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Evonik Performance
Polymers

ROHACELL® News

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Evonik's core for sandwich solutions

For the last 38 years the ROHACELL® brand has stood for continuous innovation and creativity and has constantly set new industry standards.

The product line was part of Degussa and Degussa is now Evonik, the creative industry group. Evonik provides the ideal platform for extraordinary products with outstanding performance and unsurpassed properties.

High performance ROHACELL® foams have been successfully introduced into numerous applications in a wide range of markets and applications ranging from top sport applications to latest state-of-the-art aerospace components. The huge demand in the markets prompted Evonik to invest in a major capacity increase. In mid 2008 the new US production plant in Mobile Alabama will be operational. This facility covers the production of all ROHACELL® Grades, and also offers 5-axis NC machining capabilities.

Also in the German headquarters of the product line, additional capacity has been installed to meet the rapidly growing demand for ready-to-use high-performance foam cores. ROHACELL® shaping has become an integral and rapidly growing part of the business.

Evonik is well equipped to meet the constantly growing demands of the markets.

We stand for expertise in sandwich engineering, excellent engineering service and outstanding product quality. ROHACELL® is explicitly named in more then 190 specifications worldwide, including MIL specs, ISO 14001 and ISO 9100. Our Sandwich Technology Centers in Darmstadt Germany and Shanghai service our customers and constitute an ideal platform for developing cost-effective sandwich solutions for our customers.

ROHACELL®-filled A-stringers

ROHACELL® sandwich foam cores are successfully used in a number of aircraft applications. The use of stringer profiles has proven to be the most suitable method for stiffening thin CFRP-shells. The most effective stiffening can be achieved by using A- or hat-profiles, e. g. A-stringers. One of the latest applications for foam filled stringer profiles is the rear pressure bulkhead of the Airbus A340 and A340-600 (Figure 1, left and center).

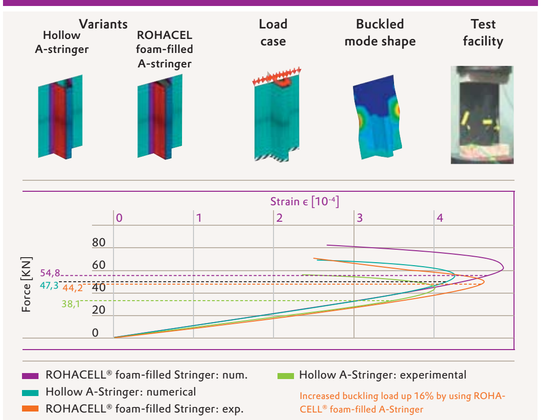
1 | Airbus A340-600, rear pressure bulkhead (left), CNC-machined and net-shape-thermoformed ROHACELL® A-profiles (right)

To date, over 4600 CNC-machined and net-shape-thermoformed A-profiles made of ROHACELL® 71 WF-HT for the A340 have been delivered ready-to-use to the Airbus plant in Stade, Germany (Figure 1, right). The net-shaped foam serves as a mandrel during lay-up and cure. Its high resistance to compressive creep and excellent dimensional stability during the cure make it possible to apply the cost effective one-step co-curing process at a temperature of 180 °C (356 °F) and a pressure of 0.35 MPa (50 PSI) for 2 hours. Therefore the use of foam profiles contributes to significant cost savings during the manufacturing process. The PMI foam ensures perfect prepreg consolidation on all surfaces of the stringer profile without surface dimpling effects. In contrast to honeycomb cores, the isotropic cellular structure of PMI foams provides dimensional stability against lateral pressure during the autoclave cure and eliminates the necessity of the core profile stabilizers typically used for honeycomb cores. Also the foam core evenly transfers the autoclave pressure to the surface layers of the shell underneath, resulting in a good consolidation without any marks or other surface imperfections. Thus it is the perfect substitute for of inflatable bladder tools known for high recurring costs and a lot of problematical handling issues. More than 500 bulkheads have been successfully manufactured without a single rejection. This underlines the reliability of the process and processing of the ROHACELL® A-profiles. Based on the decennial success of the new A340 bulkhead configuration, incorporating the ROHACELL® filled stringers, the technology concept was adopted for the rear pressure bulkhead of the A380 as well. In this case the foam stringer profiles are up to 2.5 m long with a significantly more complex geometry. The ease of machining and net-shape thermoforming of ROHACELL® was the key for the successful implementation of the foam-filled stringer design. To date approx. 780 ready-to-use foam stringer profiles have already been delivered to Airbus. More than 50 of the large bulkheads have been cured successfully, with zero rejections.

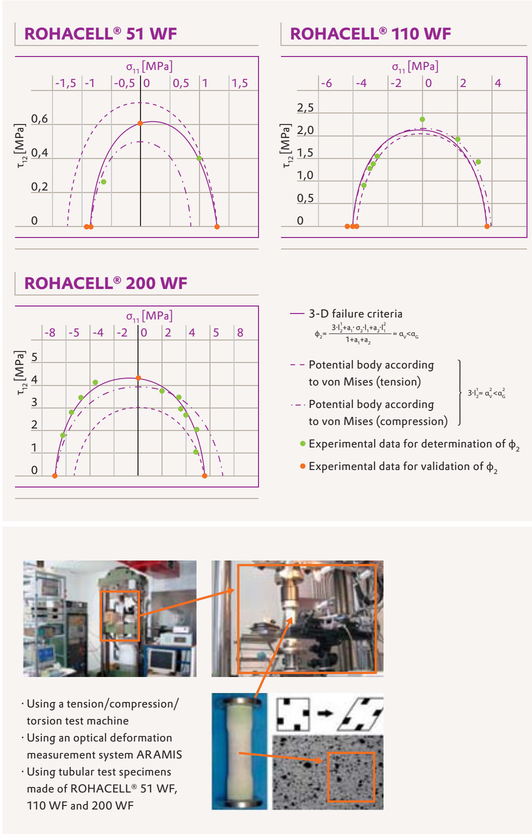
The application of modern Computer Aided Engineering (CAE) tools such as numerical Finite Element Analysis (FEA) is indispensable for designing optimized sandwich structures as well as for analyzing their manufacturing processes. The leading principle "Solutions to Customers" means providing customers with complete solutions. Therefore, and in addition to the already well known engineering services, now also FEA based on ANSYS® is available at the German headquarters in Darmstadt. The additionally provided service makes it possible to analyze both ROHACELL® foam-filled sandwich structures and ROHACELL® foam itself. Structural mechanical analysis, thermal analysis, modal analysis and buckling analysis can be carried out. The following information from our customer is needed to perform a FEA: geometry as CAD file (e. g. IGES, STEP), proper drawings, material properties of the face sheet and other possible components, loads, boundary conditions, assumptions, list of requirements and the design criteria.

The internal FEA was used to analyze the potential of a bi-functional usage of PMI foam cores for realizing cost and weight optimized A-stringer profiles. It can be concluded that a PMI foam-filled A-stringer can significantly contribute to increasing the stability and buckling resistance of a thin-walled CFRP structure up to 16 % in comparison to a hollow A-stringer design (Figure 2). Furthermore, foam-filled A-stringers can improve the strength and the fatigue life of the stiffener and the skin/stiffener interface in comparison to hollow A-stringers. If ROHACELL® is also used as a structural member, the wall thickness of the covering CFRP face sheets can be reduced, offering a "weight-neutral" solution compared to a hollow A-stringer. Thus it is necessary to take the core material of sandwich structures into account when using the bi-functional capabilities of ROHACELL® PMI foams, serving as a mandrel and as a structural member of the sandwich design. When using ROHACELL® as a structural core, it is necessary to analyze the stress distribution of the sandwich structure under loading conditions. Afterwards the effort of the core material can be determined using the three dimensional stresses and a suitable 3-D failure criterion. This would exploit the full inherent cost and weight saving potential of the ROHACELL® foam-filled sandwich design.

2 | Force/strain diagram of hollow and of PMI foam-filled A-stringer stabilized shells under axial compression load



3 | Test facility and 3-D failure criteria for ROHACELL® 51 WF, 110 WF and 200 WF in 11/12-stress plane



In cooperation with the German Institute for Polymers (DKI), a 3-D failure criterion for PMI foams ROHACELL® was developed. This model is suitable for the compressible material behavior and the strength differential effect (i. e. tensile strength ≠ compressive strength ≠ shear strength) of PMI foams. New tabular test specimens made of ROHACELL® 51 WF, 110 WF and 200 WF and a new test facility were developed to determine the mechanical properties under different loading conditions (pure tension, compression, shear as well as combined tension/shear and compression/shear). A tension/compression/torsion test machine including the optical deformation measurement system ARAMIS was used (Figure 3, left). The newly developed 3-D failure criterion needs only three free parameters to describe the surface of breakage in the 3-D stress space. These parameters can be determined by using the results of pure tension, compression and shear loading. Combined tension/shear and compression/shear loading was carried out to validate the 3-D failure criterion. The 3-D failure criteria for ROHACELL® 51 WF, 110 WF and 200 WF in 11/12-stress plane are shown in Figure 3 (right).

Furthermore, the 3-D failure criterion was independently validated by Composite Technology Center GmbH in Stade and Fraunhofer Institut für Werkstoffmechanik in Halle, Germany. The 3-D failure criterion according to DKI/Röhm as well as other criteria (e. g. von Mises, Beltrami, Sandel and Tresca) were applied in a numerical program. A loaded sandwich beam with 4-point bending and featuring PMI foam as core material and face sheet made of CFRP was simulated and analyzed. The experimental results of 4-point bending test were used to validate the numerical results. The sandwich beam failed due to a shear crack in the core material. The calculated material effort fE of ROHACELL® using the DKI/Röhm criterion agrees very well with experimental results. The new 3-D failure criterion according to DKI/Röhm is more suitable to describe the material behavior of ROHACELL® than the other potential bodies. The 3-D failure criterion is easy to implement in commercial FE programs. Given the present results the use of the DKI/Röhm criterion to determine the material effort of ROHACELL® is recommended.

Lightweight potential for automotive applications


Lightweight tailgate from the Evonik Golf V study.

For many years now, structural components of the body and undercarriage have been fabricated as sandwich structures using our ROHACELL® structural foam, particularly in racing and sports cars.


ROHACELL® sandwich roof from the Evonik Golf V study.

Sandwich construction can also help solving weight problems for buses, in particular for sections located far from the center of gravity, such as the rear end and the roof. Sandwich solutions with thermo-formable ROHACELL® are ideal, providing components of high rigidity at significantly lower weight.

Especially in cars with alternative drive concepts, such as electric cars with heavy batteries or fuel cell cars, excess weight results in a significant reduction in operating range and driving dynamics. Also in this case, using lightweight sandwich parts is key to weight reduction. Thanks to the unsurpassed properties of ROHACELL®, significant weight reduction can be achieved, even if only GFRP skins instead of CFRP skins are used in the sandwich design. The Chinese Company Shanghai Fuel Cell Dynamics for example safes as much as 40% of weight for the tailgate of their new fuel cell car, using this kind of low-cost sandwich design instead of the traditional steal sheet design. Prototypes of this tailgate and also prototype bonnets have been realized by means of resin infusion in the ROHACELL® Sandwich Technology Center in Shanghai.

The potential for weight saving in various components has been impressively demonstrated in the VOX TV channel's Auto-Motor-Sport TV program, using the example of a Volkswagen Golf V. Substitution of steel sheet components by CFRP/ROHACELL® sandwich composites made it possible to achieved significant weight reductions: more than 8 kg in the hood, 19 kg in the tailgate, about 7 kg in each of the rear doors, and more than 7 kg in the roof outer layer.

The excellent temperature resistance – up to 180°C – makes ROHACELL® IG the perfect foam core for rapid sandwich part fabrication, using highly reactive and fast curing resin systems. Moreover, ROHACELL®-cored sandwich structures can be fed into the in-line painting process with no problem at all.

Taking structural sandwich foam core to the next level

Evonik Röhm GmbH's ROHACELL® product segment has been setting industry standards for 38 years now. ROHACELL® has long become the synonym for unsurpassed performance, serving as structural sandwich foam cores in the most demanding applications.

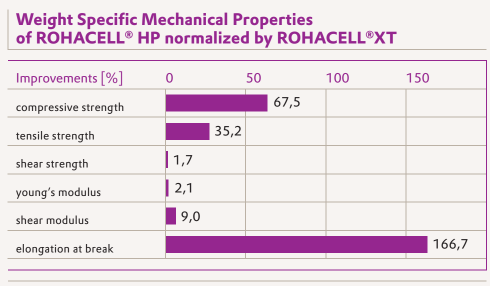
The brand also stands for continuous innovation. Over the years, 9 different Grades have been developed to meet specific demands in specific fields ranging from sports to aerospace applications.

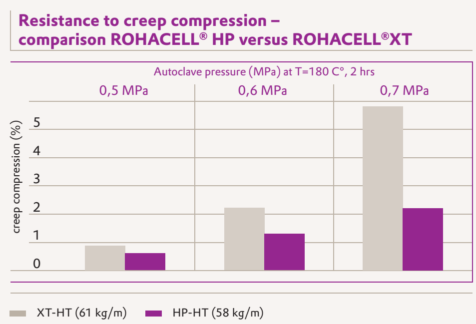
Driven by the constant demand for improvement, a new generation of even more advanced and higher performing PMI foam has been successfully developed. This new PMI foam is called ROHACELL® HP (High Performance). The new grade shows unique properties, exhibiting an even better strength-to-weight ratio compared to any other PMI foam, and 8% elongation at break (ISO 527-2/ASTM D 638). Also, its weight-specific resistance to creep compression marks a milestone in the development of rigid foams and is equal to or better than every other commercially available sandwich foam core. The product can be introduced into cure cycles at T = 180°C and at pressures of up to 1 MPa (10bar), while creep compression is < 2%. Post-curing temperatures of up to 240°C can be applied.

The new Grade will be available in a density range of 51-110 kg/m³. The particularly tailored cell size also makes it the ideal foam core for demanding RTM processes in the manufacture of high-quality parts.

An excellent NDI inspection capability is also available, as the material's reflection coefficient is very close to air.

Improvement achieved





ROHACELL® in helicopter rotor blades – continuous success

Although the first drawings of a VTOL (vertical take-off and landing) aircraft were made by Leonardo da Vinci as early as the 15th century, the first free flight of a helicopter did not take place until the 20th century. The pioneer was the French bicycle manufacturer Paul Cornu, who lifted off with a two-rotor 24-horsepower aircraft on November 13, 1907, near Le Havre. This first manned VTOL lasted 20 seconds, and reached an “altitude” of 30 centimeters. The most important components of the helicopter are the rotor blades which generate dynamic lift in relation to the air streaming against them.

In terms of construction, today’s helicopters have little in common with the earliest models. The rotor blades of the first helicopters were made completely of wood, linen and metal. It wasn’t until the 1960s that the idea of producing rotor blades from bendable materials began gaining traction. As a result, the first carbon-fiber composites conquered the rotor market.

For decades now, the most technically advanced rotor blades are built as ROHACELL® sandwich components. This method of construction results in a unique combination of low weight, maximum mechanical stability and ultimate blade performance.

The rotor blades of helicopters are subject to enormous stresses. At a travel speed of 250 kilometers per hour, the rotor of a helicopter like the EC145 rotates 400 times per minute. This means the tips are moving at speeds of about 220 m/sec. The centrifugal forces this creates can reach about 1,000 times the force of gravity.

Eurocopter has relied on sandwich technology since 1996. “With the help of ROHACELL®, production is simplified, because the material can be pressed cleanly,” explains Ulrich Denecke, head of the rotor blade construction division at Eurocopter.

Because ROHACELL®, unlike other foam plastics, tolerates the temperatures applied by the company in its materials processing systems, applications for the foam have already multiplied by a factor of 2.5 to 3 in the last ten years. Eurocopter produces about 500 blades annually using the structural PMI foam. Another reason for the growing demand is the material’s outstanding durability. Indeed, sandwich structures using ROHACELL® are superior to most metals. “Compared to structures made of aluminum-titanium, the life cycle of these structures is four to fives times longer, because no material fatigue occurs,” says Dennecke. With the help of sandwich technology, therefore, operating periods of 15,000 hours or 40 years – the maximum service life of a helicopter – can be reached. This is why Eurocopter is committed to this technology and is using it in all current and future models.

Because of its outstanding material properties – primarily its excellent weight-specific resistance to creep compression and its unsurpassed strength-to-weight ratio, ROHACELL® has proven to be an excellent structural sandwich foam core in the manufacture of advanced components for the aircraft industry. The applications range from winglets, through landing gear doors, pressure bulkheads and A-stringers for engine cowling, all the way to the folding tray-tables in the passenger cabin.

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