



Componentes estruturais híbridos em **VICTREX®PEEK**

Voando mais leve, economizando combustível

November 13th , 2014

Feiplar
Ricardo Ehlike

Agenda

- Victrex Introduction
- What is VICTREX® PEEK?
- Victrex Product Portfolio
- Take a PEEK into Aerospace
- Composite solutions comparison
- Processing alternatives
- New hybrid technologies
- Open Discussion



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World Leader in PEEK Polymer Solutions

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Your Partner VICTREX

35 Years

PEEK Polymer Innovation + Experience

Technology Centers

Shanghai • Tokyo • Hillhouse

> 650 Employees

In 30 Countries

60 scientists, engineers and technicians

Technical support across 30 countries

4,250 Tons

Production Capacity Increasing to 7,150 tons in 2015

London Stock Exchange



Global Organisation



UK



China



Japan

Take a PEEK into Aerospace



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Victrex: Aligned with the Aerospace Industry

Assembly speed, simplification and cost improvements are critical

Major OEMs have significant backorders for next generation aircraft

Improving fuel efficiency through weight reductions is necessary

Rising fuel costs and environmental effects such as CO₂ emissions are major challenges

Longer service life and reliability are required

Airlines expect their investments to be safe with minimal maintenance requirements for 30+ years

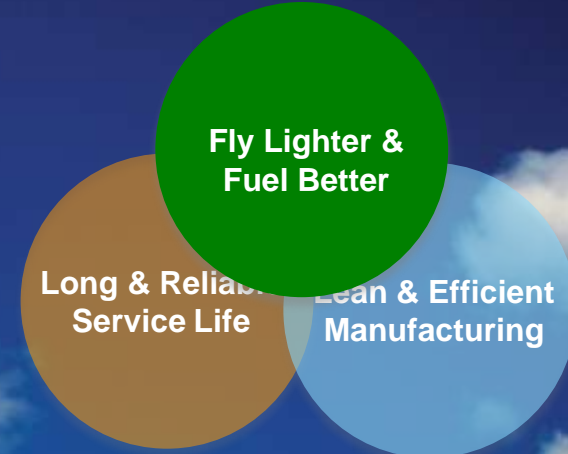


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Fly Lighter and Fuel Better with VICTREX® PEEK



Improve Fuel Burns and Save Millions of Dollars in Fuel Costs

VICTREX PEEK is up to 70% lighter than traditional aerospace materials

Replacing 15,000 aluminum clamps = up to \$10,500 per year in fuel savings
A fleet of 500 would **save up to \$5.25 million per year in fuel costs**

Replacing thermal acoustic blankets using PVF film = up to \$6,600 per year in fuel savings
A fleet of 500 would **save up to \$3.3 million per year in fuel costs**

Replacing 100 meters of metal tubing = up to \$3,300 per year in fuel savings
A fleet of 500 would **save up to \$1.65 million per in fuel costs**

VICTREX PEEK - Lightweight Solutions for Increasing Fuel Efficiency

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HIGH PERFORMANCE PEEK POLYMERS

What is PEEK?



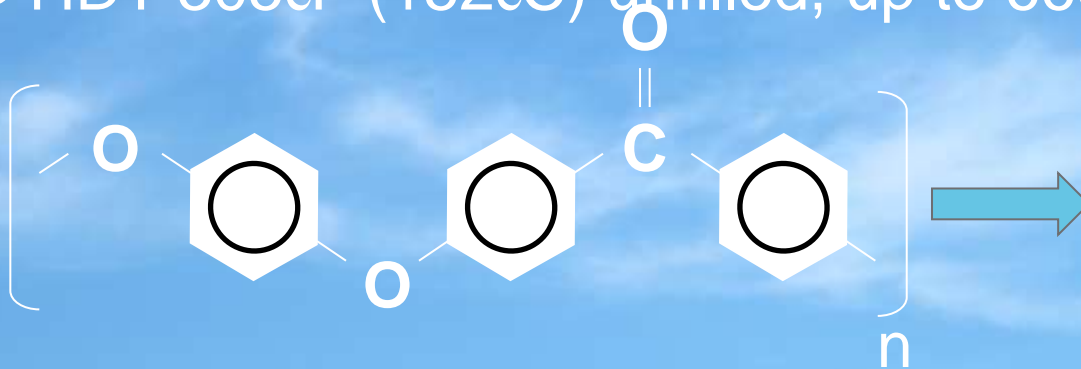
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PEEK - Polyetheretherketone

- Different viscosity grades - 90, 150, 381, 450, 650
- Granule/pellet, powder, and fine powder forms
- T_g 289°F (143°C), T_m 649°F (343°C)
- HDT 305°F (152°C) unfilled, up to 660°F (349°C) filled



Polymer Pyramid

Thermoplastics

Commodity Thermoplastics

PE PMMA
 PVC PVA
 PP PVDC
 PS PET
 ABS etc..

Engineering Thermoplastics

Commodity ETP

PA
 POM
 PC
 PPE
 PBT

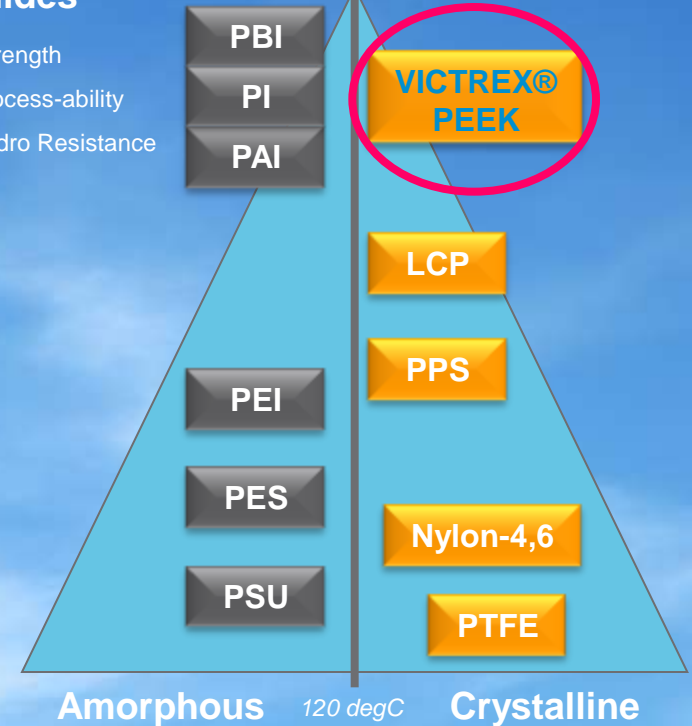
Super ETP

PSU
 PES
 PPS
 PAI
PEEK
 PEI
 PI
 LCP

Polyimides

- High Strength
- Poor Process-ability
- Poor Hydro Resistance

Heat Resistance
 300 degC +



- Transparency
- Good Formability
- Relatively Poor Chem Resistance
- Poor on Fatigue

- Opaque
- Good Chem Resistance
- Resistant to Stress Cracking
- Good on Fatigue

Victrex Product Portfolio

victrex[®]
HIGH PERFORMANCE PEEK POLYMERS



Composites
Made with VICTREX[®] PEEK polymer



victrex pipes[®]



victrex[®]

aptiv.
VICTREX[®] PEEK FILM TECHNOLOGY



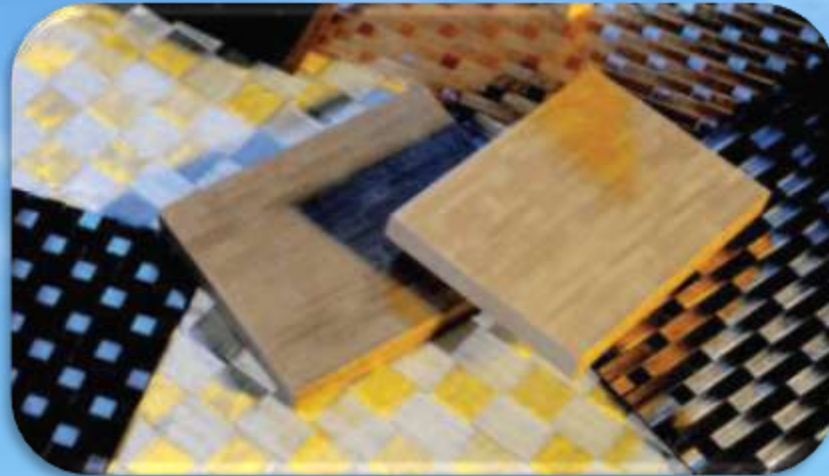
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VICTREX® PEEK Composites



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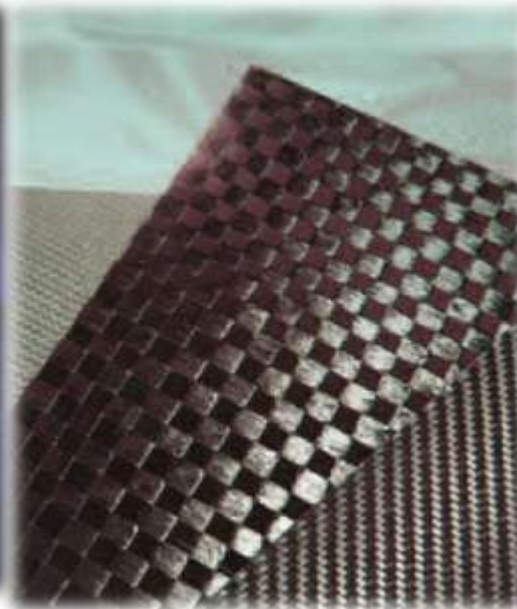
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Thermoplastic Prepregs

Formats



**Unidirectional Tape
(TenCate)**



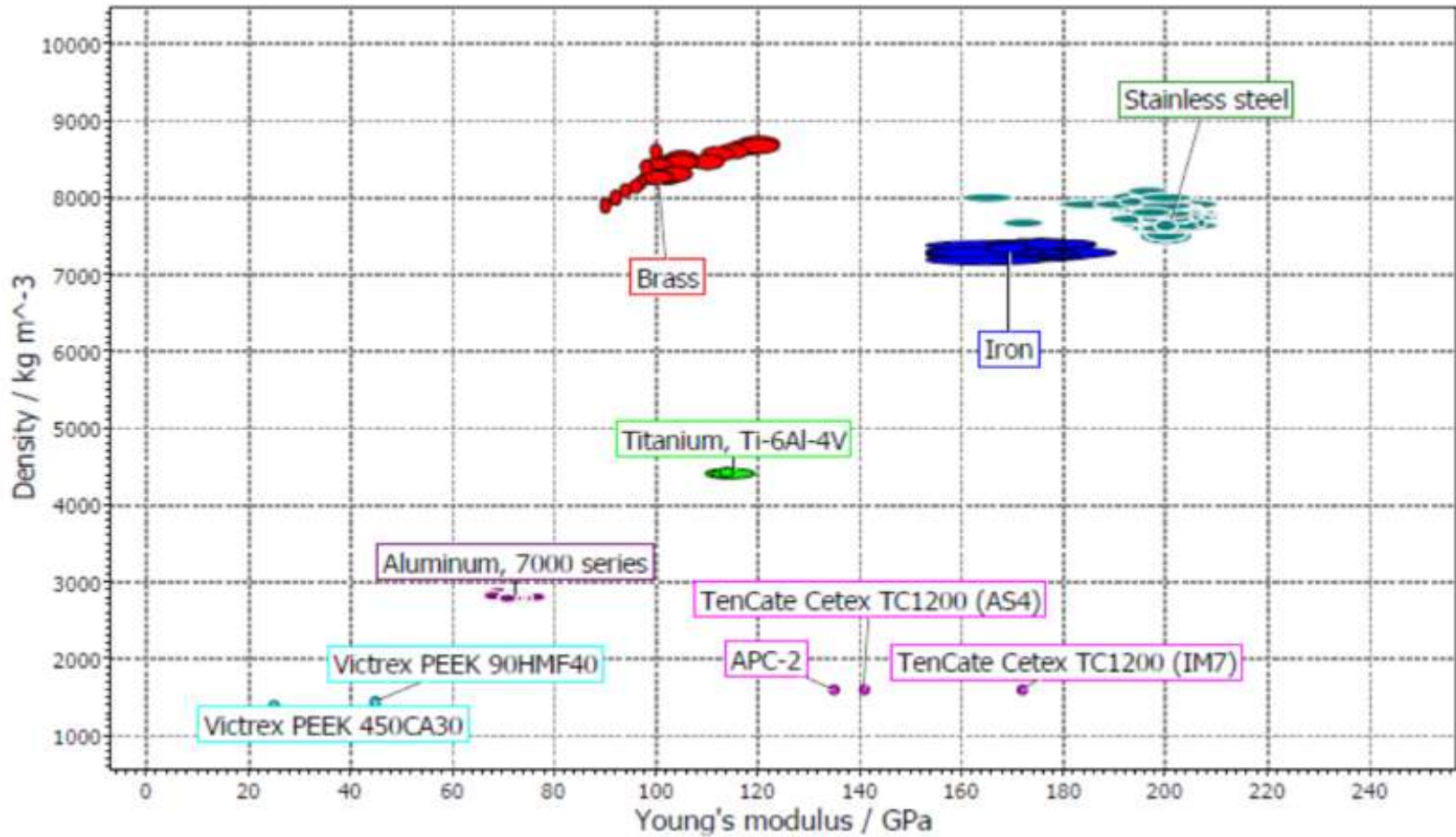
**Carbon Fabric
(Porcher Industries)**



**Profiles
(Suprem SA)**

Performance Overview

Mapping



PEEK Composite vs. Metal

Overview

Add Value

- **30 – 60% weight savings**
- **Corrosion/chemical resistance**
- 4x higher fatigue resistance vs. Al
- 5x higher specific strength vs. Al
- 5x higher specific stiffness vs. Al

Add Value

- Low coefficient of friction
- Vibration/noise damping
- **Thermal insulation**

- Thermal expansion
 - In x-y plane better
- Thermal resistance
- Impact resistance

- Conductivity
- Cost vs. Al
- **Damage detection**

Keep Part Working

Potential Hurdle

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PEEK Composite vs. Thermoset

Overview

Add Value

- Chemical resistance
- **Impact resistance**
- **Fatigue performance**
- FST properties

Add Value

- Recyclability
- **Faster processing**
- **Out-of-Autoclave**
- **In-Situ**
- Longer shelf-life

- Stiffness and strength
- Thermal expansion

- Natural tack
- **Large scale processing**
- **Market acceptance**
- Production infrastructure

Keep Part Working

Potential Hurdle

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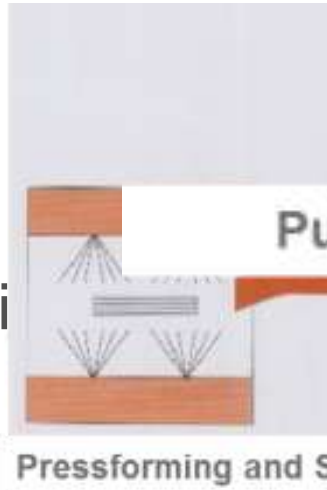
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Processing

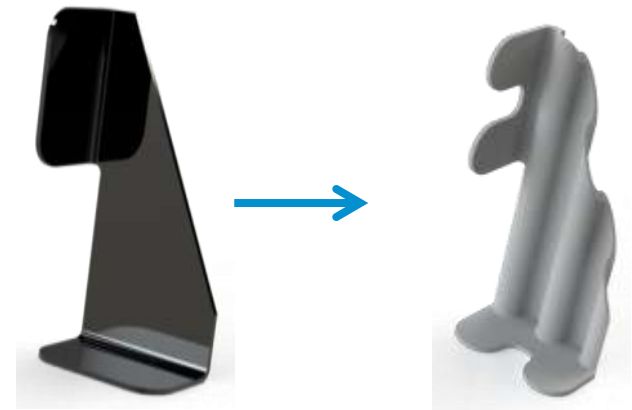
- Injection molding (high modulus fiber)
- Compression moulding
- Compression Flow Moulding
- Pressforming and Stamping
- Autoclave
- Pulltrusion
- Tape placement/winding
- Hybrid moulding



IM - Improving the Design

VICTREX® PAEK Brackets

- Curved non-linear surfaces
 - Concave and convex surfaces
 - Increased stiffness
 - Improved torsional performance
- Weight reductions
 - Hollow sections
- New VICTREX PAEK-based polymer
 - Reduced processing costs



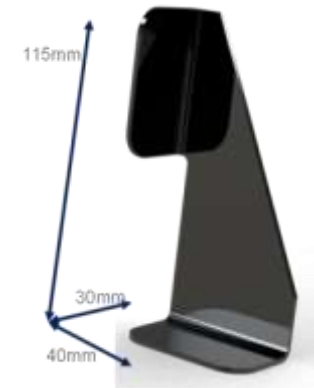
Bracket Design	Maximum Deflection / mm		Weight / g
	side load	rear load	
plain (PPS Laminate)	35.6	1.7	20.51
wave (VICTREX 90HMF40)	4.9	2.4 (in tab)	20.15

100N applied load

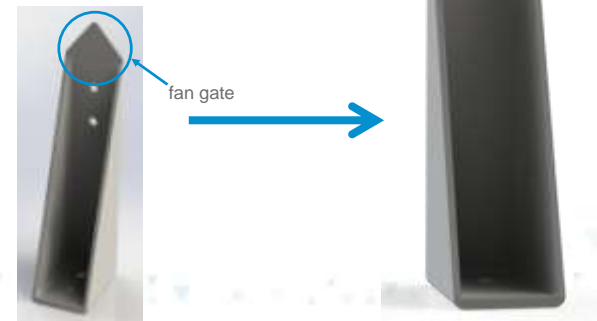
Performance Comparison

VICTREX® PAEK Brackets

- Simplify the design
- Design for injection molding
- Fan gate
 - Generate uniform flow
- Uniform flow
 - Uniform fiber orientation
- Uniform fiber orientation
 - Flatter surfaces



vs.





Performance Comparison

VICTREX® PAEK Brackets

Property	90HMF40	PPS laminate
Manufacture	✓	✓

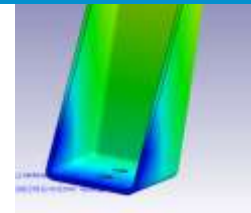


Applied Force / N	Deflection / mm	
	90HMF40	PPS Laminate
50	0.16	0.84
100	0.32	1.67
150	0.48	2.51

**Loaded VICTREX® PAEK Injection-Molded Brackets Work when...
Properly Designed
Maximizing the Benefit of the Anisotropy**

**Take Advantage of Lower Part Costs using VICTREX® PEEK...
90HMF40
150CA30 & 450CA30**

Mechanical Performance	✓	✗
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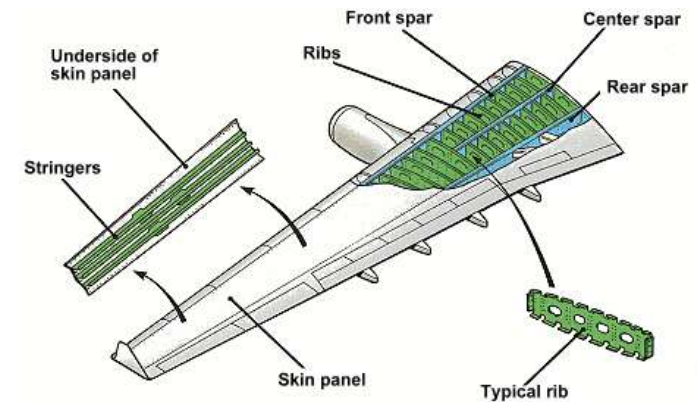


Moldex 3D filling analysis

CM - Structural Attachments

Case Study

- Product
 - PEEK/AS4 carbon fiber tape
- Process
 - Chopped tape molding
 - Carbon-fiber reinforced laminate compression molding
- Application areas
 - Fuselage/wing/engine brackets, clips, ribs
- Weight reduction
 - 40-60% lighter than metal
 - Up to \$22,000 annual fuel savings per plane



Composite Fasteners

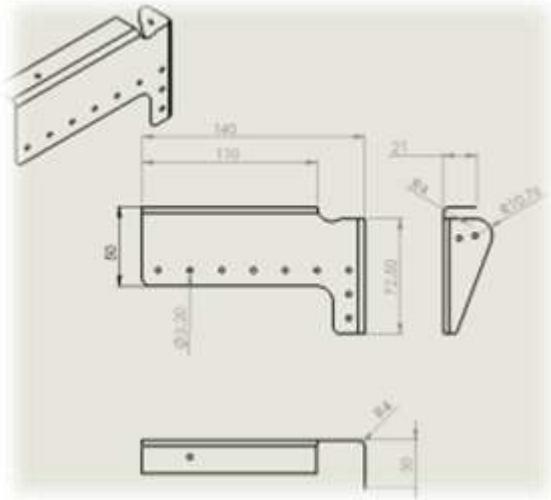
- Fly lighter and fuel better
 - 40% weight savings vs. aluminum
 - 67% weight savings vs. titanium
 - 80% weight savings vs. steel
- Long and reliable service life
 - Contact corrosion resistance
 - Improved vibration dampening
 - Electrical and thermal insulation
 - High fatigue resistance



(courtesy of Click Bond)

PF/S - Composite Bracket

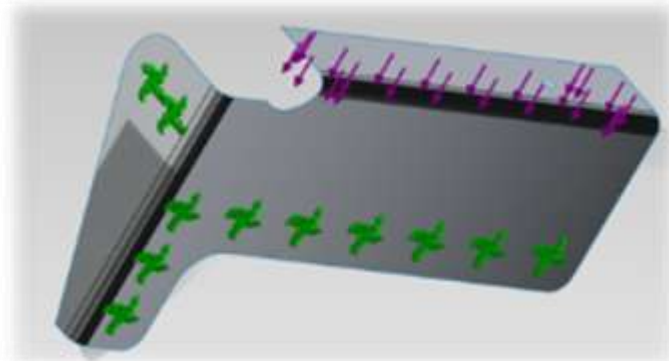
Light weighting Case Study



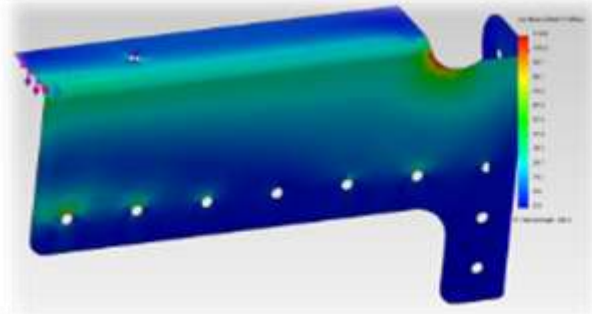
Aluminum 2024-T4 – 1.6mm thick



PEEK Composite – 0.9mm thick (3-ply)



Load Scenario



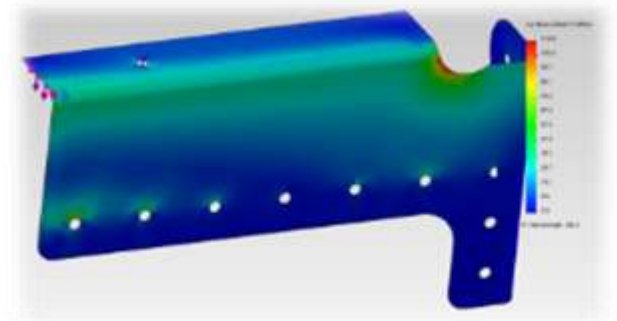
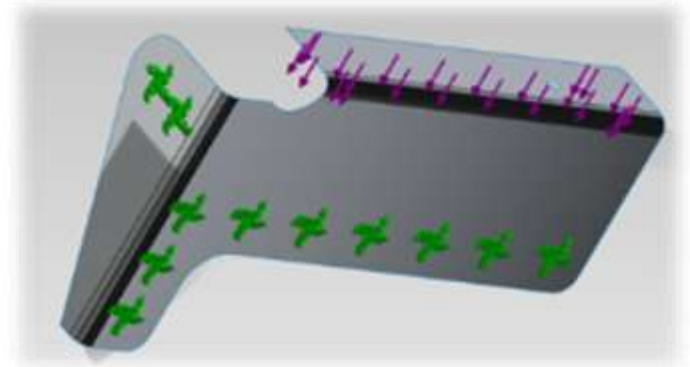
Stress Levels

74% Weight Savings

Bracket Development

Light weighting Case Study

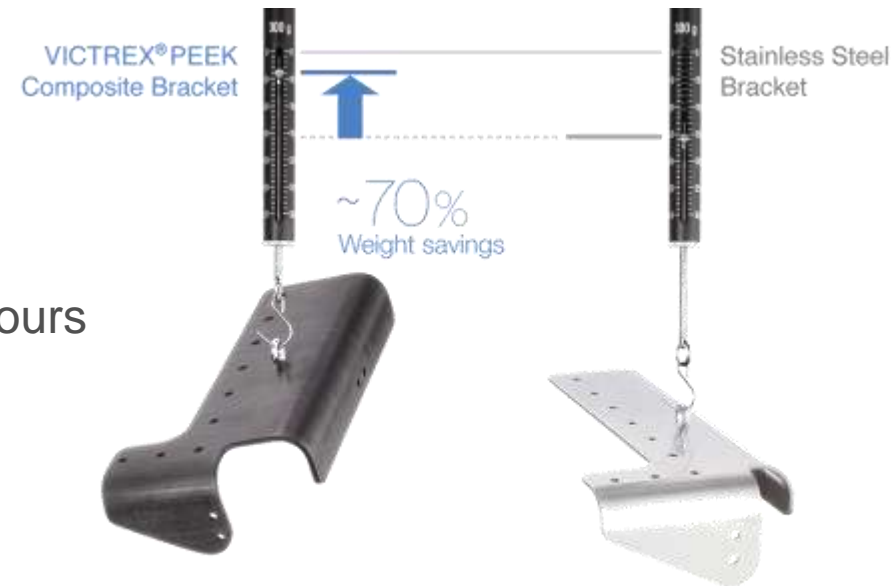
- 4 brackets from common materials
 - Aluminum
 - Titanium
 - Stainless steel
 - PEEK/AS4 composite
- Loading and stress
 - Thicknesses optimized at equivalent loading
 - Fatigue-life model and cycles-to-failure



Bracket Development

Light weighting Case Study

- Weight results
 - Aluminum = 77.2 g
 - Titanium = 68.3 g
 - Stainless steel = 185.1 g
 - PEEK composite = 44.4 g
- NADCAP-certified data
 - Testing at 204°C (400°F) for 1,000 hours
 - Mechanical properties
 - Creep performance
 - Fatigue performance



Joining Technologies

Thermoplastic Composites

- Fusion techniques
 - Ultrasonic welding
 - Laser welding
 - Fillet welding
 - Induction welding
 - Resistance welding
- Adhesive bonding
 - Requires surface treatment
- Mechanical joining



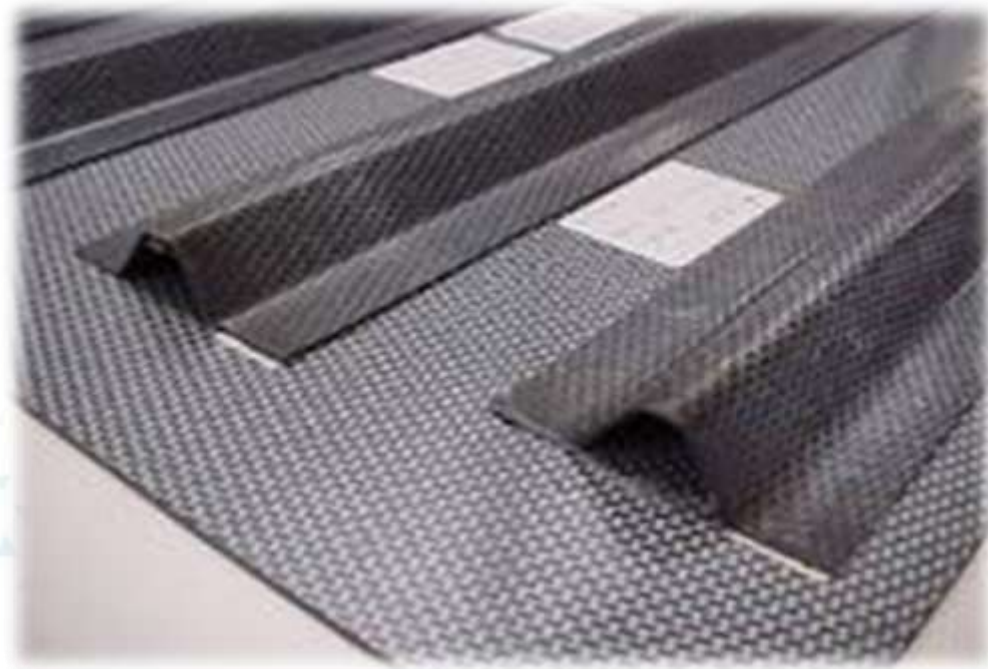
Part Manufacturing

Thermoplastic Composites

- Process becoming increasingly automated
- Cycle time advantages
 - Robotic tape-laying arm



- Alternative solution
 - Panels, beams, and clips
- Sub-component welding
 - Slightly more complex procedure
 - Quality assurance of welds
- Many techniques
 - Ultrasonic
 - Laser
 - Induction
 - Thermal
 - Friction





New Hybrid Molding Technologies

● Drivers

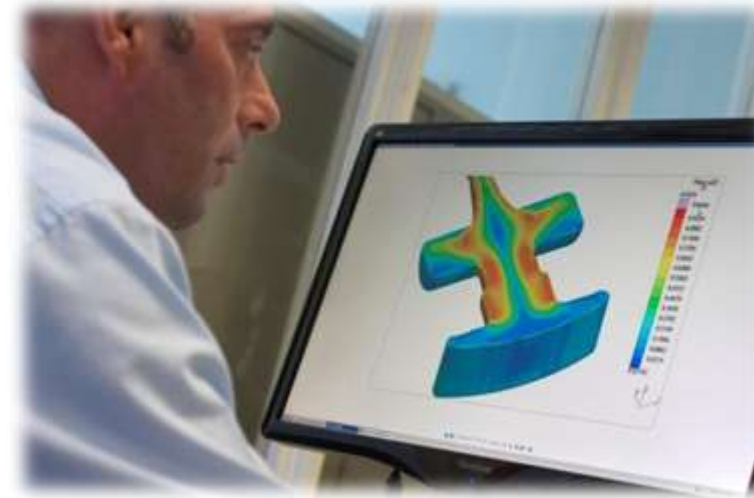
- Manufacture of complex shape parts
- Reduction in recurring costs
- Geometrical optimization
- Functional integration
- Improved mechanical performance
- Improved damage tolerance
- Ease of processing

● Applications

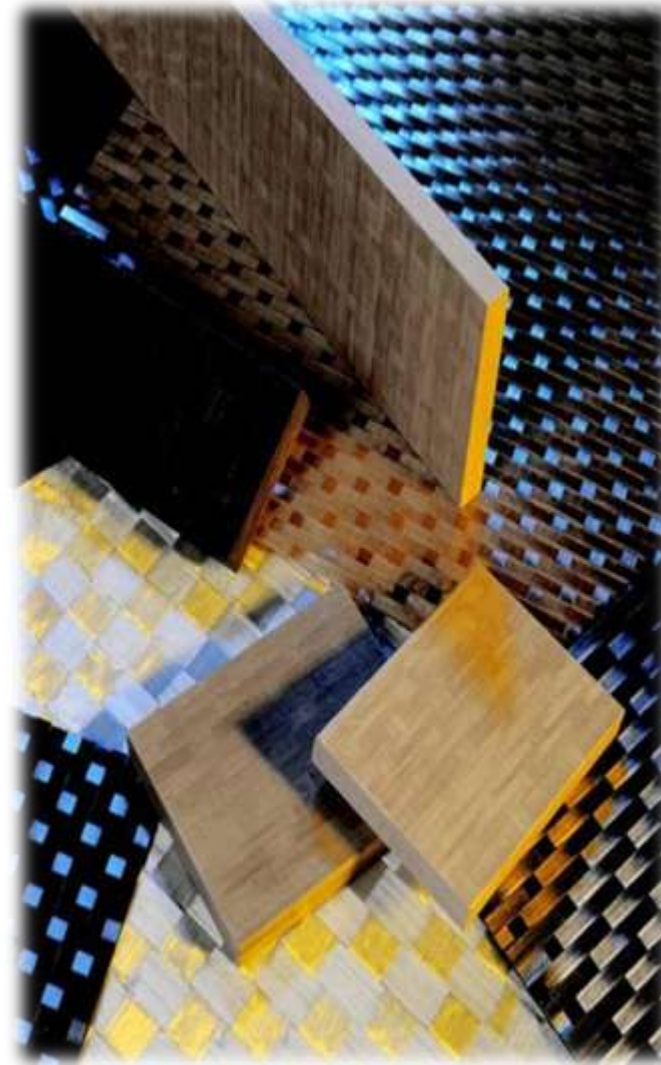
- Cleats, clips, brackets, window frames

● Approach

- Investigate hybrid technology opportunities for complex-shaped structural parts



- Hybrid materials
 - Overmolded metal
 - Overmolded composite technologies
- Existing composites technology
 - Melt the matrix in the composite
 - Form to shape
 - Injection mold
- New composites technology
 - Pre-cut/formed 'cold' composite
 - Insert into molding tool and overmold



Overmolded Metal

VICTREX® PAEK Solutions

- Dual clutch transmission shift fork
 - 65% weight reduction (338g vs. 131g)



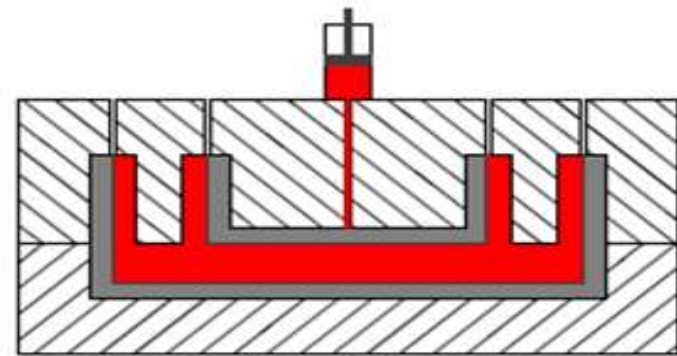
Current shift fork with steel and plastic

**PEEK shift fork with
two steel parts needed for function**

Overmolded Composite

Current Technologies

- State-of-the-art solution
 - Polyamide and polypropylene

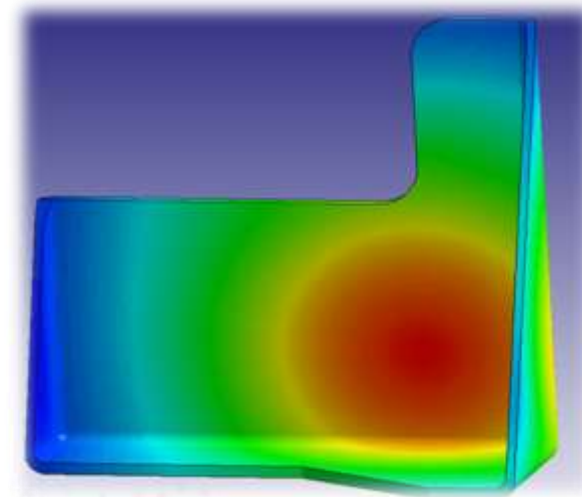
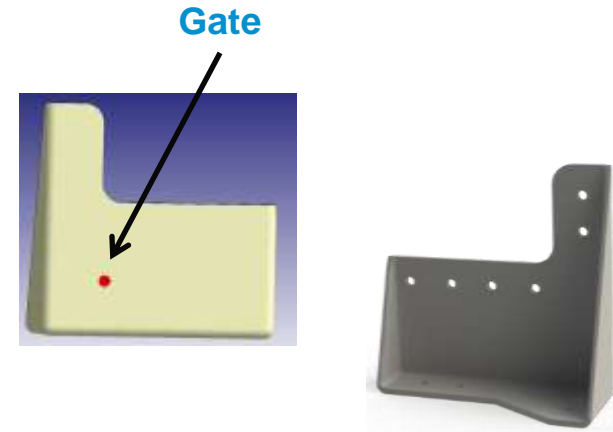


- Continuous fibre (fabric) insert (grey)
- Short fibre filler (red)

Filling Analysis

VICTREX® PAEK Brackets

- Typical bracket
 - Gate position specified by software
 - Radial flow from the gate
 - Complex fiber orientation
- Orientation pattern
 - Different levels of shrinkage in different directions
 - Distortion of the component
 - Variation in mechanical properties



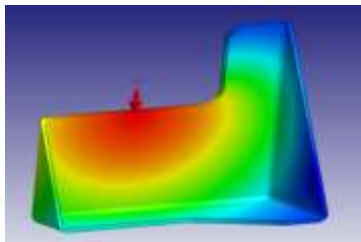
Moldex 3D R12

Alternative Gating

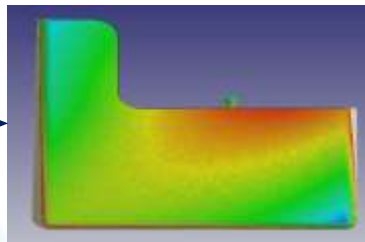
VICTREX® PAEK Brackets

- Change the gate position
 - Changes fiber orientation pattern
 - Influence flatness and mechanical properties

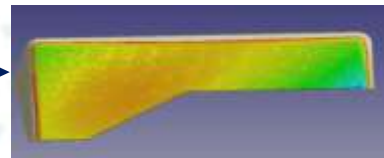
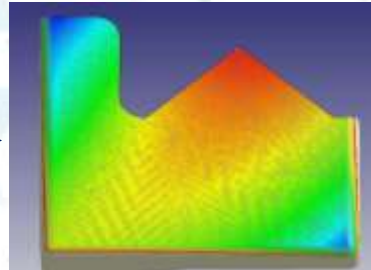
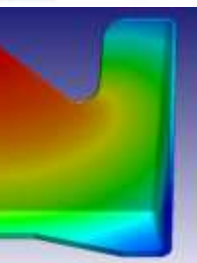
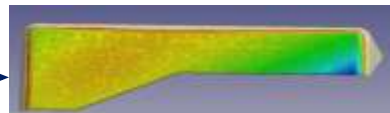
Filling



Flatness – Z plane

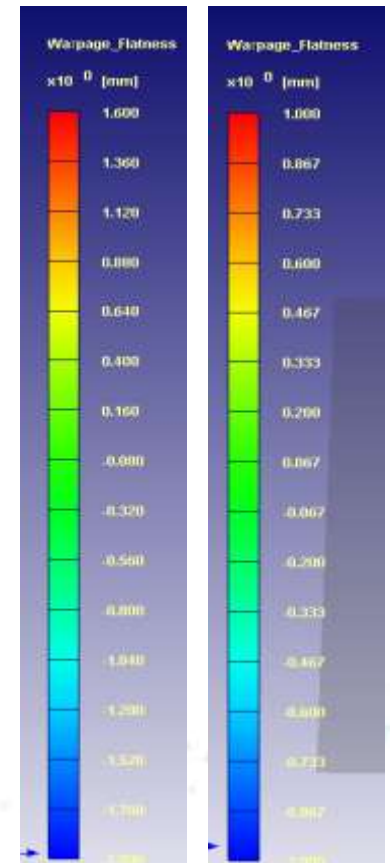


Flatness – Y plane



Moldex 3D R12

Scaling
Z Y



Overmolding Principles

VICTREX® PAEK Solutions

- PEEK-on-PEEK composite
 - Molding and bonding not possible unless composite is fully melted
- New VICTREX PAEK-based polymer
 - Combined with Victrex molding material is unique
- **PEEK-on-New PAEK-based polymer composite**
 - **Molding and bonding is possible using pre-heated composite**

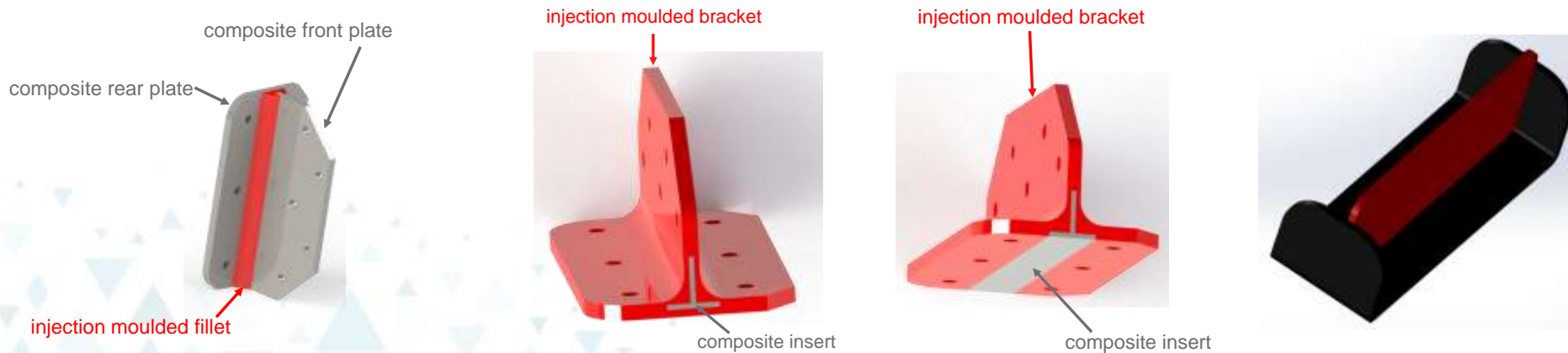


Overmolding Applications

VICTREX® PAEK Solutions

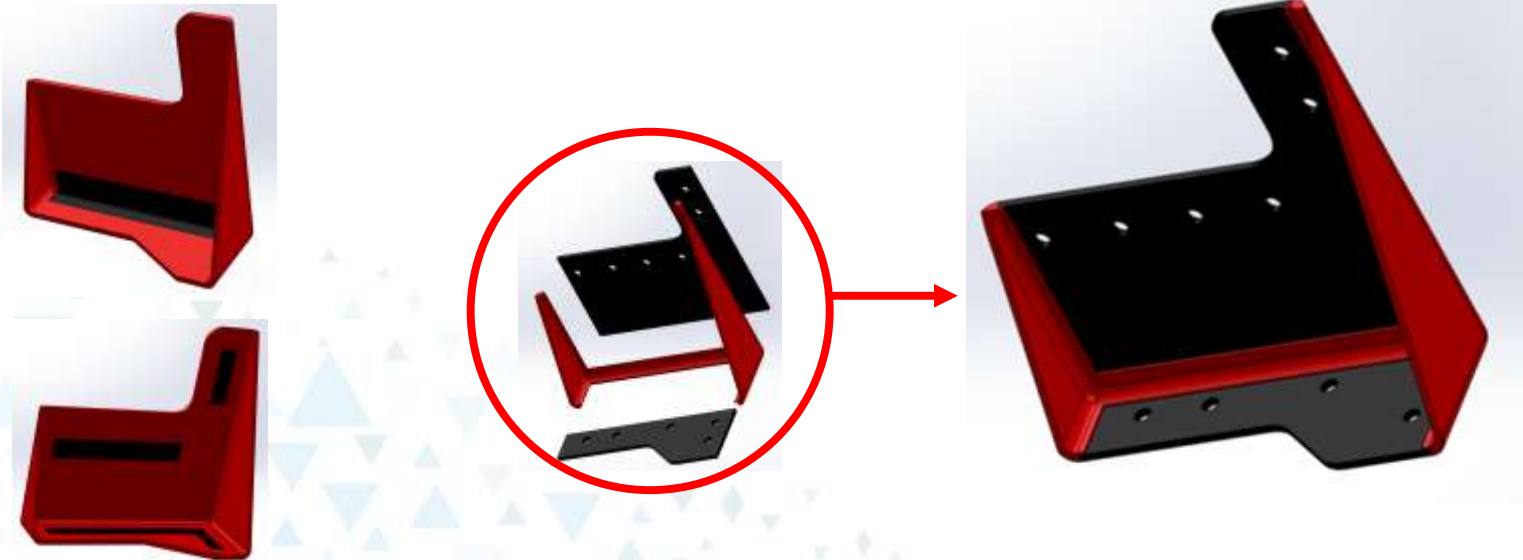
● Brackets

- Composite insert(s) based on new VICTREX PAEK-based polymer
- Injection-molded components based on standard grades
- Mold onto VICTREX PAEK-based laminates



Red – VICTREX PEEK injection molding grade
 Grey/black – New VICTREX PAEK-based polymer

- VICTREX PAEK hybrid brackets work in loaded applications with proper designs
- Take advantage of lower part costs using...
 - 90HMF40
 - New VICTREX PAEK-based polymer

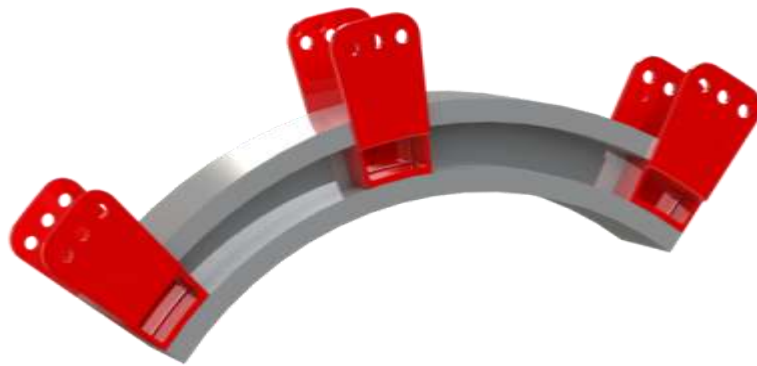


Red – VICTREX PEEK injection molding grade
Grey/black – New VICTREX PAEK-based polymer

Fuselage Structures

VICTREX® PAEK Solutions

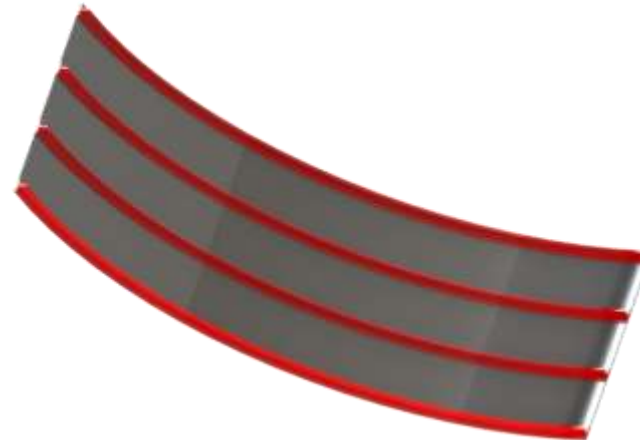
- Potential for hybrid VICTREX PAEK technologies is ENDLESS!



Beams with integral molded brackets



Window frame



Panels with integral molded stringers

Red – VICTREX PEEK injection molding grade
Grey/black – New VICTREX PAEK-based polymer

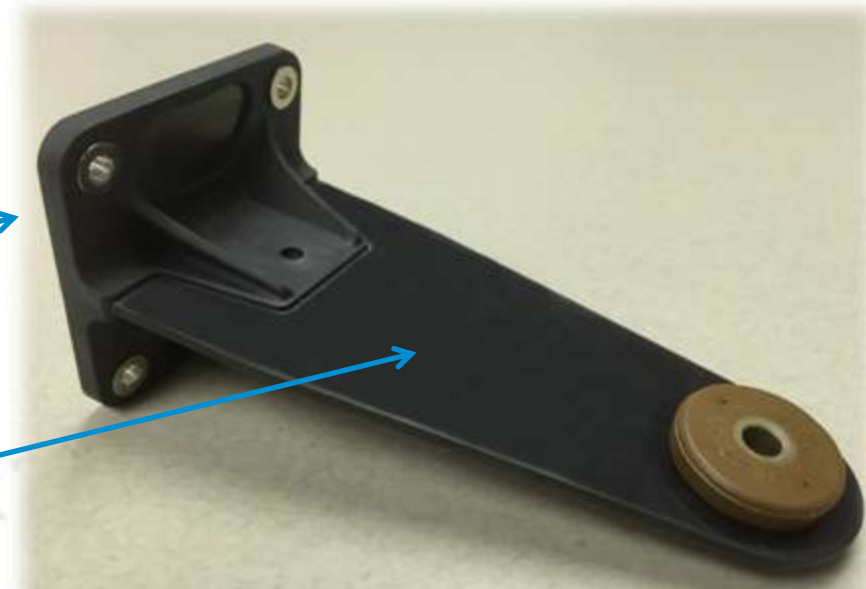
Hybrid Bracket

Case Study

- Joint development with Tri-Mack Plastics Manufacturing Corp.
- Benefits
 - 60% lighter than metal and thermoset solutions
 - Manufactured in minutes vs. hours for thermosets
 - Lower processing costs due to lower processing temperature
 - Equivalent/better strength, stiffness and fatigue vs. stainless steel and titanium

VICTREX PEEK injection molding grade

New VICTREX PAEK-based composite



- Technological advancements
 - Manufacture of complex shaped parts
 - Reductions in recurring costs
 - Geometrical optimization
 - Reduced part count
 - Functional integration
 - Improved mechanical performance
 - Improved damage tolerance
 - Ease of processing
 - Lower part costs



Rest Assured – VICTREX® PEEK is Proven

25+ year track record in the aerospace industry

More than **15,000** aircraft and growing
rely on VICTREX PEEK solutions



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PASSION • INNOVATION • PERFORMANCE

Your Partner in the Future of Flight

VICTREX® PEEK Polymer Solutions

- Lean and Efficient Manufacturing
- Fly Lighter and Fuel Better
- Long and Reliable Service Life
- Security of Supply
- Meets Specifications
- Proven Track Record





Thank You!



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