# Polyaryletherketones (PAEK)

PEEK reduces the weight of a toothed gear by 68 %, as against steel
(figure: Metaldyne)

**Continuous Growth.** Polyaryletherketones are already overtaking in many domains classically reserved for metals or are competing with other polymers and helping improve yields and efficiency, enhance performance and reliability in safety critical applications, enable miniaturization, save weight, energy and reduce costs. With increasingly demanding requirements, applications in the aerospace and automotive industries, semi conductor, electronics and the oil and gas industry and medical sector predominate this trend.

Along with PEK, PEKK and PEKEKK, the most widely used member of the polyaryletherketone (PAEK) family is polyetheretherketone, or PEEK for short. The semi-crystalline thermoplastic material is characterized by its excellent resistance to temperature, chemicals and wear, for example. It exhibits very good dimensional stability across a very broad temperature range and withstands continuous service temperatures of up to 260 °C. Additional features include high strength and stiffness, exceptional performance over a wide range of temperatures, hydrolytic stability, resistance to aggressive substances and very good tribological properties. The plastic is highly robust and especially impact-resistant in the unreinforced state.

Translated from Kunststoffe 10/2013, pp. 124–128. **Article as PDF-File** at www.kunststoffe-international.com; Document Number: PE111513

## Manufacturers, Capacities, Production

The world's leading manufacturer of PAEK is Victrex plc., Thornton Cleveleys, United Kingdom. Its Victrex Polymer Solutions division produces Victrex PEEK polymer, Victrex HT, ST and WG, Aptiv film, Vicote coatings and Victrex Pipes. Its biomaterials solutions division, "Invibio", markets a PEEK-Optima product family of implantable grade polymers.

Since Victrex was spun off from ICI (Imperial Chemical Industries) as part of a management buy-out in 1993, Victrex has continuously expanded its product range, applications and production capacity. At its headquarters in Thornton Cleveleys Victrex has PAEK production operations with a current capacity of PAEK of 4,250 tonnes – including the production of PEEK films (Aptiv), compounds, coatings (Vicote), pipes and tubes, and granules – and at two other sites in the UK, production of the key raw material for producing PEEK, enabling Victrex to offer a unique position with a fully integrated supply chain. With technical centers at its headquarters and technology centers in Shanghai and Tokyo Victrex provides testing, prototyping and application development to processors and end customers. Through the targeted expansion of a global sales and marketing organization with its own locations in major regions, Victrex covers important worldwide markets – including those of →

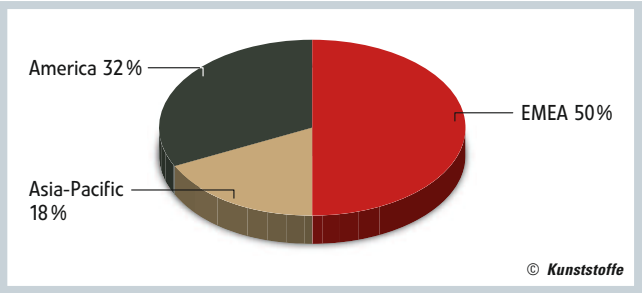


**Fig. 1. Global PEEK sales, according to regions** (figure: Victrex)

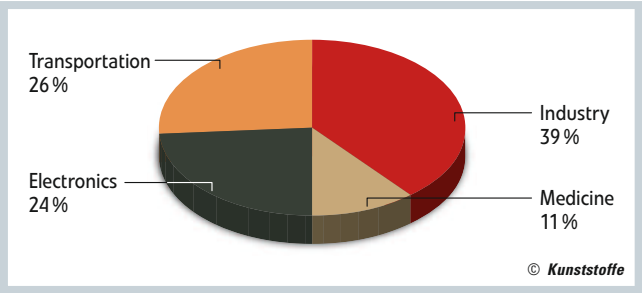


**Fig. 2. PEEK sales according to market segments** (figure: Victrex)

Europe, the USA and Asia. Victrex is also currently investing in additional production capacity to ensure it can meet the security of supply that customers need. Just five years after completion of the most recent production expansion in 2008, the next plant in Thornton Cleveleys – which will be the third one – is already in progress. When it goes into operation in 2015 it will raise Victrex's total PAEK capacity by 70 % to 7,000 tonnes per annum.

The other PAEK manufacturers produce the material in India or China. Solvay SA, Brussels, Belgium, for example, took over the PEEK manufacturing operations and production facility from Gharda Chemicals Limited, Mumbai, India, in 2006. In 2011 Solvay began a capacity increase of 70 % from a base of approximately 500 t/a. This was followed in 2013 by the start-up of a compounding plant to produce PAEK and PEEK compounds in Changshu, China. The company's products are marketed under the trade names KetaSpire PEEK and AvaSpire PAEK, and also under the name Zeniva (PEEK). Evonik Industries AG, Essen, Germany, offers PEEK under the trade name Vestakeep PEEK. The plant in Changchun, China, where the joint venture Jida Evonik High Performance Polymers has been producing since 2005, has a capacity of approximately 500 t/a. Other PAEK manufacturers include local based Chinese PEEK producers such as Panjin Zhongrum Chemicals Co. Ltd., Panjin, China, Jilin Zhongyan High Performance Engineering Plastic Co, Ltd., Changchun, China, and India based PEK/PEKK producers such as Rallis India Limited, Mumbai and Gharda Chemicals. Their actually capacity is to be validated.

## Worldwide Sales

Apart from a lapse in demand in 2009 due to the economic crisis, the estimated manufacturer sales of PAEK has increased continuously since PAEK was first introduced on the market. In 2010 (volumes are based on Victrex financial year which runs from October

of previous year through to September of year stated) sales were approximately 2,760 t, slightly above the level of 2008. In 2011 it reached around 3,400 t, and in 2012 it was in the area of 3,620 t. For the first six months of 2013 it was already about 1,800 t **(Table 1)**.

For the world's leading PAEK manufacturer Victrex, Europe remained the largest market in financial year 2012 (1 Oct 2011 – 30 Sept 2012), with a share of about 50 %, followed by America and Asia with 32 % and 18 %, respectively **(Fig. 1)**. The transportation and electronics sectors each use about one fourth of the polymers produced by Victrex (26 % and 24 %, respectively), while the medical sector uses about 11 % and the remaining 39 % is used in a variety of other industrial applications **(Fig. 2)**

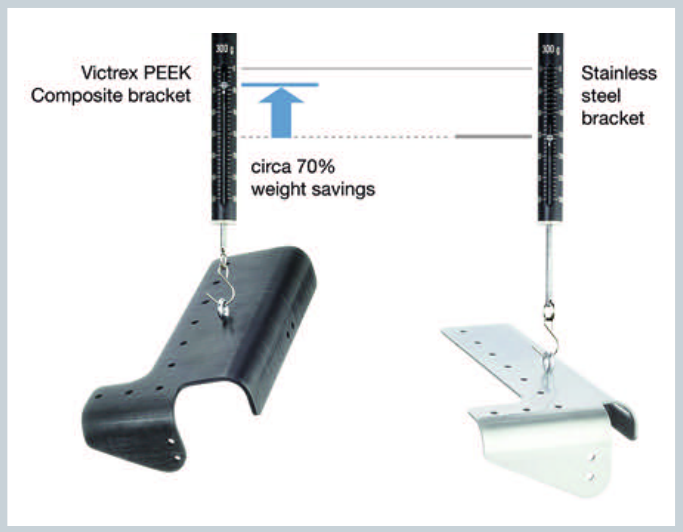


**Fig. 3. The weight of a composite angle is 70 % lower than that of one made of stainless steel** (figure: Victrex)

| Year | Sale [t] |
|---|---|
| 2010 | 2,760 |
| 2011 | 3,400 |
| 2012 | 3,620 |
| 2013 (1st half year) | 1,800 |

**Table 1. Global PEEK sales**
(source: Victrex)

## New Products, Applications and Trends

As a result of continuous research and advanced development, there are many grades of PAEK with different specifications on the market. The latest product from Victrex was launched in mid-2013, for example: Victrex PEEK 90GL30BLK EU. This glass fiber-reinforced thermoplastic for direct food contact applications meets the current requirements of both American and European regulatory authorities, including the EU Commission Regulation10/2011 (Plastics Implementation Measure, PIM). In 2009 Invibio launched Motis which was renamed as PEEK-Optima Wear Performance in 2013, an implantable grade polymer that is designed specifically for bearing applications against hard counterfaces aimed at hip and knee applications, whilst in the same year Evonik launched Vestakeep M and i grades for medical technology applications and implants. In 2013 Evonik added 40 % carbon fiber grades to the Vestakeep1000 and 2000 series. In 2012 Solvay introduced a radiolucent grade of Zeniva (PEEK) for medical implants.

Polyaryletherketones offer manufacturers a safe and durable alternative to ma- →

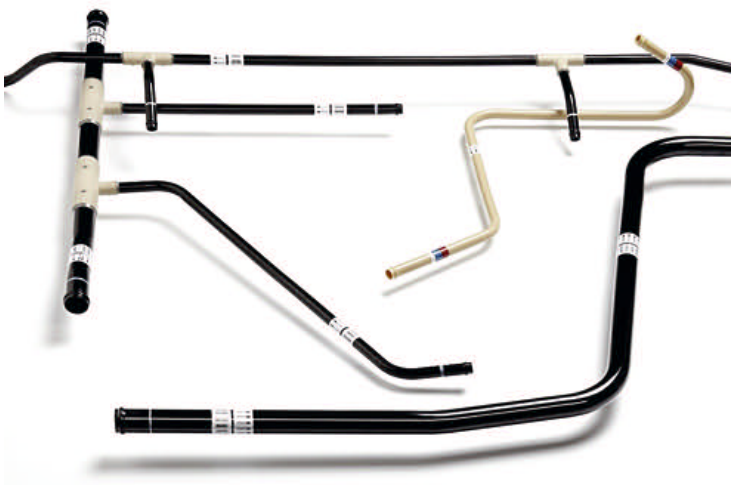

**Fig. 4. Thin-walled PEEK pipes are robust and offer high freedom of design** (figure: Victrex)

terials such as metals or other plastics. Examples of new applications can be found in many sectors. The aerospace industry, for example, demands safe, reliable materials which make it possible to reduce weight – and therefore fuel costs – and to make production more efficient. A thermoplastic composite based on Victrex PEEK satisfies those criteria. The US American company Tri-Mack uses the material to produce brackets for structural components in aircraft. This results in weight savings of up to 70 % over metals such as stainless steel, aluminum and titanium **(Fig. 3)**.

PFW Aerospace AG, Speyer, Germany, and Victrex Polymer Solutions collaborated on the development of lightweight tubing made of Victrex PEEK for the drainage system in the cargo holds of the A350 XWB and secured Airbus' approval. Along with the forming technology for Victrex Pipes, PFW Aerospace also developed PEEK molded fittings and the associated bonding system. A straight tube made of the high-performance PEEK polymer with an outside diameter of one inch (24.5 mm) and a wall thickness of 1 mm weighs just 100 g per metre without fittings. That makes it 60% lighter than equivalent stainless steel tubing which is typically being used on aircraft for low pressure fluid transport. These thin-walled PEEK tubes are extraordinarily robust and easy to install – and because they can be formed, they provide broad design latitude **(Fig. 4)**. Airbus had approved another thermoplastic grade, Victrex PEEK 90HMF40, in June 2013. The carbon fiber-filled material offers the highest specific strength currently available in the Victrex product range **(Fig. 5)**.


**Fig. 6. PEEK-Optima implants for cage fusion** (figure: Invibio)

Weight and fuel efficiency and noise reduction are also of crucial interest in automotive construction. A 68 % weight reduction in gears, for example, is also accompanied by a 78 % reduction in the moment of inertia, a 9 % increase in efficiency **(Title figure)**. The reason: low weight – i.e. reduced moving masses – and the lower friction losses typical of plastic, both of which help considerably when optimizing response or when accelerating or decelerating masses. The reduction of noise, vibration, and harshness was lowered by 3 dB, which is equivalent to a 50 % noise level reduction for the human ear.

Extremely low-wear Victrex WG polymers withstand loads under high temperatures in other transmission applications as well: due to its very good pressure creep resistance, for example, slip rings or thrust washers made of WG polymer can last up to 40 times longer under these extreme conditions than compounds formed on the basis of other PAEKs can. Unlike other tribologically modified polymer grades, its extremely low coefficient of friction remains nearly constant throughout the service life of the product. And that can translate into up to 20 % lower friction losses as a result of start-stop cycles, even in oil-lubricated environments.

The Brazilian pump manufacturer Melling Engine uses the material WG 101 in sliding bearings for a high-effi-

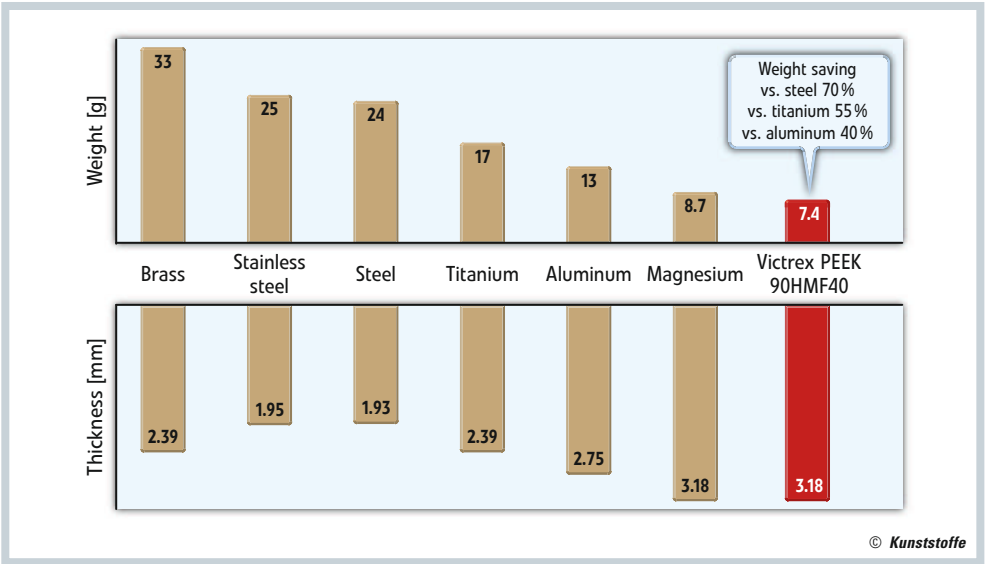


**Fig. 5. Reinforced with carbon fibers, Victrex PEEK HMF enables significant weight reduction as against metals: A comparison of different material specimens of the same rigidity, concerning thickness and weight** (figure: Victrex)

**Fig. 7. PEEK as a framework material for removable dental prosthesis** (figure: Juvora Dental Innovations)

ciency electric water pump. In this case, it facilitates several design aspects, including the reduction of package space and the minimization of friction losses, energy demand and wear, while also ensuring long-term reliability despite high temperatures, extreme bearing loads and corrosive pump media. As a result of the very low wear, few particles contaminate the cooling medium, thereby reducing the risk of failure of the electric pump.

PEEK polymers also demonstrate their very high reliability and safety in a completely different area – as an alternative to titanium in spine implants. Today 60 % of the vertebral fusion implants installed worldwide are already made almost entirely of PEEK-Optima. They are used to stabilise the spine, reduce pain and aid vertebral fusion **(Fig. 6)**.

In the case of complicated bone fractures, PEEK-Optima Ultra Reinforced (reinforced with carbon fiber; marketed so far under the brand name Endolign) trauma plates and nails are used to increase device lifetimes and accelerate bone healing in place of an alloy made of titanium, aluminum and vanadium. In this way, cold welding process is avoided and metal screws and plates no longer adhere to each other. The surgeon and patient benefits from this because the plate is easier to remove.

For the past several years now, PEEK has also been used as an alternative to metal for various applications in the field of dental technology, including dental implant systems such as healing caps and temporary abutments. Today PEEK is also being used more and more as an alternative to metal and ceramics as a framework material for removable dental prostheses **(Fig. 7)**. Its excellent biocompatibility, low weight, and strength which very closely approximates that of bone are also making this material increasingly attractive to the dental industry.

Moreover, Victrex PEEK withstands the increasingly demanding high-pressure and high-temperature conditions associated with oil and gas production opening up new application areas. One example of this is the use of Victrex PEEK in Magma Global Limited's unique carbon polymer m-pipe. This is a high strength, lightweight, corrosion and fatigue resistant solution for deepwater, sour service and high pressure high temperature (HPHT) riser and subsea applications. ■

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