Chemical properties

Swelling

General

The suitability of a plastic for a particular application often depends on its resistance to chemicals. Thermoplastic polyurethanes can have very different behavior on contact with chemical substances, since the compositions thereof are very different in some cases and the various components can react to different degrees on contact with other substances.

Therefore, it is not always possible to undertake a clear separation of the effects described below. For particular applications, a specific stability test with regard to swelling characteristics and mechanical properties is advisable.

Swelling

Swelling is the fundamental physical process of the absorption of liquid substances by a solid. In this process, the substance enters into the material without chemical interaction between the substance and the plastic. This results in an increase in volume and weight with a corresponding reduction in mechanical values. After evaporation, a reduction in swelling occurs and the original properties of the product are almost completely restored. Thus, swelling is a reversible process.

Chemical properties

Chemical resistance

General

Chemical resistance depends on the period of exposure, the temperature, the quantity, the concentration and the type of the chemical substance. In the case of chemical degradation of polyurethane, the chemical reaction results in cleavage of the molecular chains. This process is generally preceded by swelling. In the course of degradation, polyurethane loses strength, and in extreme cases this can lead to disintegration of the material.

Acids and alkaline solutions

Elastollan® products are attacked by concentrated acids and alkaline solutions even at room temperature. Any contact with these substances should be avoided. Elastollan® is resistant to short-time contact with dilute acids and alkali solutions at room temperature.

Saturated hydrocarbons

Contact of Elastollan® with saturated hydrocarbons such as diesel oil, isooctane, petroleum ether and kerosene, results in a limited swelling. At room temperature, this swelling amounts to approx. 1 - 3 % and the resultant reduction in tensile strength is no more than 20 %. After evaporation and reversal of the swelling, the original mechanical properties are almost completely restored.

Aromatic hydrocarbons

Contact of Elastollan® with aromatic hydrocarbons such as benzene and toluene, results in considerable swelling even at room temperature. Absorption can result in a 50 % weight increase with a corresponding reduction in mechanical properties.

Lubricating oils and greases

No reduction in strength occurs after immersion in test oils IRM 901, IRM 902, and IRM 903 at room temperature. There is also no reduction in tensile strength after 3 weeks immersion at 100 °C. Elastollan® is in principal resistant to lubricating oils and greases, however irreversible damage can be caused by included additives. Compatibility testing in each individual lubricant is to be recommended.

Solvents

Aliphatic alcohols, such as ethanol and isopropanol, cause swelling of Elastollan® products. This is combined with a loss of tensile strength. Rising temperatures intensify these effects. Ketones such as acetone, methylethylketone (MEK) and cyclohexanone are partial solvents for thermoplastic polyurethane elastomers. Elastollan® products are unsuitable for long-term use in these solvents.

Aliphatic esters, such as ethyl acetate and butyl acetate, cause severe swelling of Elastollan®. Highly polar organic solvents such as dimethylformamide (DMF), dimethylsulphoxide (DMSO), N-methylpyrrolidine and tetrahydrofuran (THF) dissolve thermoplastic polyurethane.

Chemical properties

Chemical resistance

For the following media, the resistance of Elastollan® has been tested:

Reagents	Code
Adblue	11.
Acetic Acid	1.
Alcohol	11./16.
Ammonium Chloride Solution	10.
Ammonium Solution	10.
Anti-freeze	14.
ASTM-Oils 1, 2 and 3	13./15.
Battery Acid	5.
Benzyl Alcohol	16.
Bleach	7.
Boric Acid	1.
Brake Fluid	14.
Butyric Acid	1.
Calcium Hydroxide Solution	9.
Citric Acid	2.
Ethanol = Ethyl Alcohol	11./16.
Ethyl Acetate	14./15.
FAM Test Fluids A, B and C, according to DIN 51604	12./16.
Formic Acid	1.
Gasoline	12./16.
Diluted Hydrochloric Acid	4.
Hydrogen Peroxide	7.
IRM Oils	13.
Iso-Propanol = Isopropyl Alcohol	11./16.
Lactic Acid	1.
LauricAcid	1.
Methanol = Methyl Alcohol	11./16.
Diluted Nitric Acid	6.
Oleic Acid	1.
Phenol Solution	1.
Diluted Phosphoric Acid	3.
Propionic Acid	1.
Sea Water	0.
Silicone Oil = Dimethyl Polysiloxane	14.
Slaked Lime = Calcium Hydroxide Solution	9.
Diluted Soda Lye	9.
Soda Solution	9.
Sodium Bisulphate Solution	3.
Sodium Hydroxide Solution	9.
Sodium Hypochlorite Solution	7.
Sodium Nitrate Solution	7.
Sodium Sulphite Solution	8.
Stearic Acid	1.
Diluted Sulphuric Add	4.
Tap Water	0.
Trichloroethane	14./15.
Triethanolamine Solution	9.
Urea Solution	10.
Water	0.

Solvents	Code
Acetic Ester	15.3
Acetone	15.4
Amyl Acetate	15.3
ASTM-Oils 1, 2 and 3	13./15.7
Benzene	15.2
Benzyl Alcohol	16.
Biodiesel Fuel	16.
Butane	15.1
Butyl Acetate	15.3
Chlorobenzene	15.6
Chloroform	15.5
Cyclohexane	15.1
Dimethyl Acetamide	15.8
Dimethyl Formamide = DMF	15.8
Dimethyl Sulphoxide = DMSO	15.8
Diesel Fuel	16.
Ethane	15.1
Ethanol	16./11.
Ethyl Acetate = Acetic Ester	15.3
Ethylene Glycol = Glycol	16.
FAM Test Fluids A, B and C, according to DIN 51604	16./12.
Fuel A, B, C and D, according to ASTM D 471	16.
Glycol = Ethylene Glycol	16.
Glycerine	16.
Hexane	15.1
Iso-Octane	15.1
Iso-Propanol = Isopropyl Alcohol	16./11.
Kerosine	15.1
Methane	15.1
Methanol	16./11.
Methylen Chloride	15.5
Methyl Ethyl Ketone = MEK	15.4
Methyl Isobutyl Ketone = MIBK	15.4
N-Methyl Pyrrolidone = NMP	15.8
Octane	15.1
Paraffin Oil	15.1
Pentane	15.1
Petroleum Ether	15.1
Propane	15.1
Pyridine	15.8
Tetrachloroethylene	15.5
Tetrahydrofurane	15.8
Toluene	15.2
Trichloroethane	15.5
Xylene	15.2

Chemical properties

Chemical resistance

Test conditions

Test Specimens
Standard 5A test piece according to DIN EN ISO 527-2, all test rods were pretempered for 20 h at 100° C.

Test Temperature
Reagents: 60° C; Solvents: 23° C

Test Criteria
Reagents: accomplishing a remaining tensile strength of 20 MPa. Solvents: reduction in tensile strength due to swelling after three weeks immersion.

The resistance is indicated roughly in terms of days, weeks, months or years. According to a general rule of thumb, resistance may be extrapolated to double when reducing temperature by 10° C, and when increasing temperature by 10° C, to half.

Tests were performed with Elastollan® standard ester grades (e.g. 500, 800), Elastollan® 85 A and standard ether grades (e.g. 1100). Swelling and solution are primarily affected by the number of hydrogen bonds effective between the linear molecular chains, which increases with hardness. From this, it can be derived that harder products suffer less swelling, and their chemical resistance is higher.

Highly polar substances may in part or completely break down the molecular interactions which in turn causes strong swelling or dissolving of Elastollan®.

Chemical properties

Chemical resistance

Chemical resistance

Code:	tested:	Elastollan® standard-ester (e.g. 500, 800) 23 °C	60 °C	Elastollan® C 85 A 23 °C	60 °C	Elastollan® ether grades (e.g. 1100) 23 °C	60 °C
0. Water	Tap Water	Years	Months	Years	Months	Years	Years
	Sea Water	Years	Months	Years	Months	Years	Years
1. Weak Acids, Carbonic Acids	3 % Acetic Acid	Weeks	Days	Weeks	Days	Years	Months
	3 % Lactic Acid	Weeks	Days	Weeks	Days	Years	Months
	3 % Boric Acid	Months	Weeks	Months / Years	Weeks / Months	Years	Months
	3 % Phenolic Solution	Weeks / Months	Days	Months / Years	Weeks	Years However, tensile strength only 50 % due to swelling	Months
	The action of 3 % solutions of formic acid, propionic acid, butyric acid, lauric acid, oleic acid, stearic acid etc., will be comparable.						
2. Chelating Carbon Acids	3 % Citric Acid	Months	Days	Months	Days	Years	Months
3. Weak Mineral Acids	3 % Sodium Bisulphate Solution	Months	Days / Weeks	Months / Years	Weeks	Years	Months
	3 % Phosphoric Acid	Months	Days	Months	Weeks	Years	Months
4. Strong Mineral Acids	3 % Hydrochloric Acid	Days	Hours	Days	Hours	Years	Months
	The action of 3 % sulphuric acid will be similar.						
5. Battery Acid	Battery Acid	Days	Hours	Days	Hours	Years	Months
6. Oxidizing Mineral Acids	3 % Nitric Acid	Days	Hours	Days	Hours	Days	Hours
7. Oxidizing Solutions, pH-value around 7	Hydrogen Peroxide 35 %	Weeks / Months		Months		Months	
	Sodium Nitrate, 3 %	Months / Years	Weeks	Years	Months	Years	Months
	Sodium Hypochlorite= Bleach (Javelle Water), 3 %	Weeks	Days	Weeks	Days	Months	Weeks
		Surface becomes tacky					
	Bleach (Javelle Water), 0.5 %	Months	Weeks	Months	Weeks	Years	Months
		Surface becomes tacky					
8. Reducing Solutions	Sodium Sulphite, 3 %	Months / Years	Weeks / Months	Years	Months	Years	Months
9. Alkaline Solutions	Saturated Calcium Hydroxide (Slaked Lime)	Months / Years	Weeks	Years	Months	Years	Months
	3 % Soda Solution	Months / Years	Weeks	Years	Months	Years	Months
	3 % Soda Lye (Caustic Soda)	Weeks	Days	Months	Weeks	Years	Months
	3 % Triethanolamine Solution	Months	Weeks	Months / Years	Months	Years	Months
10. Basic Solutions	3 % Urea Solution	Months	Weeks	Months / Years	Weeks	Years	Months
	3 % Ammonium Solution	Days	Hours	Weeks	Days	Years	Months
	3 % Ammonium Chloride Solution	Months / Years	Weeks / Months	Years	Months	Years Reduced tensile strength due to swelling	Months

Chemical properties

Chemical resistance

Code:	tested:	Elastollan® standard-ester (e.g. 500, 800)		Elastollan® C 85 A		Elastollan® ether grades (e.g. 1100)	
		23 °C	60 °C	23 °C	60 °C	23 °C	60 °C
11. Adblue	Adblue	Weeks	Weeks	Months	Weeks	Months / Years	Months
12. Alcohols	Methanol	Days		Weeks / Months		Months	
	Ethanol	Months		Months		Years	
	Iso-Propanol	Months		Months		Years	
13. FAM Test Fluids acc. to DIN 51604*	Test Fluid C	Months		Years		Years	
	Test Fluid B	Days		Months		Years Strong swelling	
	Test Fluid C	Days		Weeks		Years Strong swelling	
14. ASTM-Oils acc. to ASTM D 471-06**	IRM 901	Years	Months	Years	Months	Years	Months
	IRM 902	Years	Months	Years	Months	Years	Months
	IRM 903	Years	Months	Years	Months	Years	Months
15. Miscellaneous	Anti-freeze (Glysantine/Water 1/1.5)	Months	Weeks	Months / Years	Weeks	Years	Months
	Silicone Fluid (Dimethyl Polysiloxane)	Years	Months	Years	Months	Years	Months
	Brake Fluid	Hours	Hours	Hours	Hours	Hours	Hours
				Brake fluid/many hydraulic oils attack TPU			
	Ethyl Acetate	Months		Months		Months Reduced tensiled due to swelling	
	Volume swelling:	75 %		70 %		70 %	

* DIN 51 604, 03.1984, is the standard, etablished by FAM to assess the resistance of plastic materials to automotive fuels.

** The IRM reference oils are mineral oils with different paraffin and aromatics contents. The formerly used ASTM oils 1, 2 and 3 were replaced by the IRM oils 1, 2 and 3 owing to health risks, and are no longer available. The IRM oils 1, 2 and 3 are very similar in terms of their characteristics, but not identical.

(FAM = Fachausschuß Mineral- und Brennstoffnormung-Professional committee for standardization of fuel stuffs)

(ASTM = American Society for Testing and Materials)

Test fluid A consists of:
50.0 % by volume toluene
30.0 % by volume iso-octane
15.0 % by volume di-isobutylene
5.0 % by volume ethanol

Test fluid B consists of:
42.0 % by volume toluene
25.5 % by volume iso-octane
13.0 % by volume di-isobutylene
15.0 % by volume methanol
4.0 % by volume ethanol
0.5 % by volume water

Test fluid C consists of:
20.0 % by volume toluene
12.0 % by volume iso-octane
6.0 % by volume di-isobutylene
58.0 % by volume methanol
2.0 % by volume ethanol
2.0 % by volume water

Chemical properties

Chemical resistance

Solvents resistance

16. Solvents	No degradation of Elastollan® products occurs, however, according to the solvent class a variable degree of swelling and consequent reduction in tensile strength (after evaporation of the solvents, the tensile strength recovers approx. its original value). Methanol should be considered more as a chemical reagent than as a solvent. TPU is soluble in some solvents. As test procedure, 5A test rods (DIN EN ISO 527-2) were immersed in the solvent for three weeks at 23° C, and tested for tensile strength and residual swell 15 minutes after withdrawal. The values of volume swelling and reduction of tensile strength are rounded values.

Code:	**tested:**	**Elastollan® standard-ester (e.g. 500, 800)**		**Elastollan® C 85 A**		**Elastollan® ether grades (e.g. 1100)**	
		% Swelling	% Reduction of Tensile strengh	% Swelling	% Reduction of Tensile strengh	% Swelling	% Reduction of Tensile strengh
16.1. Aliphatic Hydrocarbons	Pentan	3	20	4,5	10	10	20
	Cyclohexan	4	15	7	10	22	10
	Isooctan	2.5	none	2.5	none	7.5	none
	Elastollan® grades behave similarly in other aliphatic and cyclo-aliphatic hydrocarbons such as methane, ethane, propane, butane, hexane, octane, petroleum ether, paraffin oil, diesel oil and kerosine (although additives can present problems).						
16.2. Aromatic Hydrocarbons	Toluene	52	55	60	45	65	50
	Other aromatic hydrocarbons such as benzene and xylene have a similar affect.						
16.3. Aliphatic Esters	Ethyl Acetate	75	70	70	65	70	75
	Other short-chained esters such as butyl acetate and amyi acetate have a similar affect.						
16.4. Aliphatic Ketones	Methyl Ethyl Ketone	105	80	110	80	130	90
	Other short-chained aliphatic ketones such as acetone and methyl isobutyl ketone = MIBK have a similar affect.						
16.5. Aliphatic Halogenated Hydrocarbons, 1 C-atom	Methylene Chloride	175	75	155	65	190	95
	Chloroform	280	75	260	70		practically dissolved
		20	40	28	35	50	45
2 C-atoms and higher	Tetrachloroethylene	54	39	65	39	75	54
	Trichloroethane						
	Other aliphatic halogenated hydrocarbons with 2 C-atoms and higher have a similar affect.						
16.6. Aromatic Halogenated Hydrocarbons	Chlorobenzene	90	60	100	55	110	60
	Other aromatic halogenated hydrocarbons have a similar affect.						
16.7. ASTM-Oils acc. to ASTM D 471-06**	IRM 901 at 100 °C 500 h	none	1	none	none	1	6
	1000 h			none	6	1	14
	IRM 902 at 100 °C 500 h	3	8	3	none	9	4
	1000 h			4	18	10	5
	IRM 903 at 100 °C 500 h	7	20	7	none	18	8
	1000 h			12	50	20	30
16.8. Agents Dissolving TPU	Tetrahydrofurane	> 450	practically dissolved	> 450	practically dissolved		dissolved
	Dimethyl Formamide (DMF)		dissolved		dissolved		dissolved
	Dimethyl Acetamide		dissolved		dissolved		dissolved
	N-Methyl Pyrrolidone (NMP)		dissolved		dissolved		dissolved
	Dimethyl Sulphoxide (DMSO)		dissolved		dissolved		dissolved
	Pyridine		dissolved		dissolved		dissolved

Chemical properties

Chemical resistance

Code:	tested:	Elastollan® standard-ester (e.g. 500, 800) % Swelling	% Reduction of Tensile strengh	Elastollan® C 85 A % Swelling	% Reduction of Tensile strengh	Elastollan® ether grades (e.g. 1100) % Swelling	% Reduction of Tensile strengh
	Methanol	18	80	18	58	28	60
			poor resistance	limited resistance for sev. weeks			
	Ethanol	16	52	18	52	33	64
	Iso-Propanol	14	44	17	42	30	50
17. Alcohols and Fuels	Benzyl Alcohol	300	95	270	85	not	partly
			poor resistance	poor resistance		measurable	dissolved
						poor resistance	
	Ethylene Glycol	2	none	2	none	4	15
	Glycerine	none	none	none	none	none	none
FAM Test Fluids acc. to DIN 51 604*	Test Fluid A	39	55	45	50	67	60
	Test Fluid B	38	72	38	55	68	74
			poor resistance	limited resistance for sev. weeks			
	Test Fluid C	21	60	24	50	43	70
				limited resistance for sev. weeks			
Diesel Fuel	Diesel Fuel	3,0	15	5,0	none	11	none
Biodiesel Fuel RME at 60°C	Biodiesel Fuel			9	9	27	21
	Fuel A = Iso-Octane	2.5	none	2.5	none	7.5	none
	Fuel B = Iso-Octane Toluene 70 % / 30 %	13	30	18	32	25	36
Fuel Types ASTM D 471	Fuel C = Iso-Octane Toluene 50 % / 50 %	21	40	27	38	38	44
	Fuel D = Iso-Octane Toluene 60 % / 40 %	17	37	21	36	31	44

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0.5 % by volume water

Test fluid C consists of:
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12.0 % by volume iso-octane
6.0 % by volume di-isobutylene
58.0 % by volume methanol
2.0 % by volume ethanol
2.0 % by volume water

Chemical properties

Microbiological resistance

Microbiological resistance

When using polyester-based thermoplastic polyurethane under climatic conditions of high heat and humidity, parts can be damaged by microbiological attack. In particular, micro-organisms producing enzymes are able to affect the molecule chains of polyester-based TPU. The microbiological attack initially becomes visible as discoloration. Subsequently, surface cracks occur which enable the microbes to penetrate deeper and to cause a complete destruction of the TPU (ref. Fig. 40).

Polyether-based thermoplastic polyurethane is resistant to microbiological attack. The saponification number (SN) formerly DIN VDE 0472, part 704 is an important criterion for microbiological resistance. Unfilled TPU is resistant to microbes up to a saponification number of 200 mg KOH/gm, which is the limiting value according to VDE 0282/10.

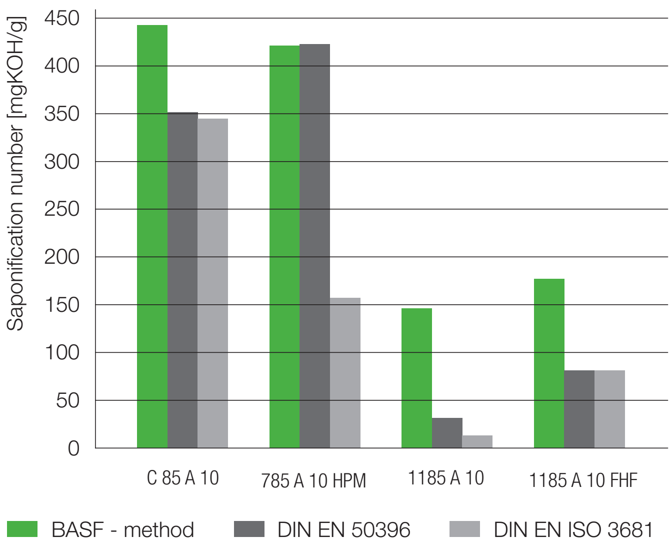

Fig. 40: Saponification number of selected Elastollan® grades

Depending on formulation and hardness, polyether-based TPUs achieve a saponification number of around 150, polyester-based TPUs around 450. With regard to polyether-polyester mixtures, the saponification number can be calculated from the quantitative portions. Small inclusions of up to approx. 10 % of ester urethane in ether urethane (e.g. addition of ester-based color masterbatches) do not impair the microbiological resistance (SN remains < 200). Larger inclusions of ester-based TPU result in a reduction in the microbiological resistance.

Chemical properties

Hydrolysis resistance

Hydrolysis resistance

If polyester based polyurethanes are exposed for lengthy periods to hot water, moisture vapor or tropical climates, an irreversible break-down of the polyester chains occurs through hydrolysis. This results in a reduction in mechanical properties. This effect is more marked in flexible grades, where the polyester content is correspondingly higher than in the harder formulations. Due to a good stabilization, a degradation of polyester-based Elastollan® is rarely experienced at room temperature.

Because of its chemical structure, polyether-based Elastollan® is much more resistant to hydrolytic degradation.

The following diagrams compare hydrolysis resistance of polyether- and polyester-based TPU.

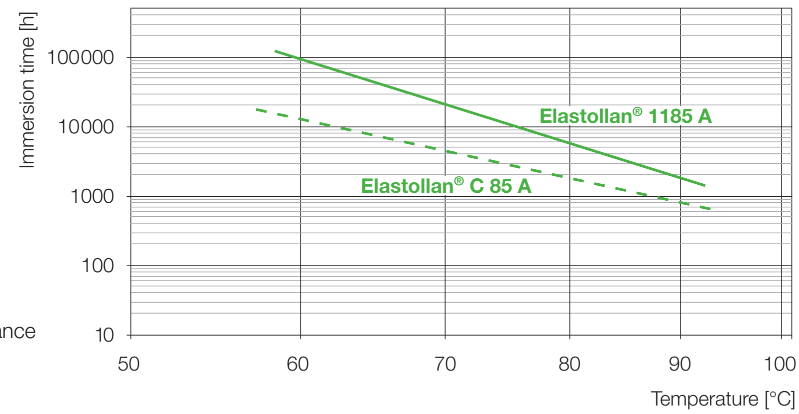

Fig. 41: Long-term hydrolysis resistance

End criterion: tensile strength 20 MPa

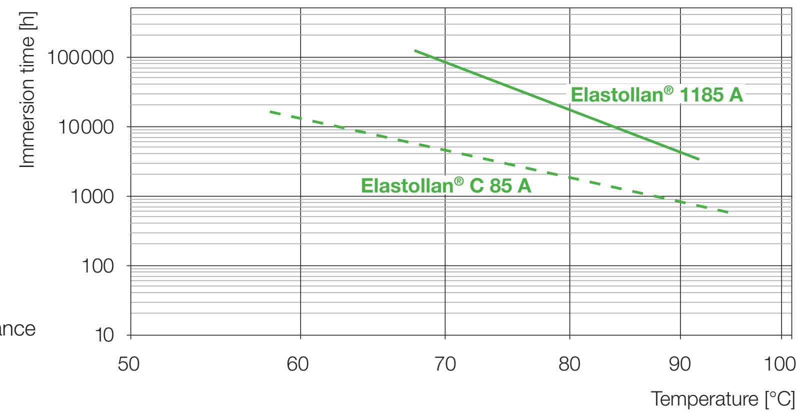

Fig. 42: Long-term hydrolysis resistance

End criterion: Elongation of break 300 %

Chemical properties

Radiation resistance • Ozone resistance

UV radiation

Plastics are chemically degraded by the effect of UV radiation. The degree of ageing depends on duration and intensity. In the case of polyurethanes, the effect is seen initially as surface embrittlement. This is accompanied by a yellowing in color and a reduction in mechanical properties.

It is possible to improve UV resistance by addition of color pigments which prevent the deep penetration of UV rays and thus mechanical destruction. Moreover, dark color shades, in particular black, mask the surface discoloration. The ageing process can also be delayed by the addition of UV stabilizers. Suitable masterbatches are available.

High energy radiation

Elastollan® is superior to most other plastics in its resistance to high energy radiation. Resistance to α-, β- and γ-radiation is dependent on such factors as the intensity of the radiation, the shape and dimensions of the test specimen, and the atmosphere in the test area.

The addition of crosslinking agents and subsequent β- and γ-radiation can effect crosslinking of Elastollan®. The maximum achievable degrees of crosslinking are around 90 %. This is a method to improve short-term heat deflection temperature and chemical resistance.

Ozone resistance

The ozone molecule (O_3) is formed by the union of three oxygen atoms. It is generated from reaction of oxygen in the atmosphere under the influence of high energy UV-radiation. Ozone is highly reactive, especially with organic substances. Rubberbased elastomers are destroyed through cracking under the influence of ozone.

Elastollan®, on the other hand, is resistant to ozone. The test according to VDE 0472 results in "crack-free", stage 0. There is neither a loss of elasticity nor an increase of surface hardness.

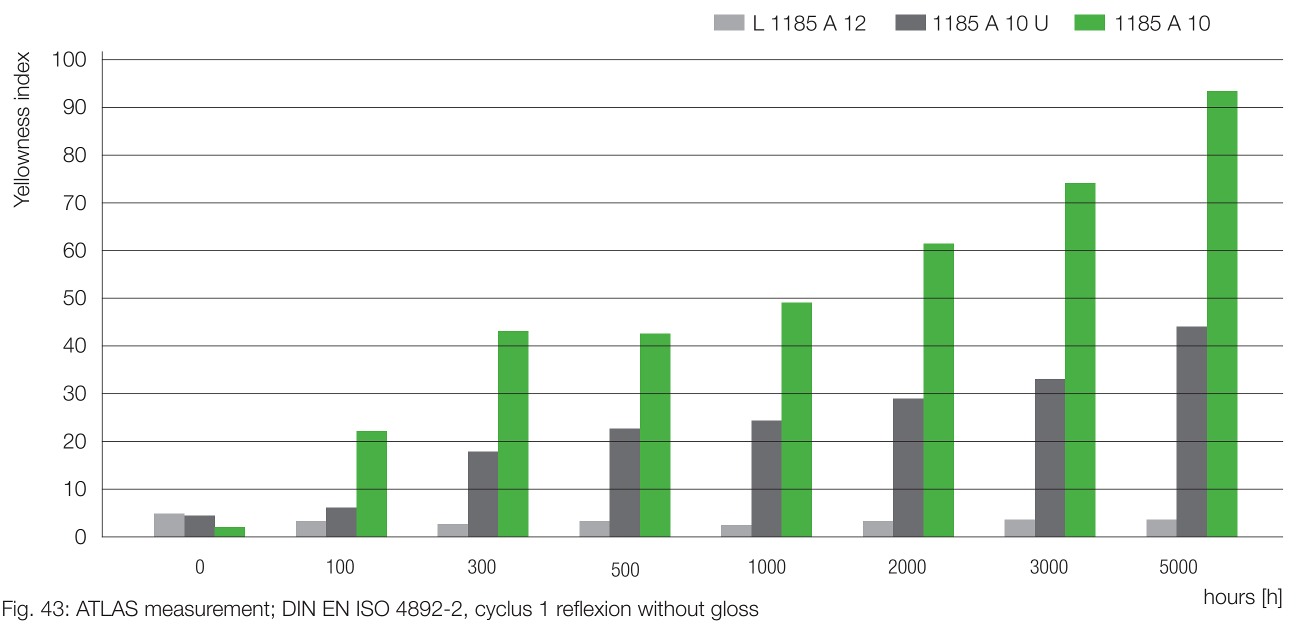

Fig. 43: ATLAS measurement; DIN EN ISO 4892-2, cyclus 1 reflexion without gloss