JEC COMPOSITES

magazine

121

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May - June 2018

coating

A new platform for producing Class A surface quality components




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This article introduces the PuriCoat platform for producing Class A surface quality, visible lightweight components within a very short cycle time. Through close technical collaboration between a coatings developer and a specialty chemicals company, products and process conditions were optimized to achieve excellent coating quality and durability. Furthermore, for industrial manufacturing, this platform's negligible emission levels address the growing regulatory demand for VOC-free solutions. With substantial cost savings and the potential for high build rates, PuriCoat makes coated visible interior and exterior parts more accessible than ever.

The automotive industry is evolving rapidly with increasingly rigorous emission targets, leaps toward electrification, and a push toward autonomous driving. These forces continue to trigger lightweight solutions, advancing the adoption of novel composite materials for diverse applications. Composite materials have been used for body parts in sports and luxury vehicles for a long time, enabling design freedom, astonishing aesthetics and leading-edge driving performance.

Today, visible composite parts are mainly produced using pre-impregnation (prepreg) or resin transfer moulding (RTM). However, the production of complex-shaped parts using prepregs is cumbersome because of their limited drapeability. In addition, the fabrication of the pre-impregnated intermediates adds an expensive process step.

In contrast, RTM is an attractive alternative that provides greater design freedom, as well as higher build rates thanks to shorter cycle times. However, there is normally a trade-off between surface quality and RTM cycle times due to the so-called fibre print-through effect. This phenomenon is caused by the mismatch between the thermal expansion coefficients of the resin and fibre, and shows up during the cool-down of moulded parts. The effect can be minimized by applying relatively low RTM operating temperatures – 80-90°C – and through additional surface treatment and coating steps.

New platform combining fast-cure epoxy RTM with an in-mould polyurethane coating

The new PuriCoat platform, jointly developed by Hexion and Votteler, allows the cost-efficient, eco-friendly production of coated exterior parts. This platform combines Hexion's fast-cure EPIKOTE™ resin 06000 / EPIKURE™ curing agent 06130 system suitable for mass-producing structural carbon fibre-reinforced polymer (CFRP) parts with Votteler's PURIFLOW® PU911IR reaction injection moulding (RIM) PU coating system suitable for in-mould coating of various substrates, including CFRP components.

The constituent products in PuriCoat are already known as high performers. On the one hand, Hexion's EPIKOTE resin 06000 / EPIKURE curing agent 06130 system is currently in commercial use for the production of structural parts by BMW [1]. Due to its low shrink characteristics, this system is also suitable for the production of visible parts. The product exhibits a low viscosity and latency as needed for RTM processes, and a short curing time. The internal mould release agent HELOXY™ additive TRAC 06805 can be used for fast, easy demoulding.

On the other hand, various car manufacturers have already approved PURIFLOW® paint systems from Votteler. These coating systems offer very high chemical and mechanical resistance, as well as resistance to heat and climate, yellowing and UV light. And since not every scratch can be avoided despite its high resistance, surfaces produced with PURIFLOW® are equipped with a self-healing effect: scratches will regress through a reflow effect.

PURIFLOW® coating systems can be adjusted or produced in transparent, pigmented, piano-black or innovative effects. The newest products are supplied with internal release agents for increased productivity and to eliminate the need for further processing, such as polishing.

The system used in PuriCoat – solvent-free, two-component PURIFLOW® coating system PU911 – is based on aliphatic polyurethanes, which are processed via reaction injection moulding (RIM). RIM is a process in which polyol and isocyanate (and possibly other additives) are mixed in liquid form in a polyurethane (PUR) reaction machine and then flooded as a reactive mass into a forming tool.

Such coating systems can be used for fibre thermoset composites and various thermoplastics, in a wide range of applications.
These include interior and exterior automotive components, consumer goods, electronics applications, and any surface components demanding high-end aesthetics.

Experimental optimization

The collaboration focused on ensuring that a durable interface is achieved between the carbon fibre-reinforced plastic (CFRP) part and the coating, while optimizing cycle time as well as surface quality.
The surface topography and the yellowing tendency of the composite were also evaluated to assess the impact of climate, temperature and visible & UV light.

The first phase of the collaboration evaluated adhesion performance.
The effects of varying epoxy chemistries, internal release agents, process parameters (e.g. cure cycle) and surface preparation were evaluated.
Optimal adhesion was reached utilizing the EPIKOTE™ resin 06000, EPIKURE™ curing agent 06130 and internal mould release agent HELOXY™ additive TRAC 06805 system, combined with the PURIFLOW® PU911IR system.

Despite the fact that both systems are self-releasing, it was possible to determine the factors that influence interface durability and to optimize the process to achieve consistently good results regarding surface quality and adhesion (see Figure 1).
Figure 1 also shows that no specific surface treatment is required to ensure good adhesion.

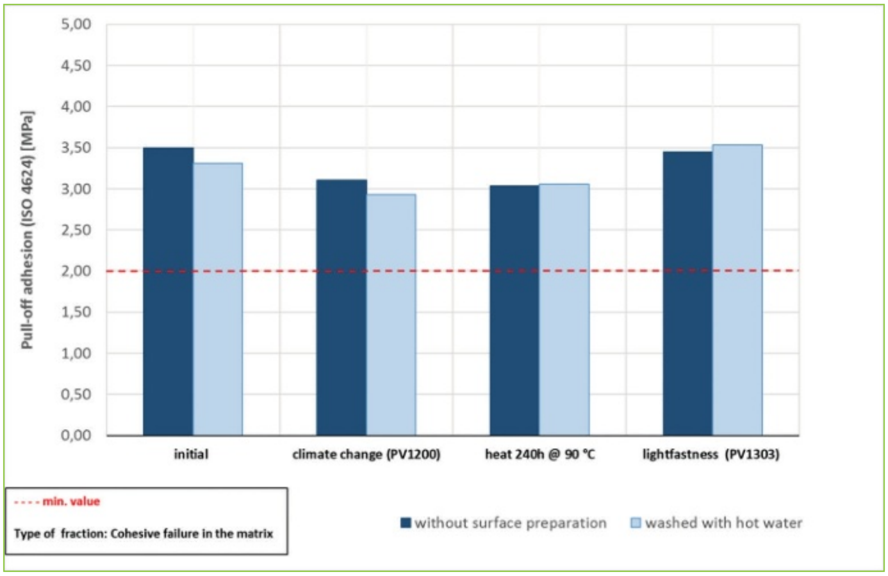

Fig. 1: PuriCoat system performance, with and without surface treatment

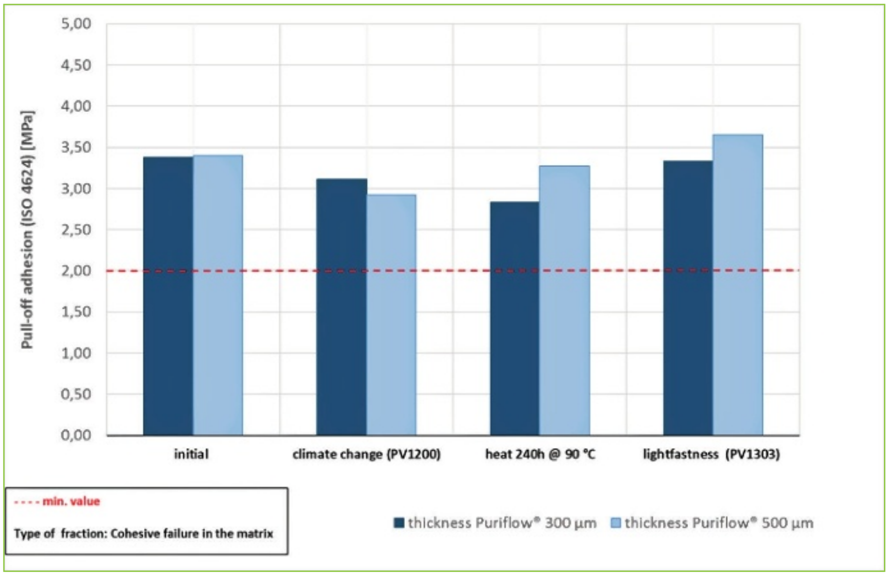

Fig. 2: Effect of coating thickness on adhesion performance

The second project phase focused on application process parameters. The impact of critical parameters for the RTM and RIM processes were analyzed. In addition, the influence of layer thickness on adhesion and surface quality was assessed.

Figure 2 shows that coating thickness has little effect on adhesion performance. Finally, the cycle time for the coating process could be reduced to 60 seconds by adapting the process parameters in the PU system. Experimental work is ongoing as part of this joint project.

Further studies will evaluate additional composite materials and processes, such as sheet moulding compounds (SMC) and fast-cure prepreg, as well as other PUR coating grades.

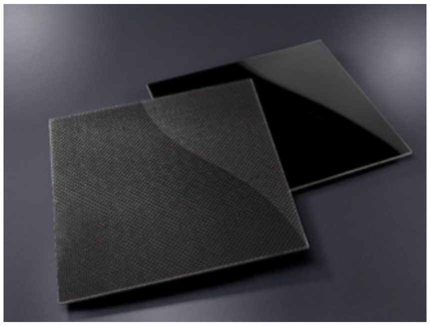

Fig. 3: Clear-coated and piano-black painted parts

Numerous options for industrialization

The PuriCoat platform is provided with compatible internal release agents, and offers great freedom in terms of industrial application. The surface requirements, existing infrastructure and targeted build rates will determine the optimal production concept. Two main routes are possible:

1) One-shot process – The CFRP part manufacturing and coating steps are carried out in a single process step, at constant temperature.

2) Two-shot process – the matrix cure and coating processes are completely separate, allowing an optimized process temperature for each step. This thermal separation has a significant impact on surface quality and cycle time.

One-shot process

The one-shot process is the classical RIM process. One example is the Surface-RTM technology from KraussMaffei [2], illustrated in Figure 4.

In this concept, the part production and coating process are carried out in the same mould. This way, the investment in tooling and presses can be minimized. Part handling is also simplified.

In the one-shot process, the coating is applied on the hot composite surface and initially has a very good appearance. The main limitation of this process is the thermal shrink after demoulding. During cooling, the resin and carbon fibre (CF) shrink differently and trigger the fibre print-through. These surface defects in the cured coating cannot be fully covered.

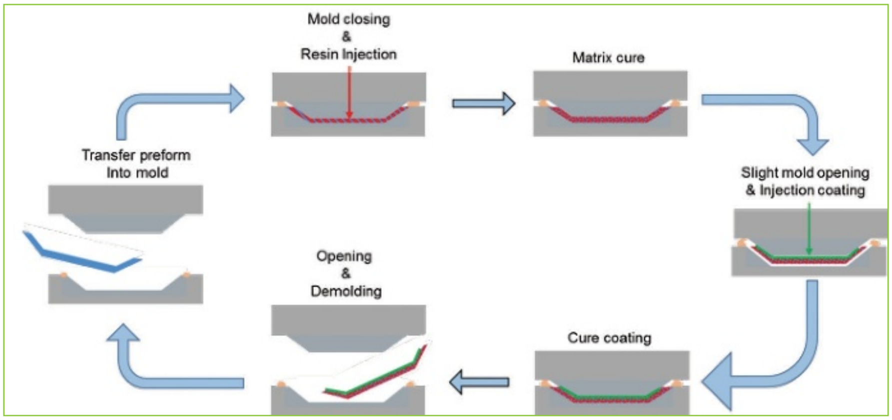

Fig. 4: Schematic drawing of the one-shot process

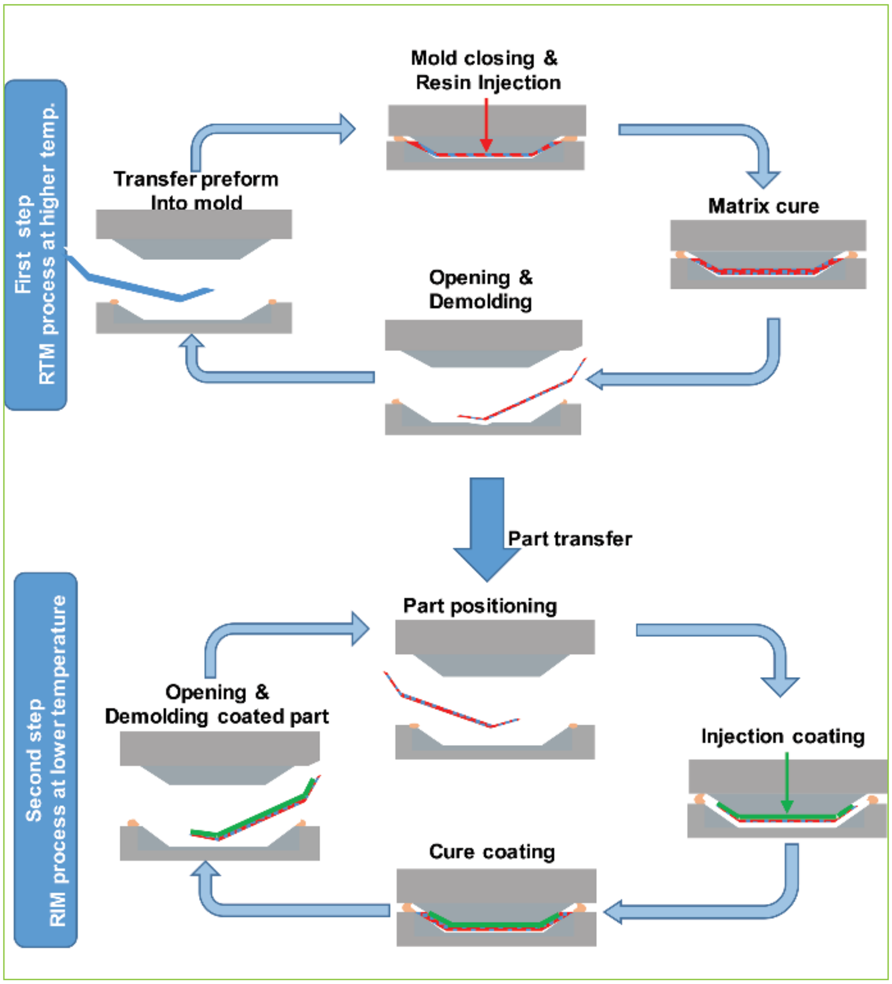

Fig. 5: Schematic drawing of the two-shot process

Print-through can be minimized by reducing the cure temperature, but this leads to longer cycle times. At typical cure temperatures of 80-90°C, cycle times of 20-30 minutes must be anticipated.

An additional issue is the limitation in terms of complexity. Mould opening can only create a gap in the vertical direction. In flanges, no or at least no consistent layer thickness can be produced. For this reason, this process is only efficient for 2-2.5D parts.

The one-shot process is, consequently, an attractive option for less complex parts at lower build rates. The main advantage is that a single tool is used to make the composite part and apply the coating, minimizing total investments.

Two-shot process

The key characteristic of this concept is the thermal separation of the part production from the coating process. This can be realized by using two tool sets, or by first producing the CFRP parts, and subsequently using the same mould for the coating process (see Figure 5).
By separating the two steps, the thermal shrink issue can be overcome. In the first step, the part is produced at a higher temperature (typically 120-130°C), allowing higher build rates.
The part can then be cooled to 80-100°C before the coating process is carried out. The coating can cover the fibre print-through generated by the higher moulding temperature. This concept can be used to maintain a very high surface quality in combination with short cycle times. Part-to-part cycle times of less than 3 minutes are possible. In the end, the achievable cycle time is mainly dictated by the acceptable surface quality, which needs to be evaluated case by case. While the need for a second tool set increases the investment, significantly higher build rates can actually result in a lower fixed cost per part.
By using a second adapted tool set, real 3D parts with a consistent applied coating thickness are possible. Also, other processes, such as edge trimming, can be integrated to ensure the coverage of all relevant areas.
The two-shot process is mainly attractive when higher build rates are targeted or when exacting surface requirements must be fulfilled.

Cost model

The cost to produce a coated composite back seat panel using a traditional spray process was compared with the cost utilizing the IMC process (see Figure 6). Material costs; investments in presses, tools and injection equipment; and the impact of the build rate and cycle time were all taken into consideration for the IMC process. Compared with the typical cost for the spray process, the two-shot process can achieve part cost savings of up 50%. The savings are mainly realized by avoiding the high fixed cost of a spray coating line. The break-even point in the evaluated part is achieved at a build rate of roughly 5000 parts/year.
A variety of investment scenarios are possible and allow manufacturers to focus on limiting capital expenditures for the IMC process, or alternatively, on maximizing the build rate.

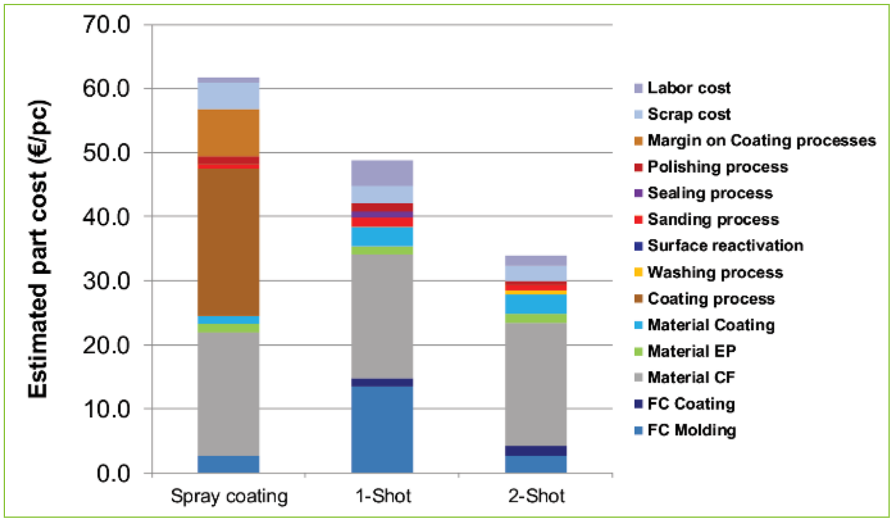

Fig. 6: Cost comparison for a back seat structure manufactured using various coating methods

Summary

The PuriCoat platform combines a state-of-the art fast-cure epoxy resin with PU RIM technologies, enabling the production of visible parts in a short cycle time, with very high surface quality.
In a close technical collaboration, the compatibility of the epoxy matrix and polyurethane coating, as well as the process conditions, were optimized. The result is a very good coating durability and inter-coat adhesion, a high surface quality, and the availability of suitable internal mould release agents for the composite resin as well as the RIM coating. The absence of solvent and negligible emissions address a growing drive for environmentally better solutions.
Depending on the surface requirements, pre-existing infrastructure and target build rates, the production concept may be optimized in the form of either a one-step or two-step process.
Significant cost savings compared with traditional spray coating make this an attractive solution for large build rate manufacturing and opens a window of opportunity for coated exterior parts. ◻

More information:
www.hexion.com

References
[1] http://www.compositesworld.com/articles/bmw-7-series-plant-dingolfing-germany
[2] https://www.kraussmaffei.com/rpm-en/surface-rtm-s-rtm.html

Main features

- Cooperation by Hexion and Votteler to develop the PuriCoat platform, combining epoxy-based RTM/LCM technology with a polyurethane-based RIM process
- Material technologies optimized for best adhesion and self-releasing performance
- High productivity with potential cycle times below 3 minutes, for higher build rates
- Significant cost savings in comparison to conventional spray coating
- Environmentally preferred low-emission coating solution