Polyetheretherketones (PEEK)

Versatile Material for Cross-Industry Performance Parts

Many companies constantly need to make crucial decisions on materials. Are the outcomes they are looking to achieve being met by traditional metals, or should they investigate new high-performance materials? PEEK polymers are increasingly recognized as a dynamic driver for efficient applications.

Polyetheretherketone (PEEK), one of more than 300 members of the high-performance polyaryletherketone (PAEK) family, is located at the top of the polymer pyramid. Only a handful of these PAEK polymers have been commercialized; in addition to PEEK, other members include PEK, PEKK and PEKEKK.

Structurally, the linear aromatic PEEK polymer consists of repeating ether, ether and ketone linkages separated by aryl groups. Its many (poly) etheretherketone arrangement gives the semi-crystalline polymer its name. Its very good mechanical and chemical characteristics mean that it uniquely supports a combination of multiple requirements. For example, the light weight, high strength PEEK polymer provides high resistance to wear, temperature, fatigue and aggressive fluids/chemicals. Furthermore, it can contribute to enhanced fuel efficiency, improved safety, extended part life, greater comfort (smooth operation, less noise), more design freedom, and/or production cost efficiencies.

For medical technology: Metal-free distal femur fracture fixation plate made with PEEK-Optima Ultra-Reinforced polymer, a carbon fiber composite from Invibio (the trauma plate shown is not available for distribution or implantation) (© Invibio)

Compared to metals, PEEK-based materials are light in weight, easily processed, resistant to corrosion and can have considerably higher specific strength (strength per unit weight). Since the first commercialization of "Victrex PEEK" in the 1980s, continuous development from Victrex plc, Thornton-Cleveleys, UK, has resulted in material and technology advances today that have changed and increased the use of the polymers.

Today, a broad range of industries, including automotive, aerospace, electronics, energy and manufacturing, as well as the medical sector, are all benefitting from the use of this versatile, high-performing PEEK thermoplastic. By replacing metals or other materials, PEEK often functions as an enabler, allowing customers to develop innovative, competitive applications.

Commonly there are two key needs that trigger material selection: The requirement for greater (cost-)efficiencies (in respect of manufacturing and assembly, operational, and overall cost reduction) and improving performance (e.g. meeting reliability targets and reducing downtime).

Improve Efficiencies in Automotive and Aerospace Industry

In the automotive sector, Victrex PEEK has been making an impact in a number of demanding applications, for example in improving efficiency of gears (**Fig. 1**). When compared to metal gears, PEEK gears show up to 68 % weight reduction and the moment of inertia can be reduced by up to 78 %. This translates to improved responsiveness and consequently lower power consumption, in turn contributing to lower CO_2 emissions. In addition, a 50 % (3 dB) reduction in noise, vibration and harshness can be achieved.

Aerospace manufacturers face the challenge of needing to increase the pace at which new aircraft are assembled – without conceding on function, cost or weight (**Fig. 2**). Targeted enhancements of PAEK polymers can enable highly functional injection molded PEEK components to be designed and produced, thereby consolidating the number of parts, while also simplifying and speeding up manufacturing processes. A major development has been the introduction of new materials such as Victrex »

Fig. 1. Mechanically resistant precision gears, e.g. in the automobile industry, are an important area of application for PEEK (© Victrex)

Fig. 2. Combines high strength and light weight: Grid stiffened demonstration panel, a Victrex PAEK thermoplastic composite overmolded with Victrex PEEK (© TPRC)

AE 250 composites (**Fig. 3**) to develop parts in combination with hybrid molding processing techniques. This offers continuous manufacturing processes with cycle times measured in minutes versus hours for thermoset alternatives. Structural brackets have been a key development area where, as well as having capability to speed up the manufacturing of parts and consequent assembly of aircraft, the new brackets can deliver up to 60 % reduction in weight, while having to meet the required strength of the components.

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Market Information

All performance claims refer to solutions using Victrex´s or Invibio´s PAEK polymers and can be supported on request.

Service

References & Digital Version

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German Version

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Energy Industry: Meeting Reliability Targets – Reducing Downtime

With benefits including the potential to double the service life of electrical connectors compared to glass ceramic connectors and an up to two times higher load bearing capacity compared to other PEEK sealing systems, Victrex PEEK scores highly within the energy industry. The "high performance" polymer meets the needs of the oil and gas sector to go deeper to extract from new non-conventional oil reserves. Its ability to withstand very high pressures, high temperatures, aggressive chemicals, and corrosive environments can contribute directly to avoiding costly downtimes.

It also offers efficiency and reliability benefits in the reciprocating compressors used extensively in the oil and gas or chemical industry. In a natural gas compressor, for example, valve plates made of PEEK have been proven to work continuously for twelve months, whereas steel plates generally were found to have fractured after about a month. Besides having a significantly longer service life, the valve plates made of PEEK have potential to save energy, as flow loss is reduced due to the better wear characteristics, surface matching, elasticity and sealability. Interestingly, the polymer plates also produce a lower noise level than steel.

Following the joint development of Magma carbon composite m-pipe (**Fig. 4**) utilizing PEEK, Victrex recently invested in a minority interest in Magma to further facilitate the adoption of its pipe for subsea applications. The innovative technology is expected to reduce exploration and production costs and risks in demanding subsea applications.

Medical: Accelerating the Delivery of Medical Developments

The first commercialized implantable PEEK grade, PEEK-Optima, was introduced over 15 years ago. Since then, there has been a rapidly growing acceptance within the medical world that implants and prostheses using bio-compatible PEEK have the potential to replace metal equivalents. In the process this can deliver considerable advantages for practitioners and patients alike – whether in spinal implants, plates for long bone fractures and other trauma injuries (hero image), or dentures made with all the convenience and clinical accuracy of CAD/CAM design. The medical profession, working in collaboration with manufacturers and providers such as Invibio Biomaterial Solutions is delivering its verdict: around 9 million devices, worldwide, produced using PEEK-Optima from Invibio are now in use, with PEEK implants now being cleared by authorities in the EU, the US and Asia.

A number of factors converge to make this biomaterial suitable for medical implants. PEEK has a modulus of elasticity close to that of bone. In addition, different PEEK grades offer implant makers wear [1, 2] and fatigue performance [3] and a chemical inertness that is fully bio-compatible, with none of the biochemical side effects that can arise when metals are introduced into biological environments. It can be sterilized successfully,

with resistance to multiple cycles of steam sterilization or high-dose gamma irradiation [4].

An example of the tailoring of PEEK grades for medical applications is the addition of carbon fiber to unfilled PEEK, resulting in bio-compatible carbon-fiber-reinforced PEEK (CFR-PEEK), whose optimized strength and stiffness rival that of metal [3], as is the case with PEEK-Optima Ultra-Reinforced from Invibio. In many instances, the use of CFR-PEEK has also allowed thinner-walled, smaller and more minimally invasive device designs to be developed [5].

In the medical sector, once an implant is in place, its status must be monitored, whether for complications, such as breakages, or progress towards bone ongrowth for spinal fusion. Metals, such as titanium, can present challenges for imaging by X-ray, MRI and CT due to their radiopacity and potential for artefact generation. The advent of radiolucent PEEK implants has, however, turned that around. They can be readily imaged, allowing physicians to monitor spinal fusion progression or carry out other diagnostic investigations. This ability to achieve accurate assessment of therapeutic progress and patient outcomes, ultimately has the potential to enhance the quality of life of patients.

Fig. 3. Victrex AE 250 composites such as unidirectional tapes (UDT) and laminate panels offer benefits in terms of speed of component manufacture and cost-efficient installation (© Victrex)

Manufacturing Advances and Partnership Expansion

Victrex plc is a leading manufacturer of PAEK. Operating from world-class facilities in Thornton Cleveleys, United Kingdom, its PAEK production capacity exceeds 7000 t/a. A new co-located Polymer Innovation Centre, scheduled for completion in autumn 2017, provides additional resources for future developments as part of a global network of centers that assists users with their technological developments, wherever they are located in the world.

Recent developments in PEEK are wide-ranging, from new polymer grades to forms, as well as parts for selected applications. Advanced forms center on unidirectional (UD)-tapes, composites (Victrex AE 250) or films, while parts development has included medical trauma plates, aerospace brackets and automotive gears. In addition, specific grades for 3D printing are currently in development along with other customer-specific PEEK-based material solutions.

Recently introduced material grades include Victrex OGS 125, Victrex CT 100 used in seals for oil and gas equipment as well as PEEK Optima HA Enhanced, a new implant material with the potential to enhance bone apposition.

New commercial partnerships to service the needs of specific markets have also been forged, including the partnership with Magma, mentioned above, and the establishment of TxV Aero Composites, a 2017 joint venture with Tri-Mack Plastics Manufacturing Corporation, with the aim of accelerating the commercial adoption of PAEK composite applications within the aerospace industry. The acquisition of UK fiber expert Zyex in April 2017 has also seen Victrex accelerate the development of existing and new markets for PEEK fiber applications. In 2015, Victrex acquired Kleiss Gears, which paved the way for Victrex to meet the needs and demands of automotive partners when developing gear solutions for use in extreme and demanding environments.

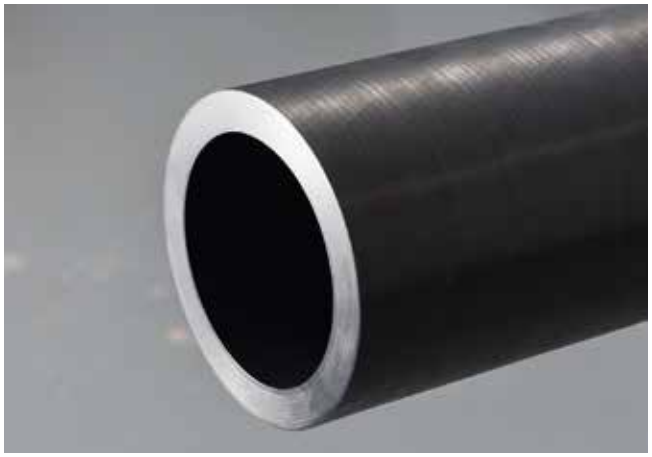

Fig. 4. PEEK is used in the m-pipe carbon composite pipe developed by Magma and Victrex for use in subsea applications (© Victrex)

Dedication Underpins Future Advances

Driving polyetheretherketones into new applications in a range of key industries has seen substantial progress since 2014. First patented in 1978, Victrex PEEK has the longest track record in this area. The depth of knowledge that derives from this history when combined with the versatility of the material ensures that Victrex can continually push the boundaries of what is possible and drive into new and exciting applications areas across the globe. ■