# Bonding Automotive Bodies

**Fibre Composites.** In small to medium-sized series vehicle, fibre composites are increasingly used materials for exterior body panels. Adhesive bonding is raising in importance as it often is the only suitable joining technology.

JOCHEM SAUER

Plastics currently make up 13 to 18 % of a motor car. This is predicted to grow at an annual rate of 4.7 % in the West European automotive industry. Plastics applications are distributed between the car interior – by far the greatest proportion, followed by body exterior parts, the engine compartment and electrical/electronics systems. New plastics applications are mainly to be expected in the body, the part of the vehicle in which fibre composites are increasingly used. This is driven by the trend towards increased diversification and niche vehicles. Visible body panels of fibre-reinforced plastics (FRP) are most economical on vehicles produced in small production runs, where they could replace steel or aluminium [1]. Fibre-reinforced plastics also offer relatively high strength and stiffness, combined with low weight. They are highly corrosion resistant and permit a high degree of freedom of design, which, if possible for metals, would be extremely expensive to achieve [2]. For example, the rear door of the Mercedes-Benz C Class Coupé owes its complex form to an innovative plastics solution using SMC (sheet moulding compound) [3].

Fibre composites, such as SMC or GMT (glass-mat-reinforced thermoplastics) are established for mass production, while high-performance fibre composites, such as CFRP (carbon-fibre reinforced plastics) with thermoset matrix are suitable for small-series vehicles or technology leaders [1]. Hence, VW's "1-litre car" has an outer skin made of CFRP [4]. Other examples of CFRP applications can be found in the Aston Martin Vanquish [5]. Numerous SMC applications illustrate the high status of fibre-reinforced composites for automotive production. Typical SMC applications include the rear cover of the Mercedes-Benz CL, the rear door of the Volvo V 70, the roof spoiler of the BMW X5 and the Audi A2 and the rear door and front mudguards of the Renault Vel Satis [6, 7].

Translated from Kunststoffe 3/2003, pp. A 35–A 39

As early as 1999, approx. 35 % of European SMC consumption, or in absolution figures 66 000 t, was used in automotive applications. A large proportion of these are so-called class A outer skin applications, the class that is expected to show the highest annual growth rates of over 6 % [8]. Class A parts make the highest demands on the visual quality of the surfaces.

## Bonding – often the only Joining Technology that is Feasible

For automotives with composite parts, the choice of joining method is just as important for quality as the performance of the composite material itself. For FRP parts with a thermoset matrix, joining is limited to snap connections, rivets or screws and adhesive bonding. When conventional mechanical joining processes in composite applications reach their limits, bonding technology can contribute to optimally exploit the potential of composite materials and designs. Bonding offers numerous advantages over mechanical joining processes, including:

- no boreholes that would weaken fibres and load-bearing cross-sections;
- no visible joining elements;
- sealed joints;
- more uniform stress distribution;
- superior fatigue strength, and
- the ability to compensate for dimensional tolerances.

Adhesive bonding can therefore play a crucial role in the realisation of objectives that prompted the use of composite materials.

The adhesives most often used for the structural bonding of fibre-reinforced polymers in automotive engineering are generally based on epoxy, polyurethane or methacrylate-based formulations. These adhesive groups, as well as individual adhesives, show widely different properties depending on the chemical base or the formulation actually used by the adhesive manufacturer. Typical mechanical properties of structural adhesives are shown in Fig. 1.

Where FRP is used in automotive manufacture, bonding is often the only joining technology that is feasible. An example for this is the rear spoiler of a high-performance sports car (Fig. 2) produced by CBS, an Italian supplier to the automobile industry, from several CFRP components. The CFRP components are bonded with a two-component toughened epoxy adhesive (grade: Araldite 2015, manufacturer: Vantico Ltd, Duxford/UK). The combination of high strength and high toughness of the adhesive used permits the realisation of bonds that withstand the high dynamic loads, even at the sports car's top speed of 320 km/h. The adhesive bond is cured at 90 °C in a heated jig to ensure short production cycles, and, after one hour, the spoiler can be transferred to the downstream production stages – polishing painting and final assembly on the vehicle rear.

In racing car production, too, bonding of high-performance composites is an established joining technology. For years, the Infineon Audi R8 have been setting the pace in races in Le Mans (title photo). The different coefficients of thermal expansion of aluminium and CFRP led to adhesive bonding as the preferred method to join the aluminium radiator for the 610 horsepower V8 biturbo engine of this racing car to the CFRP frame. For this bonding task, the adhesive must meet extreme requirements. It must retain high strengths at the peak temperatures of 130 °C, and reliably withstand sudden mechanical loads and vibrations. It must also still have adequate toughness to compensate for the different thermal expansions of the joint counterparts throughout the operating temperature range. Audi Sport chose an extremely tough and resiliant two-component epoxy adhesive of the latest generation (grade: Epibond 1590 A/B, manufacturer: Vantico Ltd., UK), which stands out from other adhesives because of its outstanding test results. This "cold-curing", epoxy-based two-component paste adhesive still achieves strengths of 10 MPa at 130 °C, with a shear-strain at break of around 100 % (Fig. 3). This illustrates that it is possible to develop an adhesive that offers an excellent combination of high strength and heat resistance, combined with high toughness.

On the Italian luxury sports car "Mangusta" (Fig. 4), components of the vehicle outer skin are made of fibre-reinforced plastics, as are the vehicle doors, which are produced with a double-shell construction. The two shells of the vehicle doors are also bonded with a two-component epoxy adhesive (grade: Araldite 2015). The main demands on these adhesive bonds, which have been proved in numerous functional tests, are high strength, high heat and impact resistance and excellent sealing properties.

Class A components made of fibre-reinforced plastics for the vehicle outer skin are produced from SMC in large quantities for medium-sized and large series. Bonding is the established joining technology for such SMC components. Examples of class A SMC adhesive bonds are the rear licence plate panel for American and Japanese Audi 4 Avant versions, in which the outer SMC shell is bonded to the inner one (Fig. 5). For the Fiat Multipla, the SMC headlamp housings are bonded from the inside to the SMC upper headlamp panel (Fig. 6).

## New Adhesives for SMC Components meet Maximum Demands

The adhesive bonding of class A SMC components, makes particularly high demands on the adhesives. Though in the past, special surface preparation, such as grinding, sandblasting or priming were still acceptable for bonding SMC, the trend now is clearly towards pretreatment-free, so-called primerless bonding of SMC. The SMC surfaces to be bonded are merely dry wiped with a clean cloth to ensure that surface contaminants such as dust are removed before bonding. Adhesives for primerless bonding of SMC permit cost savings by eliminating additional production steps for surface preparation of SMC. A substantial advantage of primerless bonding of class A SMC parts is in eliminating the risk of contaminating the visible SMC surfaces with the primer that would otherwise be required, and thus impairing the surface quality. To avoid print-through of the bonded seam on the vehicle outer skin, adhesives for class A SMC applications should only show minimum cure-shrinkage of <1 %.

A frequent demand of the automotive industry on primerless adhesives is that the bonded SMC joints should fail with fibre tear in the SMC in the test, that is to say the cohesive strength of the adhesive and the bonding of the adhesive layer to the SMC are greater than the cohesive strength of the SMC material itself. The latest generation of primerless polyurethane (PU) adhesives for SMC only require curing at room temperature to meet these demands for SMC fibre failure (Fig. 7). This can save considerable investment for thermal curing equipment. Adhesives for primerless bonding of SMC are matched to conventional SMC grades containing internal release agents to assist in demoulding. For good integration of the adhesive processes in the overall production, primerless PU adhesives with various curing rates are available. For large production runs, SMC bonding nevertheless often requires precuring at elevated temperatures to achieve shorter cycle times. In this case, adhesives that only require room-temperature curing for primerless bonding to SMC can produce high-quality bonds even if not the entire length of the adhesive seam is not heated in the precuring device.

The high adhesion capability of the latest generation of primerless SMC adhesives to cataphoretic dip-painted (CDP) steel has extended the range of applications of these adhesives (Fig. 7).

Automotive body parts are subject to various environmental influences, and in some cases to chemicals such as fuels or brake fluids, throughout the lifetime of the vehicle. The adhesive bonds used here are also required to show long-term resistance to these environmental and chemical effects. This is verified for a particular adhesive/substrate combination in accelerated ageing tests (Fig. 7).

Service temperatures for body applications in automotive engineering are in the general range from –40 to +80 °C. As with all polymeric materials, the properties of adhesives also change with temperature. Many users require that the loss in strength of adhesive bonds at high service temperatures should be as low as possible. Fig. 7 shows what is possible with the latest primerless two-component polyurethanes for bonding SMC.

On the assumption that the adhesive adheres adequately to the SMC to achieve fibre tear in the SMC, the joint strengths of the SMC adhesive bonds, in the event of failure, may be of variable magnitude depending on the mechanical properties of the adhesive (Fig. 8). This is caused by the typical stress distribution in adhesive bonds. To exploit the inherent strength of the SMC as efficiently as possible, it is therefore advantageous for users if the adhesives for SMC are optimally tailored to the mechanical properties of the SMC by means of a well balanced combination of strength and deformability. Such optimised adhesives for primerless bonding of SMC must have sufficient strength

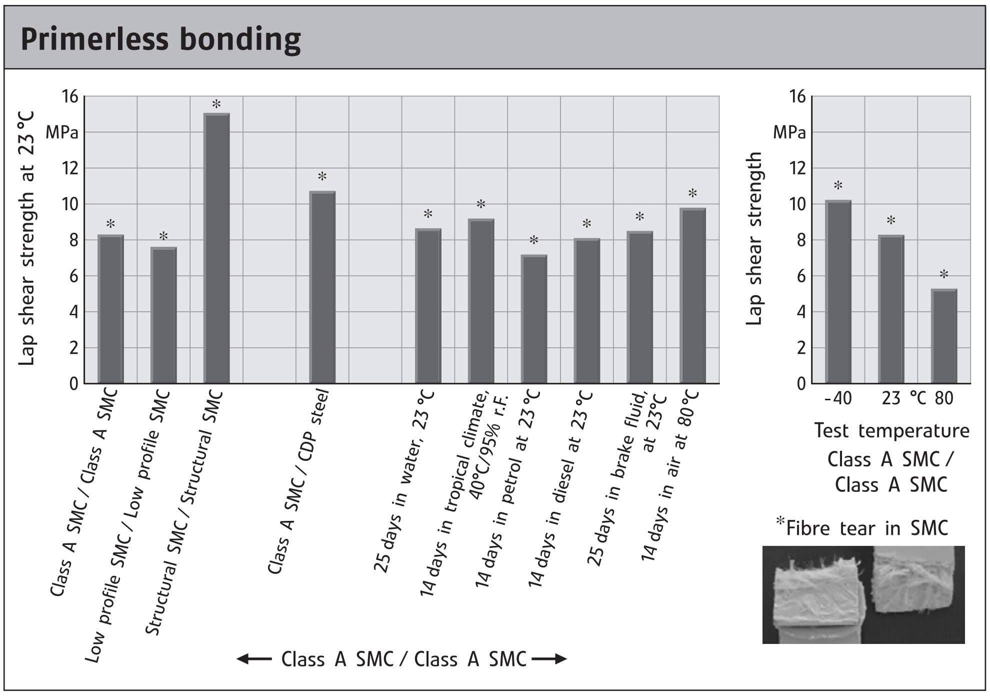


**Fig. 7. Typical properties of a two-component polyurethane adhesive (grade: Araldite 4910 A/B) for primerless bonding of SMC, preparation by dry wipe, and room-temperature curing**

that surpasses the inherent strength of SMC in the joint configuration, but at the same time relatively low moduli and a high deformability to achieve maximum load transmission of the bonded SMC joint by minimising stress concentrations (Fig. 8).

Optimisation of the mechanical properties of the adhesive in this way also benefits the dynamic and impact properties of SMC adhesive bonds.

## Chemical Thixotropic Adhesives

The two individual components of two-component adhesives must be metered and homogeneously mixed in a specified ratio. For applications with low adhesive consumption, or where the adhesive must be applied in numerous areas of production, dual barrel cartridges with a static mixer nozzle offer a fast, clean and reliable method of adhesive application. For applications with a large adhesive consumption, and where the adhesive is required centrally at a few places, it is advisable to apply two-component adhesives from drums with meter-mix-machines, which are available from a large number of suppliers [10]. For adhesive application, the application nozzle can then be either manually guided or coupled to an industrial robot.

For FRP applications in automotive manufacture, the bead of adhesive applied must generally be sag resistant. This is achieved with thixotropic adhesives. In the case of physically thixotropic adhesives, the thixotropy of the adhesive mixture or adhesive beads is achieved by making both individual components of the adhesives thixotropic. In this case, drum pumps with follower plates are required for feeding both thixotropic adhesive components from the drums to the meter-mix machine. With chemically thixotropic adhesives, on the other hand, the two individual components are free flowing. A rapid thixotropic reaction in the mixer provides sag resistant beads of chemically thixotropic adhesives. Since the two individual components of chemically thixotropic adhesives are free flowing, they can be easily fed to the metering pumps of meter-mix machines through hoses, from their drums which are positioned at a higher level. This simple principle is called gravimetric feeding. Chemically thixotropic adhesives, unlike physically thixotropic adhesives, therefore offer users the option of saving substantial investment costs for drum pumps with follower plates. Because of its simplicity, gravimetic feeding can therefore be regarded as maintenance-free and trouble-free.

**Optimum material exploitation**

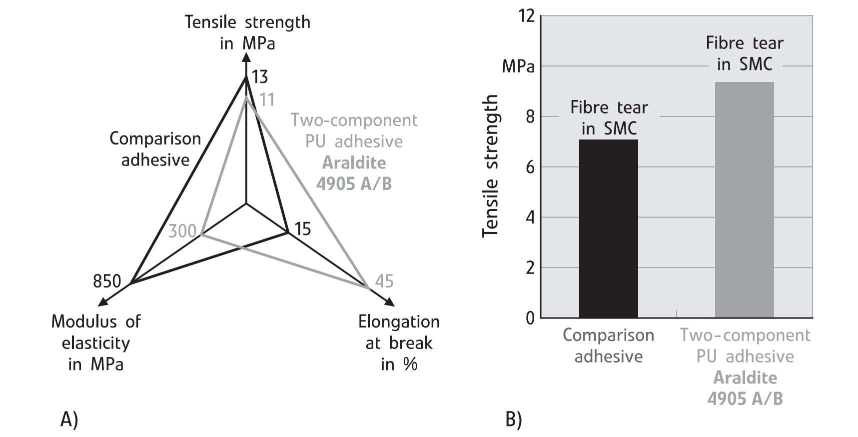


**Fig. 8. Efficient utilisation of the inherent strength of SMC (B) thanks to optimised adhesive properties (A)**

## Summary

Adhesive bonding can contribute to exploiting the full potential inherent in innovative fibre-reinforced plastics and designs in automotive manufacture. This has been proved by well established applications of composite adhesive bonds. New generations of adhesives with excellent property profiles offer users in the automotive manufacturing industry new technical possibilities and considerable potential costs savings in the joining of fibre-reinforced plastics. ■

**THE AUTHOR**

DR.-ING. JOCHEM SAUER, born in 1959, is marketing manager for adhesives at Vantico AG, Basel/Switzerland; jochem.sauer@vantico.com

**Manufacturer**

**Vantico AG**
**Klybeckstraße 200**
**CH-4002 Basel**
**Switzerland**
**Phone +41 (0) 61/9 66-3027**
**Fax +41 (0) 61/9 66-4308**
**www.vantico.com**

**Title photo. With the Infineon AudiR8, the aluminium radiator of the engine is bonded into the CFRP frame of the vehicle structure with a high-strength, extremely tough and resilient adhesive**

**Fig. 1. Adhesive strength: Typical mechanical properties of structural adhesives at room temperature**
**E-Modul = Modulus of elasticity; Klebfestigkeit = Bond strength; Reißdehnung = Elongation at break; 1K-Epoxide = 1-component epoxies; strukturelle 2 Komponenten-Polyurethane = Structural 2-component polyurethanes; 2K-Methacrylate = 2-component methacrylates**

**Fig. 2. Bonded CFRP spoiler of a high-performance sports car**

**Fig. 3. Heat resistance: Shear strength and shear-strain at break of the "cold-curing" two-component epoxy adhesive Epibond 1590A/B as a function of temperature [9]**
**Scherfestigkeit = Shear strength; Prüftemperatur = Test temperature; Bruchgleitung = Shear strain at break**

**Fig. 4. Luxury sports car with bonded body parts of fibre-reinforced plastics (model: Mangusta, manufacturer: Qvale Automotive Group S.r.l., Modena/Italy)**

**Fig. 5. Rear licence-plate panel of SMC bonded with two-component epoxy adhesive**

**Fig. 6. SMC headlamp housing of the Fiat Multipla bonded with a primerless two-component polyurethane adhesive (grade: Araldite 4910A/B)**