cycle times

Fast-curing epoxy prepreg system for automated processes with short cycle times

Daniel Grauer,
Head of Technical Sales
Steffen Perner
Senior Sales Account Manager
C-m-p gmbh

Until now, series production of CFRP components in the automotive industry has failed due to excessively long process times and high costs. A new, fast-curing epoxy resin system now makes structural and visible components in vehicle construction ready for series production.

The aerospace industry is the world's largest user of carbon fibre-reinforced plastics (CFRP). The automotive industry ranks second, both in terms of volume (37,000 metric tons) and sales (4.17 million US dollars). In 2018, the automotive industry thus accounted for about a quarter of global demand, 2% more than in the previous year. The advantages of CFRP vehicle structural components have long been known. One challenge for CFRP manufacturers is to significantly improve the cost-effectiveness of production processes, especially since the added value in the automotive industry is lower than in the aerospace industry due to the advantages of lightweight construction. Nevertheless, its importance in vehicle construction is also increasing every year.

Only advanced preform and prepreg technology can achieve the profitability and cost targets required for mass production. New development approaches such as the modified CP012 epoxy resin system from c-m-p gmbh (Heinsberg, Germany) are taking an upswing here. The company developed it mainly for the prepreg pressing process in the automotive industry (e.g. for the lamp pot and lamp holder of the Porsche GT3), but it is also suitable for other industrial applications. The sports and leisure sector (cross-country and alpine skiing), for example, has great market potential. Other areas of application for the technology include aerospace, defence, mechanical engineering and industrial components.

Founded in 2011, c-m-p gmbh specialises in the manufacture of tailor-made prepregs and textiles from carbon and other high-performance fibres. A global technology leader in the industrial production of pre-impregnated fibres and fabrics up to two metres wide, the company is known for its innovative solutions for lightweight construction and design. Companies in many industries around the world rely on these high-quality and application-oriented products.

CFRP for the mobility of the future

Lightweight construction supports the automotive industry in reducing greenhouse gas emissions as required by law without having to fundamentally change the vehicles. In addition, this technology increases the range of electric vehicles. These are the main reasons why all major manufacturers are looking for ways to replace their standard materials with lightweight composite materials. Every kilo counts for both e-mobility and conventional vehicles: a weight reduction of 100 kg reduces fuel consumption by 0.4 l per 100 km driven and means about 10 g less CO_2 emissions. Carbon fibres as reinforcing components offer the greatest potential here.

Series production requires short cycle times

The requirements of the automotive industry are clearly defined: composite materials suitable for series production must have short production cycles and consistent quality so that body components such as doors, roof modules or tailgates, as well as structural components such as columns or underbodies, can be produced quickly and cost-effectively and thus ready for mass production. These criteria were also fundamental for c-m-p gmbh in order to be able to map automated processes for the large-scale use of CFRP. The greatest challenge was to achieve a new resin formulation that ensured a very low viscosity could be maintained for a sufficiently long time. With the CP012, the company developed a resin that has a good thermal latency and thus enables a delayed reaction. This is critical for proper impregnation at high temperatures and short time cycles, accompanied by rapid curing of the resin when the specific temperature is reached.

Main characteristics of the modified epoxy resin system

The curing time of the CP012 system varies between 3 and 15 minutes depending on the temperature. The typical processing window is between 120 and 180°C. Depending on the curing temperature, a glass transition temperature (Tg) of up to 135°C is possible, which corresponds to most automotive standards for further

joining processes in the later phases of automotive production. A Tg of 165°C can even be achieved with a special formulation. The typical curing cycle in a press is 8 minutes at 140°C and a minimum pressure of 6 bar. A further advantage of the resin system is its service life of up to 21 days when stored in an air-conditioned room (21°C).

The resin's higher viscosity is required to prevent it from being rinsed out of the mould during the high pressure and temperature rise in the rapid cure cycle. The stickiness of the prepreg is adapted to the customer's requirements to facilitate processing and handling. The prepreg's low tack allows easier and faster stacking of the prepreg layers and opens up the possibility of process automation early in the production cycle. Another important feature of this specific resin system is the "hot in/hot out" function, which simplifies demoulding. This is crucial to keep pace with the short-term processing standard in the automotive industry.

Main characteristics of the epoxy resin system

Characteristic	Value
Name	CP012
Cure temperature	120-180°C
Cure time	3-15 Min
Pressure	2-6 Bar
Viscosity	High
TG	135°C/165°C
Shelf life	3 weeks @RT
Textile	UD/Fabric/MX/Scrim

Unlike other manufacturers, c-m-p gmbh can supply the fast-curing semi-finished product with various textiles, including unidirectional or woven reinforcements, and can thus react flexibly to specific customer requirements.

Application example: the Porsche 911 GT3RS suspension system

Together with its partner Dongguan Action Composites, c-m-p gmbh developed carbon fibre-reinforced composite stabilizers for the front and rear axles of the Porsche 911 GT3RS series (Figure 1). These stabilizers are now used commercially, which means that for the first time in a production vehicle, the stabilizers on the front and rear axles as well as their coupling rods are made of carbon. In 2018, Dongguan Action Composites, together with its partners Porsche AG, c-m-p gmbh, KLK Motorsport GmbH, IAB GmbH, FLURO-Gelenklager GmbH and Zund Thailand, received a JEC Asia Award in the Automotive category for this innovation.

Fig. 1: CFRP stabilizers on the front and rear axle

The main advantage of the composite material for this specific vehicle component is a weight saving of 55% compared to the steel version. Dongguan Action Composites, together with c-m-p gmbh, was able to prove to Porsche AG that the CFRP component is suitable for use as a semi-structural component in the car suspension system. Above all, the project also confirmed that composite parts can be manufactured according to the automotive industry's production standards.

The new high-speed prepreg compression moulding process with the c-m-p resin system allows a cycle time of less than 3 minutes. This makes it possible to produce 220 components per day, i.e. about 70,000 parts a year. This is a significant difference with conventional matrix systems, where the cycle time is 10 to 20 minutes, depending on the component size.

Prepreg pressing processes significantly reduce production cycle times

Pressing technologies are indispensable for mass production in automotive engineering. The goal is to minimize cycle times. With the autoclave technologies previously used, the manufacturing processes were very complex, while being among the most expensive and labour-intensive processing methods. The production of CFRP high-performance components was therefore very labour- and resource-intensive and did not allow economical production in large series. For this reason, the automotive sector used primarily light metals and high-strength steels, while CFRPs' main area of application was niche production: components for upmarket vehicle classes, special models as well as luxury and electric cars.

Compared to the established autoclave process, rapid curing technologies have several advantages. Depending on the matrix material, Press Compression Moulding (PCM) or Resin Transfer Moulding (RTM) are used. PCM is used for semi-finished products such as those manufactured by c-m-p gmbh, RTM is used for dry textiles that are not pre-impregnated. Compared to autoclave processes, both pressing processes enable faster and more cost-effective production of high-quality components. The high process reliability and possible automation with little manual effort make these solutions suitable for series production. Hydraulic prepreg presses with heatable dies achieve significantly shorter cycle times than the autoclave process. In this established method, manual assembly takes longer and the heating and hardening cycle lasts up to 7 hours.
These significant advantages are offset by relatively high investment costs for the corresponding infrastructure and high mould costs. In addition, not every geometry can be produced.

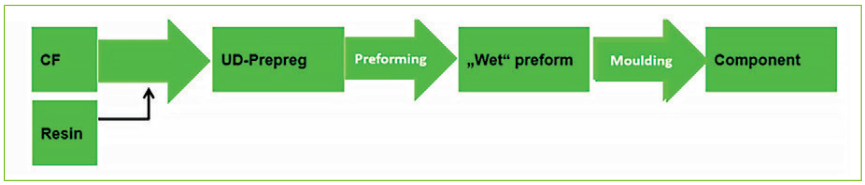

Fig. 2: Press Compression Moulding (PCM) sequence

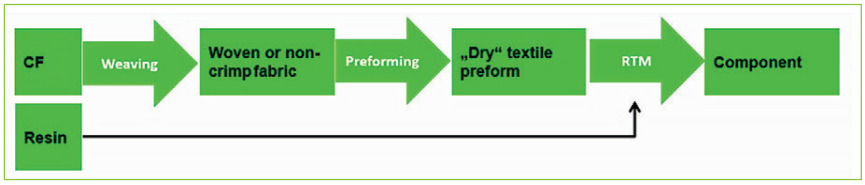

Fig. 3: Resin transfer moulding process (RTM)

Press Compression Moulding (PCM)

Prepreg presses are usually used to produce simpler contours in larger quantities, but complex components are also possible, for example with integrally-formed ribs or integrated thread inserts. In the press embossing process, prepregs are first cut to size and stacked in a desired pattern. This "prepreg stack" is then inserted into the heated preform tool. The purpose of heating is to obtain the desired preform shape. The preform is then usually automatically transferred to the mould and quickly cured there. After curing, the mould is opened automatically or manually, depending on the mould size, and the finished component is available (see Figure 2). The aim of the process is to keep the cycle as short as possible without impairing the desired properties of the finished part.

Resin Transfer Moulding (RTM)

RTM is suitable for large and complex components that place high demands on strength and geometry. For the production of complex components, it makes sense to use multilayer preformed reinforcing materials (preforms or prewovens), mainly thermoplastic-bonded scrims and fabrics that have been preformed beforehand by heat. Due to the low flow velocity of the resin and the fixation of the fibres, the intended fibre orientation is retained, resulting in reproducibly good mechanical properties of the components. With the RTM process (Figure 3), too, series production can be set up by using CNC cutters and heatable forming tools – with corresponding component geometries. This is particularly true in conjunction with new, fast-curing resin systems. RTM provides a very good surface quality of the composite material with relatively short curing cycles.

PCM versus RTM

The PCM process allows shorter curing cycles than RTM, which significantly reduces process cycle times. The automation also enables Class A surface quality without time-consuming reworking by filling, grinding, polishing, etc. OEMs demand the highest quality Class A surfaces, especially for the outer skin area.

When using PCM, the composite component manufacturer receives carbon and resin in the form of prepregs – in a single ordering and delivery process. The semi-finished product meets high requirements, the quality remains constant and repeatable, as prepregs are characterized by a precisely defined proportion of resin. The fibre-to-resin ratio and the component weight are always the same, with a small tolerance of +/-2%.

Another advantage for processors is that the prepregs are cut, inserted and processed almost completely automatically. This eliminates the need for direct contact with the semi-finished product. This means clean processing with minimized allergy risks. In contrast, the RTM process involves handling various components that have to be mixed together. These may have to be sourced from different suppliers.

A disadvantage of PCM compared to RTM is the dimensions of the parts. With PCM, larger parts can be produced than with RTM, but they must be easier to shape.

Outlook

The compression moulding system and the fast-curing c-m-p prepregs prove that composites can comply with the requirements of the automotive industry. This applies to structural components and visible applications. In order to develop further application areas and increase the number of composite parts in automotive engineering, the automotive industry and composite part manufacturers need to invest in the development of processing techniques, the design of new vehicles and materials testing.

From an economic point of view, the advantages of PCM outweigh those of RTM. Easier production scalability and growth to high-volume production with shorter cycles and lower tooling costs offer a major competitive advantage to all potential OEM partners among composite manufacturers.

So far, the fast curing system has mainly been used to produce structural components. In the future, visible aesthetic composite parts such as front flaps, bonnets, etc. will also be produced, not least because of the surface quality.

Technical progress in the field of electromobility and the associated battery technology or in the direction of the fuel cell offers manufacturers unprecedented opportunities for integrating new materials into the choice of materials for future vehicles. By 2025, up to 25% of all new car registrations in Germany will be electric cars. In the course of the new drive concepts, large parts of the entire vehicle will have to be redesigned, including the company's own selection of materials and processes. Overall, the automotive industry thus offers great potential for the use of composite materials. Without the integration of lightweight construction into vehicle concepts, future mobility is inconceivable. □

More information:
www.c-m-p-gmbh.de