components

VRTM Flybridge table
VRTM used to manufacture marine components

VRTM Flybridge steps
VRTM used to manufacture marine components

Control panels, hatch covers and bathing platforms
VRTM used to manufacture marine components

Structural screen framework
VRTM used to manufacture marine components

Rotating hatch
Large Structures?
Resin infusion.
Simple manual process when at the smaller scale........
Large-scale infusion?
Problems with the manual infusion process.

- Labour intensive
- Risk of inaccurate mixing
- Increased need for degassing
- Risk of bulk exotherm
- Wasteful
- No control of resin pressure
Mechanising the infusion process.
Direct-Infusion™
• The controlled delivery of resin directly into the fibre under a vacuum bag without any intermediate containers.

• Control of resin mixing ratio, flow rate, and mould inlet pressure.

• Use of sensors (IMPS) to accurately measure and control In-Mould Pressure

What is Direct-Infusion™
Advantages of Direct-Infusion™

• Reduced H&S risks (no open container of resin or manual contact necessary)
• Reduced risk of bulk exotherm
• Materials can be degassed prior to infusion
• Accurate pressure control
• Reduced wastage
• Improved laminate quality
• Control and monitoring for QA
• Repeatability
Developing the Direct-Infusion™ process
High Performance RIB Hull

Examples of Direct-Infusion™
Examples of Direct-Infusion™

32m Yacht Hull
Typical infusion strategy for large structures
Infusion machine supplying mixed resin on-demand to flow lines

Manifold used to distribute resin

Typical infusion strategy for large structures
Feeding central flow-line

Typical infusion strategy for large structures
Feed transferred to next flow lines as resin reaches them

Typical infusion strategy for large structures
Feed transferred to next flow lines as resin reaches them

Typical infusion strategy for large structures
Feed transferred to next flow lines as resin reaches them

Typical infusion strategy for large structures
Infusion complete

Typical infusion strategy for large structures
• Each new flow-runner is supplied with freshly mixed resin.
• Danger of resin pre-cure is reduced.
• Possibility of pausing the infusion if major corrections are needed.
• Resin in lower sections can start to cure before the end of the infusion.

Advantages of multi stage infusion strategy
Scale-up of Direct-Infusion™ at Princess Yachts International
136ft Hull Infusion at Atech, Horizon Group, Taiwan
Wind and tidal energy
Ongoing developments
• Patent registered for ‘Intelligent Manifold’ to replace the existing manual system.

• Ongoing work in the aerospace, renewable energy and civil-engineering sectors.

• Continual development of new equipment and techniques.

Understanding and controlling of the infusion process
Atmospheric pressure
950-1050 mbar abs

Controlled resin inlet pressure
(from 300 mbar to 1000 mbar abs)

Controlling the compaction of the laminate by intelligent control of the resin inlet pressure

Understanding and controlling of the infusion process
Verification of improved laminate quality by accurate control of inlet pressures.

‘Process Mapping’ to optimise results
As the **Marine Industry** becomes more sophisticated, manufacturing processes must also develop.

Working to meet the challenges of **Industry 4.0**
On-Site **VRTM** and **Infusion** Demonstration

with **CIJECT TWO**

at **Atech** Booth

(N1 Entrance, Booth No.2124)
Thank You!

For more information please visit
www.composite-integration.co.uk