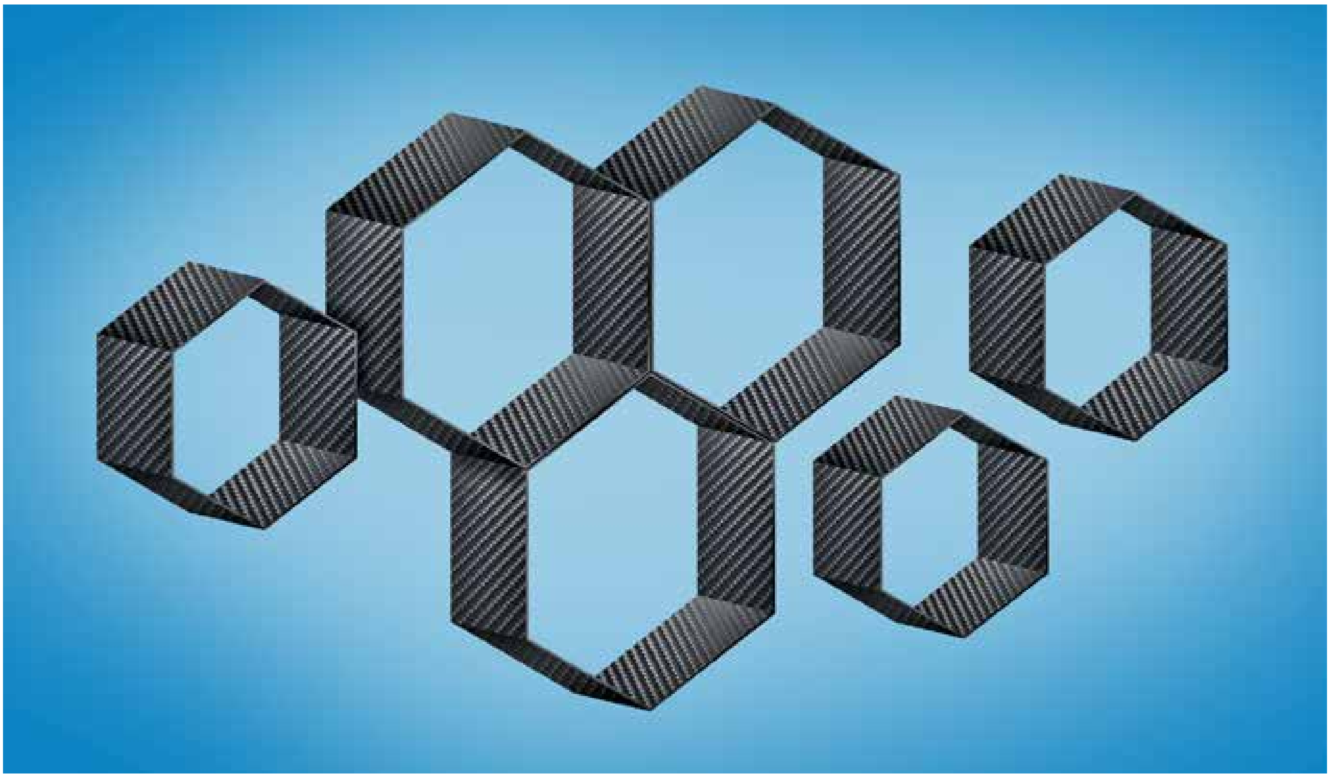
Lightweight and Innovative

Components Made from Carbon-Fiber-Reinforced Compounds

Edge trim of dry carbon-fiber fabric from automotive production can be spun into a highly engineered product. As a virgin fiber they can be conditioned to short fibers by means of an innovative process. Compounds filled with this state-of-the-art fiber can be used to make lightweight, highly resilient automotive components.



Dry carbon-fiber fabrics from production waste can be recycled (figures: Akro-Plastic)

As so often, the aviation industry was a pioneer in the area of lightweight construction. The effect of weight savings on this cost-intensive means of transport is to immediately reduce fuel consumption. A similar challenge is currently facing the automotive industry. The most important markets in Europe, USA and China have set themselves ambitious climate targets as they strive to meet legislation aimed at lowering the carbon footprint. Europe, for example, wants to reduce CO_2 emissions to 95 g CO_2/km on average by 2020.

The major automakers and their subcontractors are therefore investing huge sums of money to implement new ideas and to breathe life into those yet to be realized so that they can be used in lightweight designs for mass production. In a revolutionary approach a few years ago, the BMW Group, Munich, Germany, decided to build the entire passenger cell from carbon-fiber-reinforced plastic. As always, novel production methods generate a not inconsiderable amount of waste. These can be divided into dry fiber remnants and wet waste. Initial efforts by the automaker focused on making cut-to-length fabrics from the dry remnants for use in smaller applications. However, the remnants were not always the right shape for new components. Manual handling proved to be extremely cost-intensive, time consuming and prone to individual error. Thus new solutions had to be found.

Smart Use of Available Woven Fibers

Akro-Plastic GmbH, Niederzissen, Germany, has found a way to recycle dry carbon-fiber fabric (**Title figure**) which has not yet been in contact with a polymer matrix by incorporating it into a polymer melt in a manner which enhances the added value (**Fig. 1**). This entails shredding the fabric in a multi-step process for »

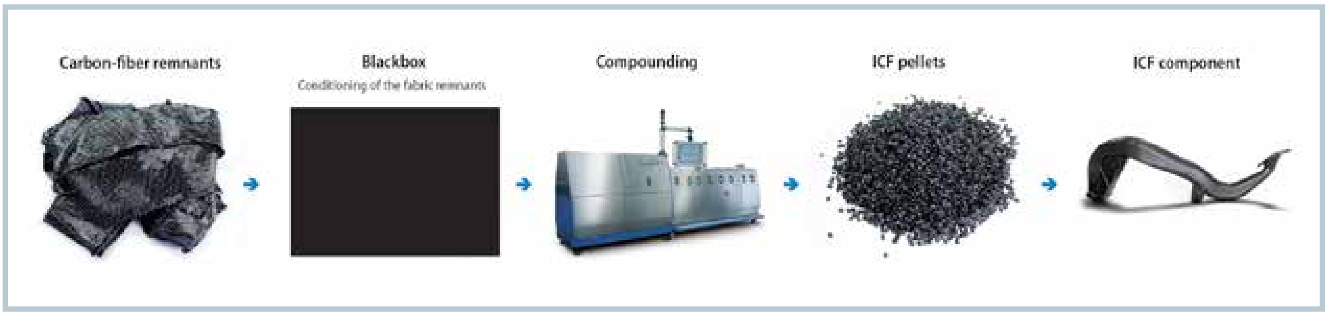


Fig. 1. Production process for components made from carbon-fiber-filled compounds

Fig. 2. Wall thickness distribution of a clutch pedal made from carbon-fiber-filled compound Akromid B3 ICF 15 black (5026)

Fig. 3. Center console made from carbon-fiber-filled compound Akromid A3 ICF 10 black (5117)

gravimetric dosing on an extruder, like conventional chopped carbon fibers. A major obstacle in this process was a powder binder applied to the fabric. It was originally used to affix several layers of superimposed carbon-fiber fabrics in place and to prevent their separation in the downstream processes.

The key to optimum dosing is precise temperature control during conditioning. The twin-screw extruder used in this case (manufacturer: Feddem GmbH & Co. KG, Sinzig, Germany) was equipped with a newly developed side feeder that is capable of gently feeding up to 40 % carbon fibers into the polymer melt. A further crucial step was to ensure proper electrical encapsulation of the machine throughout the entire process. Otherwise, the high conductivity of the carbon fibers would have led to the destruction of the electrical components.

Compounds with a Weight Advantage

The new Akro-Plastic carbon-fiber-reinforced series, called ICF, combines high strength with low density at a highly competitive price. The compounds can be furnished with up to 40 % carbon fiber. The aim of the new product line is to achieve a significant weight reduction, especially of load-bearing components. The electrical shielding and good thermal conductivity render the carbon-fiber-reinforced compounds eminently suitable for applications such as activated charcoal filters, brackets for control units, and center consoles.

The comparison in **Table 1** shows that the tensile elastic modulus of a polyamide (PA) reinforced with 15 % carbon fibers (Akromid B3 ICF 15 black (5026)) is on a par with that of a PA6 containing 30 % glass fiber reinforcement. The roughly 20 % lower flexural strength is offset by a density advantage of more than 12 %. At higher reinforcement levels, there is a clear advantage of up to 42 % in stiffness, at the expense of a mere 12 % reduction in flexural strength. But the weight advantage is a considerable 22 %.

Lighter through Foaming

Further reductions in component weight can be obtained in conjunction with the use of certain processing methods. Two of the most common, which are already established on the market, are water-assisted and gas-assisted injection technology (WIT/GIT). Foaming the polymer melt with blowing agents yields a further weight reduction of 6–13 %, the precise figure depending on the method employed.

In the trial shown in **Table 2**, the (polyamide+polypropylene) blend reinforced

Properties	Akromid B3 ICF15	Akromid B3 GF30	Akromid B3 ICF40	Akromid B3 GF60
Tensile elastic modulus [MPa]	11,000	10,300	30,000	21,000
Flexural strength [MPa]	210	270	320	370
Density [g/cm^3]	1.19	1.36	1.31	1.7
Density advantage ICF [%]	12.50		22.90	

Table 1. Comparison of the properties of compounds filled with glass fibers and carbon fibers

Fig. 4. Screw made from carbon-fiber-filled compound Akromid T1 ICF 30 black (5148)

Properties	Akromid B3 ICF 20 1 L	Akromid B3 ICF 20 1 L	Akromid B3 GF45 1 (3851)
Shot Method	Zero Value	Short Shot	
Holding pressure	with holding pressure	without holding pressure	
Part fill		part fill	
Blowing agent [%]	3.5 AF-Complex TM	3.5 AF-Complex TM	
Tensile modulus [MPa]	12,510 [100 %]	10,660 [85 %]	14,500 [115 %]
Flexural modulus [MPa]	12,100 [100 %]	12,240 [101 %]	12,800 [105%]
Flexural strain [%]	2.7	2.4	4.5
Weight reduction [%]		13	
Density [g/cm³]	1.10	0.96	1.5

Table 2. Comparison of the properties of standard polyamide blend and foamed polyamide blend Akromid B3 ICF 20 1 L

with 20 % carbon fibers was loaded with 3.5 % AF-Complex PE 990310 TM, a chemical blowing agent, in a mold for a tension rod. The density was reduced by over 13 % – to below that of water. Despite this enormous weight reduction, however, the flexural strength is not reduced. A polyamide 6 reinforced with 40 % glass fiber has roughly the same flexural stiffness, yet is about 50 % heavier. Components which are mainly subjected to flexural stress are thus ideal candidates for foaming.

In partnership with PME Fluidtec GmbH, Ettenheim, Batz S. Coop., Igorre, Spain, and Moldetipo Ii Lda, Leiria, Portugal, Akro-Plastic made a clutch pedal from Akromid B3 ICF 15 black (5026) (**Fig. 2**). This material is polyamide 6 reinforced with 15 % carbon fibers and is optimized for use with water-assisted injection technology (WIT). Compared with a clutch pedal made from standard PA6 GF30 material, this pedal has a higher (by 100 N) breaking strength of 1,100 N, and is 25 % stiffer. It is also 10 % lighter. At this year's SPE Awards ceremony, the complete component, i.e. bearing block with pedals, won 1st prize in the Powertrain category.

Potential Applications

Currently, a large number of potential applications are being tested, with a focus on high-stiffness components that are installed in black. Components installed above the vehicle's center of gravity are of particular interest to vehicle manufacturers as the weight reduction in this case has a direct positive effect on the handling.

The center console also offers great savings potential (**Fig. 3**). When made from PA66 GF30, it weighed 1,680 g. Using a 10 % ICF reinforced PA 66 (Akromid A3 ICF 10 black (5117)), it was possible to reduce the weight to 1,460 g, with comparable stiffness.

Considerable weight savings are possible not only with the large components, but also with fasteners, such as screws. A screw produced with Akromid T1 ICF 30 black (**Fig. 4**) possesses maximum stiffness, combined with excellent chemical resistance and low creep. Screws manufactured in this way are approximately 80 % lighter than standard metal screws, yet offer identical joint integrity with bolted plastic components. ■

Contact Corrosion

Contact corrosion with carbon-fiber-reinforced plastics is an issue that must not be ignored. The corresponding components behave very much like noble metals and will corrode in direct contact with screws or inserts made of aluminum or galvanized steel in a humid atmosphere. Trials have demonstrated that Akro-Plastic grades with appropriate stabilization (e.g. Akromid B3 ICF 15 (5026)) do not exhibit any corrosion on galvanized screws, as determined in the alternating climate test. This is because the stabilization system employed in the polyamide is electrically neutral. Contact corrosion cannot be prevented in highly-reinforced polyamides when the components are used in a humid environment (e.g. powertrain, exterior) and so insert components made from high-quality V4A stainless steel must be installed. This problem can be avoided by overmolding a standard sleeve of galvanized steel with high glass-fiber-reinforced plastic. The resultant electrically neutral insulating layer enables the component to be used in an application with carbon-fiber-reinforced plastic.

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Service

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