AKROTEK® PK – the polyketone with universal qualifications

AKRO-PLASTIC

Think Polyamide

AKRO-PLASTIC GmbH
Member of the Feddersen Group

Once again available, this aliphatic polyketone (PK) fills many gaps in the polymer offering with its universal qualification for a wide range of applications. The renaissance of this polymer came about in 2004 with an environmental program aimed at reducing greenhouse gases. The comonomer is CO (carbon monoxide), an industrial “waste” gas, which forms an unusual product when bonding with the polymer. The terpolymer, which forms the basis of most AKROTEK® PK formulations when using the monomers ethylene and propylene, currently has the greatest significance.

AKRO-PLASTIC GmbH, a compounder based in Niederzissen, Germany, produces two product families from this base polymer (HM = normal flow and VM = very easy-flowing), from non-reinforced to high-glass-fibre-reinforced standards, from flameretardant to carbon-fibre-reinforced custom grades.

The outstanding characteristic properties of this portfolio include:

- excellent dynamic resilience
- good barrier properties
- good tribological properties
- phenomenal resistance to chemicals
- good hydrolysis resistance
- shorter cycle times

The information on the following pages provides specifics on each of these advantages.

Typical values for natural color material at 23° C	Test specification	Test method
Mechanical properties		
Tensile modulus	1 mm/min	ISO 527-1/2
Yield stress[1]/Tensile stress at break	5 mm/min	ISO 527-1/2
Elongation at break	5 mm/min	ISO 527-1/2
Flexural modulus	2 mm/min	ISO 178
Flexural stress	2 mm/min	ISO 178
Charpy impact strength	23 °C	ISO 179-1/1eU
Charpy impact strength	-30 °C	ISO 179-1/1eU
Charpy notched impact strength	23 °C	ISO 179-1/1eA
Charpy-notched impact strength	-30 °C	ISO 179-1/1eA
Elektrical properties		
Spec. volume resistance		IEC 60093
Spec. surface resistance		IEC 60093
Thermical properties		
Melting point	DSC, 10 K/min	ISO 11357-1/3
Heat distortion temperature, HDT/A	1.8 MPa	ISO 75-2
Heat distortion temperature, HDT/B	0.45 MPa	ISO 75-2
Flammability		
Flammability acc.UL 94	1.6 mm	UL 94
Rate acc. FMVSS 302 (<100 mm/min)	> 1 mm thickness	FMVSS 302
GWFI	2 mm	IEC 60695-12
General Properties		
Density	23 °C	ISO 1183
Content reinforcement		ISO 1172
Moisture absorption	70 °C/62 % r.h.	ISO 1110
Processing		
Flowability	Flow spiral[2]	AKRO
Processing shrinkage, flow		ISO 294-4
Processing shrinkage, transverse		ISO 294-4

AKROTEK® PK

Unit	PK-HM (4773)		PK-VM (4774)		PK-HM GF 15 (4707)		PK-VM GF 15 (4705)	
	d.a.m.	cond.	d.a.m.	cond.	d.a.m.	cond.	d.a.m.	cond.
MPa	1,400	1,400	1,500	1,500	4,400	4,100	4,500	4,300
MPa	60/	60/	60/	60/	/90	/80	/90	/80
%	>300	>300	>200	>200	4.5	4.5	3.5	3.5
MPa	1,600	1,200	1,900	1,500	4,500		4,500	
MPa	60	60	70	70	130		130	
kJ/m²	n.b.	n.b.	n.b.	n.b.	55	55	50	45
kJ/m²	n.b.		n.b.		55		50	
kJ/m²	15	15	10	10	15	15	10	10
kJ/m²	4.5		3.5		7		7	
Ohm x m	10^{13}	10^{10}	10^{13}	10^{10}	10^{13}	10^{10}	10^{13}	10^{10}
Ohm	10^{13}	10^{10}	10^{13}	10^{10}	10^{12}	10^{10}	10^{12}	10^{10}
	d.a.m.		d.a.m.		d.a.m.		d.a.m.	
°C	220		220		220		220	
°C	85				210		210	
°C					220		220	
Class	HB		HB		HB		HB	
mm/min	+		+		+		+	
°C					650		650	
g/cm³	1.24		1.24		1.35		1.35	
%	-		-		15		15	
%	0.8 – 0.9		0.8 – 0.9		0.7 – 0.8		0.7 – 0.8	
mm	580		1,550		500		1,100	
%	1.8		1.8		1.2		0.7	
%	2.1		1.8		1.1		1.0	

"cond." test values = conditioned, measured on test specimens stored according to ISO 1110
"d.a.m." = dry as moulded test values = residual moisture content < 0.10 %
n.b. = not broken + = passed

PK-HM GF 30 (4709)		PK-VM GF 30 (4706)		PK-HM GF 50 (4741)		PK-VM GF 50 (4905)	
d.a.m.	cond.	d.a.m.	cond.	d.a.m.	cond.	d.a.m.	cond.
7,500	7,100	8,000	7,700	12,500	11,500	13,500	
/130	/120	/115	/100	/140	/130	/170	
3	3	2	2	2	2	1,5	
8,300		8,200		13,900			
180		165		225			
60	50	45	35	65	50	60	
60							
15	15	15	15	20	20	15	
10							
10^{13}	10^{10}	10^{13}	10^{10}	10^{13}	10^{10}	10^{13}	10^{10}
10^{12}	10^{10}	10^{12}	10^{10}	10^{12}	10^{10}	10^{12}	10^{10}
d.a.m.		d.a.m.		d.a.m.		d.a.m.	
220		220		220		220	
215		215		220		220	
220							
HB		HB		HB		HB	
+							
1.48		1.48		1.65		1.65	
30		30		50		50	
0.6 – 0.7		0.6 – 0.7		0.4 – 0.5		0.4 – 0.5	
350		980		110			
0.7		0.4		0.7		0.3	
1.3		1.0		1.2		0.6	

[1] = yield stress and elongation at break: test speed 50 mm/min for non-reinforced compounds
[2] = mould temperature: 80 °C, melt temperature: 250 °C, injection pressure: 750 bar, cross section of flow spiral: 7 mm x 3.5 mm

AKROTEK® PK

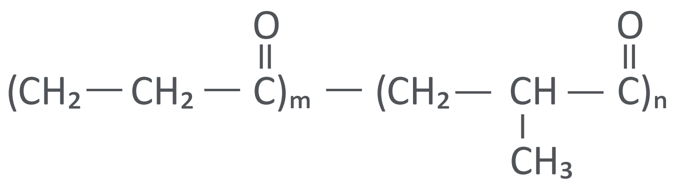
Unit	PK-VM GF 60 (4923)		PK-VM GF 30 TM (4955)		PK-VM TM (4954)		PK-HM CF 12 (4927)	
	d.a.m.	cond.	d.a.m.	cond.	d.a.m.	cond.	d.a.m.	cond.
MPa	17,500	17,300	8,300	8,500	1,500	1,500	7,300	
MPa	/180	/175	/135	/125	50/	50/	/95	
%	1.5	1.5	3	3	40	40	3	
MPa			8,700		1,500			
MPa			200		55			
kJ/m²	70	60	65	65	100	90	40	
kJ/m²			65		50			
kJ/m²	20	20	15	15	7	7	10	
kJ/m²			10		3			
Ohm x m	10^{13}	10^{10}	10^{13}	10^{10}	10^{13}	10^{10}		
Ohm	10^{12}	10^{10}	10^{12}	10^{10}	10^{13}	10^{10}	10^{4} – 10^{6}	
	d.a.m.		d.a.m.		d.a.m.		d.a.m.	
°C	220		220		220		220	
°C	215		215		75		215	
°C			220		185			
Class	HB		HB		HB			
mm/min			+		+			
°C			650		650			
g/cm³	1.8		1.6		1.35		1.35	
%	60		30		-		12	
%	0.3 – 0.4		0.5 – 0.6		0.6 – 0.7			
mm	290		700		1,200			
%			0.4		1.3			
%			0.8		1.6			

"cond." test values = conditioned, measured on test specimens stored according to ISO 1110
"d.a.m." = dry as moulded test values = residual moisture content < 0.10 %
n.b. = not broken + = passed

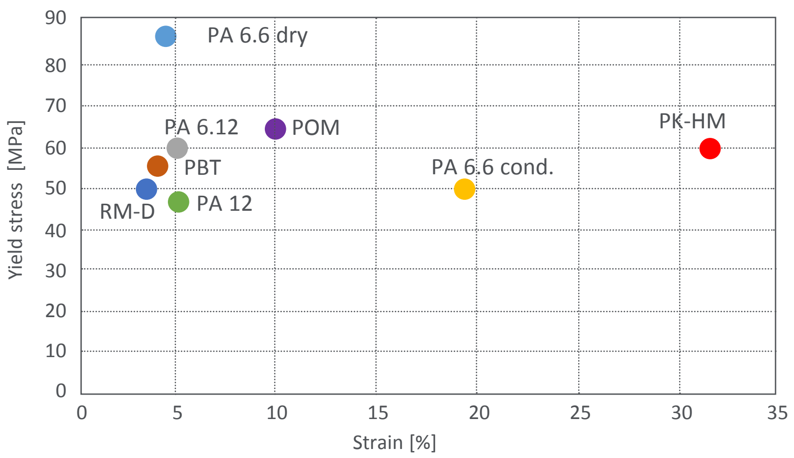
More products of ours can be found here:

Product characterisation

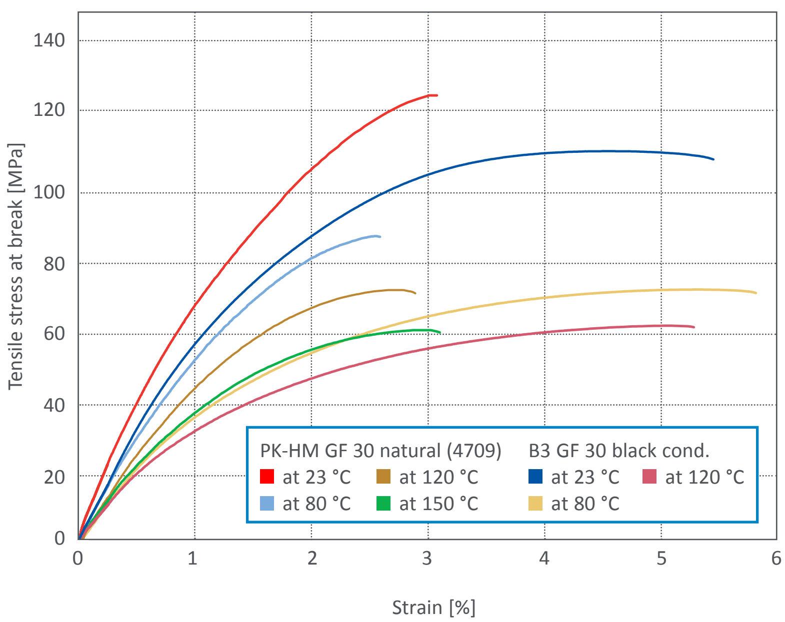
AKROTEK® PK



Mechanical properties (Fig. 1)



Stress strain diagram for different temperatures (Fig. 2)



The special feature in the structure of the polyketone is the co-monomer CO (carbon monoxide), an industrial “waste” gas which can contribute to global warming. When bonded with a polymer, it forms a highly favourable monomer, which is used to produce an unusual product by means of an extremely complex process. The terpolymer, which forms the basis of most AKROTEK® PK formulations when using the monomers ethylene and propylene, currently has the greatest significance.

Polyketone has several properties which no other polymer has in this combination. Freshly injection-moulded polyketone has the greatest yield strain (over 30 %) compared with all other semi-crystalline polymers (see Fig. 1), virtually independently of moisture. This tremendous elasticity gives many components made of AKROTEK® PK a high degree of safety in the design phase.

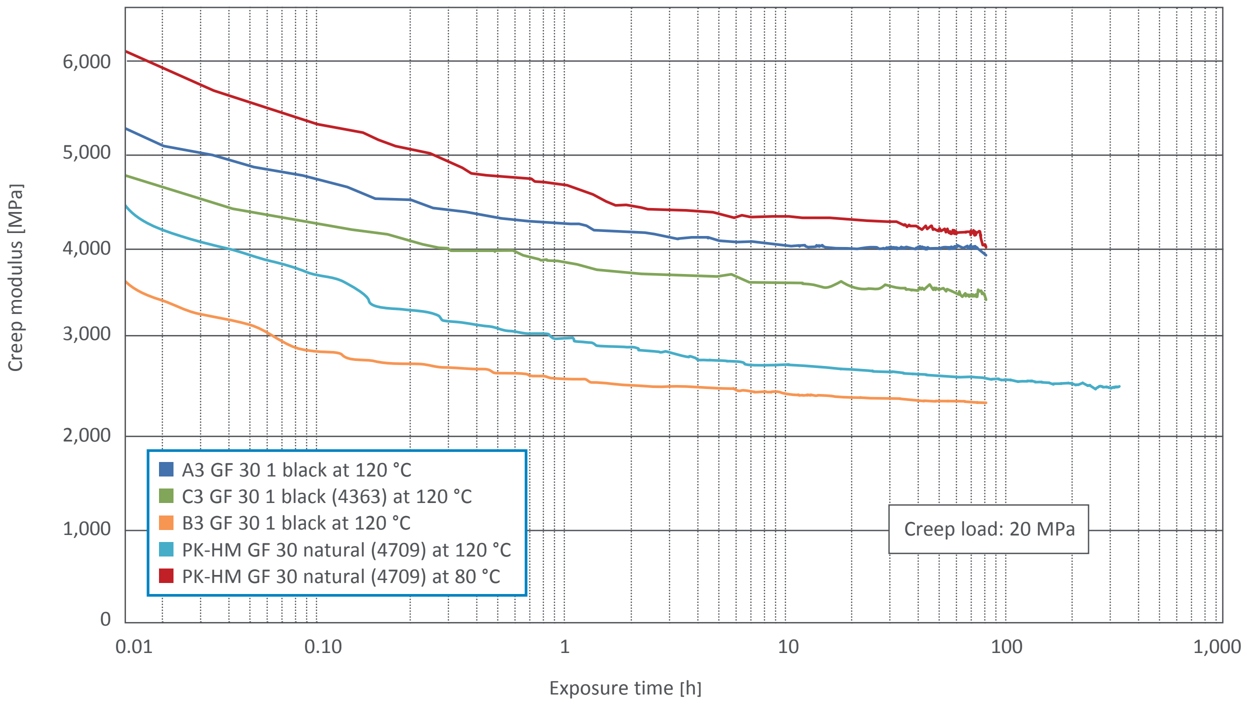
The tensile strength of AKROTEK® PK-HM GF 30 natural (4709) is greater than the conditioned value of AKROMID® B3 GF 30 black at every temperature (see Fig. 2). Thus AKROTEK® PK is particularly well suited for designs which must exhibit constant mechanics even under changing climatic conditions.

A further strength of polyketone, the ability to deform elastically and thus reversibly, results in a product with an extremely low creep tendency in combination with glass fibres.

AKROTEK® PK is available with a glass-fibre content up to 60 %. Such products are able to resist high stresses under strong chemical effects.

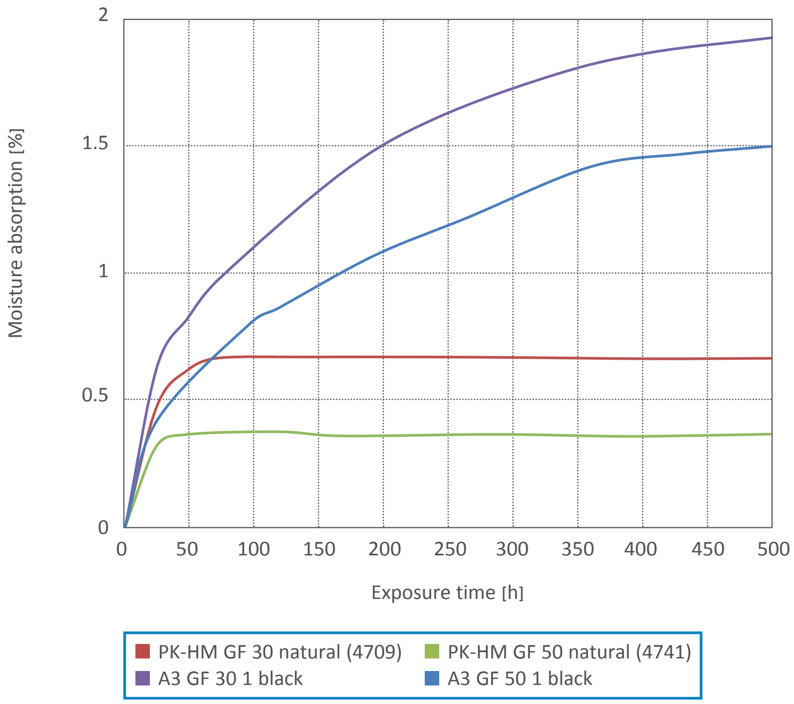
Product characterisation

Creep modulus (Fig. 3)



Moisture absorption (Fig. 4)

Moisture absorption vs. Exposure time
500 h at 70 °C and 62 % rel. humidity following ISO 1110



The creep modulus of AKROTEK® PK (see Fig. 3) at 120 °C and 20 MPa load is above polyamide 6 GF 30. It does not achieve the values of AKROMID® A3 GF 30 and AKROMID® C3 GF 30 under the same test conditions (d.a.m.), however.

Figure 4 shows the time needed by the materials to achieve equilibrium moisture. Polyketone has an inherently low moisture absorption. Tests according to ISO 1110 show that all tested AKROTEK® PK compounds reach their equilibrium moisture after just 2 to 3 days, compared with polyamide 6.6 compounds, which require over 20 days.

Barrier properties

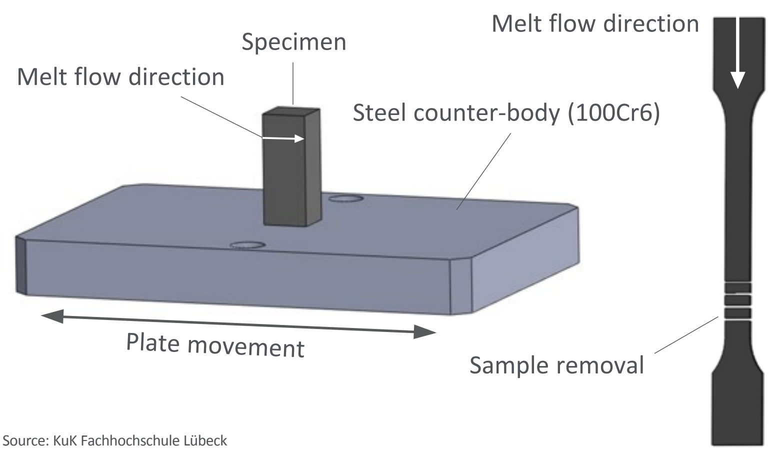
Polymer	Oxygen	Hydrogen
EVOH-F	0.01	3.8
EVOH-S	0.06	11
Barex	0.80	4.5
MXD-6	0.32	-
PVDC	0.15	0.1
PA6	3.6	22
PET	3.5	1.2
PP	160	0.7
HDPE	150	0.4
PS	260	9.0
PK	**0.06**	**11**

Source: Shell

Friction and wear

	Dynamic friction coefficient	Specific wear rate $K*10^{-6}[mm^3/Nm]$
PK-HM natural (4773)	0.52	34
PK-VM TM natural (4954)	0.33	0.8
PK-HM GF 30 natural (4709)	0.50	14.5
PK-VM GF 30 TM natural (4955)	0.44	3.9
POM-Copolymer	0.44	60

Universal tribometer set-up, pin-plate principle (Fig. 5)



Source: KuK Fachhochschule Lübeck

Another highlight of polyketone is its high barrier effect compared with many low-molecular media such as oxygen or fuel. Compared with other barrier materials such as EVOH, PVDC and MXD-6 (see adjacent table), AKROTEK® PK exhibits similarly favourable values. Depending on specific requirements, it is even possible to replace complex multiple layer systems (e.g. multiple layer pipes made of PA 12 and PVDF) with a monosystem using AKROTEK® PK.

We have tested the tribological properties of various AKROTEK® PK grades using a universal tribometer according to the “pin-plate principle”. With this method, a sample taken from a tension test bar is pressed against an oscillating steel plate (100Cr6) (see Fig. 5).

The measured dynamic friction coefficient and specific wear rate show outstanding values with even the standard AKROTEK® PK grades. Our TM (tribologically modified) grades can significantly reduce both wear and the dynamic glide coefficient (see adjacent table).

	PK	POM	PA
PK	-	+++	+
POM	+++	---	+
PA	+	+	--

It may not be possible for design reasons to avoid pairings of similar friction surfaces, AKROTEK® PK shows the least wear of all polymers tested. When different materials are used, a combination with PA is good, and a combination with POM is the best pairing by far.

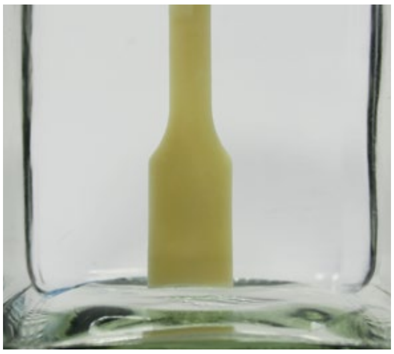
Product characterisation

Battery acid (38 % H_2SO_4)

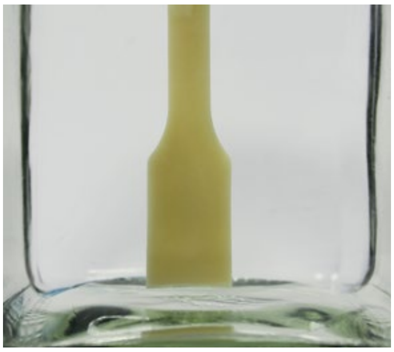
(Fig. 6)

PA 6.6 GF 30

PK-HM GF 30 (4709)



After 24 hours



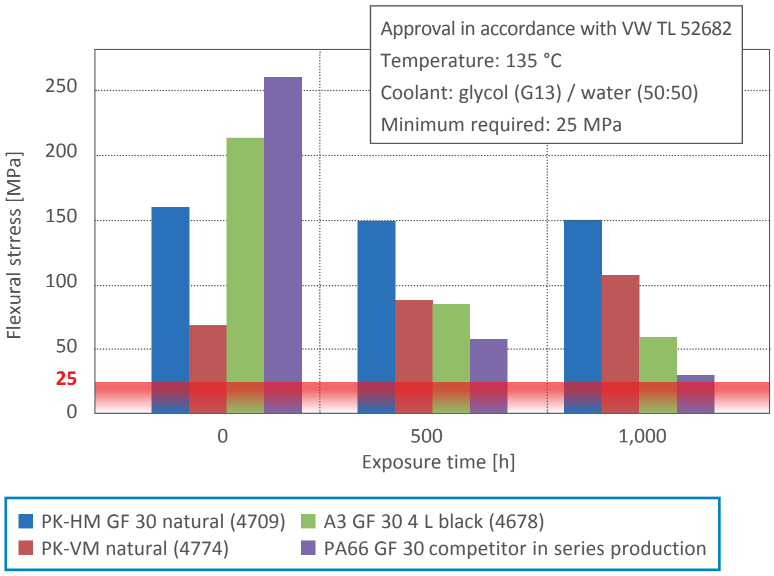
After 48 hours

The chemical resistance of AKROTEK® PK is one of the materials' biggest strengths. It resists corrosion due to weak acids, which typically corrode long-chain polyamides such as PA 12 and PA 6.6 (see image sequence on left). Only light surface discolourations can be observed after 30-day conditioning in 10 % hydrochloric acid, 30 % sulphuric acid or battery acid (see image sequence on right). The elongation at break remains virtually at the starting level, however.

Further information on the media resistance of AKROTEK® PK can be found in the tables on pages 14 and 15.

Watch the video of the test

Hydrolysis resistance (Fig. 7)



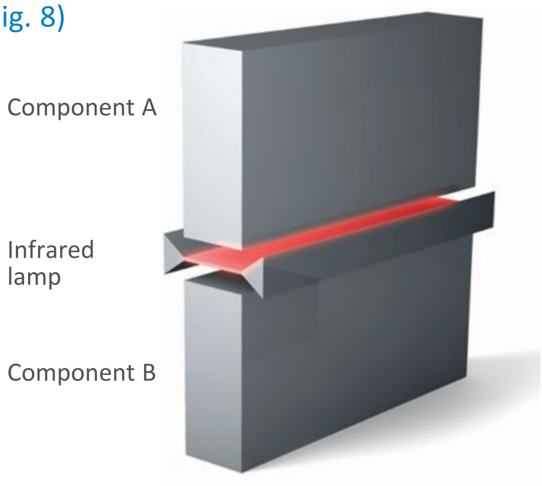
Due to the excellent hydrolysis resistance of AKROTEK® PK, only a brown discolouration on the polymer appears after ageing as per the VW standard (TL 52682) for over 1000 h / 135 °C, compared to a polyamide 6.6 GF 30 HR, as used today as the standard for water tank applications (see Fig. 7). An aged component from this standard generally exhibits full-blown glass fibres. This is not the case with AKROTEK® PK-HM GF 30, since the polymer is not dissolved by the glycol (G13) / water mixture.

Infrared welding is a contact-free welding method (see Fig. 8) in which the components are warmed with an infrared lamp and then welded under joining pressure.

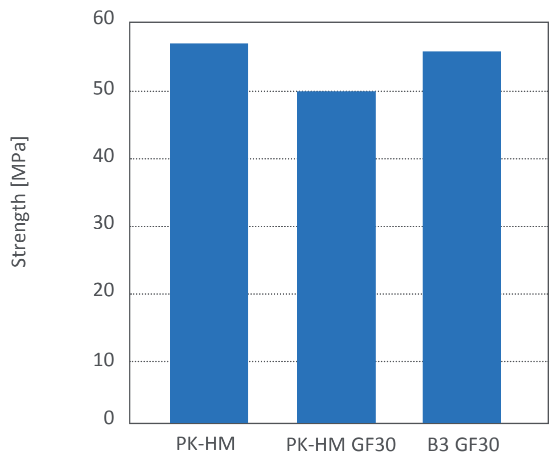
In the infrared welding method, AKROTEK® PK-HM demonstrates welding seam resistances of over 90 % of the initial stability. This extremely high figure enables welded designs with virtually no mechanical weakness in the seam area. The strength of AKROTEK® PK-HM GF 30 is almost at the same level as dry AKROMID® B3 GF 30 (see Fig. 9). Thus nearly 90 % of the polymer strength is achieved with glass-fibre-reinforced polyketone.

Laser welding is also a contact-free welding system that is used for very narrow tolerances of the components to be joined. The shear forces measured on components overlapping with diode-laser-welded components exhibit the same level for both AKROTEK® PK-HM and AKROTEK® PK-HM GF 30, but less than AKROMID® B3 GF 30 (see Fig. 11).

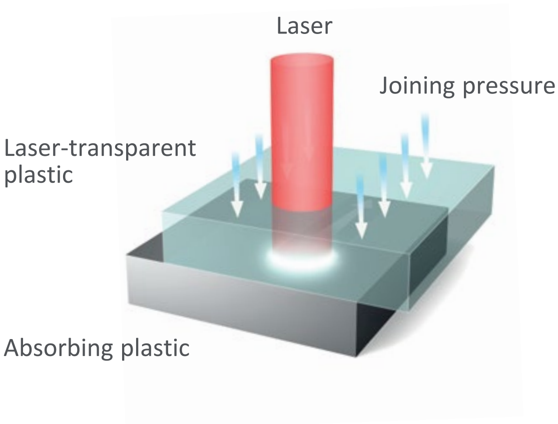
Schematic diagram of infrared welding (Fig. 8)



Weld-seam strength infrared welding (Fig. 9)

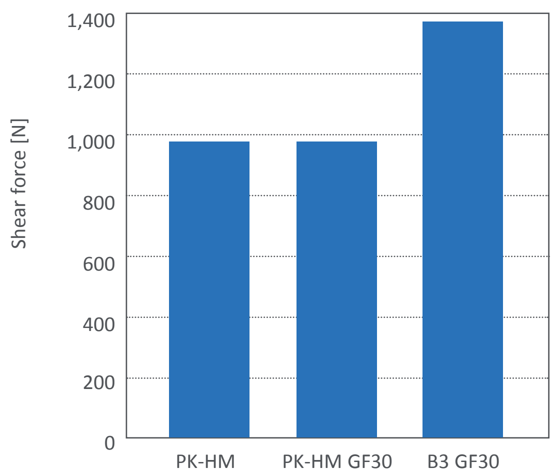


Schematic diagram of laser welding (Fig. 10)



Source: LPKF

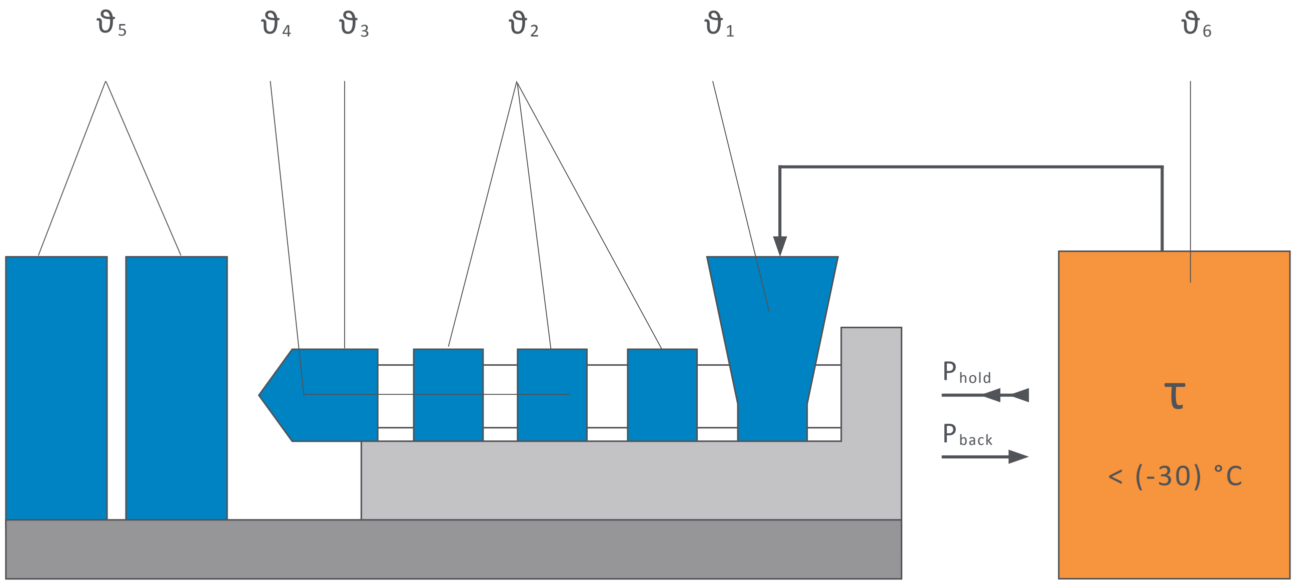
Weld-seam strength laser welding (Fig. 11)



Processing recommendations

AKROTEK® PK can be processed on all injection moulding machines suitable for polyamides with standard screws as recommended by the machine manufacturers.

Please see our recommended settings for machines, tools and driers below:



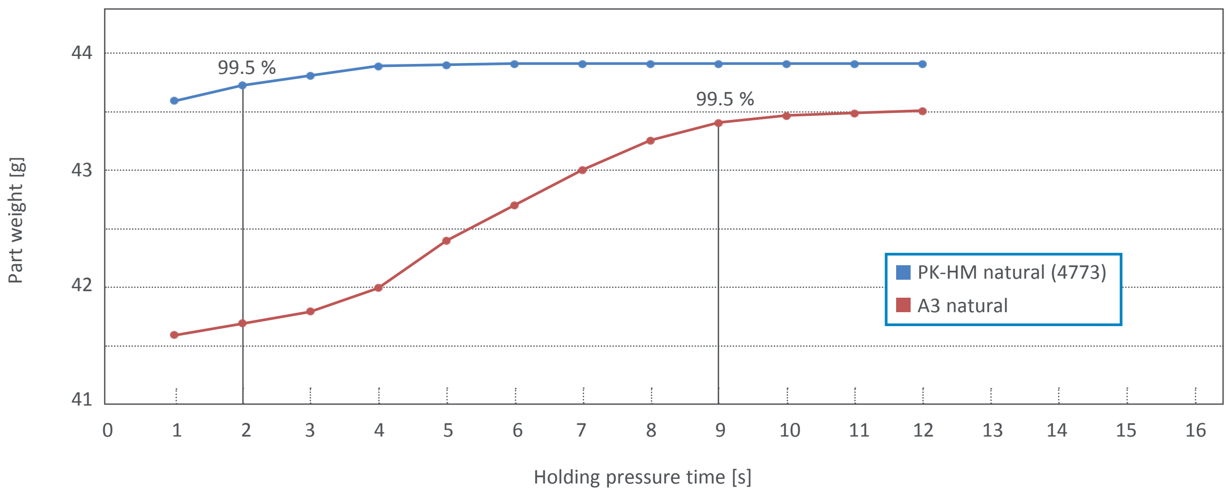
		AKROTEK® PK
Flange	ϑ_1	60 – 80 °C
Sector 1 – Sector 4	ϑ_2	210 – 250 °C
Nozzle	ϑ_3	230 – 250 °C
Melt temperature	ϑ_4	230 – 250 °C
Mould temperaturee	ϑ_5	60 – 80 °C
Drying	ϑ_6	60 °C – 80 °C , up to 4 h
Back pressure, spec.	P_{back}	300 – 800 bar

The specified values are for reference values. For increasing filling contents the higher values should be used.
For drying, we recommend using only dry air or a vacuum dryer. Processing moisture levels between 0.02 and 0.1 % are recommended.
The drying time of freshly-opened bags is up to 4 h. It is recommended to use opened bags completely.
Material processed from silo or boxes requires a minimum drying time of 4 h.
For flame-retardant products the lower values should be used.

Important note:

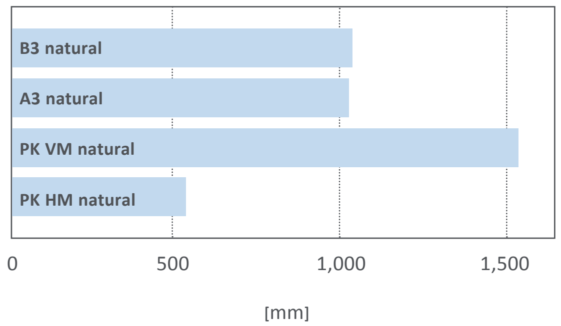
The injection-moulding machine must be rinsed with polyolefins before and after processing of AKROTEK® PK. There is a risk of cross-linking in the event of reactions with POM or amino-rich PA grade and with unsuitable colour masterbatches. Cross-linking is recognisable by the appearance of dark points. If this occurs, rinse immediately with polyolefins!

Sealing-point (Fig. 12)

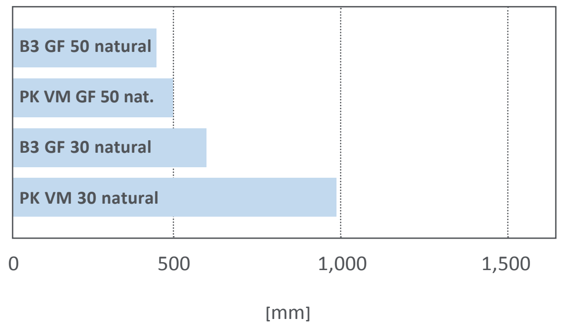


The flowability as well as the crystallisation rate of AKROTEK® PK show a significant advantage over Polyamide 6 and 6.6. A holding time of 2 seconds achieves 99.5 % of maximum possible fill for a tensile test bar mould with a 4 mm wall thickness. Polyamide 6.6, by contrast, requires 9 seconds to achieve 99.5 % of the weight. This demonstrates tremendous potential for shortening cycle times with AKROTEK® PK.

Melt flow spiral AKROTEK® PK non-reinforced



Melt flow spiral AKROTEK® PK reinforced



Recommendations Extrusion		
Feed section	ϑ_E	60 – 100 °C
Extruder sections	ϑ_Z	225 – 240 °C
Melt temperature	ϑ_S	230 – 245 °C
Drying	ϑ_T	60 °C – 80 °C, up to 4 h

Applications

AKROTEK® PK is an absolutely versatile material. The tribological properties favour the production of gear wheels (see Fig. 13) out of AKROTEK® PK-HM TM. In particular with sliding partners out of POM and Polyamide almost wear-free gears can be designed. The high elongation at yield of over 30 % allows high tolerances and thereby a longer life cycle.

Due to possible reaction mechanisms, it is a challenge to colour polyketone. Our colourists at AF-COLOR have taken this issue on by developing several masterbatches and testing these mechanically. All colours tested in Figure 14 achieve a tensile strength and elongation at break of over 90 % of the uncoloured material. We look forward to helping you create your desired colour. The following AF-Color® colours have been used for AKROTEK® PK-HM:

PA 100754 beige
PA 900600 UV white
PA 600960 green
PA 301015 red
PA 950089 black
PA 100889 UV yellow

The following in AKROTEK® PK-HM GF 30:
PA 100754 beige
PA 600960 green
PA 301015 red
PA 950089 black
PA 100889 UV yellow

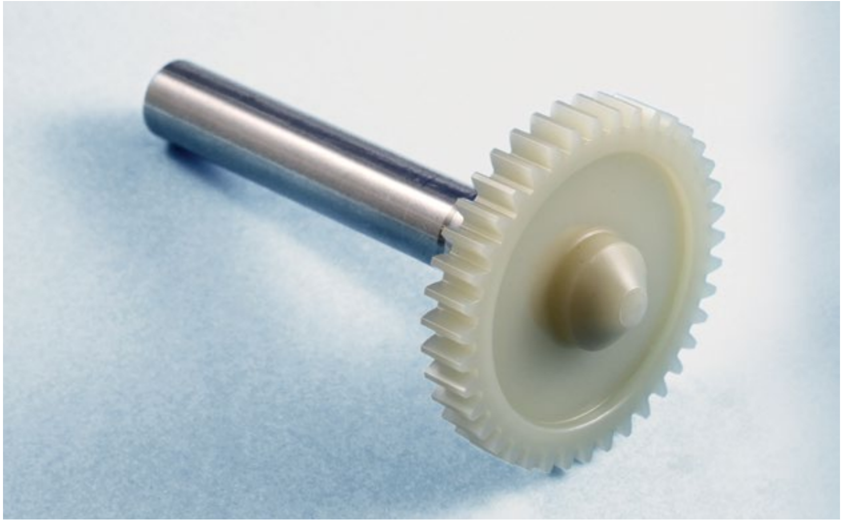


Fig. 13: Gear wheel, Öchsler AG

Fig. 14: Coloured AKROTEK® PK tension rods (non-reinforced)

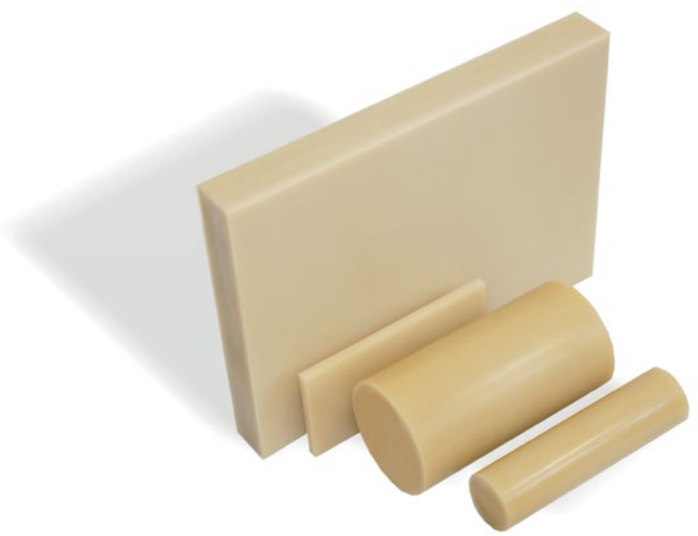


Fig. 15: Semi-finished SUSTAKON part from Röchling Sustaplast KG

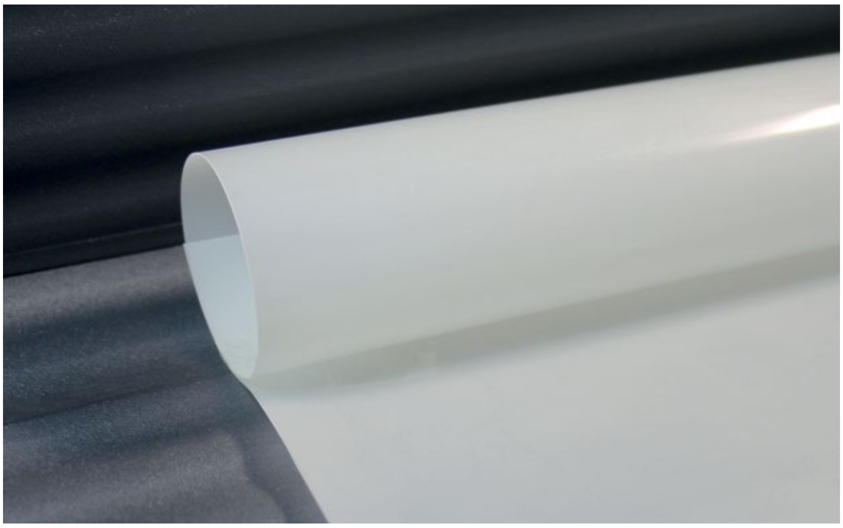


Fig. 16: Flat foil, LITE GmbH

Fig. 17: Supply line produced using the projectile-injection technique, Institut for plastics processing at RWTH Aachen; WIT system: PME Fluidtec GmbH.

Another application area for AKROTEK® PK-HM is film extrusion. Figure 16 shows a film with a thickness of 150 µm and was produced on a cast film line. The film can overtake versatile functions as a barrier layer and has an outstanding welding behavior. The film can be a protection against aggressive media or can be used as a sliding coat.

Its high chemical resistance (see pages 8, 14 and 15) to a wide range of media makes AKROTEK® PK the ideal choice for supply lines. Figure 17 shows a supply line which was produced using the projectile-injection technique (PIT). The material used is AKROTEK® PK-VM, coloured with AF-Color® PA 600960 green. The projectile-injection technique is a method used to manufacture hollow components. With this method, a projectile is forced through the still liquefied plastic, thus forming tube-shaped components with thin walls. This method enables extremely fast cycle times and reliably reproducible thin walls.

Application areas

Industry
- Gear wheels
- Containers
- Valves
- Dowel pins
- Journal bearings
- Hoses
- Cable ties
- Distributors
- Snap-hooks

Automotive industry
- Fuel lines
- Fuel tank containers
- Filters
- Gear wheels
- Wheel covers
- Components for fuel pumps
- Wheel-speed sensors
- Quick connectors
- Wheel caps, etc.

Electronics/ Electrical
- Connectors
- Switches
- Fuse holders
- Socket-outlets
- Connectors
- Housings

Resistance to media

The specifications for chemical resistance are subjective classifications based on resistance analyses as per the standards ISO 175, ISO 11403-3, ISO 4599, ISO 4600, ISO 6252, etc. These specifications should only be used as a basis for an initial evaluation.

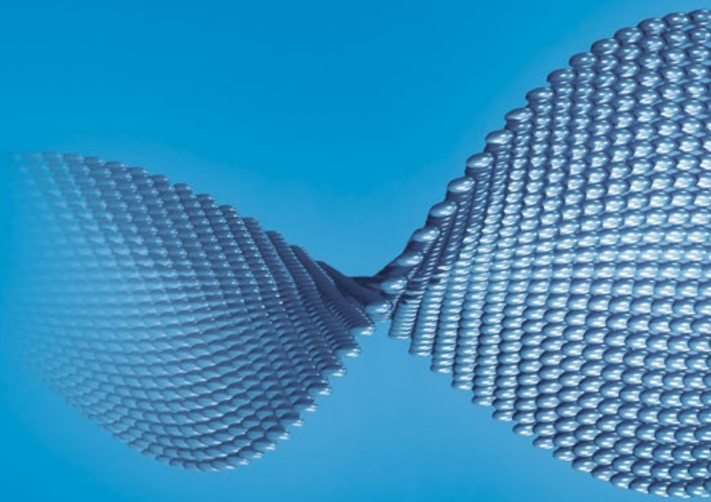
Reagent	Exposure		Yield stress	Surface appearance	Weight	Volume
	Temperature °C	Time	Change in %	Change	Change in %	Change in %
Unleaded gasoline	23	12 months	No change	Slight yellow tone	0	0
	45	12 months	No change	Slight yellow tone	1	3
Gasohol (unleaded, 10 % methanol)	23	12 months	-6	Slight yellow tone	1	0
	45	12 months	-8	yellow	3	5
Gasohol M-85 (unleaded, 15 % methanol)	23	1 month	No change	No change	1	0
	23	12 months	-11	Slight yellow tone	5	3
Methanol	23	1 month	-5	No change	2	1
	23	12 months	-11	No change	2	3
Jet fuel A	23	24 months	No change	No change	0	0
	45	12 months	No change	No change	1	2
MTBE	23	12 months	No change	No change	1	1
Motor oil 10W-40	23	24 months	No change	dark yellow	0	0
	120	6 months	+6	black	0	-1
Chassis lube	23	24 months	No change	yellow	0	0
	120	6 months	No change	black	-1	-1
Automatic transmission fluid	23	24 months	No change	yellow	0	0
	45	12 months	+9	Slight yellow tone	0	0
Brake fluid	23	24 months	No change	brown	0	0
	120	6 months	+10	black	5	5
Hydraulic fluid	23	24 months	No change	No change	0	0
	45	12 months	+11	No change	0	0
Antifreeze, 100 % ethylene glycol	23	24 months	No change	No change	0	0
	120	3 months	-10	dark brown	5	4
Antifreeze 50 %, water 50 %	23	24 months	No change	No change	0	0
	45	12 months	+8	yellow	1	1
Zinc chloride 10 %	23	12 months	-4	yellow	2	3
Calcium chloride 30 %	23	12 months	No change	No change	0	0
Acetone	23	12 months	No change	Slight yellow tone	5	2
	80	12 months	No change	dark yellow	5	5
Butyl acetate	23	12 months	No change	No change	0	0
	80	12 months	+10	dark yellow	2	2

Reagent	Exposure		Yield stress	Surface appearance	Weight	Volume
	Temperature °C	Time	Change in %	Change	Change in %	Change in %
Dichlorethane	23	12 months	-12	No change	0	0
Dimethyl formamide	23	12 months	-10	Slight yellow tone	2	0
	80	6 months	-80	dark brown	Samples swell and slowly dissolve	
Ethanol 95 %	23	12 months	-8	No change	2	1
	65	12 months	No change	Slight yellow tone	2	2
Heptane	23	12 months	No change	No change	0	0
	80	12 months	+21	dark yellow	0	0
Methylethylketone	23	6 months	-4	No change	2	2
Tetrachloroethylene	23	12 months	-8	No change	1	0
	80	6 months	-73	dark brown	3	2
Trichlorethane	23	12 months	No change	No change	1	0
	80	12 months	No change	yellow	5	1
Toluene	23	12 months	No change	No change	1	0
	80	12 months	+10	dark yellow	4	1
Xylene	23	6 months	No change	No change	0	0
Acetic acid 5 %	23	12 months	No change	Slight yellow tone	3	1
	80	6 months	-70	yellow	3	1
Hydrochlorid acid 10 %	23	12 months	No change	dark yellow	2	0
	80	1 month	No change	dark yellow	2	0
Sulphuric acid 5 %	23	12 months	No change	Slight yellow tone	1	0
	80	3 months	-70	dark brown	-1	-1
Sulphuric acid 40 %	23	12 months	No change	black	0	0
	80	3 months	-72	black	-1	-1
Ammonium hydroxide 10 %	23	12 months	-32	black	0	0
	80	6 months	+15	black	-5	-3
Sodium hydroxide 1 %	23	12 months	No change	No change	1	0
	80	3 months	+14	black	5	5
Sodium chloride 10 %	23	12 months	No change	No change	0	0
	80	6 months	+21	dark brown	0	-1
Sodium hypochlorite 4.6 %	23	12 months	No change	dark brown	-1	-1
	80	6 months	+6	black	-2	-1

The minimal loss of tensile strength in the samples exposed to ethanol, methanol or mixtures of the two materials results from the plasticising effect of alcohol. The tensile strength can be restored by drying the samples before testing.

Source: Shell

We will be pleased to meet you!



AKRO-PLASTIC GmbH
Member of the Feddersen Group

Industriegebiet Brohltal Ost
Im Stiefelfeld 1
56651 Niederzissen
Germany
Phone: +49(0)2636-9742-0
Fax: +49(0)2636-9742-31
info@akro-plastic.com
www.akro-plastic.com

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