

A Forward-Looking Approach to the Sustainable Manufacture of Hybrid Components

Hybrid Seat Structures – Efficient and Suitable for Large-Scale Production

Seats in commercial aircraft consist of multiple components, which are usually a mixture of plastics and metals. This makes recycling difficult and increases the cost of manufacturing and maintaining the seats. Fraunhofer Institute for Chemical Technology has consequently developed an aircraft seat that not only meets requirements for space- and weight-savings and fire resistance, but is also easy to recycle. The seat consists of only five components and is suitable for large-scale production.



Monomaterial aircraft seats, with lightweight construction, reduce the CO₂ footprint by about 20%. © Fraunhofer ICT

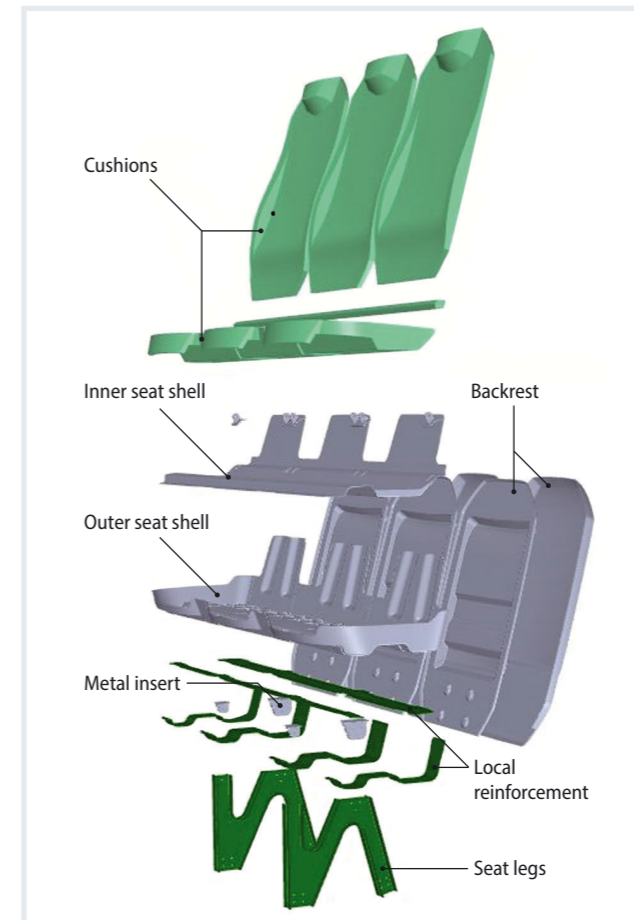
Currently, the biggest challenge in designing a sustainable and recyclable product is the recycling process. In the case of aircraft seats, the mixture of different plastics they contain makes them particularly challenging to recycle. For this reason, we used only polyurethane (PUR) in the newly designed seats, as this material is available in various forms including solid material, foams

and adhesives. A particular advantage is that there is an established chemical recycling process for PUR, which is already being used on an industrial scale. As the seat (Fig. 1) is made exclusively of PUR, it can be chemically recycled at the end of its service life without the need for costly separation and sorting processes. The seat structure is shown in an exploded view.

Design of the Hybrid Aircraft Seat Structure

The cushions of the aircraft seat are made of PUR foam, while the structural components are made of carbon fiber-reinforced PUR and metal inserts. The polyurethane must be reinforced to ensure the stability of the aircraft seat. To further increase the stiffness and

Fig. 1. Exploded view of the seat structure which, apart from the metal inserts, is made solely of PUR.
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strength of the seat, unidirectional preregs made of carbon fiber-reinforced PUR are positioned along the load paths.

The integration of functions within the lightweight design has reduced the number of structural components to just five, namely the outer and inner seat shell, the outer and inner backrest and the seat legs.

The inner seat shell is manufactured using wet compression molding (WCM). In WCM, dry fiber blanks made of carbon

or glass fibers are placed in a mold, impregnated with a reactive polyurethane resin and then molded. Under pressure and heat, the matrix materials harden during molding. The wet compression molding process has proved to be an extremely cost-effective method for the large-series manufacturing of lightweight and high-strength components.

The outer seat shell is manufactured using the SMC (sheet molding com-

ponent) process. Here, dough-like plate-shaped molding compounds are processed from a thermosetting resin with fiber reinforcement, and then pressed into shape and cured. The SMC process enables the cost-effective mass production of high-strength components with complex geometries and with good surface quality.

Surface Treatment of the Metal Inserts

The metal inserts, which are bonded directly to the polyurethane in the manufacturing process, form the bridge between the seat and the legs, and anchor the belt. A reliable and high-strength joint is therefore essential for passenger safety.

Plasma processes can be used very effectively to coat the surface of the metal inserts with a thin, glass-like nanoporous layer. The glassy layer adheres chemically to the metal surface and generates a strong bond between the polyurethane and the metal parts. The liquid PUR diffuses into the pores, forming a bond during curing [1].

This new adhesion principle achieves a high-strength bond (37 MPa) between the metal and the PUR. Flame-retardant additives were also introduced into the PUR for the solid seat components.

Production of the Outer Seat Shell

The SMC process was used to produce the outer seat shell. Since the SMC material is not strong enough alone, the seat shell must be additionally reinforced with preregs. These preregs are made of PUR reinforced with unidirectional carbon fibers, and are positioned »

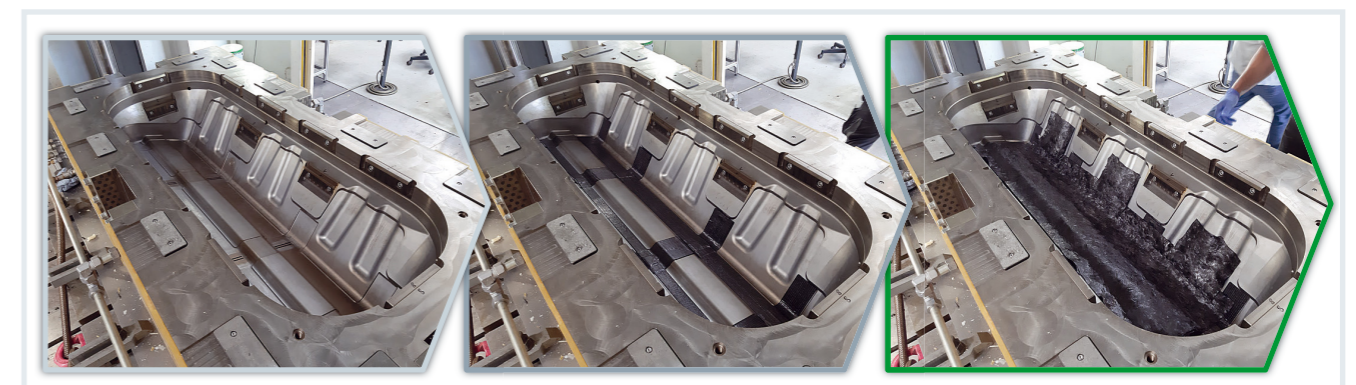


Fig. 2. Lower half of the mold used to create the outer seat shell: Open mold, insertion of local reinforcement, insertion of SMC material into the mold (from left to right). © Fraunhofer ICT

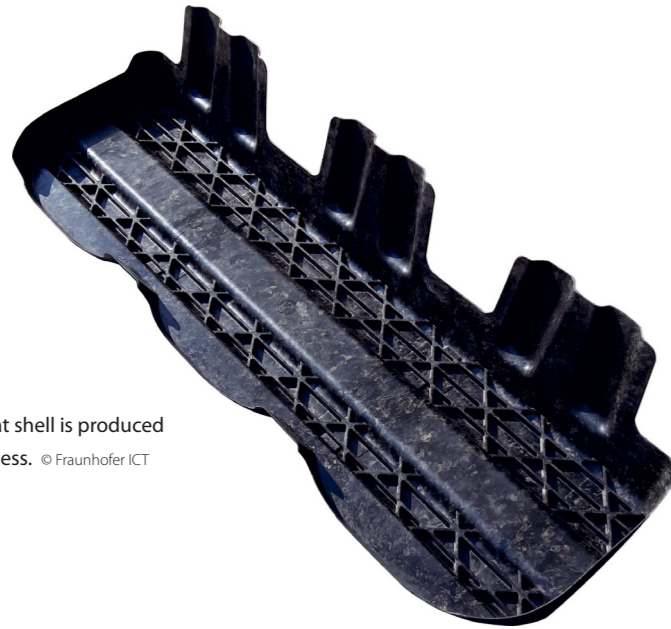


Fig. 3. The outer seat shell is produced using the SMC process. © Fraunhofer ICT

along the load paths. To facilitate handling during production, the prepregs are assembled beforehand to produce a preform, which is then inserted into the mold (manufacturer: Alpex Technologies, Mils, Austria) and overmolded with SMC. The metal inserts for the legs are also integrated into the prepregs.

The local reinforcements are inserted first into the mold, followed by the SMC material (**Fig. 2**). Subsequently, the compression molding unit (type: Compress Plus DCP-G 3600/3200; manufacturer: Dieffenbacher GmbH Maschinen- und

Anlagenbau, Eppingen, Germany) is closed and the resin begins to cure. The mold temperature is 140 °C, and the pressing force is 8000 kN. After a cycle time of 300 s, the mold is opened and the finished part can be removed (**Fig. 3**).

Production of the Inner Seat Shell

The WCM process is ideally suited to the cost-effective production of high-strength and lightweight components. It is therefore used to manufacture the inner seat structure. The pre-prepared

nonwovens (with eight layers and quasi-isotropic fiber direction) are inserted into a mold (manufacturer: Alpex Technologies), together with the metal inserts to secure the belt. Resin is then poured over the nonwovens (**Fig. 4**). The mold is closed and the resin begins to cure. The mold temperature is 80 °C, the pressure is 80 bar and the cycle time is 800 s. As soon as the resin has cured, the mold is opened and the inner seat shell can be demolded (**Fig. 5**).

Assembly and Crash Test

The manufactured components – the backrests and seat legs were bought commercially for budget reasons – are bonded using a 2-component PUR adhesive (type: Teroson PUR6700, manufacturer: Henkel AG & Co. KGaA, Düsseldorf, Germany) to create a hybrid seat structure. The legs are bolted to the metal inserts and the seats are upholstered with cushions. During the crash test, the metal anchoring of the legs to the floor plate failed at an acceleration of around 11g. However, the seat structure itself remained virtually undamaged (**Fig. 6**).

Recycling and Initial Life Cycle Analysis

An initial study confirmed the excellent recyclability of the seat structure using

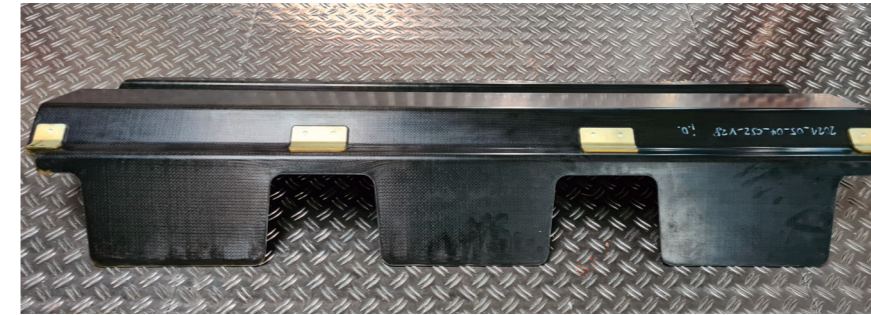


Fig. 5. The inner seat shell is manufactured using the WCM process. © Fraunhofer ICT

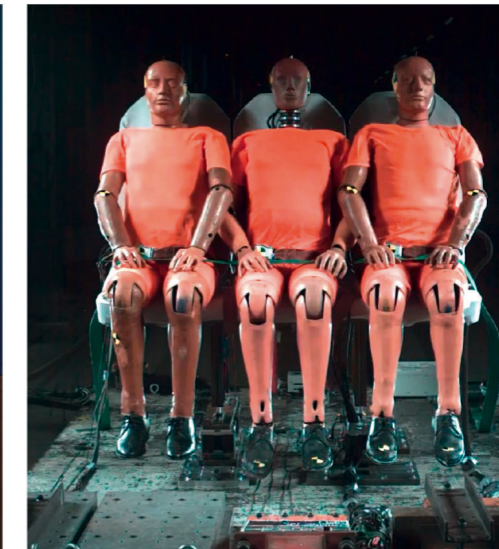


Fig. 6. During the crash test of the hybrid seat row, the metal anchoring of the legs to the floor plate was the first element to fail.

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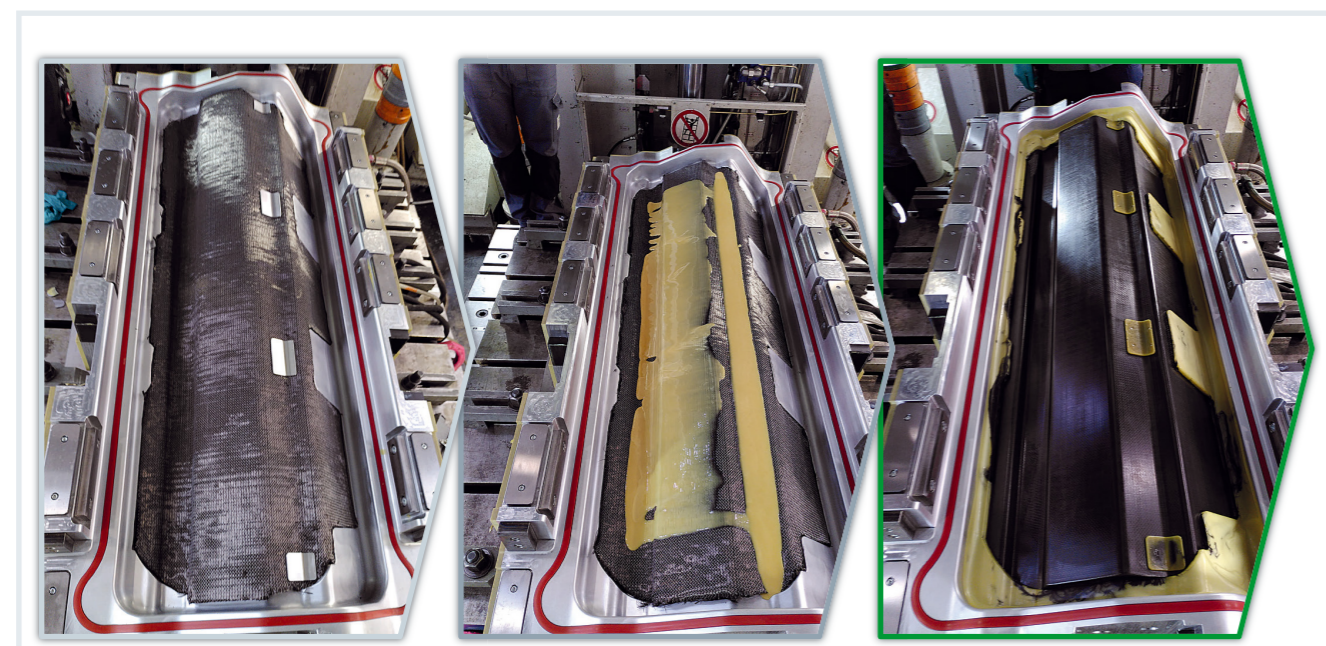


Fig. 4. Manufacturing steps for the inner seat shell: Carbon fiber fabric in the mold, resin poured onto the fabric, cured inner seat shell (from left to right). © Fraunhofer ICT

the solvolysis process. This process uses solvents to split the chemical bonds in the PUR into oligomers and monomers. The oligomers and monomers serve as raw materials for the production of recycled polyol, which can be used for example to produce new PUR foam. The carbon fibers separate completely from the PUR, leaving no residue. The mild processing parameters during solvolysis do not damage the carbon fibers.

The manufacture of the hybrid seat structure has an overall CO₂ footprint around 20% smaller than that of a conventional seat of the same size. This was the conclusion of a life cycle assessment (LCA), which analyzed the material and energy flows throughout the process. In addition, the low weight of the seat structure saves fuel during flight.

Conclusion

The results clearly show that the application of only one type of plastic in the seat structure enables recycling at the

end of the use phase, without the need for complex separation and sorting processes. Lightweight construction with integrated functions reduces the number of seat components and thus the maintenance effort for the seat structure.

The components can be produced very efficiently using manufacturing processes suitable for large-scale production. The SMC process generates decorative surfaces with high quality, which are particularly suitable for visible components. Plasma-coated surfaces can be bonded with the plastic directly in the mold, achieving maximum strength. This has enabled us to reduce the weight of aircraft seats, and to decrease the overall CO₂ emissions in their production and recycling by around 20%.

The concept of this seat is not limited to airplanes, but can also be used for other applications, such as trains or buses. The hybrid seat structure development won the JEC Award for Aerospace Parts in 2023. ■

Info

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References

You can find the list of references at www.plasticsinsights.com/archive