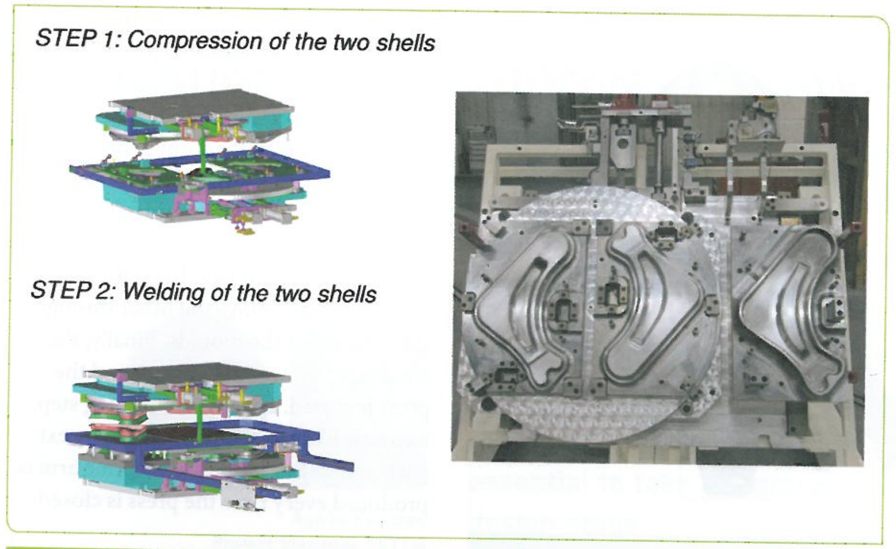

Fig. 5: Tool picture and sketches

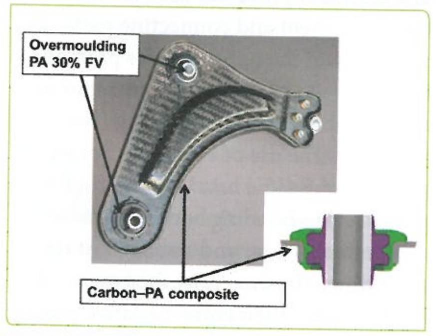

Fig. 6: Overmoulding the pivot joint

the plate on the ball joint end is covered on both sides. This solution limits the risks of offset attachment points and improves the assembly's durability.

Concept validation – Simulation control

Mechanical characterisation tests are in progress to refine the calculation model. Following the tests, the results of the finite element model will be compared to tests performed on a real part and the damage modes will be analysed, among other things. The purpose of this phase will be to better understand the relationship between tests and calculations in order to evaluate the confidence level of the simulation results. The modelling process will also be improved so as to be as close as possible to reality, as the automotive industry requires reliable simulation tools.

High production rates for cost optimisation: the project is taking shape

As described above, CETIM and ONERA teamed up to design a wishbone arm complying with PSA's mechanical specifications while reducing weight by 50% as compared with a steel solution. The process developed for this study can also achieve production rates compatible with the automotive sector. Raw material costs still prevent the use of composites for consumer products in the automotive industry. The significant cost of semi-products such as prepreg plates results from the high number of upstream operations (weaving, impregnation, consolidation, etc.), to which should be added material losses when cutting the semi-products to obtain, e.g., the required fibre orientation. To overcome these problems, CETIM is leading a platform dedicated to composite part manufacturing at high production rates within the framework of the Jules Verne Technological Research Institute in Nantes, France, in behalf of the French transportation industry. The production line will include several modules including thermoplastic projection and Resin Transfer Molding (RTM), and an innovative patching process (see Table 1). The latter is of most interest to the partners for the wishbone arm. The principle of this line is to avoid as many semi products as possible and be able to position the fibres precisely where they are needed. The partners consider that the best solution is to use pultruded tapes with variable thickness and width and then cut these tapes as required (while ensuring minimum material scrap) to make a preform. The preform is defined using a numerical tool which optimises fibre positioning with respect to mechanical stresses. The preform is then heated before final manufacturing by thermo-compression. By limiting the number of semi-products and minimising material scrap, this line will make it possible to manufacture structural parts using high-performance composites at acceptable costs for the automotive industry. ■

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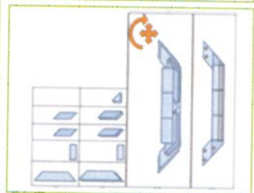
Tab. I: Patching/paving/stamping innovative process for low cost/high volume composite pieces

Extrusion + pultrusion	Discontinuous cutting	multi-axial and multi-material preforming	Induction heating Thermo-compression	Injection - overmoulding
Pultrusion line	 www.dewalt.com	Perform assembling station		
				
Thermoplastic extrusion	Specific cutting		Thermoforming press	Injection overmoulding unit

Thermoplastic composites for automotive seats

By
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Weight reduction is a key objective in automotive seats and a multi-material approach combining continuous-fibre-reinforced thermoplastics, short-fibre plastics, and metals is being investigated for front seat applications. Collaborative projects have been launched to reduce weight by 30% and to develop materials and processes that can be used in large series.

The automotive seats market is currently strongly pushing for cost reductions (part cost and investment) and standardization of components. However, two other drivers are also very important: weight reduction and the use of "green" materials. In 2013, a set of seats for an average car is around 60-80 kg, with metal structures representing two thirds of this weight (including mechanisms). The optimization of metal structures in terms of weight is forecast to reach an asymptote, and polymer/composite technology is a strong candidate to reduce the weight of seats. Seats have to meet various safety standards and regulations. The most stringent specifications are front, rear and side crash conditions.

Continuous-fibre-reinforced thermoplastics are known to offer a high weight-saving potential in crash relevant structures. Two breakthroughs now make it possible to develop composite seat structures. The first one is the development of CAE tools that are highly predictive even in the case of a severe crash. The second is the development of short-fibre-reinforced thermoplastics with high elongation at break and their combination with continuous-fibre thermoplastics.

Interest and limitations of composites in car interiors

The materials used in seat structures need to combine a high specific strength and modulus and be ductile during crash. Except for its density (7.8), steel is an ideal material for seat structures: it has a high modulus and strength and its plasticity is very useful to avoid failure during crash. Figure 1 shows that the specific strength and modulus of steel, aluminium and magnesium are in a similar range, indicating that weight savings with light alloys can be obtained only when the use of steel is limited by processes and buckling. Chopped-fibre-reinforced plastics have, at best, the same specific strength as metals and their specific modulus is low but can be improved through part design (ribs, variable thickness) to stiffen the part. The main limitation of these materials in structural crash applications is their low elongation at break (typically only a few percent). Continuous glass fibre com-

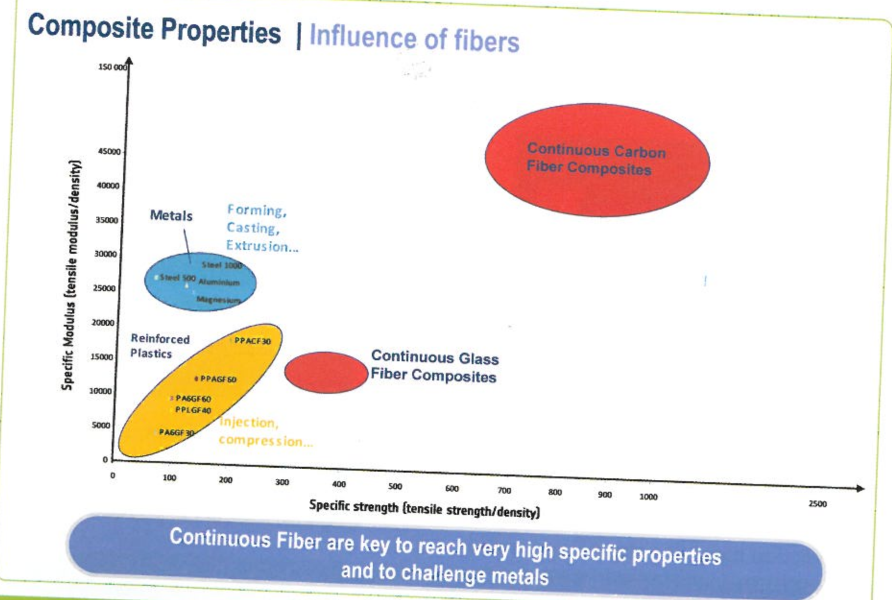

Fig. 1: Specific modulus vs. specific strength of metals and composites

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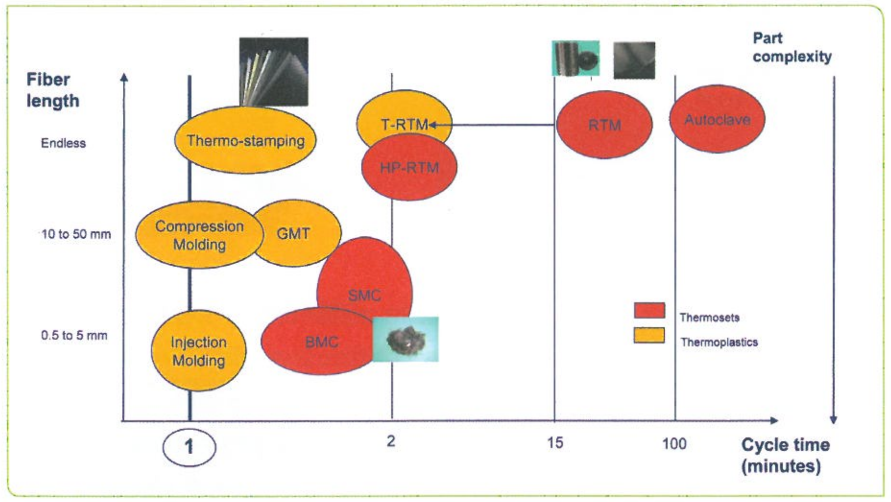

Fig. 2: Composite process comparison for cycle time and fibre length after processing

posites combine high specific strength, average specific modulus and elevated impact resistance which make them a good candidate for interior parts. Carbon fibre composites have superior properties but their cost is still prohibitive for automotive applications.

The processes used in automotive applications should have a cycle time of 1 minute or less. Figure 2 shows the wide spectrum of composite processes that can be used with thermosets and thermoplastics. Some thermoset processes are close to 2 minutes and are compatible with medium series production. However, thermoplastics (TP) are preferred to thermosets (TS) in car interior applications for the following reasons:

- lower cycle time,
- higher impact resistance,
- easier process control (no chemical reaction in TP),
- better recyclability,
- volatile organic compounds emission and odour are less problematic.

The targeted processes for a one-minute cycle time combine:
- thermostamping to form a continuous-fibre-reinforced thermoplastic (CFRT) insert for the structure, and
- an injection moulding step to overmould the CFRT insert with chopped-fibre-reinforced thermoplastics (for function integration).

Multi-functional seat pan

A multi-functional seat pan made of injection-moulded, high impact resistance PA6GF30 was developed jointly by Faurecia and Solvay Engineering Plastics (formerly Rhodia Engineering Plastics).
The project focused on the function integration and weight reduction potential of reinforced thermoplastics. The case study concentrated on the front seat cushion cross-member of an electric seat with tilt and cushion length adjustment functions. An existing steel design for this perimeter is presented in Figure 3. It is composed of 28 assembled parts (including screws and rivets) and weighs 2,750 g.
The new multifunctional seat pan is a combination of parts produced by injection moulding of high impact resistance PA6GF30. In this application, it was found that the use of CFRT was not necessary to meet the specifications. The total number of parts is reduced to 15 (including screws and rivets) for a weight of 1,665 g, i.e. close to 50% reduction in the number of parts and a 35% weight reduction. The benefits of the multifunctional seat pan include:

- function integration (15 parts instead of 28),
- 35% weight reduction (1 kg),
- lower investment for injection-moulded parts than for steel parts.

The parts were designed jointly by Faurecia and Solvay, making an extensive use of simulation tools including integrative simulation techniques developed by Solvay (MMI ConfidentDesign™). They used an advanced database on the mechanical behaviour of polyamide matrices, a Digimat MX material database and, in parallel, an injection moulding simulation of glass fibre orientation that was then mapped from the moulding mesh to the structure mesh. The data was used to simulate the crash performance of the multi-functional seat pan. Prototypes of the assembly shown in Figure 3 were injection moulded with a high-impact PA6GF30. Full validation of the prototypes was successfully performed and included frontal crash, rear crash, misuse test, noise, vibration and durability to reach a level where the parts are ready to be included in generic seat structures. Environmental factors (operating temperature ranging from -30°C to 80°C and moisture) were included in the validation plan.
This achievement shows that the simulation tools used to design reinforced thermoplastic parts have now reached a sufficient prediction level to engineer complex seating parts subjected to severe crash loads, including the effects of temperature and humidity on the part's mechanical performance.

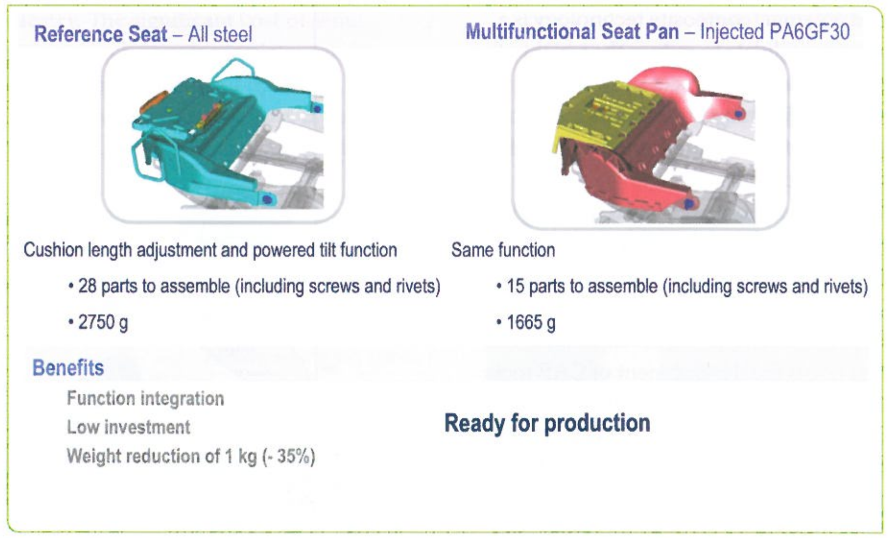

Fig. 3: Comparison of the multi-functional seat pan and the reference seat

Composite backrest

A composite backrest for a front seat was developed jointly by BASF and Faurecia as a case study to develop the hybrid thermoplastic moulding (CFRT+overmoulding).
The complete trimmed backrest was considered. The reference component weighed 8.3 kg and was based on a standard seat design (steel frame, PU foam pad, textile cover, plastic back panel).
The study's goal was to develop a new seat architecture with reduced weight while taking advantage of the design possibilities provided by plastics.
Therefore, the development process moved away from the standard two-step design, where a frame is designed first to fulfil the safety specifications and regulations and layers are then added for comfort and aesthetics. The new seat structure has a structural function while at the same time contributing to the seat's comfort and aesthetics. The shell design of the composite backrest enables a sympathetic shape to the human form whereas a standard steel frame focuses on pressure. As a result, the foam thickness required for comfort can be reduced with the composite backrest.
In a standard seat design, the back panel is a plastic part assembled onto the metal frame with snap fits and/or screws. In the composite backrest, the back panel is directly integrated in the seat backrest as shown in Figure 3, which eliminates all assembly problems. Based on this shell design, the materials were selected through CAE analysis including integrative simulation techniques to model thermoplastic materials accurately. The most severe crash cases were selected to validate the concept (rear crash with 95th dummy and luggage test).

Due to the need for energy absorption in a dynamic crash event and the high impact loads the seat back would undergo, a plastic material with higher properties than the available glass-reinforced PA6 materials was required. The material development targets thus included: high elongation while maintaining a similar strength and stiffness to existing PA6GF35 materials, Class A surface appearance for exposed surfaces, colourability, improved melt flow, good impact resistance, and maintaining all of these properties in the operating environment of a typical seat back. The new material has a high elongation at break at room temperature in dry as-moulded conditions while retaining other mechanical properties such as tensile strength and modulus.

As shown in Figure 4, the starting materials for the CFRT inserts are unidirectional tapes, which are simply continuous glass fibres impregnated with a polymer. The CFRT tapes are stacked in the required layer orientation, heated in an infrared oven and thermo-stamped under pressure.

The formed insert is then trimmed to its final shape. The final injection moulding process uses a standard injection moulding press.
The performance level of the composite backrest was evaluated in the most severe operating conditions of a car seat. The key characteristics of a seat back are its behaviour in rear crash and luggage impact conditions.
To simulate the PA6GF35 material, a rheology injection moulding simulation software was initially run on the seat back geometry, tracking and mapping the glass fibre distribution and orientation. The glass fibre orientations were then utilized by the ULTRASIM™ proprietary software to accurately model the varying material properties of the seat back in all dimensions. A highly detailed, non-linear FEA model was required to accurately model the dynamic behaviour of a seat system in a crash scenario. Specifically for this project, the simulation of short-fibre-reinforced thermoplastics was expanded with material data related to continuous-fibre-reinforced plastics, so that it can now reliably predict the crash behaviour of components with a very high (fibre) anisotropy and fibre content.
Considering the fact that mechanical properties strongly vary with temperature and moisture, it was decided to validate the seat at room temperature in dry as-moulded conditions, but also to test

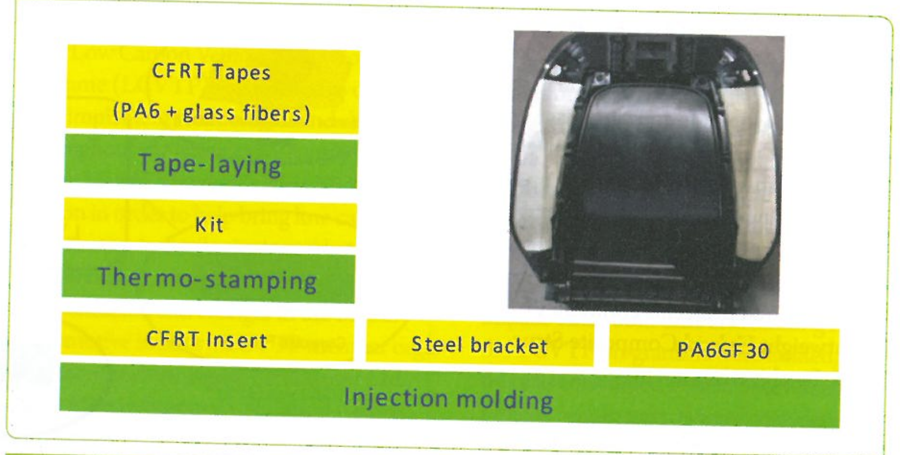

Fig. 4: Three processes are used for the manufacture of the composite backrest: 1) standard stamping of steel brackets, 2) thermostamping of CFRT inserts, and 3) over-moulding of inserts (steel and CFRT) with PA6GF35 by injection moulding

Fig. 5: Rear crash impact for composite backrest: correlation of simulation and experimental test

it at low temperature (-30°C) and high temperature (80°C). The seat passed the test in all conditions and the integrity between the CFRT, the metal insert and the overmoulded plastics was maintained. There was a very good correlation between the simulation and the experimental tests, as shown in Figure 5. The deformation of the seat back was adequately predicted, as well as the dummy's kinematics in the case of the rear crash.

A new seat backrest was developed using a one-piece composite-plastic hybrid part that replaces the existing metal structure and minimizes foam and trim. The complete trimmed seat back weighs about 20% less than the reference car seat and is approximately 30 mm thinner.

Collaborative projects: LYCOS and DEMOS

The combined use of continuous fibre reinforcement and overmoulding of injected plastics is ready for production, as shown in the example of the composite backrest, but the technology is still in its infancy and a lot of optimization is needed before it reaches a suitable maturity level for use in high-volume car applications. Therefore, Faurecia decided to start two collaborative projects to further develop the materials, engineering tools and processes. The first project is entitled LYCOS (Lightweight Hybrid Composite Structures). Its objectives are to:

- develop and characterize continuous-fibre-reinforced thermoplastics (CFRT),
- design and validate a seat cushion structure,
- develop a robust process for forming and overmoulding CFRT inserts.

LYCOS is a FUI (French funded) project led by Faurecia that involves 10 partners. Three universities contribute to the development tasks, as shown in Figure 6. INSA Lyon develops the CFRT forming step (materials characterization, thermostamping process simulation). Mines de Douai optimizes the process parameters for overmoulding of the CFRT inserts by injection moulding. Mines ParisTech is in charge of CFRT characterization and mechanical simulation. Other partners include Solvay (CFRT development), ESI (simulation tools) and four SMEs (Activetech, Prodhag, RJP Modelage, Styl'monde) involved in the process development.

A second project entitled DEMOS (Design and Manufacturing of Composite Seat Structures) was launched more recently, at the end of 2012. It is funded by ADEME and Investissements d'Avenir and will focus on the development of a multi-material front seat structure with a target to reduce weight by 30% as compared to standard steel structures. Beyond the design work, the project will develop suitable processes for the mass production of such automotive structures.

Concluding remarks

The multi-functional seat pan and composite backrest projects demonstrate that materials and simulation tools are now available for the development of efficient thermoplastic composite parts for automotive seating applications. Current weight savings for the complete seat range from 15 to 20% and the technologies need to be optimized to further reduce the weight of the functions and to reach a price level where they can compete with standard platform seat structures.

In the short term, plastic and composite seat components can be used in niche applications to take advantage of the design possibilities offered by plastics, combining comfort with a modern, thin-walled, high-end component affording greater design freedom and improving the feeling of space. For mid- to long-term applications, the integration of these technologies in the current metal industrial footprint and the strategy of platforms will need to find a way to become modular while retaining the advantages of function integration, one of the key assets of moulded materials. ■

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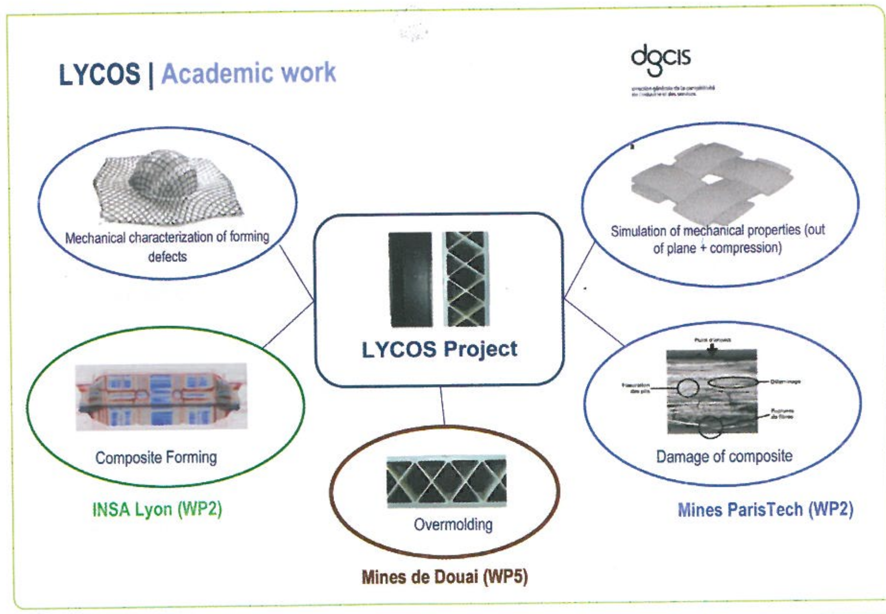

Fig. 6: The LYCOS collaborative project – Tasks performed by the academic partners