PROCESSING GUIDE

Finishing Operations

victrex

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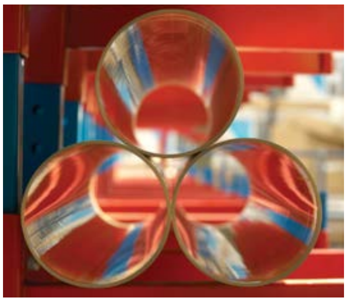
In today's competitive world, you want more from an advanced materials supplier than simply materials. Getting the most from high-performance polymers means considering component design hand-in-hand with material selection and optimised processing. This is the key to maximising an application's value in-use and achieving high manufacturing efficiencies at the lowest possible component cost. With design and material selection decided, processing optimisation becomes critical to drive your product quality and manufacturing yields higher.

With more than 30 years' experience, Victrex Polymer Solutions is uniquely placed to help customers get the very most from polyaryletherketone (PAEK) polymers and products. We offer a wide variety of VICTREX PEEK products that provide exceptional performance over a broad range of temperatures and extreme conditions. Each can be easily processed on standard equipment.

We are able to offer our customers an unrivalled technical capability encompassing design, material selection and processing support for polyaryletherketones. As part of this, we've created this guide to help you optimise your finishing operations. In addition, our technical teams located around the world can assist you with prototyping, application development, design and simulation as well as support for metal replacement opportunities.

Our increasing number of Technical Centres have processing equipment to support trials for the full range of VICTREX PEEK products, offer hands-on processing training and extensive materials analysis and characterisation capabilities. We can offer bespoke data generation for specific application programs and our resources are backed up by extensive product and application-based datasets which are continually expanding. We are also involved in a number of industry-leading research projects with academic institutions to further extend our knowledge and help us develop more creative solutions with our customers.





VICTREX™ PEEK

VICTREX™ PEEK polymer, along with its higher-temperature variants, VICTREX HT™ polymer and VICTREX ST™ polymer, is widely regarded as one of the highest performing thermoplastics in the world. Products are available as melt filtered granules, milled fine powders, or compounds containing a variety of functional fillers and reinforcements. They are used in the design and manufacture of high performance applications to replace metals and other materials to improve performance, increase design freedom and reduce system costs.

APTIV™ Films

Victrex APTIV™ film provides all of the properties of VICTREX PEEK polymer in a thin, flexible format. The extensive range of properties which includes thermoformability and excellent acoustic performance makes it the highest performing, most versatile thermoplastic film available. APTIV films are a technology enabler to facilitate reduced system costs and improved product performance whilst providing increased design freedom and ease of processing.

VICOTE™ Coatings

VICOTE™ Coatings are a dedicated range of eco-friendly high performance coatings made from VICTREX PEEK polymers. The powder and aqueous dispersions provide high temperature performance, exceptional scratch and wear resistance, high strength and durability. When compared with traditional coatings, these coatings can be considered to improve performance, extend application life, facilitate design freedom and reduce system costs.

VICTREX Pipes™

VICTREX Pipes™ are durable, lightweight pipe and tube extruded from VICTREX PEEK polymer which offer high temperature performance and a unique combination of properties.
An excellent alternative to metals and lower performing polymers, VICTREX Pipes provide chemical and corrosion resistance, low permeability, wear abrasion and impact resistance in a polymer-based pipe and tube.

High Temperature Performance
Excellent high temperature resistance, with continuous use temperatures of 260°C, which can offer longer life, reliability and increased safety margins in harsh environments.

Mechanical Strength and Dimensional Stability
Excellent strength, stiffness, long term creep and fatigue properties of Victrex materials allow parts to be designed with reduced weight, greater durability or strength.

Wear Resistance
In wet or dry abrasive environments, a low coefficient of friction and excellent wear resistance can help maintain part life and integrity.

Chemical Resistance
Resists corrosion even at elevated temperatures thanks to its ability to withstand a wide range of acids, bases, hydrocarbons and organic solvents.

Hydrolysis Resistance
Victrex materials have been used successfully to increase component reliability because it does not hydrolyse in water, steam or sea water even at elevated temperatures due to its low moisture absorption and low permeability.

Electrical Performance
Excellent electrical properties maintained over a wide frequency and temperature range to meet demanding electrical and electronic engineering needs.

Low Smoke and Toxic Gas Emission
Inherently self extinguishing without the use of additives and has low toxicity of combustion gases.

Purity
Offers exceptionally low outgassing and extractables for cleaner manufacturing.

Environmentally Friendly
Fully recyclable, halogen free, RoHS and REACH compliant.

Quality and Supply Security
All manufacturing is under ISO 9001:2008 registration and EU safety and environmental legislation. Our rigorous attention to detail – we perform over 50 tests on each batch of polymer – assures our customers of product quality and consistency.

As the only vertically-integrated polyketone solutions provider in the world, we have complete control over our key raw material – essential for consistent polymer quality.

Our policy to invest in capacity ahead of demand means that we have an unrivalled capability to assure customers of supply security. Our two independently-operated polymer plants are capable of up to 4,250 tonnes per year. We can also offer fast delivery – typically within 7 days – anywhere in the world through our centralised logistics system and local distribution warehouses.

MACHINING

Machining is often used as a secondary operation for injection moulded or extruded components to obtain part features or maintain tolerances that are not possible with the as-moulded or as-extruded part. For prototype designs, short production runs, or unique geometry parts it is common to machine materials from stock shapes to form components.

TOOLING AND OPERATING CONDITIONS

Victrex materials can be machined by all common methods using the same techniques and equipment as with metals or other engineering thermoplastics with some changes to machining parameters and cutting tools used. A summary of the suggested machining guidelines is shown in Table 1.

Victrex materials may also be machined by water jet and laser cutting. Grinding may be used to achieve very tight tolerances, especially with filled grades. Lapping processes may be used to improve flatness or surface finish where necessary.

Due to the physical properties of Victrex materials and the abrasive nature of some compounds, it is necessary to use carbide, coated carbide, or diamond tipped tools and bits. Using other materials can lead to rapid tool wear and poor surface finish on the machined part.

Machining and finishing operations on polymeric materials can create stresses or release residual stresses. Annealing to relieve residual stresses may be necessary before machining or as an intermediate step in the machining process. An annealing protocol is detailed in the 'Annealing' section. If a large amount of machining and finishing is to be carried out on a component, a second annealing step is recommended prior to final machining.

Victrex materials have a relatively low modulus compared to metals, and can easily be warped or distorted by high clamping forces. Material should be removed evenly, taking cuts symmetrically from the work piece where possible.

The thermal conductivity of all polymeric materials is lower than that of metals, so heat build-up during machining is rapid. Cooling fluids can be used to remove some of the heat generated by the machining process. Victrex materials are compatible with water-based and oil-based coolants.

Table 1: Suggested machining guidelines for Victrex materials

TURNING			
Tool Inserts		Unfilled / unreinforced Victrex materials	Filled / reinforced Victrex materials
Cutting Speed	m/min	100 - 300	120 - 180
Feed	mm/rev	0.1 - 0.7	0.1 - 0.3
Relief Angle	°	5 - 15	5 - 15
Top Rake Angle	°	5 - 15	5 - 15
Cutting Depth	mm	1 – 6.5	1 - 7.5
Coolant		None, or Water/Oils	None, or Water/Oils
MILLING			
Cutters		Standard or Carbide Tip	Carbide tip or Diamond Tip
Cutter Speed	m/min	180 - 230	50 - 120
Coolant		Water/Oils	Water/Oils
DRILLING			
Cutting Speed	m/min	120	75 - 120
Feed	mm/rev	0.05-0.20	0.05-0.20
Lip Angle	°	118	118
Clearance Angle	°	12	12
Coolant		Water/Oils	Water/Oils
REAMING			
Runners		Spiral Flute	Spiral Flute
Speed	rpm	100 - 200	100 – 200
Coolant		Water/Oils	Water/Oils

PERFORMANCE OF MACHINED VS. INJECTION MOULDED PARTS

Many low-volume or complex production parts are best made by machining from stock shapes, and machined prototype components are generally the best option to evaluate the performance of a material before investing in a custom mould. However, the physical performance of a component machined from a stock shape can differ from that of a seemingly identical injection moulded component. There can be significant differences in mechanical properties for different production methods. These phenomena may be explained in terms of the inherent differences in the production methods, including crystallinity, thermal history, and fibre orientation. The issue is particularly pronounced when machining thin wall parts from fibre-reinforced shapes.

ANNEALING

Components formed from Victrex materials will be optimally crystalline if moulded or extruded under appropriate conditions. For the majority of applications, secondary annealing is not necessary. Some applications will require annealing to increase levels of crystallinity, remove any thermal history, limit subsequent dimensional changes at high temperatures, or to remove stresses. The appropriate annealing procedure will depend on the objective of the process as detailed below. Please contact a Victrex technical representative with questions on your specific part and process.

ANNEALING FOR OPTIMUM CRYSTALLINITY

Increasing crystallinity within a component may be necessary if the material does not reach a proper level of crystallinity during melt processing. In natural coloured grades, this is usually characterised by a brown amorphous skin. Every effort should be made to obtain optimum crystallinity during moulding or extrusion, whether by increasing the mould temperature for injection moulded parts or reducing the speed of cooling for extruded material. If the material must be annealed to reach the proper level of crystallinity, the following cycle is recommended:

(a) Allow the component to heat up until an equilibrium temperature of 200°C is reached.

(b) Hold the part at the annealing temperature. The holding time for components is dependent on section thickness; hold parts at temperature for 1 hour for each millimetre of wall thickness.

(c) Allow the component to cool at 10°C per hour until the system falls below 140°C for PEEK, below 150°C for HT, and below 160°C for ST. Slow cooling is critical to minimise residual stresses in the material.

(d) Switch off the oven and allow the component to cool down to room temperature.

Increasing the temperature and holding time will affect the level and type of crystallinity developed in annealing. A holding temperature at least 20°C greater than the maximum service temperature is recommended. Annealing temperatures in the range of 200 – 250°C are widely used. Annealing temperatures up to 300°C and higher can be used to maximise crystallinity, which improves some mechanical properties (e.g. strength and modulus) and chemical resistance. However, these effects are accompanied by a significant decrease in ductility in unfilled grades. Surface oxidation or yellowing can also occur because of the high annealing temperature. Please contact a Victrex technical representative for assistance if needed.

ANNEALING TO REMOVE STRESSES

Injection moulding or machining operations may add stresses to a component. These stresses reduce the physical performance of devices and may be removed by annealing the sample as described above, with a holding temperature up to 250°C.

ANNEALING FOR DIMENSIONAL STABILITY

Components of Victrex materials exposed to high continuous service temperatures may experience post-crystallisation and/or internal stress relaxation which result in dimensional changes. Components may be annealed to remove distortion effects or thermal history, and prevent shrinkage or other dimensional changes to the component while in service. Anneal the sample as described above, with a holding temperature at least 20°C greater than the maximum service temperature. If the part is machined, annealing should be done prior to the final machining step.

JOINING VICTREX MATERIALS

All joining techniques applicable to thermoplastics are suitable for Victrex materials. Adhesive bonding and welding require special procedures as detailed below. Joining by means of rivets, bolts, snap fits, interference fits, and other mechanical methods should follow common plastics guidelines.

ADHESIVE BONDING

Victrex materials and compounds may be bonded using a variety of common adhesives.

SURFACE PREPARATION

Surfaces which are to be joined by an adhesive must be prepared to achieve acceptable results. The surface to be bonded should be absolutely clean, dry and free from grease and other contamination. There are a variety of surface treatments available which increase the strength of adhesive bonds made with Victrex materials. A comparison of bond strengths achieved using the most common of these techniques is made in Table 2. For these measurements PEEK 450G samples were bonded together in a single overlap shear geometry with a two-component epoxy from Huntsman (AV138M/HV998) and using a 15 minute 100°C curing cycle.

Table 2: Comparison of surface preparation techniques for adhesive bonds to PEEK 450G

	Bond Strength/MPa
Untreated	**0.7**
Roughening	**2.1**
Acid Etch	**5.5**
Excimer Laser	**5.6**
UV Lamp	**5.0**
Plasma Chamber	**5.0**

ADHESIVE TYPES

Epoxy, cyanoacrylate, and silicone adhesives have been shown to successfully bond Victrex materials. A list of typical adhesives and their corresponding bond strengths is shown in Table 3. Adhesive should be chosen according to the requirements of the application, such as temperature, mechanical property, and regulatory requirements.

Table 3: The bond strength of various adhesives used with Victrex materials*

			Failure Stress/MPa			
Adhesive	**Type**	**Manufacturer**	**23˚C**	**120˚C**	**150˚C**	**200˚C**
Araldite AV138M + HV 998	Epoxy	Huntsman	5.5 IF + CF	3.4 CF	-	-
Araldite AV 119	Epoxy	Huntsman	42.0 SF	4.0 CF	1.5 IF + CF	-
HAF 8401	Nitrile rubber phenolic resin	Tesa AG	47.0 SF	2.4 IF	1.9 IF	-
Duralco 4460	Epoxy	Cotronics Corp.	1.7 IC	-	0.5 CF	0.4 IF + CF
Duralco 4703	Epoxy	Cotronics Corp.	17.0 SF	-	3.4 CF	1.0 CF
EPO-TEK 353 ND	Epoxy	Epoxy Technology	36.0 SF	-	3.1 CF	1.0 IF + CF
Duralco 4525	Epoxy	Cotronics Corp	3.3 CF	-	-	0.6 CF

IF : adhesive failure at the adhesive / substrate interface
CF : cohesive failure of the adhesive, leaving adhesive on both sides of the substrate
SF : the adhesive is of sufficient strength to cause failure within the PEEK substrate
IC : mixed mode failure with fracture propagation switching between interfacial and cohesive failure

WELDING

Victrex materials may be bonded using conventional thermoplastic welding techniques. Satisfactory results have been obtained using hot plate, friction and nearfield ultrasonic welding. Hot-melt welding is also possible. Victrex materials have exceptionally high melt temperatures, and considerable amounts of energy focused on the bond area are required to achieve a good bond.

Laser welding allows precise joining of parts, and can be used to encapsulate or seal components in Victrex materials. Laser welding allows a laser transparent part (natural colour) of 1mm thickness or less to be bonded to a laser absorbing part (black in colour).

For all welding methods, Victrex suggests working with welding equipment suppliers who have experience with welding our materials. Please contact Victrex technical service for recommendations on welding methods, joint designs, and welding service or equipment providers.

Precise joining of naturally coloured and black Victrex PAEK parts can be achieved through laser welding.

*Use of any particular adhesive named in this publication or used in these laboratory tests does not constitute a recommendation. Adhesive performance is a function of many variables including sample and surface preparation, adhesive application, curing time, test geometry and speed and may not be representative of material or adhesive performance in real applications.

METALLISATION

VACUUM METALLISATION

Victrex materials may be used as substrates in a thermoplastic metallisation process. Substrates must be clean, dry, and free of contamination before the application of the metal coating. Care should be taken when injection moulding or machining such components to ensure a good surface finish, as any imperfections will be replicated in the thin metallic coating.

PLATING

Victrex materials can be electroless plated with a variety of metals. Please contact Victrex for recommended vendors.

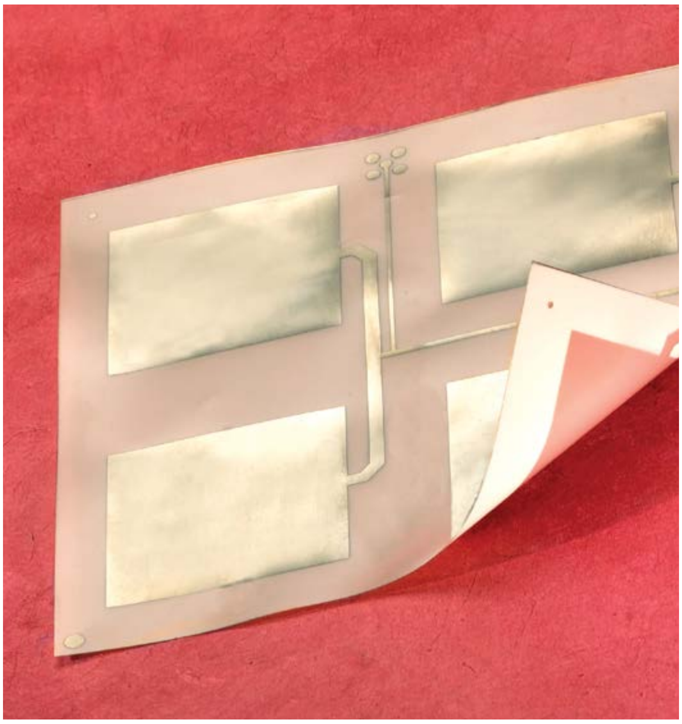
PRINTING AND LASER MARKING

Victrex materials can be marked by various methods. Inks and marking fluids can be used to print on Victrex materials. Laser marking can offer advantages such as flexibility, wear resistance, sharpness and speed, without physically contacting the part.

Please contact Victrex technical service for recommendations on suppliers of laser marking systems or marking services.

PAINTING

Victrex materials may be painted for decorative purposes or for UV protection. Surface preparation such as plasma treatment is typically required for good adhesion.
Please contact Victrex technical service for assistance.



Clean, dry and contaminant free substrates are important prerequisites in the thermoplastic metallisation process.

Products made from Victrex materials may be marked by printing or laser marking.

TECHNICAL SUPPORT

Victrex Polymer Solutions is uniquely committed to polyaryletherketone products and is well-placed to meet your full range of quality, technical and supply security requirements. In today's competitive environment, working with a leading supplier with advanced technologies and most in-depth and responsive technical services available can be critical for success.

If you would like more information or assistance, please contact your local Victrex Polymer Solutions representative or visit us at www.victrex.com.

Based in the UK, Victrex is an innovative and world leading global provider of high-performance polymer solutions for the aerospace, automotive, electronics, energy and medical industries. Every day, millions of people rely on products and applications containing our polymers – from smart phones, aircraft and cars all the way to medical devices and oil and gas installations. With over 35 years' experience, we provide cutting-edge technological solutions that shape future performance for our customers and markets and drive value for our shareholders.
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