Polyetheretherketone (PEEK)

Description

Image

Caption

1. Cervical cage made from PEEK with a modulus very close to that of bone and excellent toughness and fatigue resistance. © Eisertech, LLC 2. Complex PEEK injection part for Oil & Gas and automotive industry. © MING-LI Precision Steel Molds CO.

The material

Polyetheretherketone (PEEK) is a high-performance thermoplastic, meaning that - among thermoplastics - it has exceptionally high stiffness, strength and resistance to heat. This comes at a price: PEEK is 50 times more expensive than PP, and 10 to 20 times more than nylon. This limits it use to applications in which technical performance is paramount.

Composition (summary)

(O-(C6H4)-O-(C6H4)-C(O)-(C6H4))n

General properties

Density		81.2	- 82.4	lb/ft^3
Price	*	42.8	- 47.2	USD/lb
Date first used		1975		

Mechanical properties

Young's modulus	*	0.544	- 0.573	10^6 psi
Shear modulus	*	0.197	- 0.207	10^6 psi
Bulk modulus		0.783	- 0.827	10^6 psi
Poisson's ratio	*	0.378	- 0.393	
Yield strength (elastic limit)		9.43	- 13.8	ksi
Tensile strength		10.2	- 14.9	ksi
Compressive strength		10.4	- 15.2	ksi
Elongation		30	- 150	% strain
Hardness - Vickers		26.1	- 28.5	HV
Fatigue strength at 10^7 cycles	*	4.08	- 5.98	ksi
Fracture toughness	*	2.49	- 3.91	ksi.in^0.5
Mechanical loss coefficient (tan delta)	*	0.0101	- 0.0106	

Thermal properties

Melting point		611	- 655	°F
Glass temperature		289	- 390	°F
Maximum service temperature		462	- 500	°F
Minimum service temperature	*	-190	- -99.7	°F
Thermal conductor or insulator?		Good insulator		

Thermal conductivity	*	0.139	-	0.15	BTU.ft/h.ft^2.F
Specific heat capacity	*	0.345	-	0.358	BTU/lb.°F
Thermal expansion coefficient		40	-	108	µstrain/°F

Electrical properties

Electrical conductor or insulator?		Good insulator			
Electrical resistivity		3.3e21	-	3e22	µohm.cm
Dielectric constant (relative permittivity)		3.1	-	3.3	
Dissipation factor (dielectric loss tangent)	*	0.0015	-	0.0017	
Dielectric strength (dielectric breakdown)	*	423	-	508	V/mil

Optical properties

Transparency	Opaque

Processability

Castability	1	-	2
Moldability	4	-	5
Machinability	3	-	4
Weldability	5		

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Excellent
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Acceptable
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Excellent
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent

Silicone fluids	Excellent
Toluene	Excellent
Turpentine	Acceptable
Vegetable oils (general)	Excellent
White spirit	Acceptable

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Acceptable
Acetone	Excellent
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Limited use
O2 (oxygen gas)	Limited use
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Self-extinguishing

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 3.07e4	-	3.38e4	kcal/lb
CO2 footprint, primary production	* 22	-	24.3	lb/lb
Water usage	* 64	-	192	gal(US)/lb

Material processing: energy

Polymer extrusion energy	* 657	-	725	kcal/lb
Polymer molding energy	* 2.74e3	-	3.02e3	kcal/lb
Coarse machining energy (per unit wt removed)	* 148	-	165	kcal/lb
Fine machining energy (per unit wt removed)	* 1.02e3	-	1.14e3	kcal/lb
Grinding energy (per unit wt removed)	* 1.99e3	-	2.21e3	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.454	-	0.502	lb/lb
Polymer molding CO2	* 1.9	-	2.09	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.103	-	0.114	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.709	-	0.784	lb/lb

Grinding CO2 (per unit wt removed)	* 1.38	-	1.53	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 1.04e4	-	1.15e4	kcal/lb
CO2 footprint, recycling	* 7.47	-	8.25	lb/lb
Recycle fraction in current supply	* 1	-	2	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 3.3e3	-	3.47e3	kcal/lb
Combustion CO2	* 2.83	-	2.97	lb/lb
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

Peek can be recycled if unreinforced and uncontaminated.

Recycle mark

Supporting information

Design guidelines

PEEK can be used up to temperatures of 300 C for a short time and 250 C for a long time. It offers high hardness and therefore abrasion resistance; it has excellent fatigue properties and good creep resistance. It has a low coefficient of friction, a low flammability, and low smoke emission during combustion. Chemical resistance is very good (and retained to the same high temperatures) and there is very low water absorption. Unreinforced PEEK offers the highest elongation and toughness of all PEEK grades. Glass-reinforcement significantly reduces the expansion rate and increases the flexural modulus. PEEK can be used as a matrix in continuous carbon fiber composites.
Carbon-reinforced PEEK has high compressive strength and stiffness and low expansion coefficient, and its thermal conductivity can be 3 times better than pure PEEK. Processing PEEK is not difficult, despite its high heat resistance, provided the temperature is held at 375 C. It can be injection molded, extruded (into rod, profile, film or wire insulation) and compression molded. It is available as extruded film and sheet in thicknesses from approximately 0.001" to 0.040".

Technical notes

PEEK is a semi-crystalline thermoplastic. It has a high glass transition temperature (Tg = 150 C) and can be used well above this temperature, but its stiffness falls and its expansion coefficient rises above Tg.

Typical uses

Electrical connectors, hot water meters, F1 engine components, valve and bearing components, wire and cable coatings, film and filament for specialized applications, pump wear rings, electrical housing, bushings, bearings.

Tradenames

Ketron PEEK, Thermocomp, Victrex

Links

Reference

ProcessUniverse

Producers