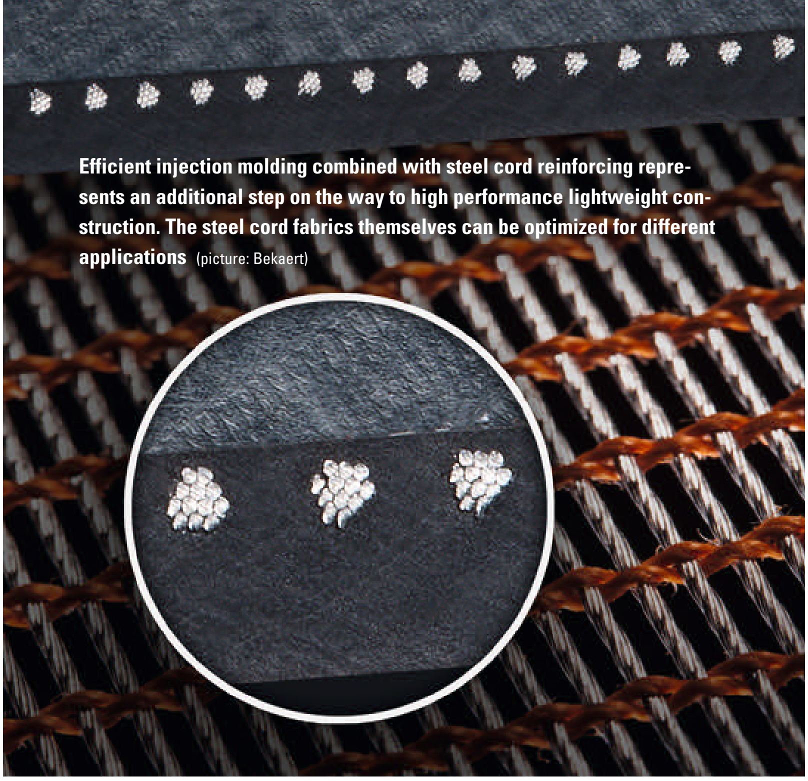
Reinforcing with Steel Cord



Efficient injection molding combined with steel cord reinforcing represents an additional step on the way to high performance lightweight construction. The steel cord fabrics themselves can be optimized for different applications (picture: Bekaert)

EASI-Component. A novel technology for manufacturing injection molded parts with continuous steel cord reinforcement (EASI) opens up an entirely new performance class for polymer components. The technique allows the production of crash resistant, lower weight component parts whilst at the same time providing for a high degree of design freedom.

ANDREAS RADTKE ET AL.

NV Bekaert SA, Kortrijk, Belgium, Voestalpine Plastics Solutions BV, Roosendaal and Putte, The Netherlands, and BASF SE, Ludwigshafen, Germany, have jointly developed a technology with which novel polymer components for structural applications can be manufactured. In contrast to conventional types of component reinforcement like continuous fiber reinforced laminate parts or other textile carbon or glass fiber structures, steel cord inserts in particular provide for the retention of component functionality during crashes **(Fig. 1)**.

Bekaert, Voestalpine Plastics Solutions and BASF started working on steel cord reinforcement, or EASI technology, for injection molded components in 2010. EASI stands for Energy, Absorption, Safety and Integrity. This captures the fact that the application for these components is found in safety relevant areas where on the one hand energy absorption is required, but on the other the part should not be completely destroyed under collision loading, but rather retain its integrity as a functional component. The first mass produced components of the forerunner compression molding technology based on GMT won the 2008 AVK Innovation award. After this the three companies concentrated on classic injection molding of components with steel cord reinforcement. In doing so the original technology was converted to a one step process with reduced material and process costs **(Title picture)**.

Within the know-how alliance Bekaert provided the expertise in the reinforcement of polymers with steel cord, whilst Voestalpine Plastics Solutions is responsible for the component concepts and development as well as the processing technology and production of the component parts. BASF takes on the further development of crash optimized short and long fiber reinforced polyamide specialties from the Ultramid range for combination with steel cord inserts. In addition the company works on strengthening the associated predictive expertise and extends its simulation tool Ultrasim to include depiction methods and material models for the new composites.

Contact

Bekaert SA
Press Office
BE-8500 Kortrijk
Belgium
TEL +32 56 23 05 71
→ **www.bekaert.com**

Contact

BASF SE – Trade Press Office
Performance Polymers
D-67056 Ludwigshafen
Germany
TEL +49 621 60-43348
→ **www.plasticsportal.eu**

The Limits of Conventional Fiber Reinforcement

At present various concepts for composite materials are being considered. If the conventional approaches are compared in respect of stiffness and strength then steel cord reinforced thermoplastic components do not at first glance seem to offer any significant advantages. It is however →

Translated from Kunststoffe 11/2012, pp. 67–71
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE111189

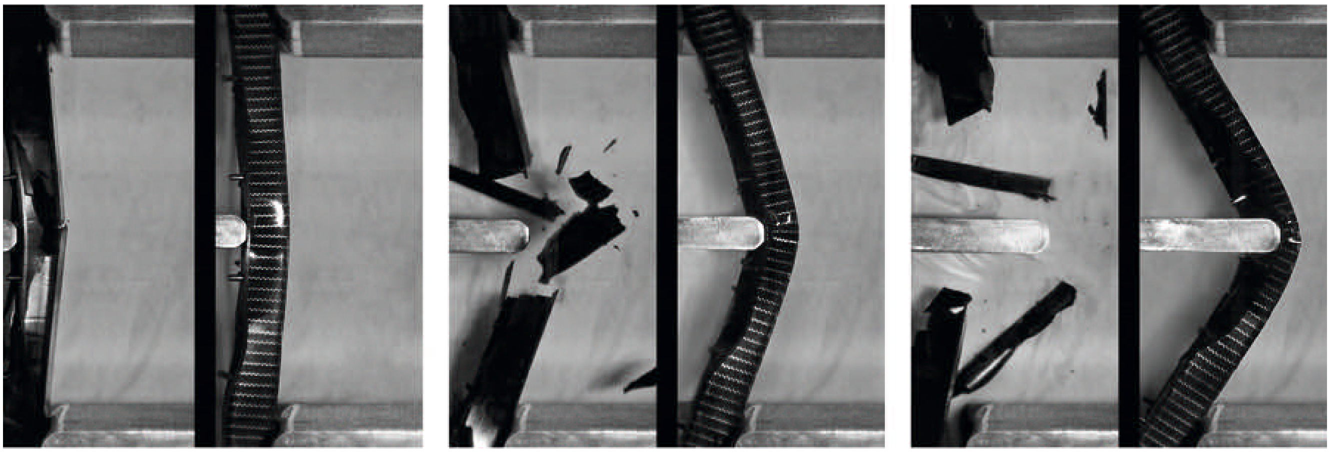


Fig. 1. In contrast to other commonly available reinforcing agents steel cords ensure that loaded components remain intact during crashes even at high collision energies (left: normal glass fiber reinforcement; right: steel cord reinforcement; see video) (picture: BASF)

in crash situations that their unique properties come to the fore **(Fig. 2)**.

The steel cord reinforcing of the EASI concept ensures that a polymer component can retain its structural integrity under highly dynamic loading. EASI components can indeed be damaged during crash loadings, however even after this damage has commenced they are still able to absorb energy and provide force transfer. This is the decisive innovation in comparison to conventionally reinforced polymer parts which tend to fracture or rupture during failure. These kinds of performance levels cannot be achieved with other types of reinforcing technology.

Video

A high speed video of the performance of steel cord reinforcement can be found at: www.plasticsportal.eu/ultramid-steelcord or → **www.kunststoffe.tv/steelcord**

Steel Cords for Polymer Components

Under the EASI concept the steel cords used are individually optimized in respect of their structure and surface treatment for use in thermoplastic components. The steel cords developed and produced by Bekaert can be constructed from various types of individual wires in different thicknesses. They are galvanized and have a high carbon content. In addition they have an anti-corrosion coating that prevents corrosion over the lifetime of the part, which has been confirmed by long term salt spray tests of the steel cords as well as the injection molded steel cord reinforced components **(Fig. 3)**.

The steel cords are very stiff and strong, with tensile strengths of more than 2,800 MPa. These strengths, which are the highest found in the steel sector, allow the steel cord fabric to hold the thermoplastic matrix together during an impact. Even after repeated collisions the steel cord fabric can resist very high incident loadings.

In order to guarantee exact positioning of the steel cords in the injection molded component Bekaert developed a special textile structure for the steel cords **(Fig. 4)**. This structure is so open that it can be easily laid up in the injection molding tool without any pretreatment and also completely encapsulated by the thermoplastic. In this way the steel cords cannot be displaced during the injection molding process.

Benefiting from the Advantages of Polyamides

As is well known injection molding of thermoplastics such as Ultramid allows even complex shapes to be manufactured simply and is an established highly automated polymer processing technique for mass production. Thus the combination of polyamide injection molding and steel cord reinforcement is a very efficient method for realizing component parts that can survive collisions largely intact.

Injection molding steel cord reinforced thermoplastics is almost identical to the classic process, however the steel cord fabric has to be laid up in the tool cavity before the mold is closed. Reliable processing of such inserts presents challenges in

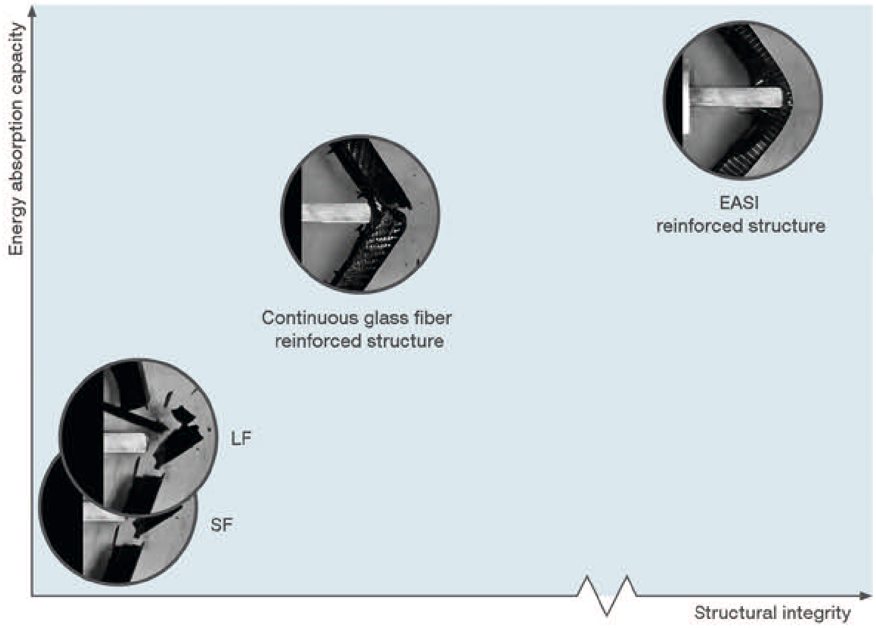


Fig. 2. The strength of steel cord reinforced thermoplastics is comparable with long fiber reinforced polymer parts. Due to their ductility they are however less vulnerable during crashes and the structural integrity of the part is maintained for a particularly long period of time (SF: short glass fiber reinforced, LF: long glass fiber reinforced, EASI: new steel cord reinforcement) (picture: BASF)

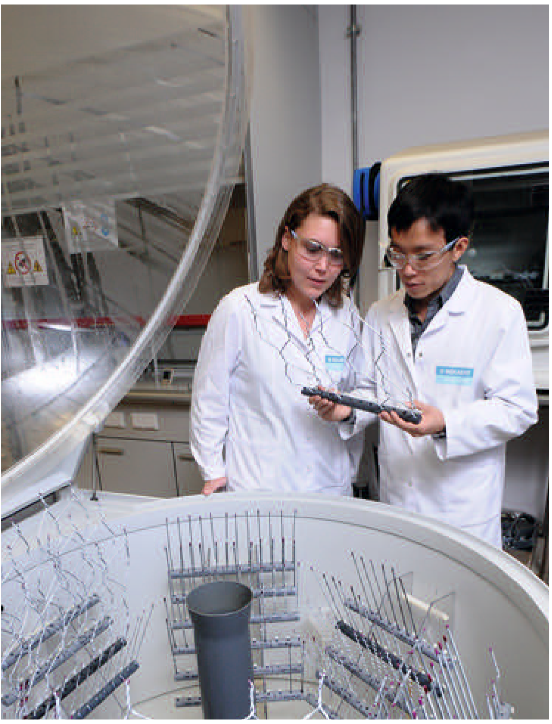


Fig. 3. The corrosion resistance of steel cords and steel cord reinforced components is assessed in salt spray tests (picture: Bekaert)

respect of tooling technology and process control, since the positioning and fixing of the steel cord fabric in the tool as well as potentially a preforming have to be allowed for. Depending on the geometry and complexity of the insert, cycle times can be slightly longer than standard injection molding processes.

Amongst the interesting examples of metal substitution in vehicle manufacture over the last few years are engine mounts, stabilizer and cross links, bumper supports and pillar inserts made from engineering thermoplastics such as polyamide. Both standard and specialty BASF Ultramid grades have been used in many of these applications. EASI components likewise benefit from polyamide as the injection molding material: They can be cathodic dip coated and used either as mounted or BIW (body in white) parts. Materials with improved flow properties such as Ultramid B3WG6 High Speed as well as the new long fiber reinforced products from the BASF Ultramid Structure range can be used for EASI parts. These components combine the necessary performance for structural requirements such as strength and stiffness with the ductility of tough materials so that in a crash situation extremely high energy absorption as well as structural integrity can be guaranteed. In this way EASI components fill a gap between purely thermoplastic parts, complex glass or carbon fiber composites and heavy sheet metal/polymer hybrids.

Performance Envelope of the Composites

The combination of steel cords with a thermoplastic matrix leads to fundamentally new material behavior, in particular at high elongations. With conventional fiber composites at high elongation rates cleavage fractures occur across the whole composite, which ends in a spontaneous failure. EASI technology prevents separation of the polymer matrix from the steel cords and therefore demonstrates high ductility after the onset of a break. This material behavior results in the performance envelope and behavior of EASI composites being either not or only inadequately captured by conventional testing and data sheets. The exceptional structural integrity of EASI can only be demonstrated by non-standard, component part oriented investigations. One of these is the three point bend test (**Fig. 5**).

A glance at the energy/displacement diagram (**Fig. 6**) shows that the energy absorption of the steel cord reinforced polyamide component is much higher than that of the base 30 % glass fiber reinforced polyamide parts (in this case the flow optimized Ultramid High Speed grade).

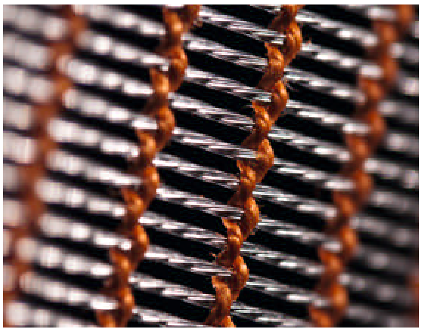


Fig. 4. Steel monofilaments can be twisted into various steel cords with different densities and break strengths and then fixed in place with textile fabrics (picture: Bekaert)

Predicting Behavior through Simulation

It is not only the ongoing further development of matrix polymers that has contributed to the success of polymer applications, but also the growing ability to be able to predict the behavior of a polymer part under loading with computers, for example with sophisticated instruments such as the Ultrasim simulation tool from BASF. With this continuously updated simulation system it is now also possible to predict the quasi-static and dynamic behavior of steel cord reinforced Ultramid components with high precision (**Fig. 7, Fig. 5 right**).

Applications and Recycling

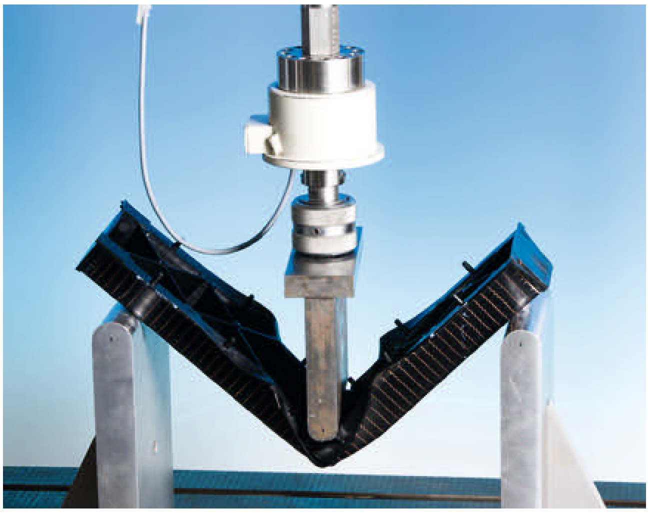
Steel cord reinforced polyamide is predestined for areas that provide energy absorption and harmonic energy distribution of crash energy (see video). Vehicle components where these characteristics can be exploited include structure-relevant attachments such as bumper beam carriers or front ends as well as BIW parts that have to retain their load bearing capacity and structural integrity in order to distribute forces during a crash and in post failure modes. Applications in A, B and C pillar reinforcement as well as inner door and sill areas can also be envisaged. An early inclusion of the steel cord concept in the design and layout phase of these novel components is absolutely essential. Incorporation of steel cords into existing designs or prototypes can improve the component part characteristics, but will not fully exploit the potential of the technology as a whole. It is only when the use of steel cord inserts is introduced within the concept phase of component development that optimal properties of the component can be achieved.

In the case of crash load chains EASI offers the potential to decide between conventional sheet metal construction with expensive mass production tooling and slightly more complex parts with lower overall investment. On top of that come all the well known advantages of polymer injection molding such as functional integration and modularization.

The possibility of recycling the steel cord and polymer after the service life of the component could be demonstrated for the first mass produced parts made using compression molding technology. A large scale test at Voestalpine in Linz, Austria, showed that it was possible to fully separate the polymer fraction from the steel fabric for complete components: Following mechanical coarse size reduction and shredding the steel fraction could be passed back to the blast furnace. The polymer content, i.e. shredder light fraction, is also well known for its ability to be recycled.

Outlook: Combination with Laminates

Particular synergies can result from the combination of thermoplastic glass or →



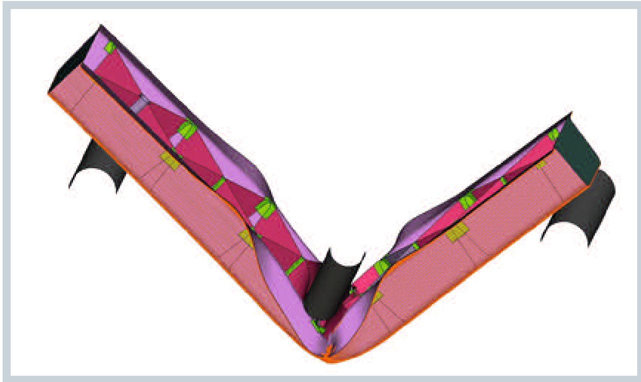


Fig. 5. Left: Three point bend test on a ripped top hat profile demonstrator component made from steel cord reinforced polyamide. Right: In order to generate the red curve in Fig. 7 the experimental three point bend test is recreated in a computer simulation (pictures: BASF)

carbon fiber laminates with steel cord reinforcement. In respect of strength, stiffness and energy absorption the combination of the EASI concept with local continuous fiber reinforcement (CFR) opens up further significant improvements, especially regarding the baseline stiffness of components. Impregnated unidirectional tapes or semi-finished parts known as thermoplastic textile reinforced laminates are suitable for the localized reinforcement of components.

In both cases the semi-finished component is shaped in three dimensions via thermoforming and then over-molded in an injection molding process with, for example, a glass fiber reinforced polyamide, producing a hybrid part with high levels of strength and stiffness. Where this is combined with EASI only a second semi-finished part – the textile stabilized steel cord fabric – has to be placed in the mold.

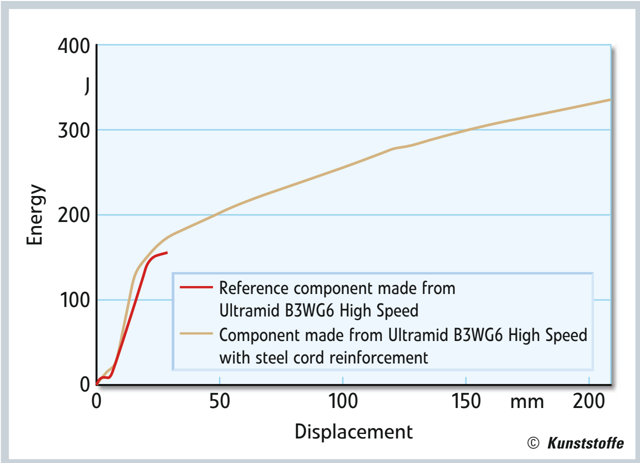


Fig. 6. The energy absorption of the steel cord reinforced Ultramid component is much higher than the base 30 % glass fiber reinforced Ultramid (in this case a highly flow optimized Ultramid High Speed grade) (picture: BASF)

Conclusion

EASI is a new component part concept developed by Bekaert, Voestalpine Plastics Solutions and BASF that enables crash resistant, weight reduced components to be produced whilst at the same time allowing a high degree of design freedom. This represents a further step towards cost effective lightweight construction for structural components. ■

Contact

Voestalpine Plastics Solutions BV
Press Office
NL-4704 RG Roosendaal
The Netherlands
TEL +31 165 575 475
→ www.voestalpine.com/polynorm

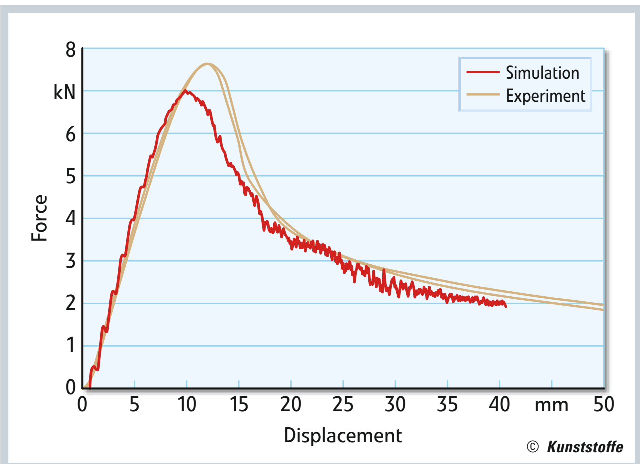


Fig. 7. Three point bend test: Simulation (red) and experiment (beige) for a conditioned demonstration part (ribbed top hat profile). The universal simulation tool Ultrasim from BASF has been upgraded so that the behavior of steel cord reinforced parts can be precisely predicted by a computer. This saves development time and costs (picture: BASF)

THE AUTHORS

ANDREAS RADTKE works in the marketing department of the Engineering Plastics Europe business unit of BASF SE, Ludwigshafen, Germany.

VEERLE VAN WASSENHOVE is an R&D Project Manager at NV Bekaert SA, Kortrijk, Belgium.

KEES VAN KOERT is Application Manager Business Development at Voestalpine Plastics Solutions BV, Roosendaal and Putte, The Netherlands.

FRANK VÖGE is Manager Business Development at Voestalpine Plastics Solutions, Roosendaal, The Netherlands.

DRIES MOORS is Innovation and Marketing Manager at NV Bekaert SA, Kortrijk, Belgium.

OLIVER GEIGER works in the Business Development Automobile department of the Engineering Plastics Europe business unit of BASF SE, Ludwigshafen, Germany.

DANIEL FERTIG works in Simulation Engineering at the Engineering Plastics Europe business unit of BASF SE, Ludwigshafen, Germany.