Eliminating the need for gel-coat surfaces in composites

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Abstract

This work aims to demonstrate one such case, where the gel coat is substituted for a polyester veil (in this case a patterned wood effect) and a novel UV resistant resin, employing a closed moulding infusion process. Different types of surface veil were investigated on the basis of their finish quality and drapability around concave corners. Three resin types by Scott Bader (9933PA, 936PA, and 196) were selected for UV resistance development, and novel blends of the three subjected to accelerated weathering tests through UV irradiation and moisture cycles in accordance with ISO 4892-2 and ISO 4892-3. Finally, a demonstrator part was produced to assess the suitability of the approach of the veil and 9933PA resin blend as a closed moulding, relative to typical approaches. Initial results suggest increases in productivity are possible through the approach, whilst aesthetically improved capability and performance is gained.

1. Introduction

Glass fibre reinforcement accounts for over 90% of the global composites market, and by 2024 is expected to grow to US$ 17.4 Billion [1]. Thus, glass fibre reinforced composites are ubiquitous; being used in industries as diverse as oil and gas, marine and wind energy, and automotive [2]. Most glass fibre composite structures on a consumer level are used in applications requiring a high tolerance aesthetic/surface finish, for decoration or environmental protection. To achieve this, it is typical to use a high gloss coating resin or gel-coat of either polyester or vinyl ester that is mostly applied by hand to the mould and allowed to cure in ambient conditions, prior to reinforcement drape and resin addition through infusion processing or contact moulding. This method ensures a high-quality surface finish and matching mould geometry are rapidly and flexibly achieved, without significant investment in complex or costly operations. Due to the chemistry of polyester and vinyl ester resins, styrene emission is inherent to the gel coat process; and despite good practice for its workplace control, it is rapidly becoming a significant safety concern. For example, the UK's styrene occupational exposure limit (OEL) is 100ppm (parts per million) time-weighted average (TWA)/250ppm Short-term Exposure Limit (STEL), whilst in the EU this is at 20-50ppm TWA/40-100ppm STEL [2,17]. However, Europe is likely to adapt to 10ppm limit due to government imposing stringent OELs. Thus, alternate moulding options are required to continue to offer flexibility and retain the surface finish of consumer goods that extremely price sensitive (limiting the application of other potential resins and investment in automation or extraction).

1.1 Gel coat

Gelcoat is usually based on unsaturated polyester or vinyl ester resin. It has typically 30-50% styrene during the polymerisation. Styrene is a cross-linking agent in polyester resin; and a volatile organic compound (VOC). Styrene is released into the atmosphere until the resin vitrification stage is achieved during the curing process of the composite laminate, i.e. unsaturated polyester (matrix) and glass fibre (reinforcement) [3].

1.2 Health and environmental effects of styrene

VOCs are incredibly hazardous substances that affect local air quality. They pose a threat to the laminators or workers health; Challenor and wright study showed that exposure to styrene causes headaches, fatigue, weakness and depression [4]. This is significant evidence to show that styrene affects both environmental and health. Therefore, action must be taken to reduce or eliminate the use of styrene entirely and create a work environment that is pleasant and safe.

2. Materials and Methods

Whilst there are some papers in mould gel coating and in mould surfacing with shim plate used to reduce the styrene emission without elimination of gel coat [3,5]. However, there are few journal paper mention about alternatives to gel coat process [6-7].

This paper addresses the manufacturing of a gel-coat free, high-quality wood effect surface of a top cover immersion suit cabinet that is used in the cruises and marine environment in the Middle East [19]. Open mould is the typical manufacturing process for using the wood effect polyester veil. Clear gel coat is applied and cured, and then polyester veil laid up whilst the gel coat is still tacky. Glass fibre mat is then draped into the mould, wet-out with a brush and consolidated with rollers. The disadvantage of this process: high styrene emission, high level of voidage occurrence, in addition, the quality varies from operator to operator. Furthermore, ~700ppm styrene is emitted during the brushing the gel coat, which suggests that it is an Immediately Dangerous to life or Health Concentrations (IDLHC) according to the National Institute for Occupational Safety and Health (NIOSH). Moreover, zero styrene emission during the infusion of a bagged laminate [3].

2.1 Wood effect polyester veil

The pattern polyester veil has been around for many years. Three different polyester veil manufacturers were investigated based on their quality, drapability, ease of manufacturing. All three suppliers are from different countries, i.e. USA, India and China [8-10]. Figure 1 depicts the different suppliers of a polyester veil. Based on trials of the veils in quality, drapability, and workability; the USA version of the veil stood out and was selected for the part.

Figure 1 Three different samples of the wood effect polyester veil in the market (from left to right: Indian, US and Chinese polyester veil respectively)

2.2 UV resistant resin and Sample manufacturing process

Collaborated with Scott Bader to develop a UV resistant resin. This was done by the novel blending of current resins (modifies 961, 936PA and 9933PA). Table 1 shows the materials used for the samples, which are 500mm x 500mm test panel manufactured by Resin Transfer Moulding process made out of Aluminium material [11]. This to keep the consistency and quality of the samples. The sample is 3mm thick. The experiment aims to manufacture high-quality samples with selected resins using RTM process.

Table 1. Materials used to manufacture the samples

Materials	Crystic 195 (modified)	Crystic 936PA (modified)	Crystic 9933PA (modified)
Surface finish	Wood effect polyester veil	Wood effect polyester veil	Wood effect polyester veil
Reinforcement	1x 450/180pp/450 glass fibre 1x continuous glass fibre	1x 450/180pp/450 glass fibre 1x continuous 0/90^0 glass fibre	1x 450/180pp/450 glass fibre 1x continuous glass fibre
Catalyst	MEKP Butanox M50	MEKP Butanox M50	MEKP Butanox M50
Matrix	Light stabilised polyester resin	Tough isophthalic polyester resin	Polyester resin

2.3 Laboratory accelerated weathering test

The tests were carried out at Scott Bader in Wollaston, UK in accordance with ISO 4892-2 and ISO 4892-3. The machine used for the tests are Suntest XLS+ and QUVA machine [12-13]. Natural weathering test such as natural Florida weathering and EMMAQUA (Natural Accelerated Weathering Equational Mount with Mirrors for Acceleration with Water) is costly and time-consuming. Therefore, Xenon arc (which replicates sunlight by using the Xenochrome 300 filter), QUVA (which replicates the condensation cycle) and UV radiation were used. These are most successful laboratory scale experiments. Table 2 shows the condition and exposure used to test the samples. This condition used to replicate Middle East weather, i.e. UAE, which was driven by the company market.

Table 2. Conditions used to simulate the Middle East environment

	Xenon arc (ISO 4892-2)	QUVA (ISO 4892-3)
Exposure (h)	1000	1000 (4 UV cycle; 4 condensation)
Filter type	Daylight	UVA-340
Irradiance (W/m^2nm)	0.55 at 430	0.76 at 340
Temperature (°C)	60	60
Condensation, (°C) (relative humidity)	NA	50

The limitation of the experiment is that it does not give the actual weathering data, for example, the exact time or years for the degradation, due to the fact that substantial environmental changes occur in natural weathering [18]. However, it provides immediate comparative results rather than absolute data. The experiment aims to choose the resin based on the UV performance (degradation and colour change) of the three resins under harsh environment.

2.4 Gloss measurement

The gloss meter tool BYK Micro-TRI-Gloss (Model No: 4446 and Serial number 1105701) was used to measure the gloss level of the sample's surface [14]. "The measurement results of gloss meter are related to the amount of reflected light from black glass standard with a defined index of refraction and not to the amount of incident light" [16]. The measured value of standards is equal to 100 gloss units. For example to obtain a clear differentiation over the complete measurement range from high gloss to matte. Semi-gloss surfaces are measured at an angle of incidence of 60° and should fall within a range from 10 to 70 gloss units. Highly reflective surfaces with measurement values exceeding 70 units in the 60° geometry should be measured at 20°. On the other hand, matte surfaces with less than 10 gloss units (at 60°) should be measured at the 85° geometry [16]. Thus, for this study, the gloss level will be measured at the 20° angle due to the high gloss surface finish of the laminate. The aim is to evaluate and compare the three samples following the accelerated weathering test to examine the gloss level.

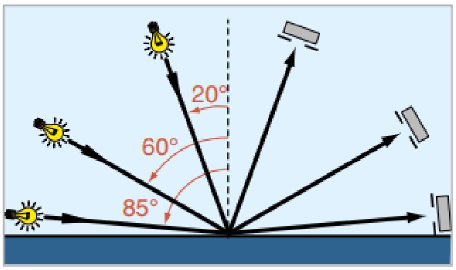

Figure 2. Measurement angle of specular reflection [16]

2.5 Vacuum Assisted Resin Transfer Moulding (VARTM)

The VARTM manufacturing process was used to test both novel resin and polyester veil. The main benefits of this process are: lower tooling cost due to another half of the mould being vacuum bag, large low volume bespoke part can be fabricated with high fibre volume fractions and low void contents, low styrene open-air emissions due to closed mould process [15]. Hence, it fits this application. The test aimed to manufacture demonstrator part using novel UV-resistant resin and polyester veil.

Table 3. Materials used to manufacture the demonstrator part

Materials	Crystic 9933PA (modified)
Surface finish	Wood effect polyester veil
Reinforcement	1x 450/180pp/450 glass fibre
Catalyst	MEKP Butanox M50
Matrix	Polyester resin

3. Results

This section evaluates the results of three different samples under three different environmental conditions. The Figures 3-5 show (weathered area marked in a black box) the effect of those samples that were left at 1000 hours under test conditions, i.e. Controlled room temperature, QUVA and Xenon machines. The gloss level in Controlled Room Temperature (CRT) is expected to be higher than 80 gloss units not exposed to any harsh environments. Hence, it gives a benchmark to work out samples which are exposed to the harshest environment.

3.1 weathering test result for resin Crystic 195

Figure 3 195 depicts the effect of the sample after the accelerated weathering test. It shows noticeable colour change and degradation in QUVA sample. Table 4 and Figure 6 shows that the gloss unit measurement at the 20º angle is 60, which translates to the level of glossiness of the sample. The gloss level measurement at CRT is 83.6. However, there is no change in the sample at room temperature. Still, there is a significant colour change in the Xenon exposed sample, and the glossing unit is 70.2. It would be a concern if it were a solid colour. However, the colour change simulates the natural wood effect closer, and it has an appealing appearance.

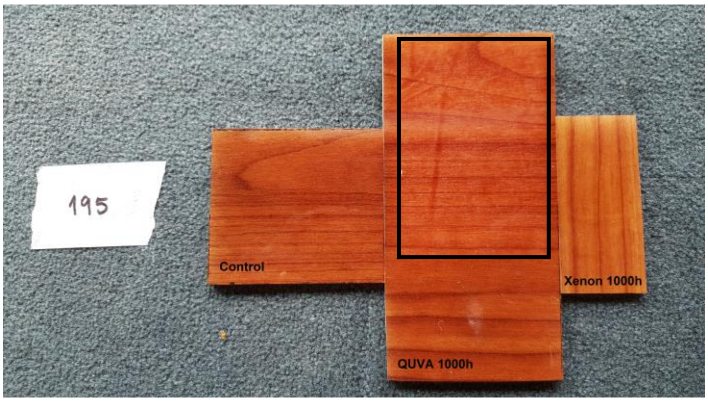

Figure 3. Resin 195 sample after the weather accelerated test

3.2 weathering test results for resin Crystic 936PA

Figure 4 shows the effect on the sample 936PA after the accelerated weathering test. Table 4 and Figure 6 show the gloss measurement in QUVA is 71.5 at 20º angle. There is small colour change, and no degradation was found. The sample in Xenon has a significant change in colour and reduction in glossiness, which is 64.2. However, it maintains the integrity of aesthetic appearance, there is no change in the sample at CRT, and the glossing unit is 77.8. This could be due to small interference with voids defect on that sample.

Figure 4. Resin 936PA sample after the accelerated weathering test

3.3 weathering test results for resin 9933PA

Figure 5 shows the effect left on the sample 9933PA after the accelerated weathering test. The sample left in QUVA had small colour change. Table 4 and Figure 6 show that the gloss measurement is 74.6 and no degradation was found. Significant colour change in sample left in the Xenon machine, but no gloss level reduction, which is 79.3. However, there is no effect in the sample at CRT, the gloss measurement for that is 79.3.

Figure 5. Resin 9933PA sample after the accelerated weathering test

Table 4. Gloss measurement results

Samples	QUV			Xenon			CRT		
	20º	60º	85º	20º	60º	85º	20º	60º	85º
Crystic 195	60	81.7	94	70.2	87.4	98.1	83.6	91.4	94.2
Crystic 936PA	71.5	88	92.8	64.8	80.5	89.5	77.8	88.2	94.4
Crystic 9933PA	74.6	87.3	93.4	79.3	91.0	98.6	79.3	90.4	96.7

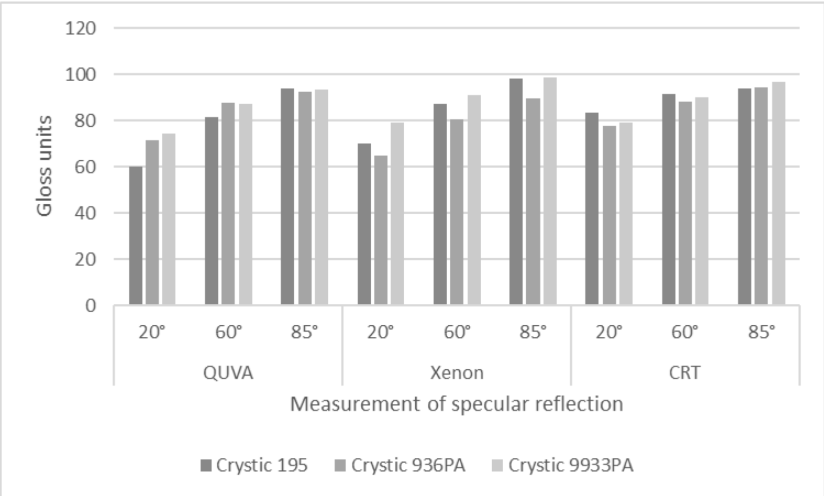

Figure 6. Glossmeter measurement comparison graph

3.4 Demonstrator part

The part was demonstrated on the top cover of the life jacket/survival suit chest, which holds 40 life jackets or 21 survival suits. The size of the top cover is 900mm (height) x 2395mm (width). Figure 7 illustrates the final part showing aesthetic appearance possible using the polyester veil and UV resistant resin.

4. Discussion

Further comparing the sample results after the accelerated weathering test, it comes out that QUVA provides the more realistic results because it has both UV irradiation and moisture cycle, while Xenon only simulates direct sunlight exposure but no moisture cycle. The colour change on the wood effect sample surfaces does not have a significant effect as it blends well with natural wood effect, due to the fact that natural wood does change colour over time when exposed to sunlight and air. This new method does not only eliminate the gel coat process and the styrene open air emission but also removes the non-value added activity within the process, which is the waiting time (20-30 mins at ambient temperature) during the gel coat curing process.

Figure 7. Moulded demonstrator in the as-released finish, showing the aesthetic quality possible using the wood effect polyester veil and novel high UV resistance resin

5. Conclusion

Wet/Hand lay-up process can be labour intensive and emits high VOC during the manufacturing process for this particular part. Therefore, investment in automation and extraction needed to minimise the styrene emission. This paper compares three different wood effect veils and UV resistant resins using VARTM process to eliminate the need for gel coat and styrene exposure. The USA version polyester veil and resin 9933PA was selected based on the accelerated weathering test, where resin 9933PA performed well with other two resins 195 and 936PA. Finally, a demonstrator part was produced to assess the suitability of the approach of the veil and 9933PA resin blend as a closed moulding, relative to typical approaches. Initial results suggest increases in productivity are possible through the approach, whilst aesthetically improved capability and performance is gained.

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