

PROCESSING GUIDE



# Compression Molding



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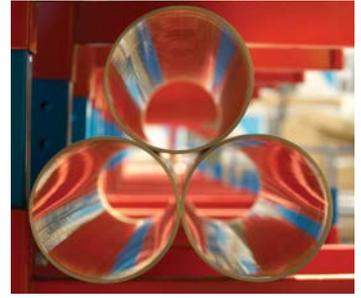
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In today's competitive world, you want more from an advanced materials supplier than simply materials. Getting the most from high-performance polymers means considering component design hand-in-hand with material selection and optimised processing. 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 compression moulding processing conditions. 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.

## INTRODUCTION

The compression moulding process is a traditional technique which is still very useful and cost effective when dealing with small volume manufacture or large components, for example, large diameter seal rings for oil and gas applications, or shapes for machining prototype parts during the early stages of a project.

Advantages of compression moulding when compared to injection moulding include:

- Low capital investment for equipment and tooling.
- Ability to mould large and thick components (injection moulding is typically limited to thicknesses up to 15mm to 20mm).

The most significant disadvantage of compression moulding is low productivity. For thermoplastics such as VICTREX PEEK, VICTREX HT and VICTREX ST the cycle time is typically several hours or longer.

## REQUIREMENTS FOR EQUIPMENT AND TOOLING

The hydraulic press should be capable of delivering sufficient pressure for void-free mouldings; typically 350bar pressure is required within the mould cavity during the packing stage. The hydraulic press should be fitted with two heated platens, capable of heating the tool up to 400°C for PEEK or HT and up to 450°C for ST.

It is recommended to fit an independently controlled heater band around the tool to ensure there are no cold spots during moulding; this is particularly recommended for longer tools. Typically the tools are more than double the length of the finished mouldings so it is necessary to ensure that the press has sufficient daylight (the gap between platens) to accommodate the tooling.

Mould tooling should be made from high temperature corrosion resistant metals (e.g. H13) with Rockwell hardness above 50HRC, which is to be maintained after many heating / cooling cycles up to 400°C (or 450°C in the case of ST). Care must be taken when designing the tool to ensure that the steel is thick enough to withstand the high pressures applied during processing without risk of fracture.

The majority of compression mouldings are thick walled and as such require high pressures to be maintained during the cooling cycle. In order to maintain high pressures at melt temperature over prolonged periods of time it is recommended to operate with tight tolerance seals to avoid excessive melt flow between moving parts. The clearance between seal ring and sliding parts should be under 50µm.

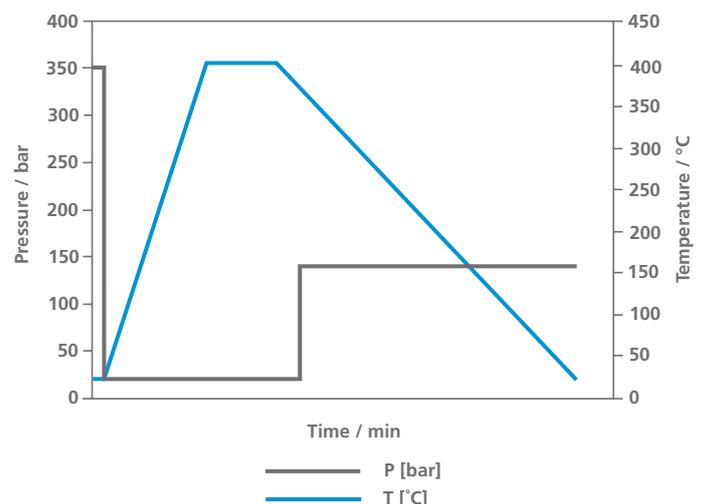
For ease of ejection a mould release agent is recommended. This should be stable to temperatures in excess of the maximum temperature reached during the processing cycle.

## 7-STEP MOULDING PROCESS

1. Clean all components thoroughly and assemble the mould. Internal surfaces must be spotlessly clean to avoid the formation of black specks in the moulding. Victrex fine powders need to be dried prior to moulding; PEEK 450PF and HT P45PF should be dried at 150°C for 3 hours while ST P45PF should be dried at 180°C for 3 hours. During drying and at all stages of the process it is essential to ensure that Victrex materials are kept clean and free from any cross contamination.
2. Coat all melt contacting surfaces with mould release and allow to dry.
3. Filling and packing the tool:  
The required quantity of powder needed to manufacture a component can be approximated by:  
$$\text{Powder weight} = \text{part volume} \times \text{density} \times 102\%.$$
  
Fill tool with powder, place the seal ring on top and apply high pressure (350 bar cavity pressure) to pack the powder. Add more powder and re-pack until mould is filled with required quantity of powder.
4. Set the heaters for platens and mould to the required temperature (typically 400°C for PEEK 450PF or HT P45PF and 420°C for ST P45PF) and heat as quickly as possible, whilst applying a low cavity pressure ( $\approx$  20bar).
5. Once the system reaches the set temperature, it should be held at constant temperature and pressure for a time (dependent on moulding size) to establish homogeneity within the melt.
6. Apply high pressure, switch off the heating and allow the system to cool down naturally to room temperature.
7. Ejection: Open the tool and take out the PEEK moulding.

A typical temperature-pressure profile for PEEK 450PF is shown in Figure 1; specifics may vary depending on tool and component design.

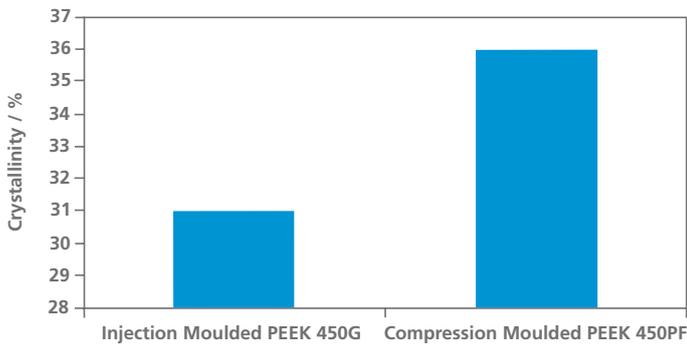
**Figure 1: Pressure and temperature profiles of a typical compression moulding process for PEEK 450PF as a function of time.**



## COMPONENT PROPERTIES

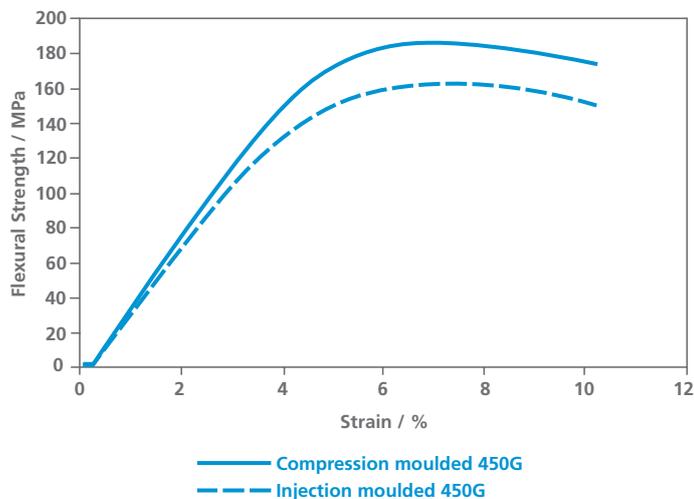
The compression moulding process allows much slower cooling than the injection moulding process; consequently, the bulk of material will reach higher levels of crystallinity in a compression moulding ( $\approx 35\%$ ) in comparison with injection mouldings ( $\sim 20\% - 30\%$ ). This will have an impact on the mechanical properties of Victrex materials.

**Figure 2: Typical crystallinity of PEEK 450G injection moulded components in comparison to PEEK 450PF compression moulded components.**



Samples machined from compression moulded unfilled PEEK have higher strength and stiffness than injection moulded samples; tensile properties are similarly increased.

**Figure 3: Typical flexural properties of compression moulded components in comparison with injection moulded components.**



Clean tools must be carefully filled with the correct amount of VICTREX PAEK powder.

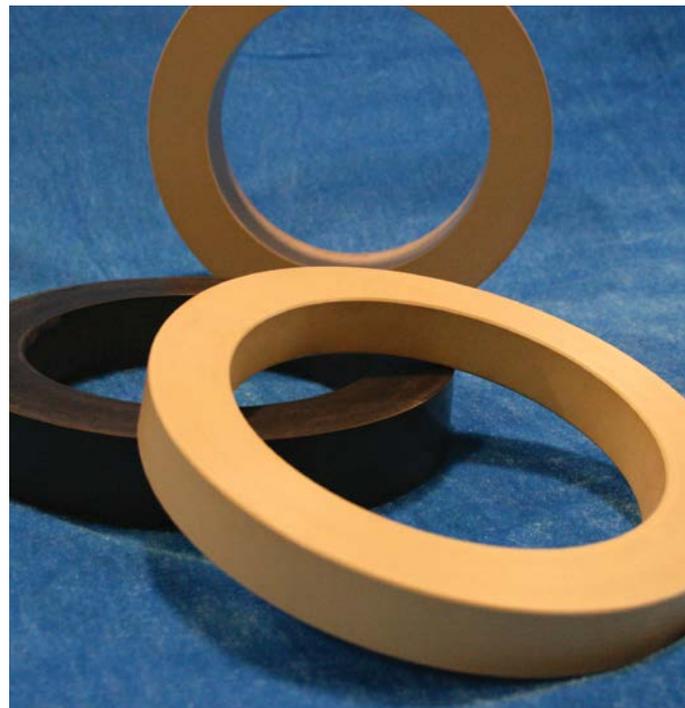
The best component performance is obtained by using Victrex fine powder grades. The lack of shear forces in the compression moulding process means it is less suited for moulding granules; the resulting parts have grain boundaries between compressed pellets which will reduce mechanical performance in a similar way to weld lines. In addition, it is more difficult to achieve an equivalently high packing density in the tool which may result in voids throughout the part.



Flexural testing may be carried out to monitor the quality of compression moulded parts.

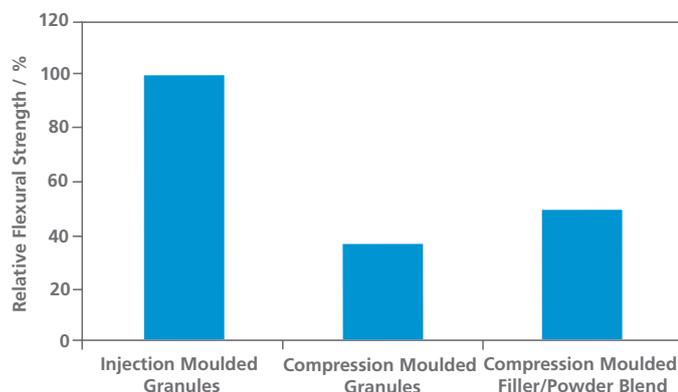
Similarly, when using fibre reinforced granules for compression moulding, the lack of shear forces will again lead to weld line type boundaries between pellets; mechanical performance would typically be lower than that of unfilled injection moulded components. Furthermore, cracking of components between grain boundaries is frequently noticed. The recommended route to moulding reinforced components is to make a blend of PAEK fine powder with milled fibres, as experience has demonstrated that components with excellent mechanical properties can be obtained with this technique.

Samples machined from compression moulded fibre reinforced granules showed significantly lower flexural strength and stiffness than injection moulded test pieces of the same grade, as shown in Figure 4 (tensile behaviour would behave in a similar fashion). However, compression mouldings made from a powder blend of PEEK 450PF and milled fibres showed significantly improved properties, similar to those expected from extruded stock shape.



The best component performance is obtained when using Victrex fine powder grades.

**Figure 4: Flexural properties of compression moulded and injection moulded 450CA30 granules in comparison with those of a milled fibre/powder blend.**



Obviously the strength is still lower than injection moulded samples, this is due to fibre orientation effects. Injection mouldings have high fibre alignment in the flow direction which gives them excellent mechanical properties in the fibre/flow direction, whereas properties in the across flow direction are significantly reduced. Properties of samples machined from compression mouldings are more isotropic due to the lack of shear in the process.

Great care must be taken when prototyping for a future injection moulded part, the properties of parts machined from compression mouldings may be significantly different, particularly in thin walled parts in which machined fibre-reinforced compression mouldings can be very weak in comparison to injection mouldings.



Secondary operations such as machining can be performed on compression moulded parts as can be seen in this electroplating ring.

## TROUBLESHOOTING

Historically, the most common processing issues are caused by incorrect process conditions or insufficient cleanliness. The table below shows an overview of frequently encountered defects, their likely cause, and recommendations for their rectification

### DEFECTS

#### Voids

<i>Possible cause</i>	<i>Remedy</i>
Insufficient pressure during cooling	Increase pressure
Excessive flashing	Check tool sealing
Cooling too quickly	Reduce cooling speed
Pressure not maintained for the whole cooling cycle	Maintain pressure until ejection

#### Black specks on the surface

<i>Possible cause</i>	<i>Remedy</i>
Contamination of tool surface	Improve cleaning of tooling (lint free cloth)

#### Black specks in the bulk

<i>Possible cause</i>	<i>Remedy</i>
Contamination of powder	Check cleanliness of drying oven and other possible sources of contamination

#### Black specks with significant discolouration

<i>Possible cause</i>	<i>Remedy</i>
Excessive holding time at high temperature	Modify process to minimise temperature and times

#### Degradation

<i>Possible cause</i>	<i>Remedy</i>
Excessive temperature	Reduce temperature settings, check accuracy of set temperatures
Excessive holding time	Optimise process
System heating too low	Consider increasing heater power or adding extra heaters where possible
Too much air remaining in cavity	Adjust the initial packing process

#### Unmelted powder

<i>Possible cause</i>	<i>Remedy</i>
Insufficient temperature	Increase set temperature
Insufficient holding time	Increase holding time
Unbalanced tool	Check for cold spots in tool

### 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](http://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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