LIGHTWEIGHT STRUCTURAL PARTS WITH RIGID INTEGRAL PUR FOAMS

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Introduction

With climate change and the current situation regarding energy and environmental policy dominating the agenda, car manufacturers are faced with the complex problem of drastically lowering the fuel consumption of their vehicles in order to reduce CO_2 emissions. One way of tackling the problem is to pursue a consistent strategy of lightweight construction.

Self-activated as well as thermally activated rigid integral polyurethane foams from BaySystems can help to realise reductions in weight. They are ideal for use in structural parts. The presentation covers some of their state of the art solutions and techniques, followed by a vision of a new composite design for roof modules which combines the aforementioned polyurethanes and their processing technologies with a sprayed polyurethane barrier layer.

Self-Activated Rigid Integral Skin PUR Foams for Interior as well as Exterior Parts

Self-activated rigid integral skin PUR foams[1,2], in the following named PUR A, show a good bending resistance and torsional stiffness. Their two source materials – a polyol and an isocyanate – are mixed by high pressure. After this, their processing can vary. They can either be directly injected into a closed mold (table I) or they can be sprayed (figure 1) (table II) onto the bottom half of an open mold to be pressed afterwards. Regardless of which process is used grained or glossy foils and inserts can be inlaid into the mold. After curing they are firmly connected to the polyurethane. Due to the foamed nature of PUR A the weight of its panels can be lower than that of metal panels if the construction is adapted to it.

Table I: Mechanical data of PURs belonging to the PUR A types applied by reaction injection molding and reinforced by glass fiber mats

Mechanical data of PUR A types reinforced with glass fiber mats					
Glass mat weight	g/m²		225	300	450
Specimen thickness	Mm		5	5	5
Overall density	kg/m³	DIN ISO 845	440	460	490
Polyurethane density	kg/m³		395	400	400
Flexural modulus	MPa	DIN EN ISO 178	660	940	1390
Flexural strength	MPa	DIN EN ISO 178	21	28	40
Elongation	%	DIN EN ISO 527	2,5	2,5	2,3
Impact strength	kJ/m²	DIN EN ISO 179	15	21	22
Heat resistance	°C	DIN ISO 53432	113	143	162

Table II: Mechanical data of PURs belonging to the PUR A types applied by spraying techniques known as LFI, CSM or Interwet

Mechanical data of PUR A types with long glass fiber reinforcement					
Tests	Standards		Values		
Specimen thickness	DIN ISO 1923	mm	6	6	6
Density	DIN ISO 845	kg/m³	600	700	900
Glass content in the elastomer		%	15	23	30
Flexural modulus	DIN EN ISO 178	MPa	1380	3040	5210
Impact strength	DIN ISO 179	kJ/m²	8,1	23,9	52,4
Coefficient of expansion	DIN ISO 53752	10^{-6}/K	19	19	16
Tensile modulus	DIN EN ISO 527	MPa	1049	2656	5281
HDT-B	DIN EN ISO 75	°C	129	170	201

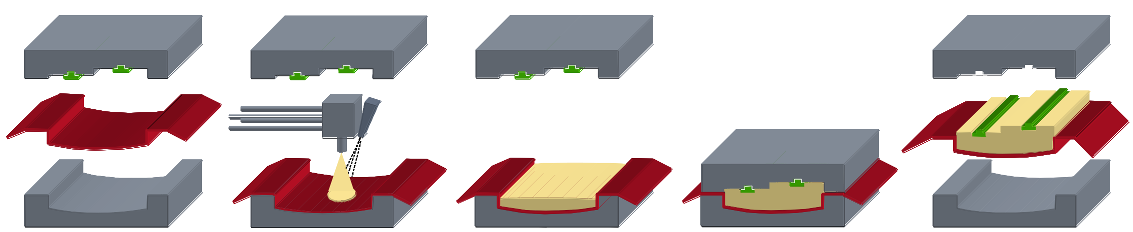

Figure 1: Scheme of backfoaming foils with long glass fibre reinforced Baydur®

Highlights of this technology are exterior foil-PUR composites which have a high gloss thermoplastic top layer and a rear side done in glass fibre reinforced PUR A. These exterior parts were primarily used with a rough mat foil for a Smart ForTwo roof module in 1998. Now after evolutionary improvement they are becoming now more and more popular. They allow the complete fixing of roof modules or roof sections onto the car body structure on the assembly line. Moreover, innovations can also be found in conventional manufacturing processes like reaction injection molding. One example is a new high reactive type of PUR A that is characterized by a very short demolding time and that is currently used to manufacture sun roof cassettes with multiple injection points.

The PUR A are used in the following applications: sun roof cassette, instrument panel carrier, seat shell, interior panels and exterior panels, truck boxes, underbody panel of engine, roof module, bumper carrier, front and roof spoiler and rear wing.

Thermally Activated PUR Spraying System as Matrix Material for Light and Stiff Parts

Thermally activated PUR spraying systems[3,4] (figure 2), in the following named PUR B, are used for flat modules, which need to have a high bending stiffness at a minimal weight (table III). In this regard, glass fibre reinforced sandwich constructions are nowadays setting the benchmark in their field of applications in terms of lightweight. Thanks to the evolutionary development of chemistry and processing, the degree of freedom concerning geometry and the productivity is continuously increasing. As a matter of course natural fibres can be used instead of glass fibres and indeed they are preferred for thin pressed PUR parts without honey comb cores. Additionally PUR B is characterized by a relatively high impact strength and a fibrous appearance of fracture.

The PUR B is used in the following applications: load floor, sun roof cassette, core of spoiler, backlight shelf and door trim.

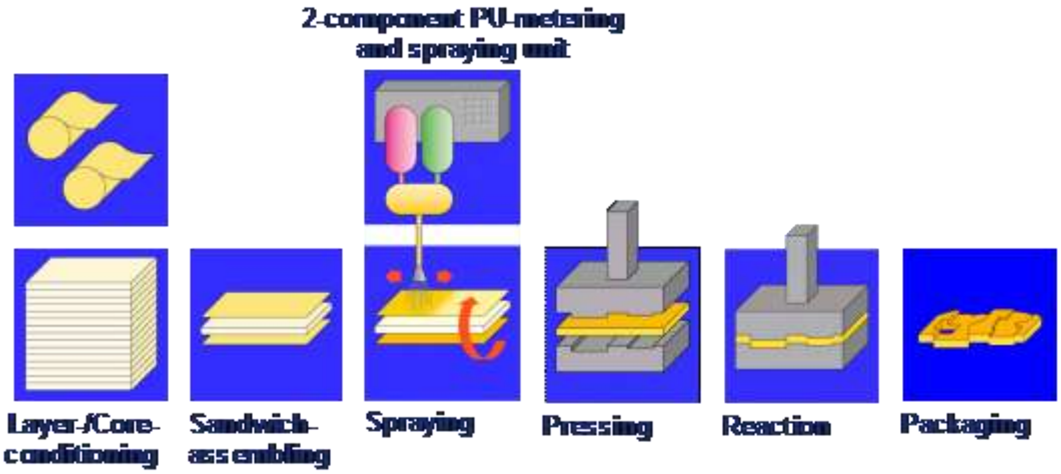

Figure 2: Scheme of processing lightweight sandwich panels with Baypreg®

Table III: Mechanical data of PURs belonging to the PUR B types applied by techniques following procedure described in figure 2

PROPERTIES OF PUR B SANDWICH PANELS MADE OF GLASS FIBER/PAPER						
Construction	Top layer Core layer Bottom layer		Glass mat Paper Glass mat	Glass mat Paper Glass mat	Glass mat Paper Glass mat	Glass mat Paper Glass mat
Polyurethane matrix			PUR B	PUR B	PUR B	PUR B
Glass fiber mat DIN 61853		[g/m²]	300	300	300	450
Thickness		[mm]	6	7	8	10
Overall density DIN 53420		[kg/m³]	368	314	304	360
Weight per unit area		[kg/m²]	2.18	2.2	2.43	3.6
Flexural strength EN 310	Lengthw. Transv.	[MPa] [MPa]	28 21	23 20	22 17	30 23
Flex. mod. of elast. EN 310	Lengthw. Transv.	[MPa] [MPa]	3250 2450	2660 2400	2540 2180	3540 2660
Impact resistance DIN 53453	lengthw. transv.	[kJ/m²] [kJ/m²]	> 20 > 15	> 20 > 15	> 20 > 15	>15 > 10
Stability to climate optical assessment			no change	no change	no change	no change
Temperature resistance optical assessment	- 10 °C + 120°C		no change no change	no change no change	no change no change	no change no change
Burning test			Extinguished	Extinguished	Extinguished	Extinguished
Odor DBL 5306	Method A Method B		No odor Slight odor	No odor Slight odor	No odor Slight odor	No odor Slight odor
Fogging DIN 75201	F G	[%] [mg]	> 90 < 1.0	> 90 < 1.0	> 90 < 1.0	> 90 < 1.0
Moisture content BN 322		[%]	1.6	1.9	2.1	1.6

Vision of a New Design for Roof Modules on Basis of PURs

A new ambitious target can be achieved by combining polyurethane sandwich technology with long fibre reinforced polyurethane technique. This step leads to a new vision for roof modules based on polyurethanes. It offers completely new opportunities for saving weight in the roof area. A prototype component has now been produced, and its weight is reduced by 25 percent compared to its conventional counterpart made out of steel. Currently we are starting to characterize and optimize the performance of prototype components together with partners and to investigate how the concept can be adapted for production-line manufacture.

The new concept is based on a polyurethane spray systems named PUR C and the afore-mentioned PUR B. During the first step of production the PUR C is sprayed without reinforcement into an open compression mold. PUR C itself forms the solid facing layer and, as such, is responsible for the quality of the part's surface. The next production step involves producing a sandwich prepreg by combining a lightweight honeycomb core with two glass fiber mat facing layers. The core layer deliberately stops short of the edges. The entire package is then sprayed with the heat-activated two-component polyurethane spray system, PUR B. Higher amounts of PUR B, together with long chopped strands, are additionally applied to the edges of the glass fiber mats during the spraying process. After that, the entire sandwich composite package is compression molded at elevated mold temperature. Within this process, the PUR B expands more or less depending on how thickly it's applied, sticks together with the honeycomb structures and permanently bonds the glass fiber mats and the facing layers of PUR C to the core layer. The geometry of the mold gives the part its shape.

Figure 3: top side of the prototype roof module (off-line coated).

The result is a roof module (figure 3) reinforced with a strong glass fiber mat / chopped strand structure at the edges, and a glass fiber mat / honeycomb sandwich structure in the middle. The high glass fiber content at the edges provides the roof module with a high level of torsional stiffness, opening up the possibility of integrating inserts. The facing layer of PUR C should prevent the glass fibers and honeycomb structures from showing through on the surface of the finished part. With its surface quality, it is seen as an instrument to provide the basis for a Class A coating surface. In future the concept might have the potential to integrate the In-Mold Coating (IMC) process into the production process to permit manufacturing of pre-coated parts. The IMC step would then be at the beginning of the production process and precede the spraying on of the PUR C facing layer.

Summary

Polyurethanes are very well placed as an alternative to metal, SMC and thermoplastics. There are manifold ways to process them and just as well they are useful in a great diversity of applications. Self-activated rigid integral polyurethanes as well as thermally activated spraying systems allow weight reductions compared to classic solutions due to the foamed nature of polyurethanes. Moreover, they are able to bind to a lot of different other materials. Therefore they are ideal for use in composites as matrix material. Apart from well established applications the combination of different PUR opens the chance to develop new composites. As example the paper describes a vision for a new design of a roof module.

References

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