PURICOAT SYSTEM - A LOW-EMISSION SOLVENT-FREE MATERIAL PLATFORM ENABLING HIGH VOLUME PRODUCTION OF EXTERIOR COMPOSITE PARTS

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Abstract

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 prepreg or resin transfer molding (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 fiber print-through effect. This phenomenon is caused by the construction of the used reinforcements and mismatch between the thermal expansion coefficients of the resin and fiber; showing up during the cool-down of molded parts. The effect can be minimized by applying relatively low RTM operating temperatures – 80-90°C – and through additional surface treatment and coating steps. But the consequences of this approach are lower productivity and higher cost. To overcome these limitations, a new in-mold coating approach is introduced.

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, lower VOC 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 fiber-reinforced polymer (CFRP) parts with Votteler's PURIFLOW® PU911IR reaction injection molding (RIM) PU coating system suitable for in-mold coating of various substrates, including CFRP components.

The PuriCoat constituent products 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. 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 mold release agent HELOXY™ Additive TRAC 06805 can be used for fast, easy demolding.

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® coating systems 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 with 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 molding (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 fiber 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 fiber-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. In the development, light fastness (PV1303) was also identified as an especially critical test. 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 mold 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).

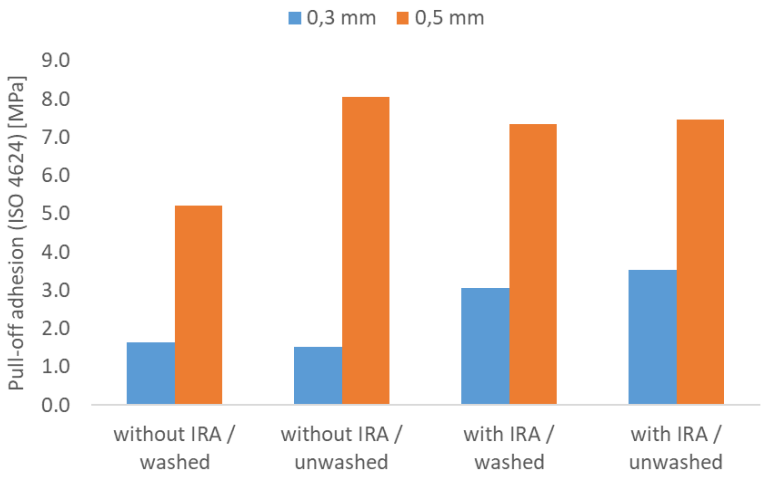

Figure 1: PuriCoat interface durability vs. internal release agent (IRA) and surface treatment

Figure 1 also shows that no specific surface treatment is required to ensure good adhesion. Test specimens were made using a one-shot process. Thus, no surface treatment is applied between the RTM and RIM process steps. Trials confirmed also a very good release performance of the PuriCoat platform.

To characterize the impact of climate cycle test on the surface quality, a set of panels with different layups were tested. A climate cycle test according to PV1200 (-40°C to 80°C; 20 cycles) was carried out; these results are summarized in Figure 2. All panels pass the test without any negative impact on surface appearance.

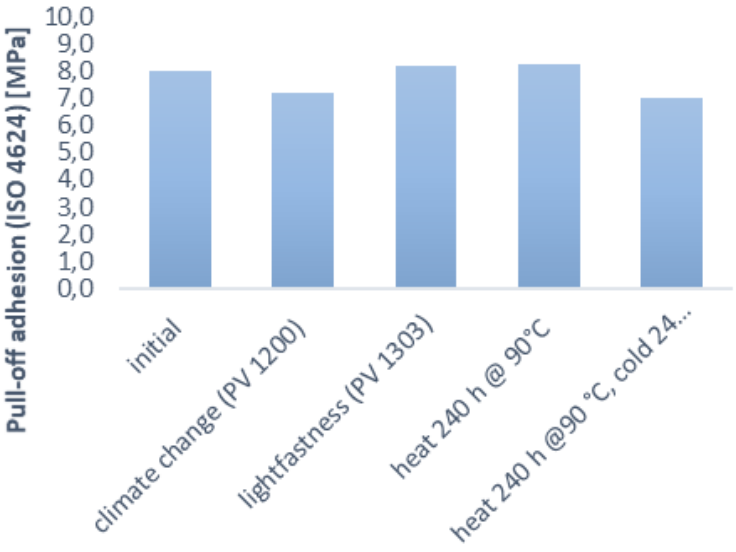

Figure 2: PuriCoat interface durability as a function of accelerated aging testing

Finally, the cycle time for the coating process could be reduced to 60 seconds by adapting the process parameters in the PU system.

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. In general, two fundamental 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 thermally separate, allowing an optimized process temperature for each step.

One-shot process

The one-shot process is the classical RIM process. One example is the Surface-RTM technology from KraussMaffei, illustrated in Figure 3.

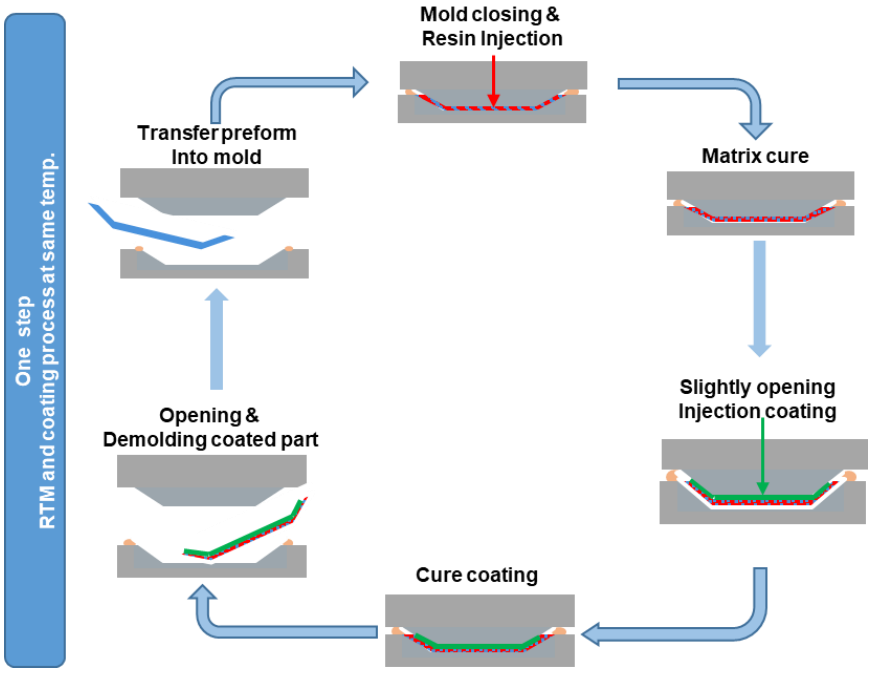

Figure 3: Schematic drawing of the one-shot process

In this concept, the CFRP part production and coating process are carried out in the same mold. This way, the investment in tooling and presses can be minimized. Part handling is also simplified. Trials demonstrated that with this concept high quality surfaces can be achieved. Optimized process parameters and an adapted cure kinetic that matches the process window, are key. It was demonstrated on a roof segment, that a part to part cycle time as short as 3-4 minutes still gives very good surface quality.

The main issue of this concept is the limitation in terms of shape complexity. Mold 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. The main advantage is that with a single tool used to make the composite part as well as to apply the coating, the total investments are minimized.

Two-shot process

The key characteristic of this concept is the separation of the CFRP production from the coating process, allowing also a thermal separation (see Figure 4).

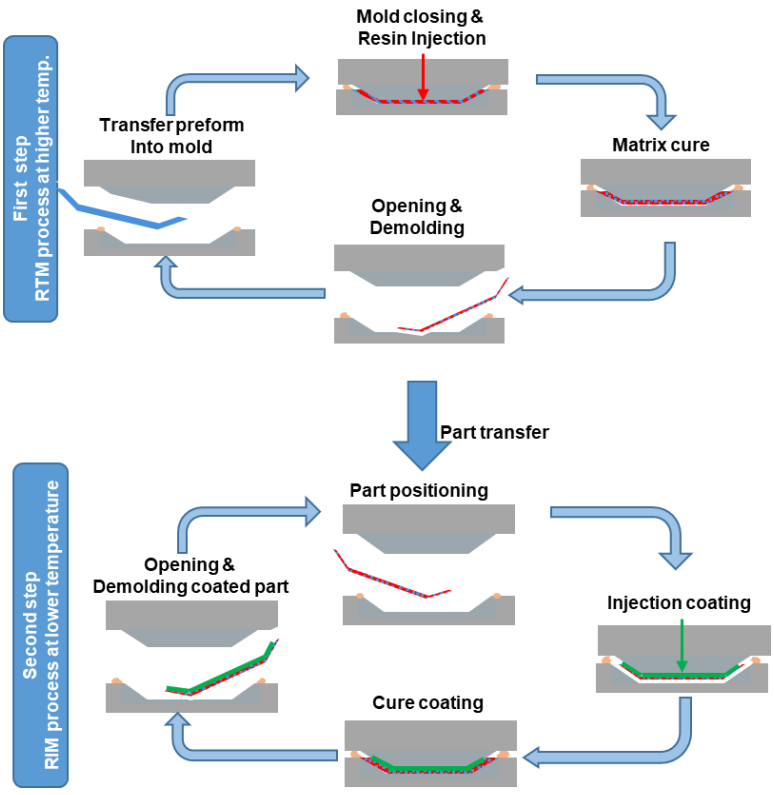

Figure 4: Schematic drawing of the two-shot process

This can be realized by a physical separation in two process steps or by integrating a kind of shuttle system to create an integrated process chain.

The main advantage of this approach is the freedom to apply coating also on more complex 3D parts. Also, other processes, such as edge trimming, can be integrated to ensure that all relevant areas are coated, with minimal rework. In addition, this concept can be used to maintain a very high surface quality in combination with very short cycle times. Part-to-part cycle times down to 2 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 result in a lower fixed cost per part.

The two-shot process is mainly attractive for more complex parts or when high build rates are targeted.

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 mold 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.