Airbag housing in polyamide 6

Greater Cost-Efficiency in Airbag Production

Polyamide. A glass fiber-reinforced polyamide 6, optimized especially for airbag housings, offers balanced properties over the whole range of temperatures at which an airbag can be deployed. At the same time, a reduced weight and shorter cycle times permit more efficient use of energy and material.

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Airbag systems are generally made up of a gas generator with an ignition device, a connector, the airbag, a cover and a housing with attachment points on the steering wheel or on the crossbeam in the passenger compartment (Title photo). The empty, folded airbag, which is attached to the housing, is located in the space enclosed by the housing and the cover (Fig. 1a). When the airbag is deployed, a high load acts on the system and particularly on the housing, which holds the gas generator and the airbag. This load is due to the pressure build-up necessary for blowing up the airbag (Figs. 1b and c). Also, at the point when the airbag has fully unfolded, mass forces additionally develop on account of the sudden deceleration (Fig. 1d).

Pressure (p_i) acts as a dynamic burst factor on the surrounding housing walls and the cover. It attains its maximum when the seam or seams on the cover tear. The mass forces act on points at which the airbag is attached to the housing, as well as on the points at which the housing is fixed to the surrounding components of the steering wheel or crossbeam. Depending on the design, these forces can generate maximum loads and stresses at each of these attachment points.

The load develops over a very short period of time. In the case of a front-mounted airbag system on the driver's side, it typically takes 30 to 50 ms for the airbag to unfold and, on the front passenger's

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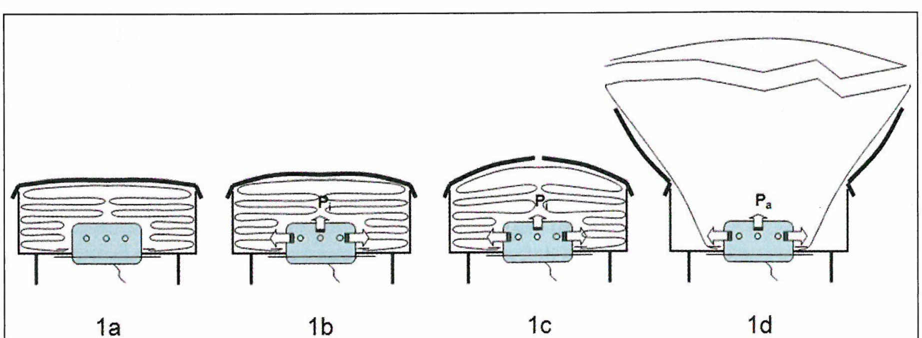

Fig. 1. Schematic overview of the airbag phases: (a) starting state, (b) pressure build-up, (c) cover seam tearing and airbag starting to unfold, (d) fully unfolded airbag

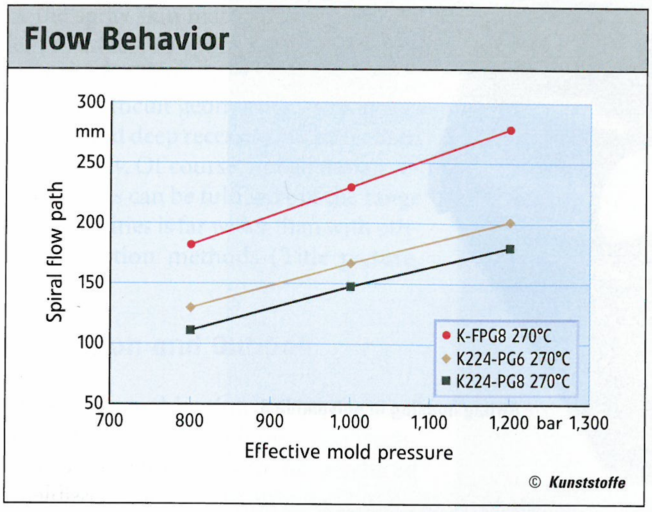

Fig. 2. Spiral flow paths of three different types of PA6 with a melt temperature of 270 °C

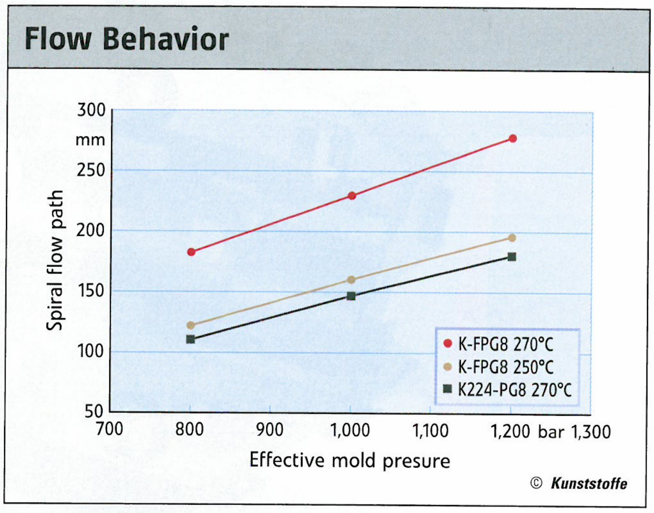

Fig. 3. Spiral flow path of Akulon Ultraflow at two different melt temperatures illustrating its processing window

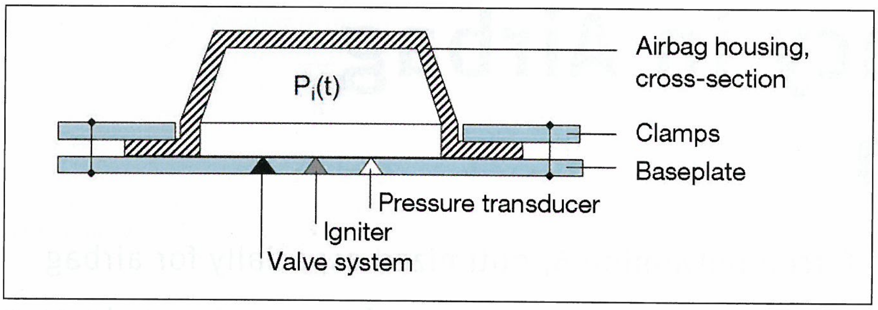

Fig. 4. Basic configuration of a dynamic burst pressure test for airbag housings

side, 40 to 60 ms. The time required for the pressure buildup and the reaction force of the housing (including the cover) is even shorter.

Loadbearing Capabilities – a Must

Apart from being able to withstand rapid loading of this type, a suitable material for an airbag housing must also offer the mechanical behavior that is required when airbags are deployed at extreme temperatures. The typical service temperature range is from -35 to +85 °C.

An optimum material for airbag housings should thus have a balanced property profile and be able to withstand the pronounced stressing of rapid loading and extreme temperatures. This includes a very good low-temperature impact strength, ensuring resistance to fracture or splintering at low temperatures down to -35 °C, and a sufficient stiffness and resistance to inadmissible deformation or the failure of the attachment points at elevated temperatures of up to +85 °C.

One material which has been proven to fulfill these requirements is Akulon (manufacturer: DSM Engineering Plastics), a glass fiber-reinforced and impact-modified polyamide 6 (PA6). The glass fiber reinforcement of the polymer ensures resistance against the high forces which develop on account of the inertia of the airbag when it is triggered. An impact modifier must also be incorporated to ensure ductile behavior at low temperatures. While this improves low-temperature impact strength, it generally reduces the stiffness and strength.

Akulon Ultraflow is a new development in this field – a family of glass fiber-reinforced and impact-modified or mineral-filled PA6 products with superior flow properties to other polyamides. Akulon Ultraflow is based on a proprietary DSM technology. Compared with general-purpose grades of PA6, this family of low-viscosity materials achieves values up to 50 % higher in the spiral flow test, has a bigger processing window and permits significantly shorter cooling and hence cycle times in injection molding. The mechanical properties are compara-

Property		Typical data for dry as molded/conditioned		
		Akulon K224-PG8 PA6-I-GF40	Akulon Ultraflow K-FPG8 PA6-I-GF40	Akulon K224-PG6 PA6-I-GF30
Density	[kg/m³]	1,430	1,410	1,320
Glass fiber content	[wt.-%]	40	40	30
Polymer type		PA 6	PA 6	PA 6
Impact modified		yes	yes	yes
Modulus of elasticity in tension	[MPa]	11,500 / 7000	11,500 / 7,300	8,500 / 5,500
Tensile stress at break	[MPa]	170 / 115	175 / 110	145 / 100
Tensile strain at break	[%]	4.5 / 7	3.5 / 7	4.5 / 9
Charpy impact strength (+23°C)	[kJ/m²]	105 / 110	90 / 100	95 / 110
Charpy impact strength (-30°C)	[kJ/m²]	110 / 110	90 / 95	100 / 100
Charpy impact strength, notched (+23°C)	[kJ/m²]	25 / 35	20 / 20	25 / 45
Charpy impact strength, notched (-30°C)	[kJ/m²]	18 / 18	13 / 13	17 / 17

Table 1. Comparison of the mechanical properties of the polyamide 6 grades Akulon and Akulon Ultraflow for airbag housings

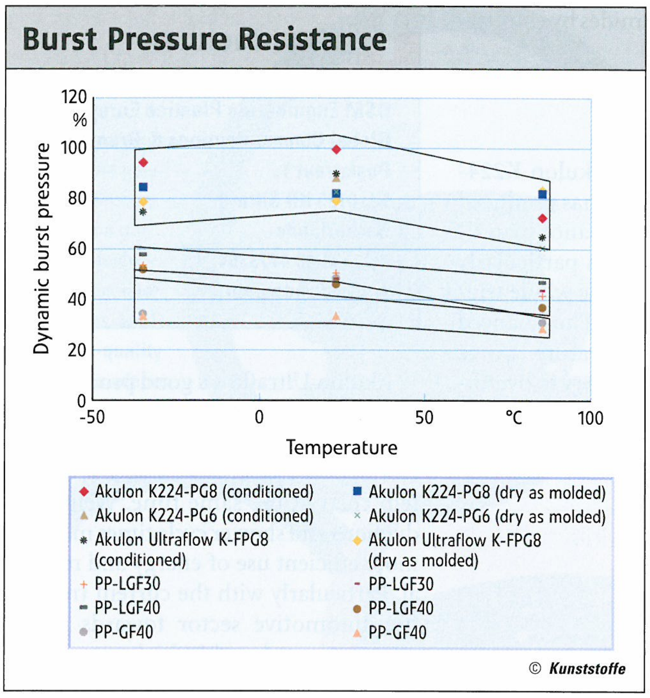

Fig. 5. Results of the DSM dynamic burst pressure test on airbag housings

ble with those of general-purpose grades of PA6.

Shorter Cycle Times

The spiral flow test is regarded as a measure of the flowability of polymers. Figure 2 shows the flowability of the new low-viscosity polyamide, Akulon Ultraflow K-FPG8, by comparison to the two polyamides that have become established for airbag housings: Akulon K224-PG8 as a reference material with the same glass fiber content and Akulon K224-PG6, which contains fewer glass fibers (Table 1). With an effective mold pressure of 1,000 bar, reference material PG8 attains a flow path of approximately 150 mm, while the figure is 230 mm already for the low-viscosity variant. This corresponds to a 50 % improvement in flowability for the same glass fiber content. The low viscosity of the basic material has a greater impact here than the glass fiber reinforcement. As is to be expected, the polyamide PG6 with 30 % glass fibers instead of 40 % has better flow properties, but not to the same extent as for the low-viscosity material with 40 % reinforcement.

The lower viscosity of the Ultraflow material can be exploited in different ways. One extreme case would be to process it at the same melt temperature of 270 °C as for reference material PG8, which would lead to lower injection pressures (Fig. 3). This, in turn, would make it possible to use molds with a larger number of cavities or to use a smaller injection molding machine with a lower energy requirement. The cooling time can be reduced by up to 10 % through the improved flowability of the new low-viscosity polyamide.

A further extreme case would be to reduce the melt temperature to between 245 and 250 °C and thus raise the viscosity to the level of the reference material. This would then lead to the same injection pressure for the same machine and the same number of cavities. The cycle time could be reduced by at least 10 %, however. Depending on the design and the mold running time, cycle times have been cut by up to 25 % in individual cases, bringing significant cost savings with airbag housings.

Special Applicability Test

Table 1 sets out a number of the mechanical performance properties of the three materials tested, as they are typically specified on product data sheets. Restraint systems and their components, however, require special material properties, which are directly associated with the rapid loading at extreme temperatures. Materials for this field of use cannot be rated on the basis of simple data sheets but need to undergo more in-depth applicability tests under conditions that come closer to those encountered in practice.

One parameter that can be appropriately employed for rating materials for applications like an airbag system is the dynamic burst pressure. DSM Engineering Plastics has developed a test method especially for airbag systems which permits the meaningful characterization of plastics at high loading speeds and temperatures. The test setup is based on a specific product geometry which is comparable with that of a typical airbag housing.

In this test, the space inside a closed housing, which has a uniform wall thickness of 2 mm, is filled with an explosive gas mixture. This gas mixture is ignited in order to generate a rapid pressure event in the system (Fig. 4). The pre-ignition pressure and the mixture's gas/oxygen ratio are set so as to give a pressure-time curve that comes as close as possible to the load experienced when an actual airbag is deployed. This curve is measured by a pressure transducer.

This setup was used to test the two reference polyamides and the newly-developed, low-viscosity polyamide (Fig. 5). In a dry as molded state (without moisture absorption) the reference material containing 40 % glass fiber (PG8) displays relatively constant behavior over the entire test temperature range. After conditioning in a moist environment up to a state of equilibrium, the burst pressure resistance increases in the low-temperature range (-35 °C), while it falls to approximately 75 % of the starting value at elevated temperatures (+85 °C). The hundred-percent mark is defined here as the dynamic burst pressure resistance of conditioned PG8 at room temperature (+23 °C). The results for the material with 30 % glass fiber reinforcement are very similar, which suggests that the behavior of the material in applications subject to impact loading like this is essentially determined by the energy consumed, or by a combination of mechanical strength and tensile strain at break at high strain rates. The burst pressure behavior of the low-viscosity polyamide is comparable, even if a certain reduction of 5 to 10 % is evident at +85 °C.

Further materials were tested on the basis of the same housing geometry, including short and long fiber reinforced polypropylene (PP-GF and PP-LGF, Fig. 5). These differ clearly from the polyamides that were tested, with a reduction of up to 50 % in their burst pressure resistance at +85 °C. At the upper end of the service temperature range, the short glass fiber grades, in particular, display an insufficient burst pressure resistance.

The different behavior of polyamides by comparison with PP-GF has a significant effect on the requisite overall wall ▶

thickness of the housing parts. Housings in one of the polyamides can thus be designed with a lower wall thickness to give the same performance. A reduction of 30 to 50 % in the dynamic burst pressure resistance – expressed in terms of the reference PG8 in a wall thickness of 2 mm – means that the overall wall thickness for the polypropylene would have to be increased to between 3.0 and 3.5 mm to offset the property loss at elevated temperatures. Even if polyamide 6 has a more disadvantageous (higher) density than polypropylene, the overall weight of the airbag housing can be considerably reduced thanks to the thinner walls that are possible with the polyamides by comparison to PP.

System Costs

The optimization of the Akulon K224-PG8 polyamide 6 polymer has produced an extremely high-performance material for airbag housings, with particularly balanced properties over the whole triggering-temperature range. The balanced behavior in this temperature range means it is no longer necessary to overdimension the parts to offset the loss of properties at low or elevated temperatures.

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Akulon Ultraflow's good processability and its dynamic burst pressure behavior offer broad scope for design and processing, with potential for saving on system costs at the same time. Weight reductions and shorter cycle times make for more efficient use of energy and material. Particularly with the current trend in the automotive sector towards global platforms produced in higher numbers, it is possible for more parts to be produced in one and the same mold. Akulon Ultraflow offers an excellent means of exploiting all this for the corresponding increases in productivity. ■

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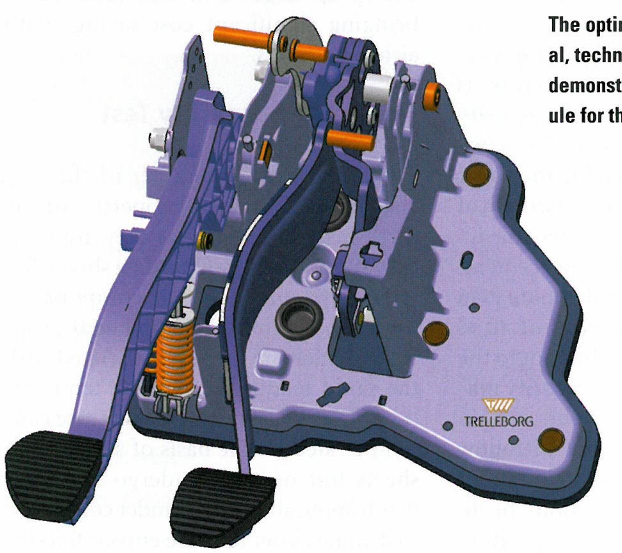
New Method

Pedal Module. In the development of the pedal and adjustable pedal module for the new Citroën C5, Rhodia Polyamide, Saint-Fons, France, and Trelleborg Automotive Carbody, Witry les Reims, France, collaborated closely. Rhodia supplied the material, a polyamide sold under the trade name Technyl, and the MMI technology to simulate component properties, while Trelleborg contributed its pedal expertise.

The new method takes into account the orientation of the glass fibers and their distribution in the injection molded component. This allows the structure of the injection molded parts to be analyzed more precisely than was possible with previous programs – particularly in terms of predicting crash behavior. With this method, component design can be optimized and time-to-market significantly reduced, according to the manufacturer.

By using the new material, Trelleborg has been able to create a much lighter pedal module, integrating the plate and the pedal. Compared with the metal design, a 50 % weight saving has been achieved, while maintaining the same rigidity. In addition, the pedals have been built into the patented module system in such a way that they disappear into the vehicle floor in the event of a crash, so protecting the driver and passenger.

▶ www.rhodia-polyamide.com



The optimum combination of material, technology and know-how is demonstrated in the new pedal module for the Citroën C5 (photo: Rhodia)

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