MECHANICAL PROPERTY DIFFERENCE BETWEEN COMPOSITES PRODUCED USING VACUUM ASSISTED LIQUID COMPRESSION MOLDING AND HIGH PRESSURE INJECTION RESIN TRANSFER MOLDING

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Abstract

Implementation of composites in automotive manufacturing is driven by cost reduction. High Pressure Injection Resin Transfer Molding (HP-iRTM) and Liquid Compression Molding (LCM) are state of the art composite manufacturing processes, which are capable of producing finished parts in 3-5 minutes. Although HP-iRTM is capable to produce thicker parts and parts with more complex geometry than LCM, LCM provides substantial cycle time advantage and potentially requires simpler equipment. The present research aims at studying the mechanical property differences between C-channel composite parts produced by HP-iRTM and LCM technologies. Tensile, flexure and inter-laminar shear strength (ILSS) measurements were done on samples taken from parts manufactured using both technologies. It was found that although vacuum assisted LCM manufactured parts contained more voids than parts produced using the HP-iRTM process, the resulting tensile and flexure properties for both processes were practically the same, while ILSS results from the two processes were different.

Introduction

High Pressure Injection Resin Transfer Molding (HP-iRTM) and Liquid Compression Molding (LCM) are two cutting edge technologies for manufacturing of lightweight structural automotive components. In HP-iRTM the multiple component resin system is mixed in a self-cleaning mixhead and then injected into the closed heated mold. In LCM the resin is applied on the fabric outside the mold followed by the movement of the wet fabric into the mold. The two processes are presented in Figures 1 and 2. Although HP-iRTM is a mature technology, LCM is only now being introduced into the industry.

While HP-iRTM accommodates high volume production due to the low cycle times, LCM provides an opportunity to reduce cycle times even further. Firstly, this is because the stage of curing and fabric wetting can be decoupled and performed simultaneously on two different parts thus eliminating the time loss associated with resin injection in the HP-iRTM process. Secondly, in LCM the resin flow length is significantly less than in HP-iRTM, allowing for a much higher mold temperature to be used, thus reducing the cure time significantly. Finally, in LCM the resin

is not injected into highly compressed fabric, but rather applied onto the composite fabric which requires simpler equipment to achieve similar product results.
Although HP-iRTM and LCM processes are similar in their nature it is unclear if the composites produced in these processes have the same properties. The current research is aimed at studying the differences in composites produced using both technologies.

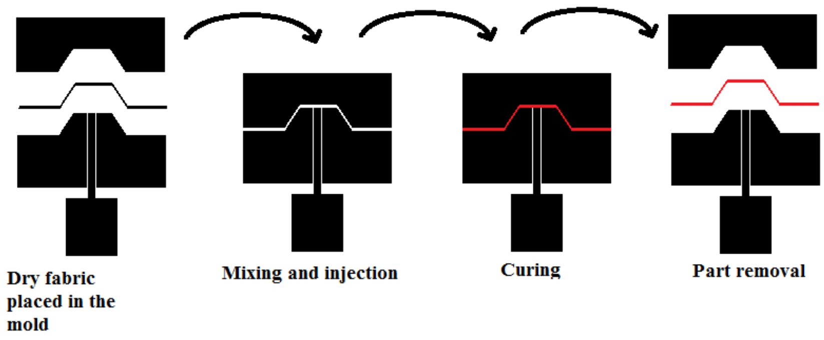

Figure 1 – Schematic representation of HP-iRTM process.

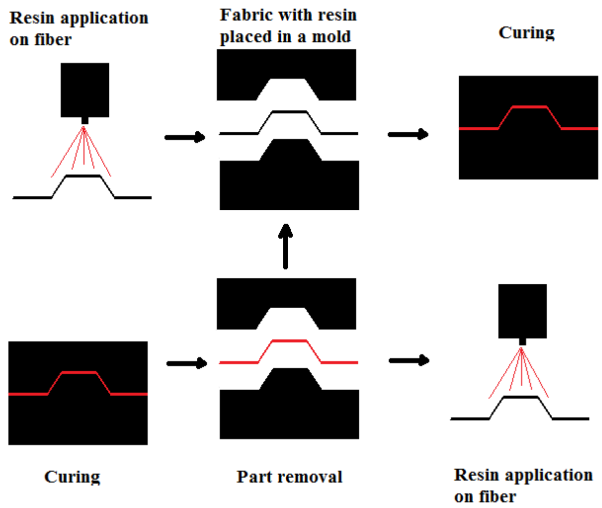

Figure 2 – Schematic representation of LCM process.

Experimental Studies

Composite panel manufacturing

KraussMaffei Rimstar 8/4/8 HPRTM and a Dieffenbacher CompresPlus 2500 ton servo-hydraulic press located at the Fraunhofer Project Center@Western, London, Ontario, were used to manufacture both HP-iRTM and LCM samples. The equipment is shown in Figure 3.

Figure 3 – HPRTM and press equipment at FPC

Samples were manufactured using the C-channel tool which is 800 mm long and 200 mm wide, shown in Figure 4. The parts were manufactured from Hexion's 6170 resin system, for which the components are shown in Table 1 and Zoltek's PX35MS4-MD carbon fiber. The conditions for HP-iRTM and LCM manufacturing are summarized in Tables 2 and 3 respectively.

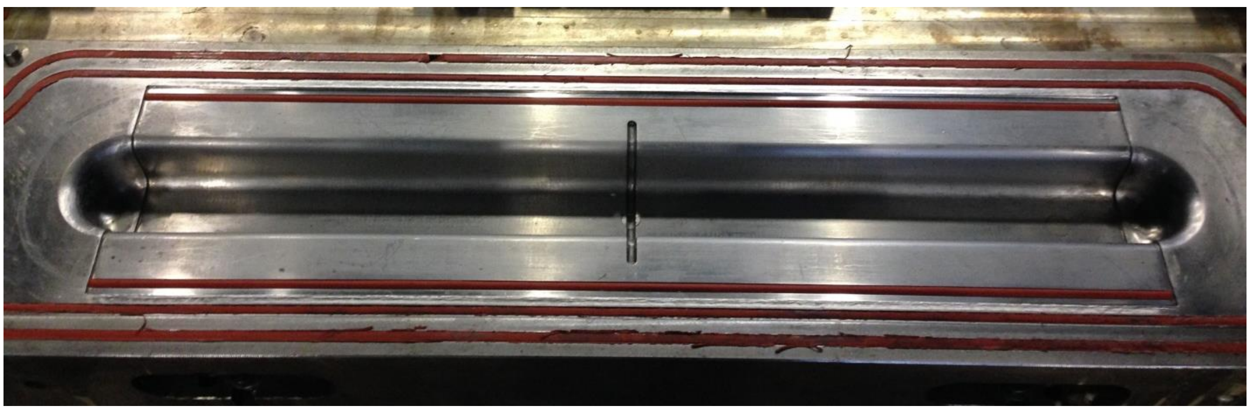

Figure 4 – HP-iRTM C-channel mold

Table 1 – Epoxy system components

Epoxy system	
Resin	EPIKOTE 06170
Hardener	EPIKURE 06170
Internal mold release	HELOXY 06805

Table 2 – HP-iRTM manufacturing parameters

	Constant process settings
Press/tool parameters	Mold temperature on cavity surface: 130 °C, 1000 kN press force during injection step, 3000 kN press force during cure step
HP-iRTM parameters	Fiber volume fraction 53% (targeted), Vacuum time: 120 s, Curing time: 180 s, Resin injection rate: 60 g/s, Resin injection amount: 360 g, Mixture ratio 100:16:1.5 (resin:hardener:IMR)
Resin parameters	Mixing head pressure: 120 bar, Resin temperature 60 °C, Hardener temperature 30°C, Internal mold release temperature 35 °C

Table 3 – LCM manufacturing parameters

	Constant process settings
Press/tool parameters	Mold temperature on cavity surface: 130 °C, 3000 kN press force during cure step
HP-iRTM parameters	Fiber volume fraction 53% (targeted), Curing time: 180 s, Resin injection amount: 360 g, Mixture ratio 100:16:1.5 (resin:hardener:IMR)
Resin parameters	Mixing head pressure: 120 bar, Resin temperature 60 °C, Hardener temperature 30°C, Internal mold release temperature 35 °C

The LCM resin system was prepared by using the HP-iRTM system where resins were injected into a degassed canister and then poured on top of the fabric.

Materials characterization

Mechanical tests were performed on a MTS Criterion tensile machine. Table 4 summarizes the different tests, standards and parameters for which mechanical tests were performed.

Table 4 – Mechanical testing parameters

Test	Standard	Load Cell	Movement Speed	Number of Samples
Tensile	ASTM D3039/D3039M-08	100 kN	2 mm/min	8
Flexure	ASTM D7264M-07	100 kN	4.26 mm/min	6
ILSS	EN ISO 14130	10 kN	1 mm/min	8

In addition, samples manufactured using HP-iRTM and LCM technologies were scanned with Nikon Eclipse L150 light microscope to look for voids. Samples for mechanical properties were cut according to Figure 5.

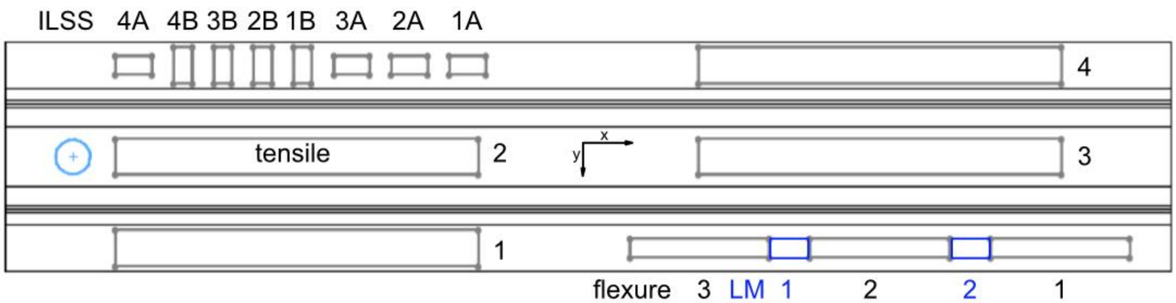

Figure 5 – HP-iRTM C-channel mold

Results and Discussion

Microscope images are shown in Figure 6. Samples created using the LCM contained more voids than the samples that were manufactured using HP-iRTM. This could be explained by the trapped air in the mold during LCM operation. This effect could have been mitigated by a use of a specifically designed mold for LCM process and optimised fabric for LCM operation; however, for this study it was desired to produce HP-iRTM and LCM parts with the same equipment and materials.

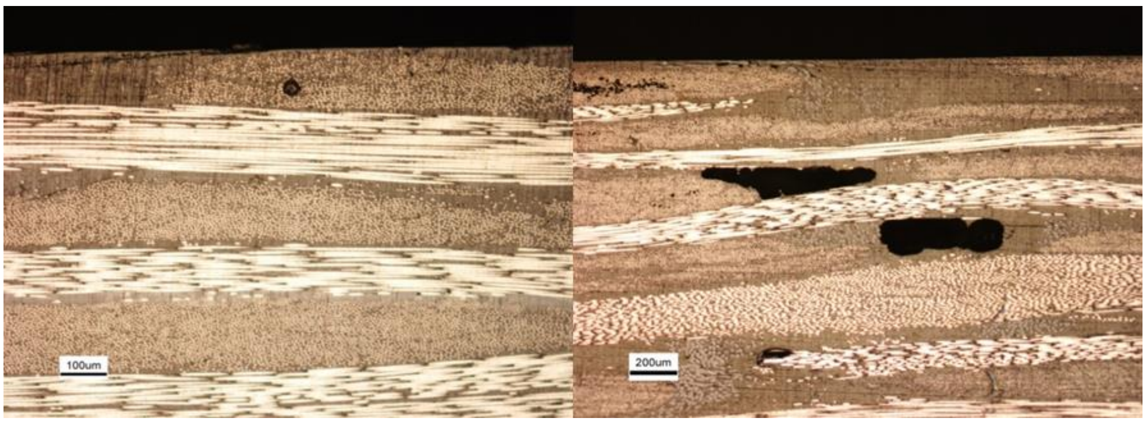

Figure 6– Light microscopy results. HP-iRTM sample on the left and LCM sample on the right

Summary of results for tensile, flexure and ILSS tests for both HP-iRTM and LCM technologies are shown in Figure 7.

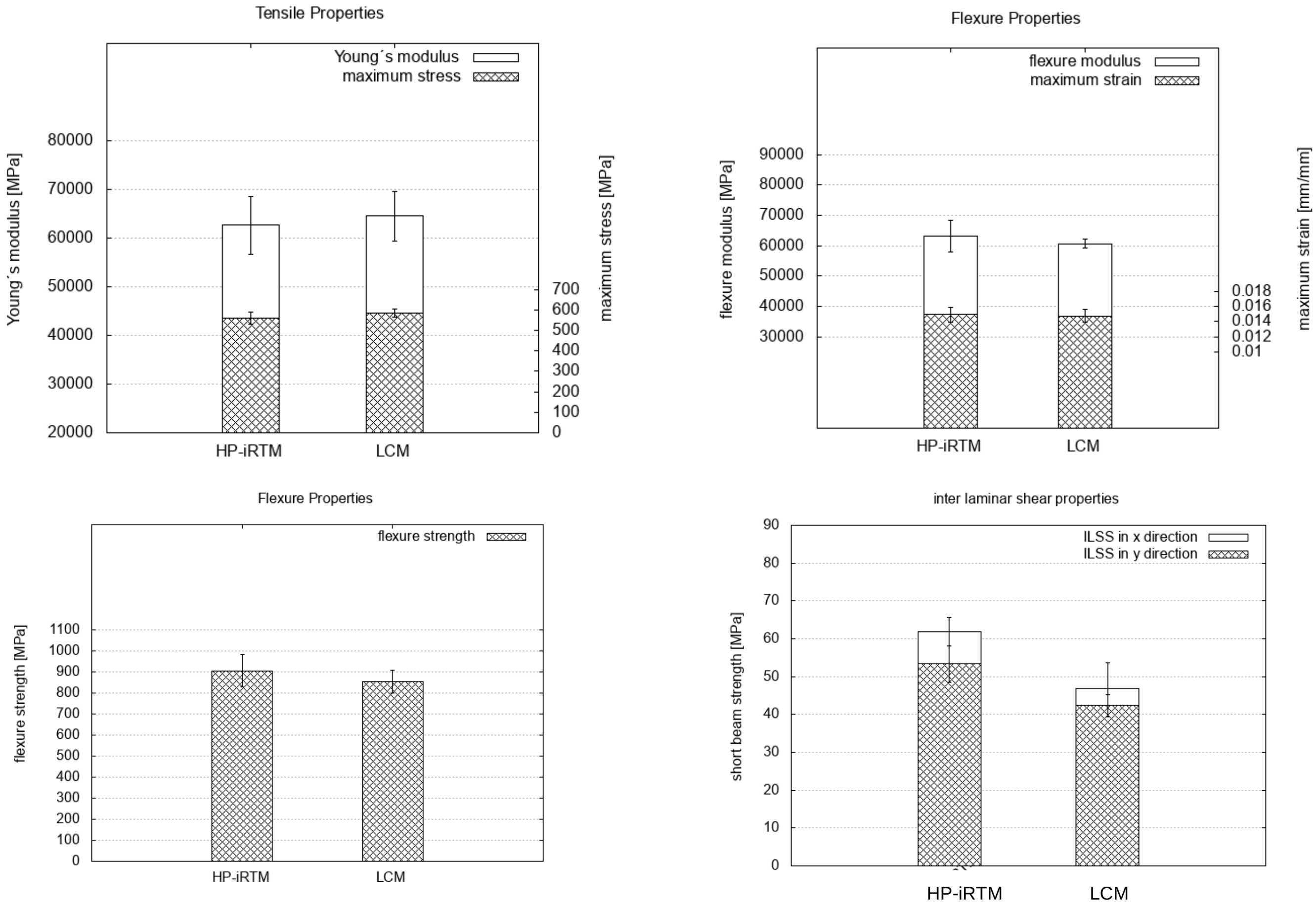

Figure 7– Tensile, Flexure and ILSS mechanical tests results

The tensile and flexure properties of samples prepared using HP-iRTM and LCM are very similar while the ILSS properties of LCM samples are lower than ILSS properties of HP-iRTM samples. Lower ILSS results for the LCM process could be expected as it is known that ILSS test is sensitive for voids [1].

Summary

LCM and HP-iRTM technologies produce composites with similar properties while LCM also proposes significant cycle time reduction. The method in which LCM was performed in this paper resulted in entrapped voids in the produced parts, but these voids could be avoided by using more conventional LCM equipment, namely mold designed for LCM application, LCM nozzle and optimised fabric for LCM operation.

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Bibliography

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