Polyetheretherketone (PEEK)

The High-Performance Polymer Opens up New Possibilities for Processing Methods and Applications

PEEK was invented a little over 40 years ago, and so is a relatively young high-performing thermoplastic polymer. Nevertheless, continuous development of products and processing technologies enables a range of advanced applications in the automotive, aerospace, electronics, energy, and food-and-beverage sectors, as well as the medical industry.

Additive manufactured PAEK demo bracket – produced by filament fusion (left) and by laser sintering (right) (© 3T-RPD)

The first batch of polyetheretherketone (PEEK) was manufactured at ICI, a major chemical company, on November 19, 1978. Only three years later, with the commercialization of the first PEEK polymers, the Victrex PEEK family, including glass- and carbon-filled products, were introduced. Demanding applications that initially seemed unlikely candidates for thermoplastics found a solution in PEEK's versatile blend of exceptional properties – as a metal replacement, for example.

PEEK is a member of the polyaryletherketone (PAEK) family, located at the top of the polymer pyramid, and can support multiple requirements. Its properties include light weight, high strength, and high resistance to wear, high temperatures, fatigue and aggressive chemicals. Together, these can contribute to enhanced fuel efficiency, extended part life, greater comfort (smooth operation, less noise), more design freedom and increased cost efficiency.

Victrex plc., Thornton-Cleveleys, United Kingdom, is a global PEEK sup- »

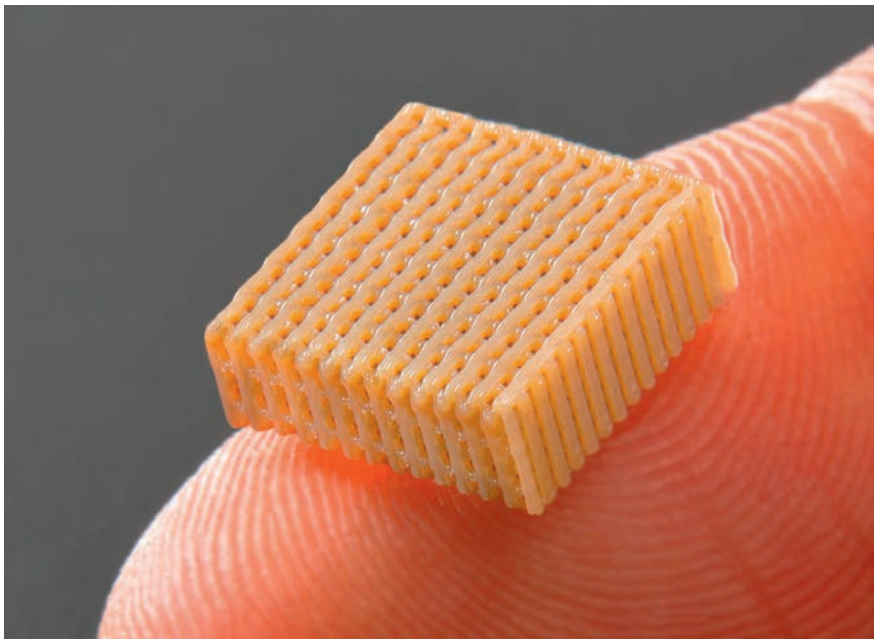

Fig. 1. Fine detailed porous structure printed in Victrex PEEK using Bond3D technology (© Bond High Performance 3D Technology)

plier with a production capacity of more than 7000 t/a. Solely focused on PAEK and PEEK, Victrex not only pioneers new grades but also develops product forms and parts for selected industries and applications.

Advances in Additive Manufacturing (AM)

Materials and processing technologies to support AM (or 3D printing) continue to emerge. Victrex has announced the development of two new AM customized PAEK products. Firstly, a high strength material for laser sintering (LS), which attains lower refresh rates, resulting in improved recycling for unsintered powder; and secondly a filament with better z-strength than existing PAEK materials and better processing for filament fusion (FF) (**Title figure**).

Bond High Performance 3D Technology, Enschede, Netherlands, has developed a 3D printing machinery and software for AM capable of printing complex, functional parts made from existing grades of PEEK that have very good mechanical properties, including in the z-direction. This enables the additive manufacture of high-strength, isotropic parts with properties comparable to those of conventional molded or machined PEEK parts (**Fig. 1**).

Composites to Spur Progress in Aerospace

For the aerospace industry, thermoplastic composites such as the PAEK based Victrex AE 250 composites are of growing interest. The objective is to deliver more cost-effective, environmentally-friendly aircraft more quickly. To achieve valuable weight and cost savings, SFS intec GmbH, Althengstett, Germany, for example is partnering with TxV Aero Composites. Bristol, RI/USA, in the re-design of an aircraft storage-bin bracket (**Fig. 2**). Originally made from aluminum, the new bracket will be made of Victrex AE 250 composites overmolded with PEEK polymer. The weight, size, complex geometry and high load-bearing specifications of the overhead storage-bin bracket made the SFS part a suitable candidate for the pioneering hybrid overmolding technique at TxV.

Composites based on traditional PAEK polymers, such as PEEK and related polymers, need to be processed at temperatures in the range of 360 °C to 400 °C. With a melting temperature of 305 °C, Victrex AE 250 is processed between 340 °C and 360 °C. This combination of performance and processability can provide mechanical properties consistent with the requirements for structural aerospace applications – which can then be processed faster and with less energy." To push the boundaries of thermoplastic unidirectional tape (TP UDT) prepreg layup and consolidation and improve the efficiency with which composite parts are manufactured Victrex and Coriolis Composites, Quéven, France, have teamed up. Their early results demonstrate that Victrex AE 250 UDT potentially enables manufacturers to exceed the speed of manufacturing with an existing TP UDT intended for the same applications, and rivals automated fiber placement/automated tape laying (AFP/ATL) deposition rates for thermosets. The lengthy autoclave consolidation time normally required for thermoset UDT (TS UDT) is no longer necessary.

Unidirectional thermoplastic tapes have a high potential for weight reduction and can result in the time- and cost-efficient production of complex aircraft parts. Another case in point is an all-thermo-

Fig. 2. Aircraft storage-bin bracket made of carbon fiber-reinforced PAEK composite overmolded with PEEK (© TxV Aero Composites)

Fig. 3. Drive-shaft system consisting of a braided preform made of Victrex AE 250 thermoplastic UD tapes overmolded with an integral gear made of Victrex PEEK 90HMF40 (© herone)

plastic drive-shaft system overmolded with an integral gear from herone GmbH, Dresden, Germany (**Fig. 3**). The drive shaft is formed from "organoTubes", which are braided preforms made from fully consolidated thermoplastic UD tapes, in this case, Victrex AE 250 unidirectional tape (UDT), a carbon-fiber-PAEK composite. In order to incorporate the gears, made from PEEK, injection overmolding creates a cohesive molecular bond between the shaft and the gear, while the drive shaft is simultaneously thermoformed to create a form-lock between the gear and the drive shaft, to further enhance the strength of the interface.

Energy: PEEK for High Pressures and Temperatures

In the oil and gas industry, m-pipe from Magma Global Ltd, Portsmouth, United Kingdom, continues to serve as one of the prime examples of the use of thermoplastic composites in this sector. Its very good properties make this subsea pipeline a cost-effective alternative to traditional steel and non-bonded flexible pipe. It requires little maintenance and, since it is not subject to corrosion, has a longer lifetime than steel.

As well, Victrex CT 200 for cryogenic temperatures was launched very recently. It is specifically designed for dynamic sealings, where gases such as liquefied natural gas are stored and transported at temperatures from –150 °C to –200 °C. This series exhibits improved sealing over a wider range of temperatures, compared to such commonly-used materials as polychlorotrifluoroethylene (PCTFE). It does so at low temperatures because of its greater ductility, and at high temperatures due to its very good creep resistance.

Using PEEK also enabled an application advancement at Rampart Products, Houston, TX/USA. The company has specified a Victrex polymer blend for a new HPHT (high pressure-high temperature) rotatable electrical connector (**Fig. 4**) for transmission of power and data used in oilfield drilling equipment. It was designed for temperatures of 200 °C (400 °F) and pressures at 1380 bar (20,000+ psi), providing a reliable electrical connection while protecting expensive sensors and electronics.

Laboratory applications can also be subject to extreme conditions, demanding high performing materials. The pressures required in liquid chromatography, for example, have been rising steadily for over five years. Vici AG International Schenkon, Switzerland, has introduced a new one-piece fitting made from Victrex HT high-performance polymer (**Fig. 5**). Based upon testing, Vici has demon- »

Fig. 4. PEEK polymers specified for HPHT rotatable electrical connector for oilfield drilling equipment (© Rampart)

Fig. 5. Multi-use Victrex HT fitting for high-pressure range up to 500 bar or 1000 bar (© Vici)

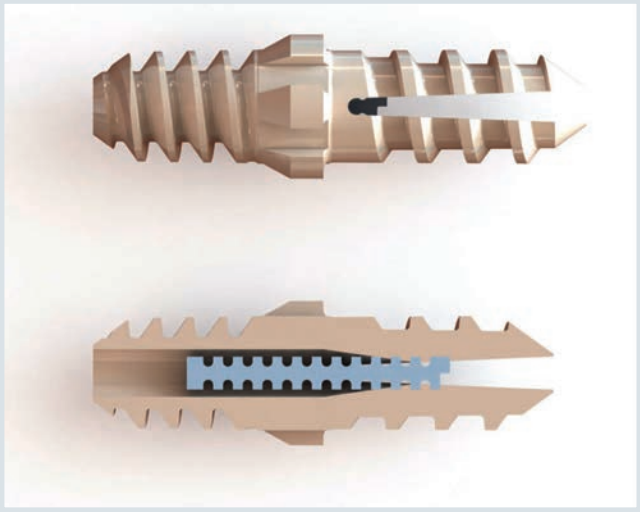

Fig. 6. Vector Hammertoe Correction-System, the first foot and ankle implant made of PEEK-Optima Enhanced cleared by FDA (© Nvision Biomedical Technologies)

strated and documented that the new fitting is capable of withstanding pressures, when tightened by hand, of up to 500 bar (7250 psi). By way of comparison, 350 bar (5000 psi) was the limit for conventional PEEK fittings. Provided the carbon-fiber reinforced Victrex HT fittings are tightened with an appropriate tool, they are suitable for significantly higher pressures of up to 1000 bar (14,500 psi).

Food-and-beverage (F&B) manufacturing equipment companies have to meet health, safety and hygiene requirements established by regulatory authorities, the industry and consumers. For such applications Victrex introduced a dedicated PEEK food-grade portfolio last October. Compared to metals, the new Victrex FG family of high-performing thermoplastics offers additional benefits in terms of cost-effectiveness, productivity and performance for OEMs.

Advancing Implantable Devices

The world´s first implantable polymer PEEK-Optima was introduced in 1999. Today, the number of implanted devices has grown to approximately nine million including dental, spine, trauma and orthopaedic implants. Invibio Biomaterial Solutions´ next-generation biocompatible material PEEK-Optima HA Enhanced potentially promotes early bone on-growth. It offers a modulus similar to that of cortical bone and reduces stress shielding while allowing artefact-free imaging. At the end of 2017, the medical device company Omnia Medical LLC, Morgantown, WV/USA, was granted the first US FDA 510(k) clearance for a vertebral body replacement (VBR) system manufactured from PEEK polymer, supplied by Invibio, for use in the thoracolumbar spine to replace a collapsed, damaged, or unstable vertebral body.

In the same year James Ellington, a UK Olympic sprinter, became the first professional athlete to choose a PEEK based carbon-fiber composite nail to fix a severe tibia fracture. He based his choice on its lighter weight and faster healing potential, and because it was less stiff than metal. In 2019, for the first time a foot-and-ankle implant made from the advanced, biocompatible PEEK-Optima HA Enhanced was cleared by the FDA. This was the Vector Hammertoe Correction System (**Fig. 6**), a bioimplant from Nvision Biomedical Technologies, which now gave surgeons the ability to correct hammertoe issues with a 100 % revisable implant.

Electrification of Vehicles

In automotive demands on construction materials are increasing due to the electrification of vehicles. In addition to being light, durable and cost-efficient, gears in these already quiet vehicles must also demonstrate excellent NVH (noise, vibration, harshness) performance to enable a better driving experience. This is the case for example for electric drives, actuators and pumps, whereas with bushings, bearings and thrust washers requirements to be met also include high RPM (revolutions per minute) and good tribological performance. Corresponding applications in traditional vehicles are expected to be translated and implemented in electric cars. While applications in electric motors (e. g. wire insulation, battery) are being evaluated, applications in powertrain and braking systems have already demonstrated their worth in practice. ■

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