



HYBRID MOULDING DESIGN CONSIDERATIONS

CONTENTS

1 INTRODUCTION	2
2 SCOPE	2
3 PAEKs and PEEK	2
4 DESIGN CONSIDERATIONS	3
5 MATERIAL PROPERTIES	4
6 INJECTION MOULDING PRINCIPLES	5
7 INJECTION VS COMPOSITE VS HYBRID MOULDING	6
8 PRINCIPLES OF HYBRID MOULDING	7
9 SINGLE-STEP AND TWO-STEP MOULDING	9
10 TECHNICAL SUPPORT	10

1 | INTRODUCTION

With more than 35,000 new aircraft needed over the next 20 years, the entire Aerospace industry supply chain faces the pressure of delivering planes at a much more cost-effective and rapid pace.

The replacement of metal and thermoset composites with next-generation thermoplastic composite solutions has the potential to reduce cost through lower cycle time and net shape moulding.

A recently developed thermoplastic PAEK polymer-based hybrid composite system enables a part to combine the mechanics of continuous fibre materials, the flexibility of injection moulded design and the short cycle time of thermoplastic processing. In addition, net shape parts can be created in the final injection moulding step, meaning costly machining steps can be avoided.

These factors are well placed to support current Aero Megatrends:

- Improving fuel efficiency through weight reductions
- Optimising and simplifying manufacturing and assembly
- Greater reliability and longer service life
- Stability and security along the entire supply chain

This document provides considerations customers may wish to take into account when designing and producing a hybrid moulded part. It is not intended to be an exhaustive list and other factors may apply. It is the customer's sole responsibility to determine the factors they take into account when designing parts.

2 | SCOPE

The injection moulding process utilises heavy equipment capable of applying immense pressures to molten polymer to force it into a pre-shaped cavity cut into tool steel. The reactive forces created by this pressure limits the size of a moulded component.

There are additional restraints that are not yet fully explored, such as the impact of thermal expansion differences between the insert material and the over-moulded material.

With these restrictions in mind, the size of a hybrid overmoulded part considered within this guideline is limited to that which will fit within a mould tool up to 500 mm x 500 mm x 500 mm. Aircraft clips, cleats, brackets and so forth generally fall within this size range and will be regarded as the 'standard size' to be considered for hybrid moulding. Larger components are considered out of scope.

3 | PAEKs and PEEK

Victrex thermoplastic materials fall within a general class of polymers termed Poly Aromatic Ether Ketones (PAEKs), which includes Polyetheretherketone (PEEK).

PEKK, PEK, PEKEKK are all members of this same chemical group and are all characterised by their high crystalline melting temperature.

Victrex has created a polymer based on similar chemistry, referred to as VICTREX LMPAEEK™, a PAEK with a lower melting point of 305 °C, nearly 40 °C lower than PEEK (343 °C).

Although PEEK and VICTREX LMPAEEK are all members of the PAEK family, we distinguish between the two by referring to PEEK as 'PEEK' and VICTREX LMPAEEK as 'PAEK'. Although the melting temperatures of PEEK and LMPAEEK differ by almost 40°C, their glass transition temperatures are almost identical (143 °C vs 147 °C).

Both VICTREX™ PEEK and PAEK polymers are totally miscible in the melt phase and can be mixed or fused together by melting.

4 | DESIGN CONSIDERATIONS MAY INCLUDE

- Design to ensure that the maximum loads are carried by the composite insert(s).
- Use mould flow simulation to avoid weld lines or minimise their impact on part performance.
- Vents should be designed in for critical areas (0.02 – 0.03 mm diameter).
- It is better to machine any required holes after moulding to avoid unnecessary weld lines and use overflow zones to improve weld line performance if they cannot be avoided.
- Gate size should be as large as possible 1-1.5 x the nominal wall thickness for direct gating to allow for long packing times and therefore reduce the void content.
- Fill the part from thick to thin.
- Tool temperature minimum 200 °C – oil heated systems preferred to avoid uncontrolled tool temperature rises.
- VICTREX LMPAEEK inserts to be pre-dried and placed into the tool at 200 – *250°C.
- VICTREX LMPAEEK overmould areas of the insert to be dust- and grease-free.
- VICTREX LMPAEEK inserts should be retained in the hot tool for 30 seconds before injection to ensure that the insert is heated evenly.
- Back pressure is to be set as low as possible – start with 5 bar.
- Injection pressures to be held as low as possible to avoid 'wash out' of the inserts.
- Gate position not with direct injection against the low melt PEEK insert part.
- Deformation of the inserts may occur during the holding pressure phase.
- Avoid keeping the inserts in place using a vacuum as the softened insert might get pressed into the sealing area.
- Holding pressure should not exceed the maximum injection pressure at 98% of filling.
- Design the mould in a way that the given wall thickness tolerances of the inserts are compensated (e.g. spring-loaded system).
- Be prepared to anneal the moulded part to relieve internal stresses.

*- Maybe taken above the melting temperature for one shot processing - see below.

5 | MATERIAL PROPERTIES

PEEK and PAEK polymers display the following key characteristics:

High Temperature Performance

Excellent high temperature resistance, with continuous use temperatures of up to 260°C, which can offer longer life, reliability and increased safety margins in demanding environments.

Mechanical Strength and Dimensional Stability

Excellent strength, stiffness, long term creep and fatigue properties of Victrex materials may allow parts to be designed with reduced weight, greater durability or strength vs traditional aerospace metals.

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 they do not hydrolyse in water, steam or sea water even at elevated temperatures due to their 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 with low toxicity of combustion gases.

Purity

Offers exceptionally low outgassing and extractables for cleaner manufacturing.

Additional Features

Recyclable, halogen free, RoHS and REACH compliant.

PROPERTIES OF VICTREX PEEK 450G™, 150GL30, 150CA 30, AND 90HMF40

PROPERTY	CONDITIONS	TEST METHOD	UNITS	VICTREX PEEK 450G (unfilled)	VICTREX PEEK 150GL30 (glass filled)	VICTREX PEEK 150CA30 (carbon filled)	VICTREX PEEK 90HMF40
GENERAL							
Density	Crystalline	ISO 1183	g/cm ³	1.30	1.52	1.40	1.45
	Amorphous	ISO 1183		1.26			
Water Absorption (3.2 mm thick tensile bar)	24h, 23° C	ISO 62-1	%	0.07	0.04	0.04	0.03
	Equilibrium, 23°C			0.40	0.30	0.30	0.30
MECHANICAL							
Tensile Strength	Break, 23°C (Yield*)	ISO 527	MPa	100*	190	260	330
	Break, 125°C (Yield*)			50*	115	150	220
	Break, 225°C (Yield*)			13*	55	70	
Tensile Elongation	Break, 23°C	ISO 527	%	45	2.5	1.5	1.2
Flexural Strength	23°C	ISO178	MPa	165	280	360	480
Flexural Modulus	23°C	ISO 178	GPa	4.1	11.5	24	37
Izod Impact Strength	0.25 mm notch, 23°C	ISO 180/A	kJ/m ²	7.5	9.0	7.0	10.5
	Unnotched, 23°C	ISO 180/U		no break	50	40	60
THERMAL							
Melting Point		ISO 11357	°C	343	343	343	343
Glass Transition (Tg)		ISO 11357	°C	143	143	143	143
Specific Heat Capacity	23°C	DSC	kJkg ⁻¹ °C ⁻¹	2.2	1.7	1.8	1.8
Coefficient of Thermal Expansion	Along flow below Tg	ISO 11359	ppm/ °C	45	20	5	3.0
	Average below Tg			55	45	40	35
	Along flow above Tg			120	20	6	1.0
	Average above Tg			140	110	100	80
Heat Deflection Temperature	1.8 MPa	ISO 75A-f	°C	152	335	339	349
Thermal Conductivity	23°C	ISO 22007-4	W/mK	0.29	0.30	0.95	2.0
Continuous Use Temperature	Electrical	UL 746B	°C	260	240		
	Mechanical w/o impact			240	240	240	
	Mechanical w/impact			180	220	200	
FIRE, SMOKE AND TOXICITY							
Flammability Rating		UL94	n/a	V-0 @ 1.5 mm	V-0 @ 0.5 mm	V-0 @ 0.5 mm	
Limiting Oxygen Index	0.4 mm thickness	ISO 4289	%O ₂	24			
	3.2 mm thickness			35			
ELECTRICAL							
Dielectric Strength	2.5 mm thickness	IEC 60243-1	kV/mm	16	17		
	50 µm thickness			190			
Loss Tangent	23°C, 1MHz	IEC 60250	n/a	0.003	0.004		
Dielectric Constant	50Hz, 0-150°C	IEC 60250	n/a	3.2	3.3		
	50Hz, 200°C	IEC 60250		4.5			
Volume Resistivity	23°C	IEC 60093/ ASTM D4496	Ωcm	10 ¹⁶	10 ¹⁶	10 ⁵	10 ⁵

*STRENGTH AT YIELD (5%) OF VICTREX PEEK 450G

6 | INJECTION MOULDING PRINCIPLES

Victrex materials are widely regarded as being amongst the highest performing materials capable of being processed on conventional thermoplastic processing equipment. All general moulding guidelines applicable to semi-crystalline polymers also apply to injection moulding Victrex materials. The higher melting points of Victrex materials require special attention in some areas, which are briefly summarised below.

Temperature capability:

The plasticising unit must be able to operate controllably up to 440°C with the allowance that settings are application dependant and that material degradation should be closely monitored when operating close to this limit. A minimum tool surface temperature of 170°C must be reached to obtain parts at standard level of crystallinity with expected material performance.

Moisture content:

Although not hygroscopic, Victrex materials must be dried prior to moulding.

Cleanliness:

Contamination must be avoided - dedicated scoops and trays for drying etc. are strongly recommended.

Gates and runners:

These are larger than those used for moulding other engineering or high-performance polymers.

7 | INJECTION VS COMPOSITE VS HYBRID MOULDING

Injection moulding involves the melting, forming/shaping and cooling of polymer material under pressure. The material must be capable of melting and flowing under pressures that can be attained and contained within practical limits. Pressure and flow viscosity requirements generally limit the amount of reinforcing fibre that can be added to a polymer and the ultimate fibre length. Consequently, the mechanical properties of injection moulded materials are restricted to a fraction of what can be achieved by other processes involving very long/continuous fibres, such as compression mould of laid composites. The advantage of injection moulding, however, is that material can be easily transformed from raw pellets into complex artefacts with a high degree of autonomy and repeatability.

Composite moulding utilises prepreg materials comprising continuous reinforcing fibres. The fibres may be unidirectionally aligned within a prepreg tape or woven into a fabric. Both forms are impregnated with polymer at an appropriate level to optimise the fibre volume fraction for maximum levels of performance. Lay-up may be automated, especially in the case of composite prepreg tapes using Automated Fibre Placement (AFP) or Automated Tape Laying (ATL) machines. Multiple layers with fibres arranged at preferred angles in a balanced arrangement to optimise performance according to the applied service loads.

Composite parts can be flat or formed into shape and may contain areas in which the ply count is reduced or built up (ply drops/ply builds) to decrease or increase thickness of the part accordingly.

Hybrid moulding provides a means of adding features to composite parts that would be difficult, or impossible, using layer stacked composites. Examples include pillars, fixing points, stiffeners in the form of iso-grids, localised stiffening ribs and bosses for metallic inserts.

8 | PRINCIPLES OF HYBRID MOULDING

Hybrid overmoulding, as defined in this guideline document, is a combination of continuous fibre reinforced PAEK thermoplastic polymer composite overmoulded with a higher melting point PEEK compound.

Figure 8.1 illustrates the principles of the process. Hot VICTREX PEEK polymer with 40% by weight carbon fibres (VICTREX PEEK 90HMF40) at a melt temperature in excess of 400 °C is being overmoulded onto a solid composite laminate made from VICTREX LMPAEK prepreg tape.

As the polymer flow front advances, it cools as heat is drawn out by the laminate and by the mould tool. The process works because of the high injection temperature which is more than 100 °C hotter than the melting temperature of the VICTREX LMPAEK polymer which melts at the interface.

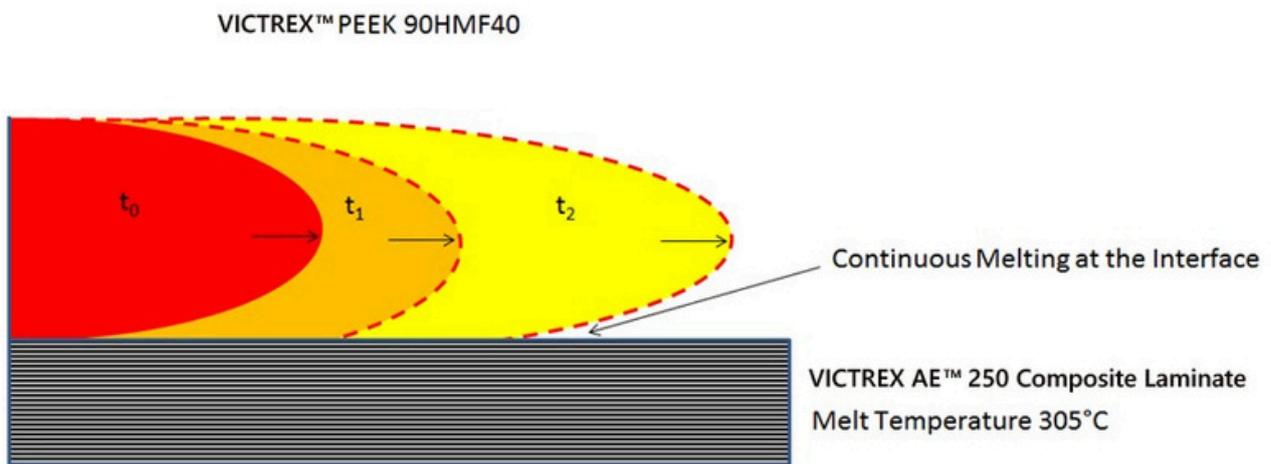


Figure 8.1: VICTREX™ PEEK 90HMF40 compound flowing over VICTREX LMPAEK™ composite laminate at time intervals t_0 , t_1 and t_2 and melting the interface.

The shared chemistry between the polymers results in total compatibility across the melted interface. As illustrated in Figure 8.2, which is a scanning electron microscope (SEM) image of fracture surfaces when the two materials are pulled apart. The ductile nature of the fracture is clear to see.

Good bond between VICTREX LMPAEK composite and VICTREX 90HMF40

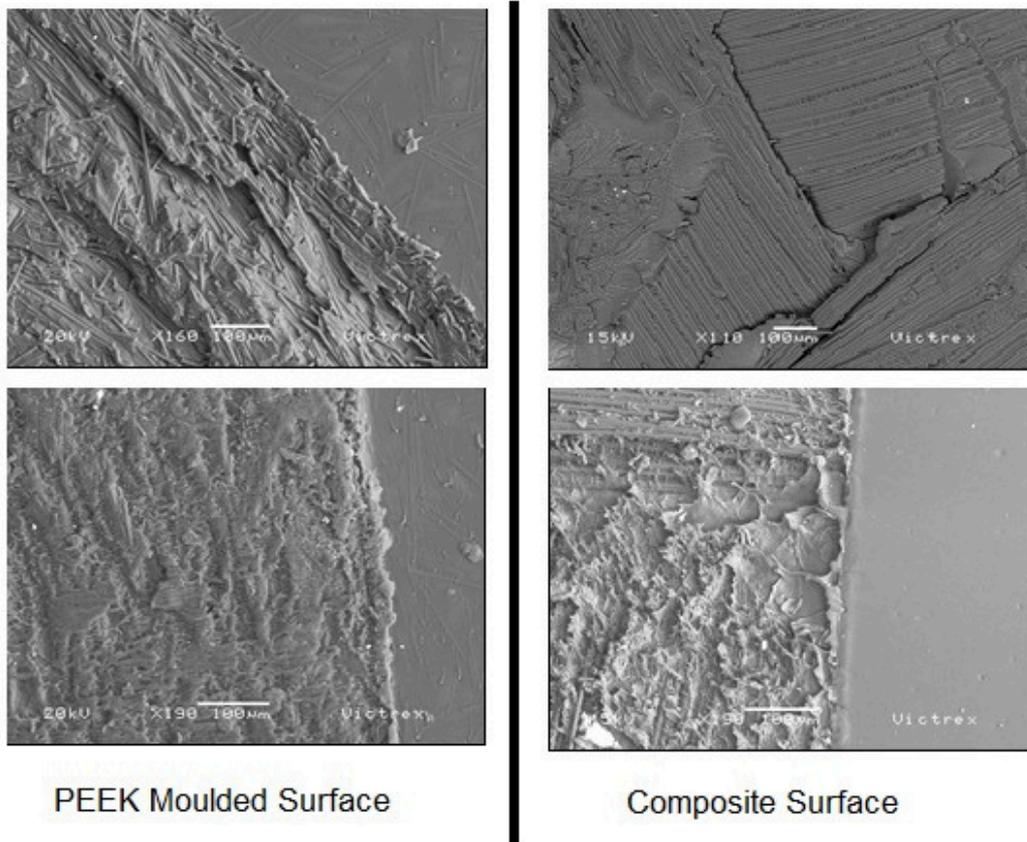


Figure 8.2: SEM images of ductile fracture surfaces when the overmoulded compound and composite laminate are pulled apart.

The advantage of hybrid overmoulding is that parts can be integrated, thereby reducing the overall part count. This can save on assembly costs and additional manufacturing steps such as welding, bonding or mechanical fastening.

Composite prepreg tapes made from continuous carbon fibre reinforced PAEK polymer (for example, VICTREX LMPAEK™ UDT from Victrex) are laid and consolidated (for example in a press or under a vacuum bag in an oven) to make a solid composite panel. This can then be formed by hot-stamping and cut (for example by water jet) to make smaller parts as inserts that will be placed within a cavity in an injection moulding tool. Closing the tool around the insert holds it in place whilst melted PEEK polymer is injected to overflow some, or all, of the insert, forming a welded interface between the two materials.

The two materials work together to enable the strong/stiff composite insert to take significant load whilst the injection moulded element serves to hold the load members in place and provide connectivity between them. Figure 8.3 illustrates this using an overmoulded bracket as an example. As will be seen from this Finite Element study, the maximum stresses on the part may be significantly reduced by the introduction of composite reinforcing pieces in the form of a baseplate and 'fin'.

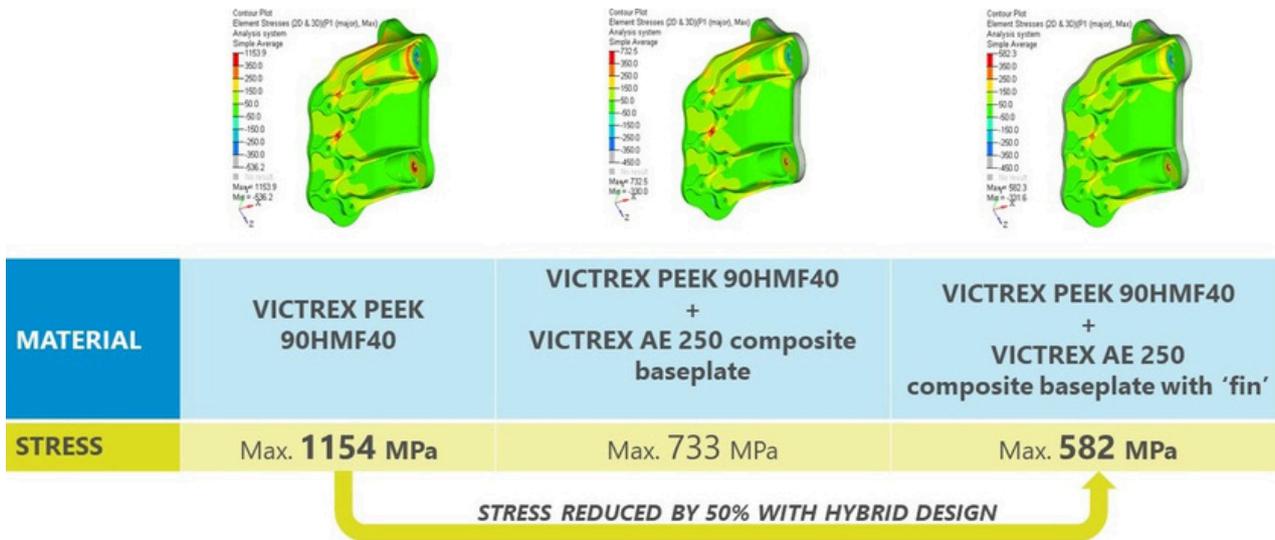


Figure 8.3: Loaded hybrid moulded bracket with and without reinforcing composite inserts illustrating reduced stresses with inserts added.

9 | SINGLE-STEP AND TWO-STEP MOULDING

Composite inserts may be formed/consolidated first and trimmed to the finished size for insertion into the tool before being overmoulded with polymer (so called two-step process) or the composite insert can be heated and formed directly in the tool during the overmoulding process (so called one-step process). One step processing has the advantage of only requiring one tool, the injection moulding tool. It may however be prone to wrinkling/tearing as forming occurs in a relatively uncontrolled manner as the tool and moulded material entry into the forming cavity will exert considerable forces. Additionally, the material is heated just prior to entering the mould tool to a temperature that makes the material soft and pliable. This can cause the material to deform in the cavities within the tool, producing witness lines and areas of surface deconsolidation which can protrude into the overmoulded elements.

Two-step processing requires the insert to be formed and trimmed first, before overmoulding, and therefore requires the expense of a forming tool, press and cutting system such as a water-jet cutting machine in addition to the injection moulding machine. The advantage however, is that precisely controlled forming can be achieved, that avoids wrinkling and tearing of the insert material, especially if the forming process is simulated first using software such as Aniform’s Virtual Forming software <https://aniform.com>

10 | TECHNICAL SUPPORT

Victrex 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 in-depth and responsive technical services can be critical for success.

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



WORLD HEADQUARTERS

Victrex plc
Hillhouse International
Thornton Cleveleys
Lancashire FY5 4QD
United Kingdom

TEL + (44) 1253 897700

JAPAN

Victrex Japan, Inc.
Mita Kokusai Building
Annex 4-28, Mita 1-chome
Minato-ku
Tokyo 108-0073
Japan

TEL + 81 (0)3 5427 4650

Follow us on social media!



or visit our website: victrex.com

AMERICAS

Victrex USA Inc
300 Conshohocken State Road
Suite 120 West Conshohocken,
PA 19428 USA

TEL + (1) 800-VICTREX
TEL + (1) 484 342 6001

CHINA

Victrex High-Performance
Materials (Shanghai) Co Ltd
Part B Building G
No. 1688 Zhuanxing Road
Xinzhuang Industry Park
Shanghai 201108
China

TEL + (86) 21 6113 6900

EUROPE

Victrex Europa GmbH
Langgasse 16
65719 Hofheim/Ts.
Germany

TEL + (49) 6192 96490

SOUTH KOREA

Victrex Korea
14th floor Superior Tower
528, Teheran-ro
Gangnam-gu
Seoul 06181
Korea

TEL +(82) 2 2182 1200

About Victrex

Victrex is an innovative world leader in high performance polymer solutions, focused on the strategic markets of automotive, aerospace, energy (including manufacturing & engineering), electronics and medical. Every day, millions of people use products and applications, which contain our materials – from smart phones, aeroplanes and cars to oil and gas operations and medical devices. With over 40 years' experience, we develop world leading solutions in PEEK and PAEK-based polymers, semi-finished and finished parts which shape future performance for our customers and our markets, and drive value for our shareholders. Find out more at www.victrex.com

VICTREX™, 450G™, LMPAEK™, and the Triangle Device are trademarks of Victrex and its group of companies.

© Victrex plc 2020 - updated 2025