

Outstanding physical properties make PEEK ideal for sealing applications

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VICTREX polyetheretherketone (PEEK) polymer is a high performance thermoplastic material with outstanding mechanical, thermal and chemical resistance properties. As this article shows these properties enable it to find extensive use in sealing applications across all industries. Also provided are examples that demonstrate the areas in which this material is used and the performance improvements it is capable of providing.

Effective and efficient sealing is an essential part of almost every modern industrial process where gases, liquids and solids are being transported. Seals are needed wherever the containment of these commodities is completed (such as end-caps), measured (flowmeters), controlled (valves) or separated from moving parts.

These countless application possibilities require an equally diverse range of sealing technologies and products. These, in turn, use a wide selection of materials – ranging from soft and flexible elastomers, and various thermoplastic and thermoset polymers to bronzes and steel.

When considering the choice of material for a sealing application designers will consider the:

- nature of the media to be sealed (for example, aggressive chemicals and abrasion);
- operating temperature range;
- operating pressure;
- materials of construction of the equipment to be sealed; and
- velocity between the seal and counterface.

Elastomers have been used for many years in such applications because of their resilience and ability to fill space under a compressive load, thereby producing an efficient seal. Where operating conditions are extreme, it is common to use metallic seals and gaskets.

Thermoplastic polymers are a broad group of materials that have a wide range of properties for sealing applications. Many come from the fluoropolymer family of materials which offer excellent chemical resistance and good temperature resistance, but relatively poor mechanical properties.

VICTREX PEEK polymer is a high performance thermoplastic material with outstanding

mechanical, thermal and chemical resistance properties, which finds extensive use in sealing applications across all industries.

In some industries, including the oil and gas sector, the primary function of the material is to serve as a mechanical back-up for softer sealing materials, such as elastomers and fluoropolymers, whereas in others, the properties of VICTREX PEEK make it ideally suited to be the primary seal.

What is VICTREX PEEK?

VICTREX PEEK polymer is a member of the broader class of polymers, commonly known as polyaryletherketones (PAEKs).

This class can include polymers such as polyetheretherketone (PEEK) or polyetherketone (PEK), which is also produced by Victrex under the trade name of VICTREX HT polymer.

VICTREX PEEK is a semi-crystalline polymer with a melting point of 343°C (649°F) and a glass transition temperature of 143°C (289°F), whose aromatic ring backbone (Figure 1) promotes many desirable properties, such as high temperature resistance, good mechanical properties and excellent corrosion resistance.

VICTREX PEEK is generally noted for the following combination of properties, many of which are vital for successful seal applications:

- high-temperature resistance: excellent long-term and short-term temperature resistance, and exceptional resistance to high-temperature ageing over long periods (Figure 2, on page 10) which shows the relative temperature index (RTI) – sometimes known as continuous use temperature (CUT) – for VICTREX PEEK and a number of other engineering polymers, indicates the long-term service temperature capabilities);
- chemical resistance: outstanding resistance to a wide range of chemical and corrosive environments, even at elevated temperatures up to 200°C (392°F);
- mechanical properties: excellent strength, stiffness and long-term properties such as creep and fatigue over a wide range of temperatures and environments;
- hydrolysis resistance: retains mechanical properties and dimensional stability when continuously operating in water, brine or steam at elevated temperatures and pressures;
- wear, abrasion, erosion resistance: exhibits high abrasion resistance and cut-through resistance, combined with low friction properties even in aggressive environments; and
- electrical properties: exhibits excellent dielectric strength, which is maintained regardless of the temperature and environment.

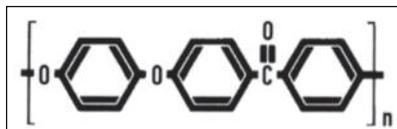


Figure 1. The structure of VICTREX PEEK polymer.

Sealing applications

In sealing applications VICTREX PEEK is used in a variety of the many forms in which it is supplied.

The polymer is supplied in a range of unfilled polymer powders, which may be compression moulded to form shapes for further machining, and unfilled polymer pellets

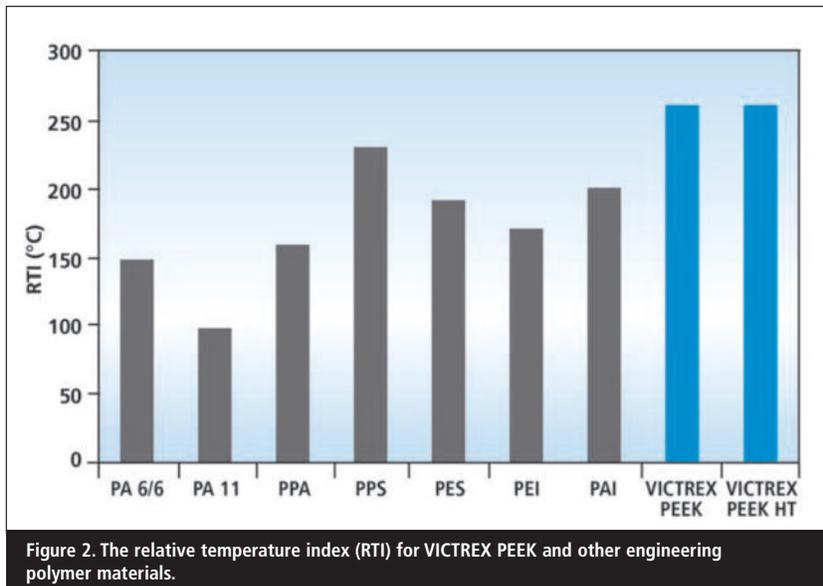


Figure 2. The relative temperature index (RTI) for VICTREX PEEK and other engineering polymer materials.

that are used for producing parts by injection moulding.

Victrex also offers fibre-reinforced grades, with high strength and modulus, and thin APTIV PEEK films for seals and gaskets. Within this range are a number of specifically engineered grades that provide additional properties such as very low wear or low friction for higher efficiency, longer lifetime and reduced maintenance.

In the paragraphs that follow a number of specific application examples are given that demonstrate the wide range of sealing applications in which VICTREX PEEK is used and the performance improvements that it provides.

Sealed to survive extremes

One of the largest markets for sealing elements made from VICTREX PEEK is the oil and gas industry, where effective sealing is often the difference between an efficient, safe-running operation and costly downtime.



Figure 3. CDI plunger packing is traditionally a multi-material stacking assembly, comprising seal rings made of polytetrafluoroethylene, VICTREX PEEK, rubber and steel. The packing is typically used in positive displacement pumps rated up to 138 MPa (20 000 psi).

Reliability is critical as malfunctions can potentially have adverse effects on the environment or put the health and safety of workers at risk. In this industry, VICTREX PEEK is found as a primary seal, back-up ring or packing in applications as diverse as valves, pipelines, compressors, packers, manifolds and blowout preventers. It is here that seals are essential for the separation of different media and phases, to contain lubrication and exclude contaminants such as sand.

VICTREX PEEK polymer is used extensively to make an anti-extrusion back-up ring in Chevron seal stacks (Figure 3). The primary seal is provided by an elastomer or fluoropolymer ring which, although chemically resistant, tends to extrude under the influence of high temperature and pressure, thereby destroying the seal.

Key engineering requirements (KERs) for such applications include high creep resistance at temperature, high levels of chemical resistance and low swelling in hydrocarbons and other oilfield fluids, and a high degree of resistance to the damaging effects of rapid gas decompression (RGD).

Not only does Victrex PEEK maintain properties at high temperatures, but it also does so in aggressive chemical environments. The polymer complies with Norsok M-710 (qualification of non-metallic sealing materials and manufacturers) and has been shown to withstand concentrations of sour gas in excess of ten times the concentration specified in this standard (also see 'VICTREX PEEK exceeds Norsok M-710, which appears in *Sealing Technology* March 2014, page 3). The polymer is equally resistant to a wide range of chemicals used in the oil and gas industry, having no known degradation in solvents below 200°C (392°F).

Victrex continues to develop more advanced PAEK polymers which are capable of fulfilling this function under high-pressure, high-temperature (HPHT) conditions found in many new oil deposits. In addition, the low thermal expansion of VICTREX PEEK polymer ensures a better fit and seal with mating steel components.

Split-ring seals and connectors

Split-ring seals, which are often used for reciprocating motion, and in hydraulic swivel joints and transmissions, are another ideal application for VICTREX PEEK.

The polymer's inherent toughness and flexibility enables the split-ring seal to be installed without breakage, whilst high strength and creep resistance provide a long service life under aggressive conditions.

Oil and gas industry electrical connectors (Figure 4), which are used for the transmission of power or data between the surface and the operating zone, have frequently been changed from glass, ceramic and thermosetting resins to VICTREX PEEK polymer because of the material's robustness, high mechanical strength, creep resistance at temperature and its ability to act as an inherent seal at pressure differentials of up to 345 MPa (50 000 psi).

In such environments, chemical and RGD resistance are also important, but the ability to manufacture these connectors using injection moulding – thereby encapsulating the connector pins – provides a highly cost-effective, reliable and reproducible manufacturing route.

Compressors

Compressors of varying designs and sizes are omnipresent in the oil and gas sector – with common requirements of long lifetimes and the ability to work in aggressive environments.

In centrifugal compressors, for example, VICTREX PEEK is used for the labyrinth seal because it delivers exceptional reliability compared with other polymers and metals, whilst working in hot gases, ammonia and sour-gas environments. A key advantage of PEEK in this application is the ability to run with tighter tolerances without fear of causing rotor damage. The slight deflection of the teeth in operation prevents excessive shaft wear and the tighter tolerances mean greater efficiency of the device. Elsewhere PEEK is used as the tip seal in scroll compressors to create a better seal with minimal wear and friction.

Many of these material attributes are carried over into the use of PEEK as a sealing element in the food manufacturing industry, with the advantage that many of the relevant grades are approved by the US Food and

Drug Administration (FDA). The product is commonly used as a shaft seal because of the polymer's low friction properties and ability to achieve tight dimensional control.

Valves

Ball valve seats for controlling a range of aggressive fluids and gases are another application for VICTREX PEEK polymer.

The compliance of the material ensures an excellent seal with the steel ball whilst the chemical and wear resistance properties ensure a long lifetime. VICTREX PEEK polymer also exhibits excellent resistance to steam, which means that it is also used in control valves in steam systems to provide durable, effective seals, ensuring tight shut off and long life – thereby reducing leaks and costly downtime and maintenance.

Enhanced driving experience

As the automotive industry is seeking ways of improving fuel efficiency, providing safety for passengers and extending warranties to remain competitive, the materials that are selected for sealing components are important to the overall performance and longevity of the vehicle.

Automobile modules, such as the transmission, engine and brakes are becoming more compact which can create extreme conditions for the components used in these systems.

The environments in which plastics and metals are now required to operate can involve continuous-use temperatures up to 150°C (302°F). In some cases, temperatures can reach up to 220°C (428°F) in turbocharger applications.

Materials are further exposed to immersion in aggressive transmission oils and exhaust condensates and are subjected to high dynamic loads, to name just a few. The ability for materials to perform in these settings is imperative especially as engineers search for safe, eco-friendly technologies and products that have enhanced durability and offer a longer service life.

Seals are typically components that prevent leakage, contain pressure, or exclude contamination where two systems join. Within the automotive industry some sealing applications are positioned against rotating steel shafts, which require a defined leakage and minimal wear in order to reduce energy losses.

Ultra-wear grade

Understanding these needs and visualising future performance requirements, Victrex has continually provided the automotive industry with innovative materials, including a new

ultra-wear grade – VICTREX WG polymer.

This recently-developed polymer offers improved wear resistance and a lower, very stable coefficient of friction, compared with other high performance thermoplastics – which can help boost the efficiency and reliability of seals.

VICTREX WG polymer delivers excellent performance in components that operate in high-pressure and high-velocity environments. The following case studies describe the use of standard VICTREX PEEK wear grades and VICTREX WG polymer in automotive sealing applications.

Transmission environments

With some engineering plastics, and even metals reaching their performance limits, VICTREX PEEK wear grades have decades of proven performance in demanding transmission environments.

Engineers are designing to achieve high-efficiency, smooth-shifting transmissions that can help deliver power whilst ensuring fuel economy and environmental standards are maintained. Because of this, sealing applications (Figure 5) require materials that demonstrate a low coefficient of friction, are dimensionally stable and can operate over a broad range of temperatures. Additionally, the materials must show resistance to the latest transmission oils and have the ability to perform in both lubricated and temporary non-lubricated settings caused by stop-start systems.

VICTREX PEEK wear grades have shown stability in transmission fluids and have matched the thermal expansion of cast aluminium. The polymers exhibit excellent performance at temperatures as cold as -40°C (-40°F) and at excursions up to 160°C (320°F). In fact, the polymers do not show any thermal oxidative ageing over the course of 5000 hours at 260°C (500°F).

The very low coefficient of friction offered by the polymer has enabled seals to withstand extreme pressure/velocity values under lubricated conditions and even allows for temporary dry-run performance.

Seal ring tests

In the latest tests, VICTREX PEEK seal rings demonstrated up to 25% less drag at 38.8 MPa (5627 psi) and generated 8°C (18°F) less heat next to the ring, compared with other thermoplastics. The Victrex polymer was also able to withstand 48 hours of wear testing, whilst another PAEK material failed after operating for one hour under the same conditions.

Low and defined lubrication leakage is also a desirable feature when specifying a seal ring material. In performance testing, VICTREX PEEK seal rings ensure proper lubrication with consistent leakage levels of 0.066 gpm (0.25 l/min).



Figure 4. In electrical connectors for down-hole and subsea environments VICTREX PEEK often replaces glass, ceramic and thermosetting resins because of its high mechanical strength and creep resistance at temperature. In addition, the material has the ability to act as an inherent seal at pressure differentials up to 345 MPa (50 000 psi) in a variety of corrosive environments, including hydrogen sulfide (sour gas) and sea water.

Additional testing also proved that the polymer can survive in lubricated settings under pressures up to 115 MPa ms⁻¹ (13 053 psi). In these extreme environments VICTREX PEEK polymers provide the desired performance for the design of highly-optimised transmissions.

Braking systems

When it comes to specifying a material for seals or supporting rings in electronic braking systems the durability and reliability of a component is crucial as passenger safety is of utmost importance. With that in mind, engineers are seeking materials with dimensional stability under high temperature conditions, resistance to aggressive brake fluids, excellent wear properties and toughness.

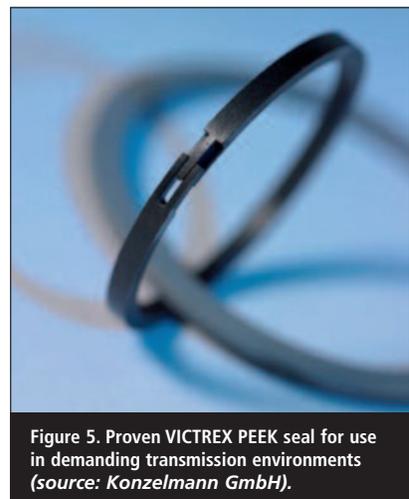


Figure 5. Proven VICTREX PEEK seal for use in demanding transmission environments (source: Konzelmann GmbH).

In braking-system seals VICTREX WG polymer demonstrates less creep compared with formerly used fluoropolymers such as polytetrafluoroethylene (PTFE). VICTREX polymers have also shown minor moisture absorption and no chemical attack at 120°C (248°F) whilst being immersed in brake fluid. The new wear-grade exhibits a thermal expansion that is in line with metal and no dimensional change under humid conditions.

Moulding tight tolerance parts is certainly achievable. This can result in less seal leakage and provides parts that are less expensive than ones made from stainless steel.

Compared with PTFE, VICTREX WG polymer has an operating life that is up to four times longer – making it a prime candidate to satisfy future market requirements. When designing for safe, high-performance braking systems, engineers – like 200 million drivers and counting – rely on the same proven track record of their Victrex PEEK braking components.

Conclusion

It is not surprising that VICTREX PEEK has been used for sealing applications for several decades because of its proven performance in today's industrial, oil and gas, and automotive markets.

This makes it a clear candidate for applications in extreme environments – from compressors and downhole tools to transmissions and braking systems. As a result, VICTREX PEEK is a reliable and proven option for your next-generation sealing needs.

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Major developer

Based in the UK, Victrex Polymer Solutions, a division of Victrex Plc, is a major developer and producer of high performance polyaryletherketone materials such as VICTREX PEEK, VICOTE Coatings, APTIV Film and VICTREX Pipes.

These materials are used in a variety of markets and offer an exceptional combination of properties to help OEMs, designers and processors reach new levels of cost savings, quality and performance. All material production comes under Victrex's ISO 9001:2008 quality registration.

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