

# IN-MOULD GEL-COATING FOR RESIN INFUSION PROCESSES USING A FLOW MEDIUM

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**ABSTRACT:** Fibre-reinforced polymer matrix composites find use in most transport applications, chemical plant, renewable energy systems, pipelines and a variety of other industries. Many of these applications require a separate surface finish for cosmetic and/or durability reasons. This coating, known as the gel-coat, is normally applied onto the mould tool before the structural laminate is moulded against the coating. The majority of the volatile organic components (VOC) in the coating will react during the polymer curing process, but the application process is such that some VOC will be emitted into the workplace and the environment.

A separate paper offered for this conference describes a project to develop an In-Mould Gel Coating process in the context of Resin Transfer Moulding. This paper will describe the use of the same novel concept (British Patent GB 2 432 336A) in the context of Resin Infusion under Flexible Tooling (RIFT) using a flow medium. Gel-coated laminates have been manufactured using several process variations. The new in-mould gel-coating process has potential to improve workplace safety and reduce environmental impact during the manufacture of composite components.

**KEYWORDS:** resin infusion, in-mould gel-coating, RIFT

## INTRODUCTION

The resin infusion processes date back to the Marco patent in 1950 [1] for flow between complementary mould tools and to the Green patent in 1963 [2] for flow into dry reinforcements contained by a polymeric bag or an elastomeric membrane. The technology experienced a significant revival about twenty years ago and has been the subject of a number of recent reviews [3-6].

The application of a gel-coat to a composite is normally achieved by either spray or brush coating the mould tool before lamination or by mould opening after composite manufacture and injecting resin into the newly created space. The former method releases volatile organic compounds (VOC) into the workplace while the latter method cannot be easily implemented for components with both horizontal and vertical

surfaces. Layton [7] has provided a good summary of the key considerations for the use of gel-coats.

The Crystic Polyester Handbook [8] suggests that the gel-coat thickness should be in the range 0.4-0.5 mm for most applications, or 0.5-0.6 mm thick for mould tools. At a thickness below 0.4mm, there may be incomplete cure, reinforcement print-through and an increased probability of osmosis leading to blistering. At higher thicknesses, the gel-coat surface will be brittle and the additional cost is not justified.

In British Patent GB 2 432 336A [9], a new method is proposed for the in-mould gel-coating of composite structures. The face of the laminate which is to be coated is covered by a trilaminar separator layer being an impermeable plastic film with a fabric adhered to both surfaces. Resin for the structural laminate is injected on one side of the film while the gel-coat is infused into the space created by the fabric stand off on the opposite side of the film. The concept has been previously demonstrated for the resin transfer moulding process [10, 11]. A separate paper offered for this conference describes a project to develop an In-Mould Gel Coating process in the context of Resin Transfer Moulding. This paper will describe the use of the same novel concept in the context of Resin Infusion under Flexible Tooling (RIFT) using a flow medium. Gel-coated laminates have been manufactured using several process variations. The new in-mould gel-coating process has potential to improve workplace safety and reduce environmental impact during the manufacture of composite components.

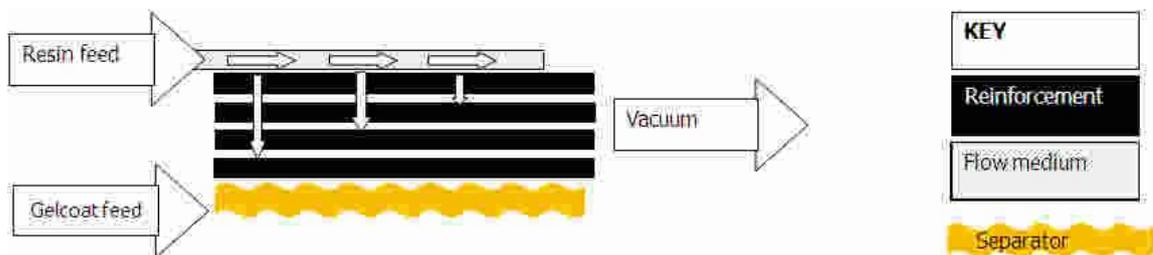


Figure 1: Schematic representation of Type II infusion with a flow medium and through-plane flow process, and a separator layer for in-mould gel-coating (the bagging film (above) and mould tool (below) are omitted for clarity)

## EXPERIMENTAL METHODS

Experiments were conducted using a glass plate as the mould tool against which the gel-coated surface was produced. The separator layer for the initial trials were vacuum bagging film, then custom layers were supplied by either Anowa/Cerex (34 gsm non-woven polyamide-66 2dtex continuous filaments chemically bonded on both sides of an impermeable film) or Baltex trilaminates (0.75mm thick polyester fabric either side of PU film). Experiments were conducted with one, two or four layers of 1400 gsm biaxial stitched glass fibre non crimp fabric in the laminate. An epoxy (Sicommin SR8100 with 22w/o SPA824 hardener) resin system was initially used for both the gel-coat (GC) and the laminate resin (LR). In accordance with the resin data sheet, the plates were allowed to cure at ambient temperature for 24 hours before being post-cured (temperature ramped to 60°C over four hours then held at 60°C for eight hours before cooling to ambient temperature over one hour).

Four process sequences were considered:

1. inject laminate resin first, allow to gel, then inject gel coat.
2. inject gel-coat first, allow to gel, then inject laminate resin.
3. inject laminate resin first, then inject gel-coat before the laminate resin cures.
4. inject gel-coat first, then inject laminate resin before the gel-coat cures,

but only the first two were studied to reduce the variables in the experiments. Initial trials were conducted with two parallel input pipes, but the vacuum applied (<10 mbar absolute in all experiments) to the cavity compressed the respective materials and the pipe was found to constrain flow in the adjacent layer.

Introducing laminate resin and gel-coat through pipes on adjacent edges of the plaque was adopted to address this issue.

The following parameters were monitored in the respective plates:

- percentage of fill on the gel-coat surface,
- quality of gel coat surface  
(on a five point scale from 1= incomplete fill to 5 = “class A” finish),
- gel-coat thickness determined by optical microscopy of polished sections.

## RESULTS

For the initial trials with vacuum bag as the separator layer, GC coverage was found to decrease with increasing number of layers of reinforcement, from 100% for both injection strategies with one layer of reinforcement to 95% (GC first) or 81% (LR first) for four layers of reinforcement. GC surface finish was found to reduce with increasing number of layers of reinforcement, from 5 for both injection strategies with one layer of reinforcement to 3 for both injection strategies for four layers of reinforcement. GC first with two layers also achieved a surface quality rating of 5. GC thickness was found to decrease with increasing number of layers of reinforcement, from 0.6 mm for both injection strategies with one layer of reinforcement to 0.41 mm (GC first) or 0.39 mm (LR first) for four layers of reinforcement.

In the second series of experiments, four resin feed configurations were considered:

- A. GC inlet and LR inlet pipes parallel to the vacuum vent line.
- B. GC inlet parallel and LR inlet perpendicular to the vacuum vent line.
- C. GC inlet perpendicular and LR inlet parallel to the vacuum vent line.
- D. GC inlet normal to the plane of the laminate (z-direction) and LR inlet parallel to the vacuum vent line.

The z-direction flow produced 100% GC coverage for both injection strategies in configuration D with the coverage for the four strategies ranked D > B > A > C (the latter being 67.5% for GC first and 52.5% for laminate resin first). Some mixing of the GC and LR did occur due to sealing issues with quality of finish ranked D > B = C > A.

In the third series of experiments, three different GC resin viscosities were trialled (150 mPa.s for stoichiometric epoxy, 250 mPa.s for non-stoichiometric epoxy using 5% hardener, and 600 mPa.s for a polyester resin with 1% catalyst). GC coverage decreased from 100% at 150 mPa.s to 88-89% (GC first) or 79-82% (LR first) at 600 mPa.s. GC thickness decreased with decreasing GC viscosity with 4-layer laminates having thinner gel-coats than 2-layer laminates and with LR first having consistently

thinner GC by between 5-18%. Surface quality decreased with decreasing GC viscosity.

In the fourth series of experiments, the Baltex fabric produced a thicker gel-coat (0.43-0.44 mm) than the Cerex fabric (0.41-0.42 mm), took slightly longer (~20%) to achieve complete fill and showed less print-through of the separator layer pattern. Both fabrics were experimental samples which had not been optimised for this application.

Although z-direction tensile tests were conducted on the laminates with separator fabric, the failures all occurred at low loads at the fixture-laminate interface and hence were not valid measurements of the strength of the gel-coated laminate.



Figure 2: Reflection of a light fitting (left) and a packaging label (right) on the surface of a pigmented IMGC RIFT II plate.

## SUMMARY

The In-Mould Gel-Coating (IMGC) process has potential to improve workplace safety and reduce environmental impact during the manufacture of composite components. This paper has described the use of a novel concept, described in British Patent GB 2 432 336A, in the context of gel-coating composites manufactured by Resin Infusion under Flexible Tooling (Type II RIFT) using a flow medium. The study has considered different flow line configurations, resin viscosities and injection sequences. The gel-coated panels were judged using GC coverage, thickness and surface finish.

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## REFERENCES

1. IE Muskat, [Method of molding](#), United States Patent 2 495 640, 24 January 1950.
2. PR Green, [Improvements in or relating to methods of producing reinforced plastic structures](#), British Patent 944955, 18 December 1963.
3. C D Williams, J Summerscales and S M Grove, [Resin infusion under flexible tooling \(RIFT\): a review](#), Composites Part A: Applied Science and Manufacturing, July 1996, 27A(7), 517-524.
4. D Cripps, T J Searle and J Summerscales, Open Mould Techniques for Thermoset Composites, In R Talreja and J-A Manson (editors): Comprehensive Composite Materials Encyclopædia, volume 2: Polymer Matrix Composites, Elsevier Science, Oxford, July 2000, Chapter 21, pp 737-761. ISBN 0-08-043725-7.
5. J Summerscales and T J Searle, [Review: Low pressure \(vacuum infusion\) techniques for moulding large composite structures](#), Proc IMechE Part L: Journal of Materials: Design and Applications, February 2005, L219(1), 45-58.
6. J Summerscales, Resin Infusion under Flexible Tooling (RIFT), In Luigi Nicolais (editor-in-chief), Encyclopedia of Composites – second edition, John Wiley and Sons, Hoboken NJ, in press.
7. J Layton, Weathering, In G Pritchard (editor): Reinforced Plastics Durability, Woodhead Publishing, Cambridge, 1999. ISBN 1-85573-320-x.
8. Crystic Polyester Handbook, Scott Bader Company Limited, Wellingborough (UK), 1994.
9. AR Harper, J Summerscales and N Brooks, [Production of composite mouldings](#), British Patent GB 2 432 336A published 23 May 2007.
10. J Summerscales, C Hoppins, P Anstice, N Brooks, J Wiggers, D Yahathugoda, A Harper, C Wood and M Cooper, *In-Mould Gel Coating for Resin Transfer Moulding*, International Conference on Manufacturing of Advanced Composites, Belfast, 18-19 March 2009.
11. J Summerscales, C Hoppins, P Anstice, N Brooks, J Wiggers, D Yahathugoda, A Harper, C Wood and M Cooper, In-mould gel coating for resin transfer moulding, The 10<sup>th</sup> International Conference on Flow Processes in Composite Materials (FPCM10), Monte Verità, Ascona, CH – July 11-15, 2010.