IN-MOULD GEL COATING FOR RESIN TRANSFER MOULDING

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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 consortium funded by the Technology Strategy Board call Meeting the Challenge of the Zero Emission Enterprise is developing a proprietary system for In-Mould Gel Coating in the context of Resin Transfer Moulding and related processes. Gel-coated laminates have been manufactured using several process variations. The surface finish has been measured using both fractal dimension determined from digital images and Wavescan DOI. Z-direction tensile strength tests have been undertaken to establish the interfacial bond strengths. The new in-mould gel-coating process has potential to improve workplace safety and reduce environmental impact during the manufacture of composite components.

INTRODUCTION

Gelcoat is a surface layer of (normally unreinforced) resin applied to a laminate to provide either (or both) a cosmetic surface and enhanced durability in environments where the laminate might otherwise be degraded. This technology has been described more fully by Layton [1] and the selection of appropriate system components has been summarised by Searle and Summerscales [2]. In traditional composite manufacturing operations, it is normal to apply the gelcoat to the open mould by brush or spray and permit partial cure before starting to build the laminate. Gel coat systems normally use a volatile organic compound (VOC) as the carrier. The release of VOC into the workplace should be minimised for both worker health and environmental reasons.

Components may be manufactured in a closed mould using compression moulding, resin transfer moulding or resin infusion. Each of these processes has the potential for the coating to be applied in the mould during the process to limit release of solvents to the atmosphere and to improve the accuracy of the film thickness.

Rogers and Summerscales [3] have reviewed this approach. The majority of in mould coating (IMC) systems rely on mould opening along a single axis by either controlled movement or increased pressure. This limits the geometry of moulded parts to those having low moulding angles or it increases the complexity of the tooling where surfaces parallel to the mould opening axis are to be coated. Multi part moulds would have to be produced in these cases, at considerable expense.

Separation layers are used in RIFDT (Resin Infusion under Double Flexible Tooling) [4, 5] to allow a resin to be infused into a fibre pack with minimal disturbance from a thermo-formable paint film, which is inserted into the mould before infusion and cured by heat after infusion.

THE NEW PROCESS

Harper et al [6] have patented a novel in-mould gel-coating (IMGC) process. The laminate resin and gelcoat are kept apart by an impermeable separator layer with textured surfaces to provide good adhesion to the respective resin systems. The texture on the gelcoat surface maintains a controlled thickness gap into which gelcoat can flow.

Separator layer

Initial trials have focussed on the use of a trilaminate separator layer with an impermeable film substrate supporting textile faces. A typical section through such a trilaminate is shown in Figure 1. The gelcoat and laminate resin systems can infiltrate the respective textile layers to achieve better adhesion than would occur at a smooth surface.

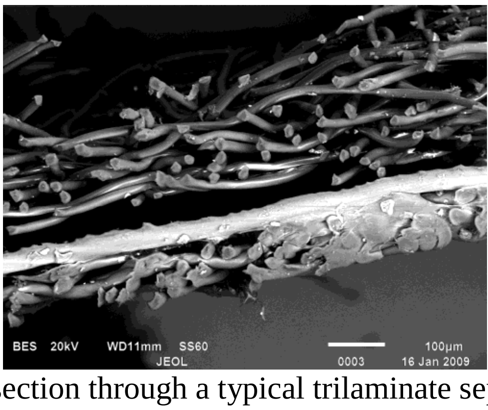

Figure 1: A section through a typical trilaminate separator layer.
(Image acquired by the University of Plymouth Electron Microscopy Centre).

	Laminate first	**Gelcoat first**	**Simultaneous**
Good			
Poor			

Figure 2: Photographs of typical in-mould gel-coated laminate surfaces for 10% fibre volume fraction composites. The central defect arises from the position of the gel-coat inlet gate.

The IMGC Process

The IMGC process could be used for any closed mould process where it is possible to achieve a seal between the cavities for each of the resin systems. It could be applied in compression moulding, resin transfer moulding (RTM) or resin infusion under flexible tooling (RIFT) technologies.

The project reported here has concentrated on RTM. Experiments were conducted with (a) laminate injection first, (b) gel coat injection first, and (c) “simultaneous” injection of both the laminate and the gel coat (Figure 2). All experiments have been conducted with Saint Gobain Vetrotex Unifilo U813 (300g/m^2) as the reinforcement, Scott Bader Crystic 785PA pre-accelerated unsaturated polyester resin for the laminate and Scott Bader Crystic PD9947PA pre-accelerated gelcoat using Scott Bader Catalyst M (MEKP). Separator fabrics have been sourced from Baltex or Cerex. Target fibre volume fractions were 10%, 15% (typical of normal industrial usage), 20% and 30% (to tests the system at extreme conditions) assuming a 0.5 mm gel coat.

The laminates produced have been characterised (e.g. as in Figure 3) by measurement of the gel coat thickness, the depth of penetration of the separator fabric into the gel coat, fibre print-through and “surface quality (see below).

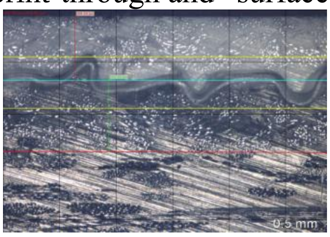

Figure 3: Typical cross-section of a composite with the Baltex separator fabric showing wrinkling of the separator layer substrate (the continuous line from left to right) and the larger separator layer fibres in both the gel coat (above) and the laminate (below).

SURFACE FINISH

The surface finish of a moulded component will normally only be as good as the surface against which it is moulded, at best. For the results reported here the composite was moulded in a double glass-plate mould, so very high integrity surfaces are possible. However, as noted above, under some conditions laminates were produced with incomplete fill or surface defects. Laminate quality was assessed using (i) percentage coverage, (ii) gloss grade, (iii) print-through/distortion and (iv) surface defects, each translated to a ten-point scale and radar plots (e.g. Figure 4).

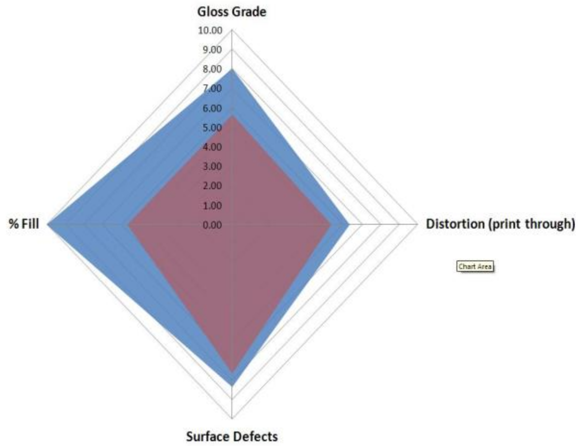

Figure 4: Radar plot for comparison of two Baltex fabrics

Z-Direction Testing

An important aspect of the performance of the IMGC system is the adhesion of the various components at the four interfaces, i.e. both the resin-trilaminate adhesion and textile-film adhesion within the trilaminate on either the gelcoat or laminate sides of the separator layer. Z-direction tests are in progress to establish strength levels achievable using IMGC. Failure loads have high variability even for the same manufacturing sequence and even for the same panel. A study of failure modes should permit further development of the system to achieve more consistent values.
Laminate quality was judged (a) using photographs of white light reflected from the laminate onto a white screen and (b) by human observation. The digital photographs were quantified as a fractal dimension (FD) using Image J software [7] with the FracLac add-in [8] in an apparatus designed by Labrosse [9]. Three individuals (Richard Cullen, Quentin Labrosse and John Summerscales) each independently ranked the plates from poor (low rank) to good (high rank). Figure 5 shows the correlation of the FD number against assessment by human eye. All poor plates have FD<1.34, while those judged to be of acceptable finish all have FD>1.35.

CONCLUSIONS

This paper has reported the development of a novel patented in-mould gel coating process for RTM. The initial trials have considered gel coat injection first, laminate injection first and simultaneous injection with a range of laminate fibre volume fractions. Laminates with acceptable surface finish have been produced and that parameter has been quantified as a fractal dimension. Development of the process is still underway.

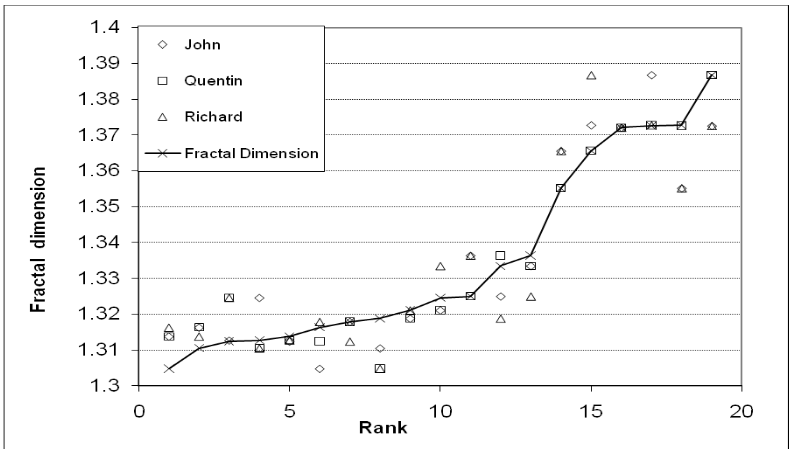

Figure 5: Correlation of the fractal dimension and human assessment of gel coat quality

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