Technical Information (Revised 2005.6)

PBO FIBER ZYLON®

TOYOBO

TOYOBO CO., LTD.

ZYLON®(PBO fiber) Technical Information (2005)

Contents

1. Basic Properties

ZYLON®(PBO fiber) is the next generation super fiber with strength and modulus almost doubles that of p-Aramid fiber. ZYLON® shows 100°C higher decomposition temperature than p-Aramid fiber. The limiting oxygen index is 68, which is the highest among organic super fibers.

There are two types of fibers, AS (as spun) and HM (high modulus). HM is different from AS in modulus, moisture regain and etc.

		ZYLON®AS	ZYLON®HM
Filament decitex		1.7	1.7
Density	(g/cm^3)	1.54	1.56
Tensile Strength	(cN/dtex)	37	37
	(GPa)	5.8	5.8
	(kg/mm^2)	590	590
Tensile Modulus	(cN/dtex)	1150	1720
	(GPa)	180	270
	(kg/mm^2)	18000	28000
Elongation at break(%)		3.5	2.5
Moisture regain(%)		2.0	0.6
Decomposition Temp.(°C)		650	650
LOI		68	68
Thermal expansion coefficient		-	$-6x10^{-6}$

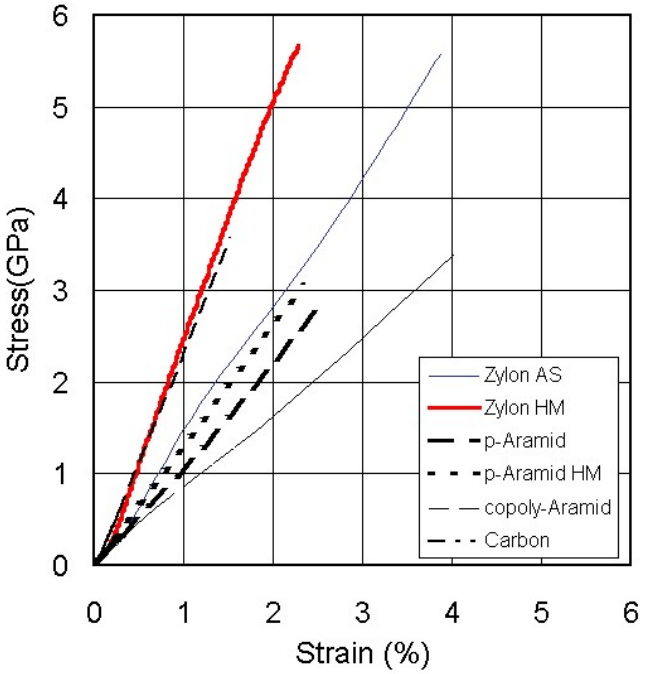
2. Comparison of mechanical properties with other fibers

ZYLON® has the highest tensile strength and tensile modulus among high-performance fibers.

	Tenacity		Modulus		Elonga-tion	Density	Moisture Regain	LOI	Heat Resistance*
	cN/dtex	GPa	cN/dtex	GPa	%	g/cm^3	%		C
Zylon® AS	37	5.8	1150	180	3.5	1.54	2.0	68	650
Zylon® HM	37	5.8	1720	270	2.5	1.56	0.6	68	650
p-Aramid(HM)	19	2.8	850	109	2.4	1.45	4.5	29	550
m-Aramid	4.5	0.65	140	17	22	1.38	4.5	29	400
Steel Fiber	3.5	2.8	290	200	1.4	7.8	0		
HS-PE	35	3.5	1300	110	3.5	0.97	0	16.5	150
PBI	2.7	0.4	45	5.6	30	1.4	15	41	550
Polyester	8	1.1	125	15	25	1.38	0.4	17	260

*Melting or Decomposition Temperature

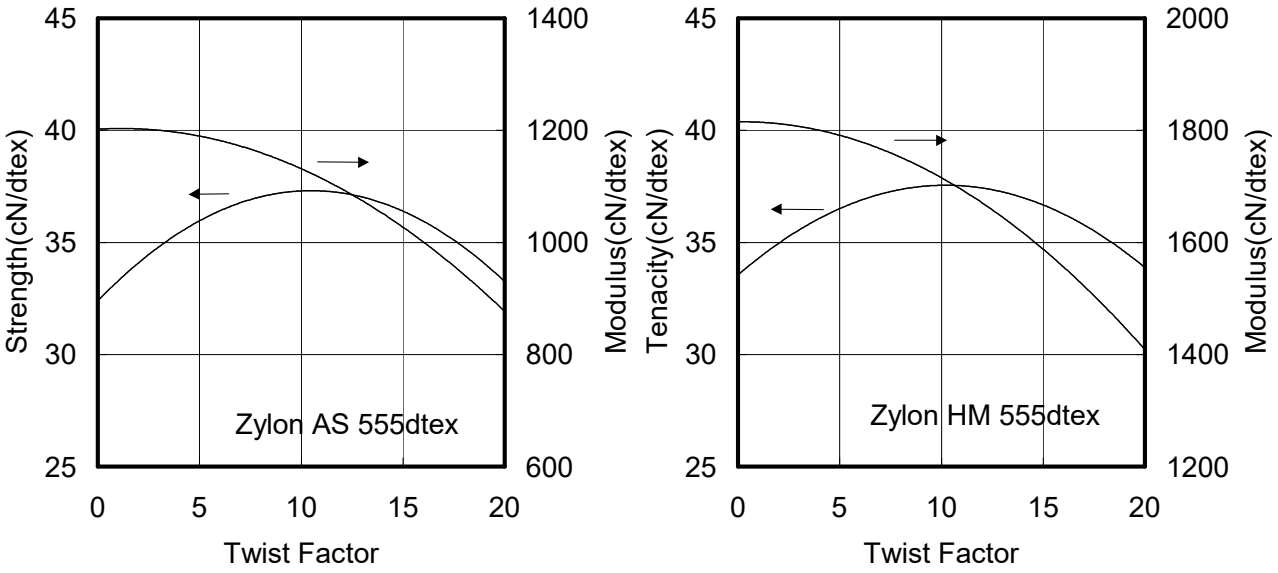
The stress-strain curves of ZYLON® compared with other high-performance fibers are shown below.



3. Influence of twist on tensile properties

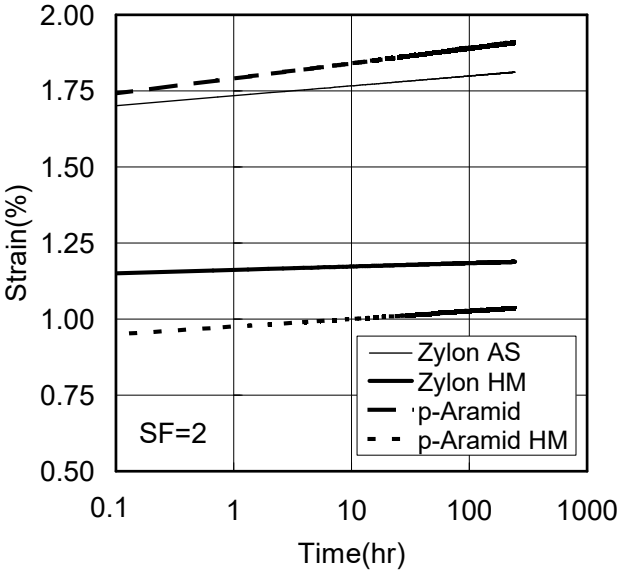
ZYLON® is shipped with zero twist. A certain twist has to be applied in order to measure its correct tensile strength. These figures show the influence of twist factor on tensile strength and modulus for 555 dtex ZYLON® yarn. For different dtex yarns, optimum twist level can be estimated by using twist factor. Twist factor is defined by the following formula.

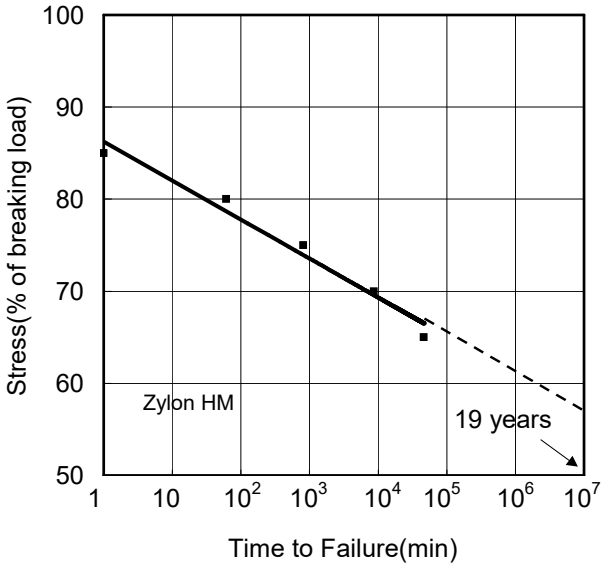
$$\text{Twist factor (TF)} = 0.124 \times (\text{turns per inch}) \times (\text{dtex})^{0.5}$$



4. Creep Properties

ZYLON® has superior creep resistance to p-Aramid fibers. (Creep means a non-recoverable strain after prolonged static loading.) When a certain load is applied to yarn, recoverable strain (initial strain) and non-recoverable strain are observed. For ZYLON® HM, non-recoverable strain after 100 hours under 50% of breaking load (Safety factor (SF)=2) is less than 0.03%.





Creep Parameter

Creep parameters (slope of straight line in above figure) are compared with p-Aramid fibers. ZYLON® shows less than half of creep parameter of p-Aramid fiber. Creep strain is measured under 50% of the breaking load for each fiber. Note that the actual load applied to ZYLON® is almost double that of p-Aramid fiber.

Creep parameter under 50% of breaking strength

Zylon AS	Zylon HM	p-Aramid	p-Aramid HM
3.2×10^{-4}	1.1×10^{-4}	5.0×10^{-4}	2.5×10^{-4}

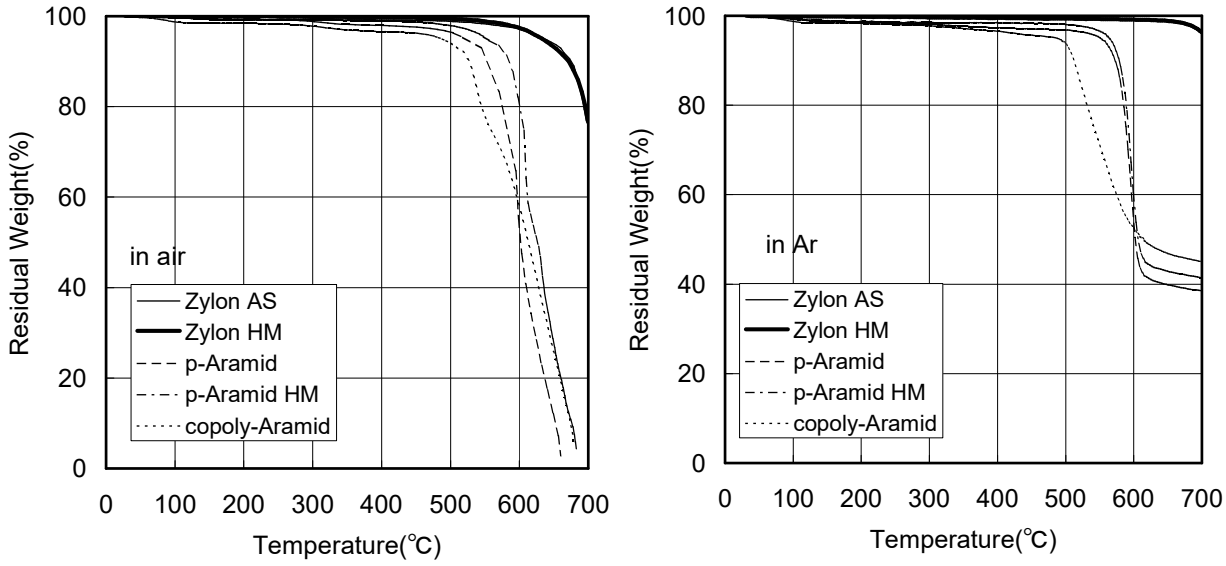
Time to failure

After a certain loading time, yarn breakage may occur. The above figure shows the relationship between time to failure and applied load level (ZYLON®HM). Based on the extrapolation, 10^7 minutes (19 years) of time to failure can be estimated under 60% of the breaking strength.

5. Thermal properties

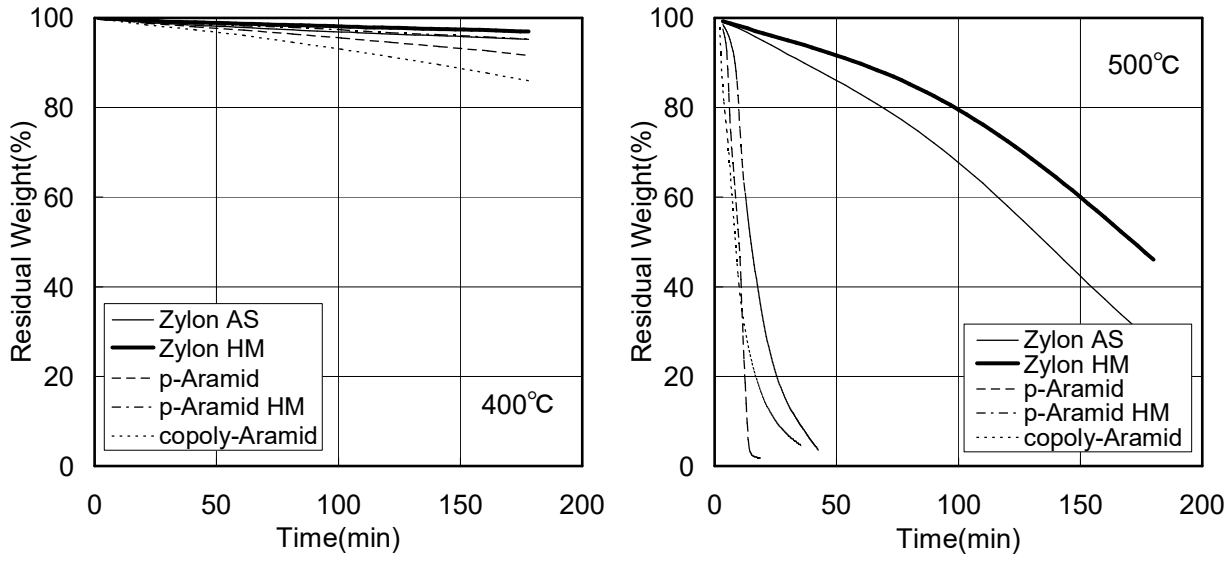
5.1 Decomposition Temperature

ZYLON® has a 100°C higher decomposition temperature than p-Aramid fibers. Thermal gravimetric analysis charts in air and argon gas are shown below. The heating rate is 20°C/min.



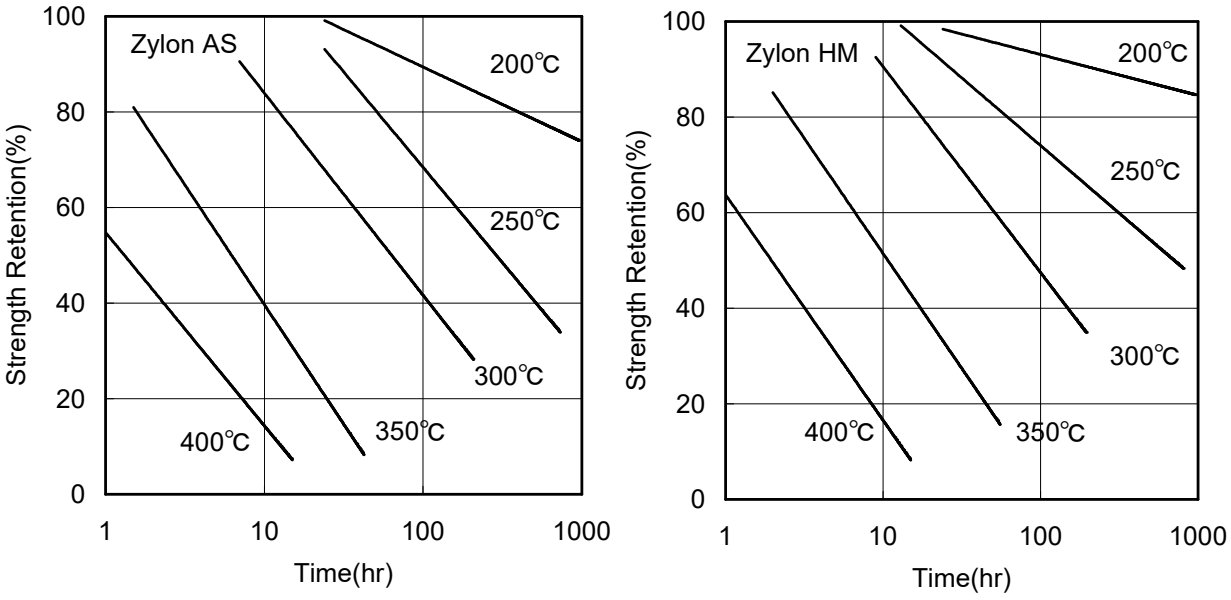
5.2 Isothermal weight loss

A significant difference of weight loss behavior is observed at 500°C between ZYLON® and Aramid fibers.

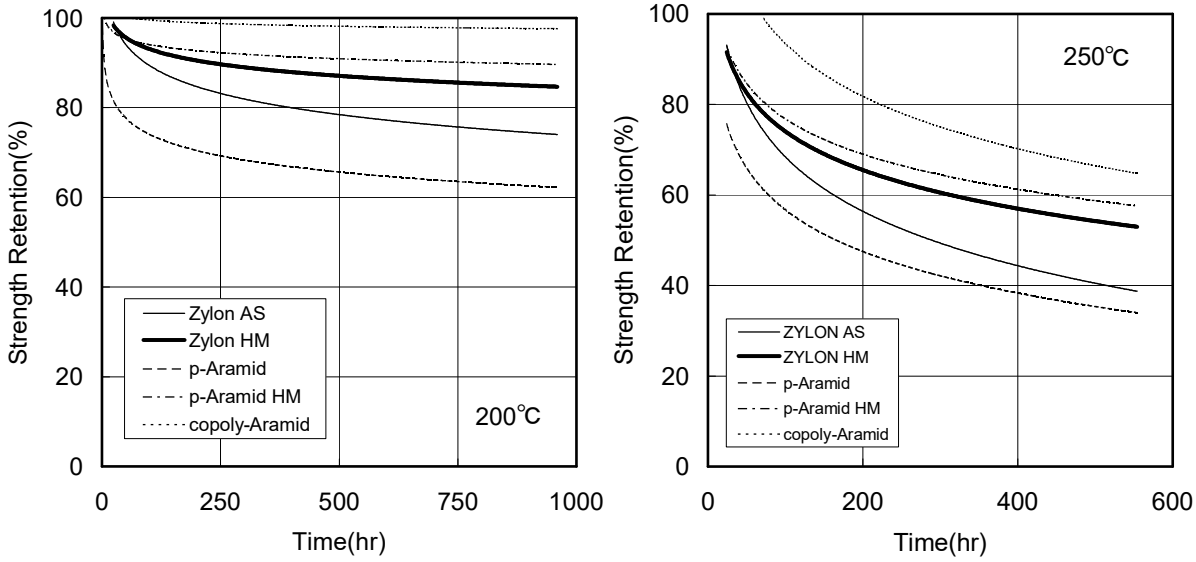


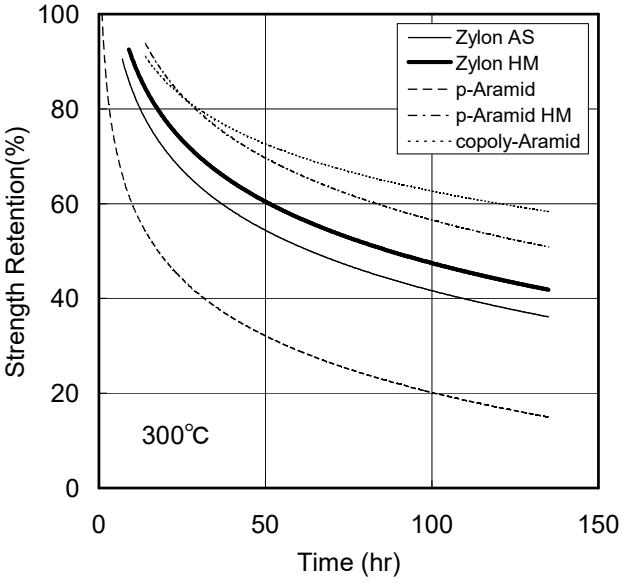
5.3 Strength retention after thermal treatment

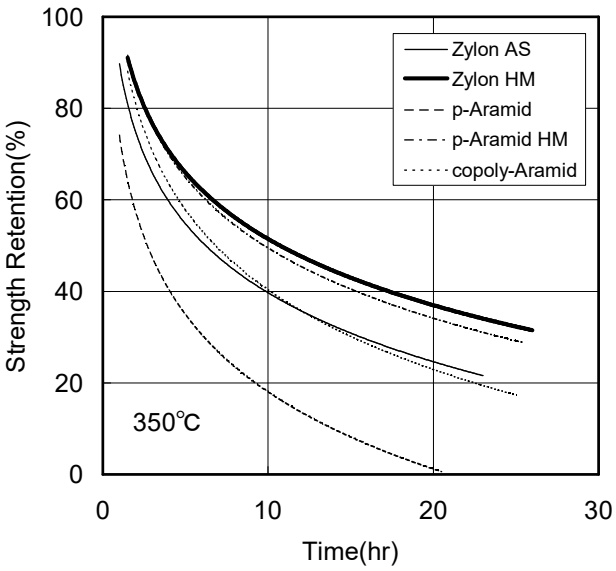
These figures show the effect of thermal treatment in air on residual strength. ZYLON®HM shows a little higher heat resistance than ZYLON®AS.

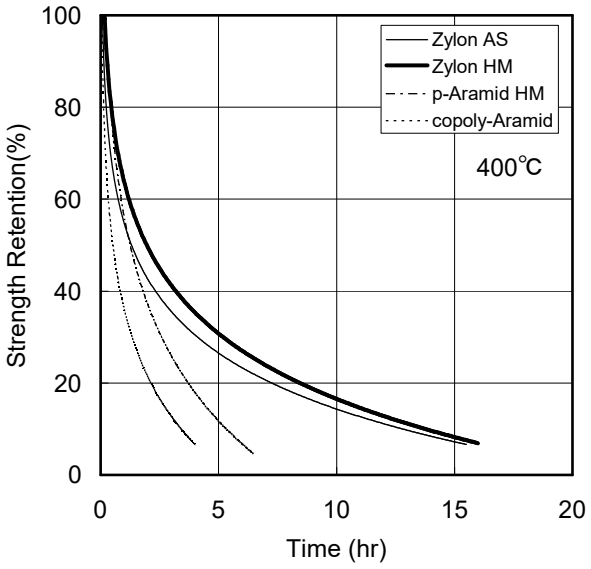


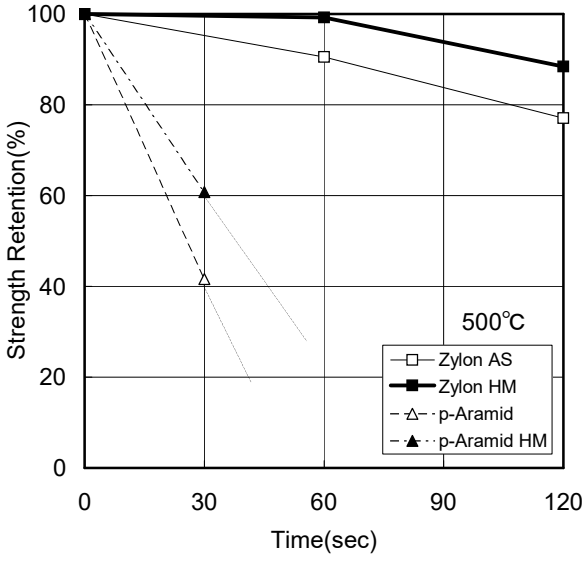
Strength retention after thermal treatment is compared with Aramid fibers at several temperatures.




Zylon AS
Zylon HM
p-Aramid
p-Aramid HM
copoly-Aramid
300℃
Strength Retention(%)
Time (hr)
0
20
40
60
80
100
0
50
100
150

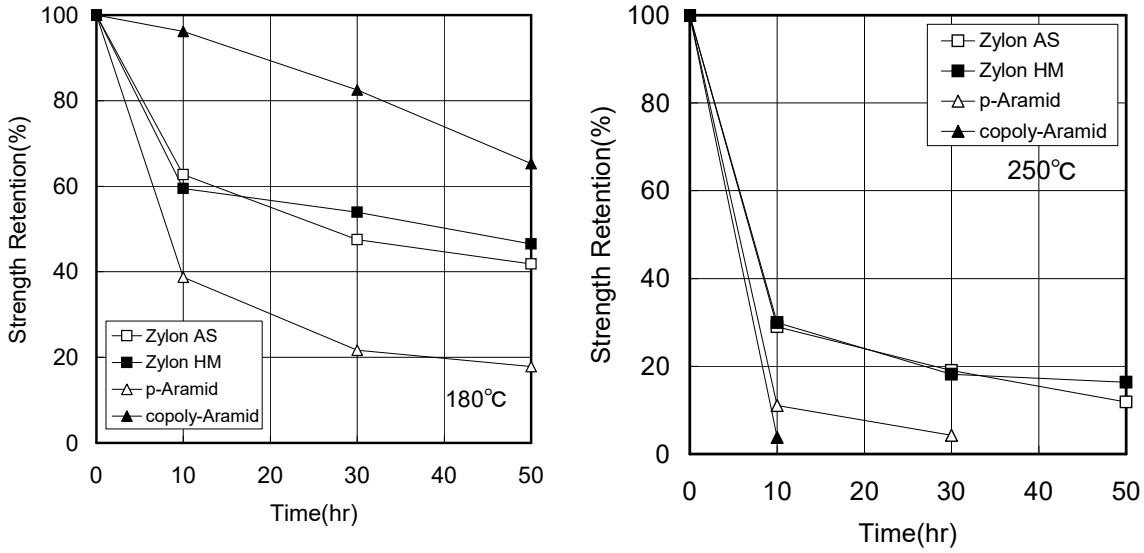

Zylon AS
Zylon HM
p-Aramid
p-Aramid HM
copoly-Aramid
350℃
Strength Retention(%)
Time(hr)
0
20
40
60
80
100
0
10
20
30


Zylon AS
Zylon HM
p-Aramid HM
copoly-Aramid
400℃
Strength Retention(%)
Time (hr)
0
20
40
60
80
100
0
5
10
15
20

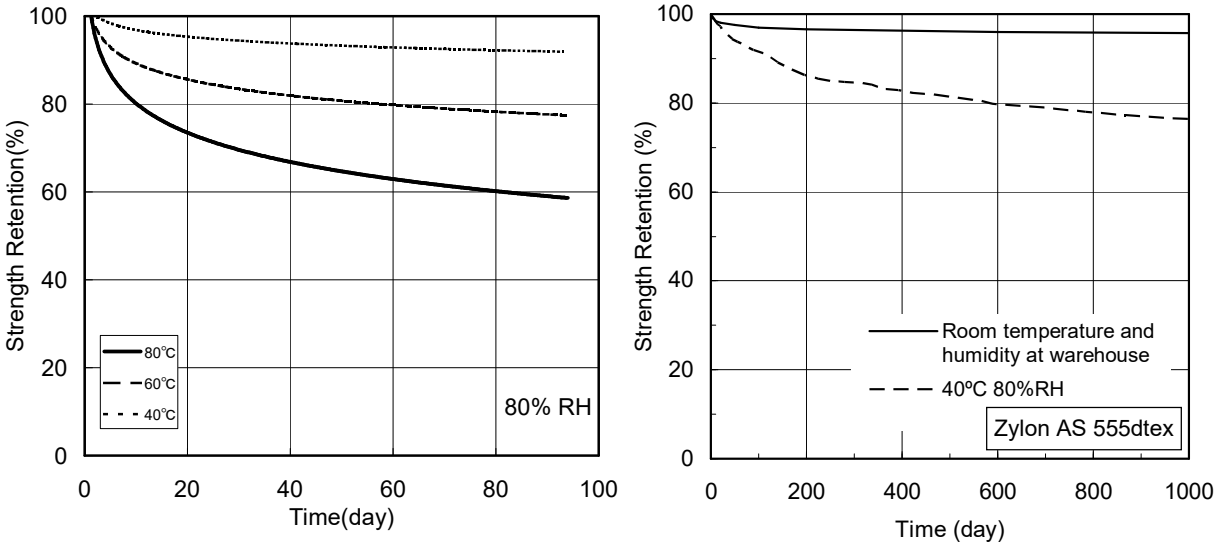

Zylon AS
Zylon HM
p-Aramid
p-Aramid HM
500℃
Strength Retention(%)
Time(sec)
0
20
40
60
80
100
0
30
60
90
120

5.4 Strength retention at high temperature with humidity

The strength of ZYLON® decreases in the condition of high temperature and high humidity. The residual strength after a 50 hours treatment with saturated steam at 180°C is 40-50%, which is between p-Aramid and copoly-Aramid fiber.



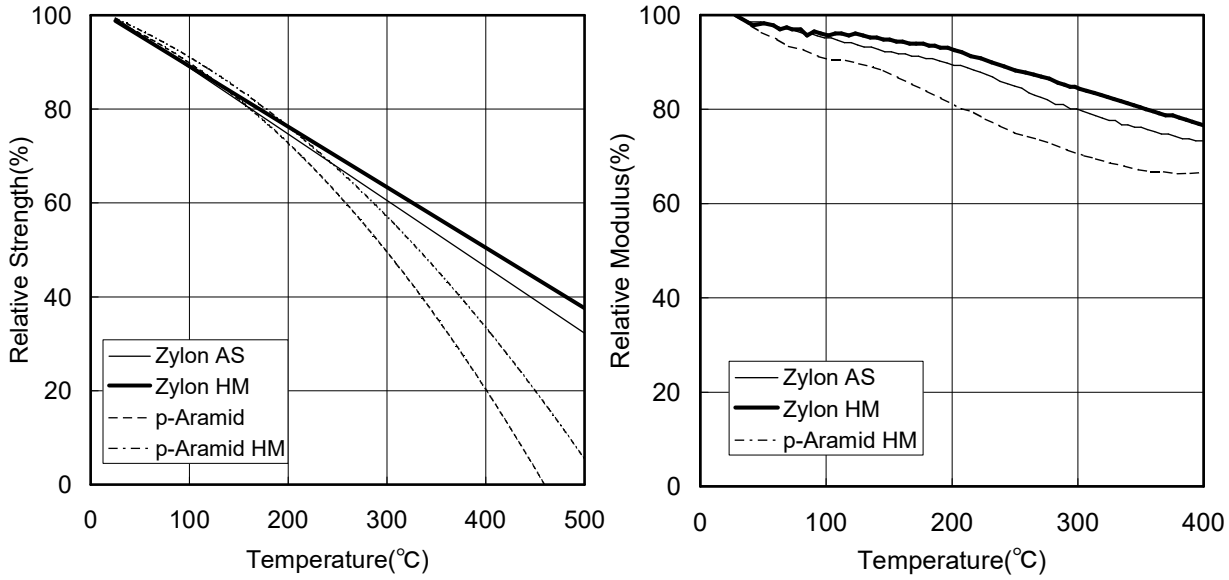
The strength of ZYLON® gradually decreases even at the temperature of less than 100°C in high humidity condition. ZYLON® fiber should be stored free from high humidity at normal room temperatures.



5.5 Effect of temperature on strength and modulus

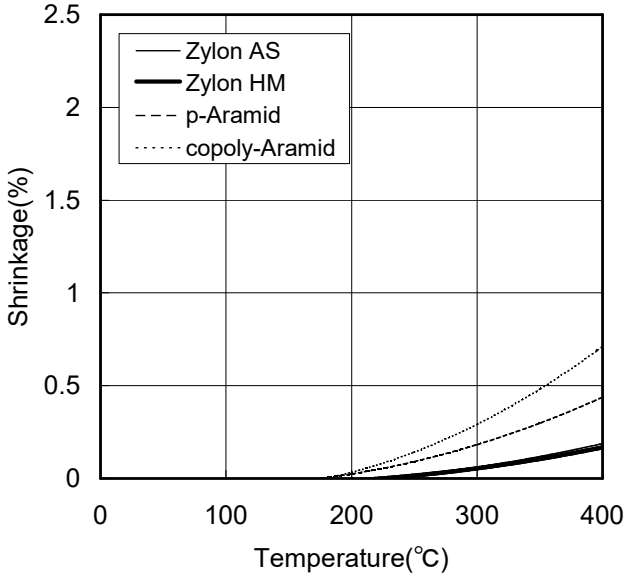
The relative strength of ZYLON® decreases from room temperature to 500°C. ZYLON® retains 40% of the room temperature strength even at 500°C.

The temperature dependence of modulus is shown below. Even at 400°C, ZYLON® retained 75% of modulus at room temperature.



5.6 Hot air shrinkage

Shrinkage (permanent) after hot air treatment for 30 minutes without load was measured. ZYLON® shows very low shrinkage as compared with other super fibers.



5.7 Flame resistance

ZYLON® shows extremely high flame resistance. In a vertical flame test (JIS L1091 A-4), char length is almost zero.

	Zylon		p-Aramid		m-Aramid	
	warp	fill	warp	fill	warp	fill
Char length(cm)	<0.5	<0.5	3	2	6	6
After flame(sec)	0	0	0	0	0	0
After glow(sec)	1	1	16	16	2	2
LOI	68		29		29	

Plain woven fabrics with 20's spun yarn

5.8 Combustion products

Generated gases at the temperature of 750°C were measured according to Japanese Industrial Standard(JIS). The amount of toxic gases such as HCN, NOx and SOx from ZYLON® is very small compared with p-Aramid fiber.

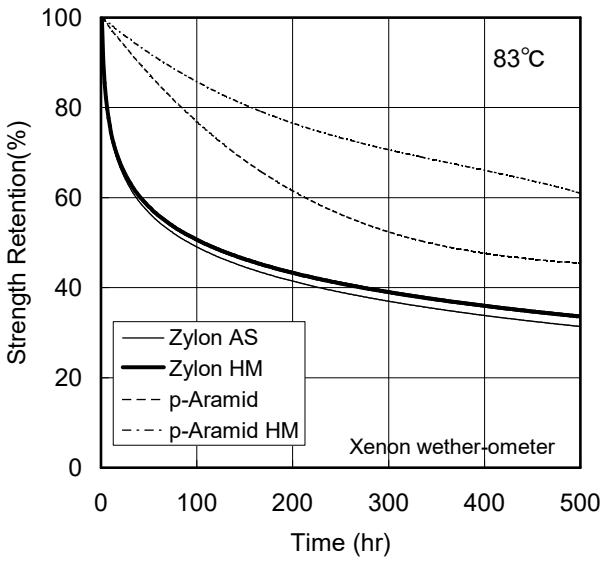
	Temp.	CO	CO_2	NH_3	HCN	HCl	NOx	SOx
Zylon	500	6.9	35.8	0.35	1.48	<0.01	0.15	<0.01
	750	1>	2660	0.05>	0.57	<0.01	0.16	0.1
p-Aramid	500	107	1230	3.95	14.8	<0.01	1.00	1.40
	750	112	2010	0.05>	25.1	<0.01	0.47	1.04

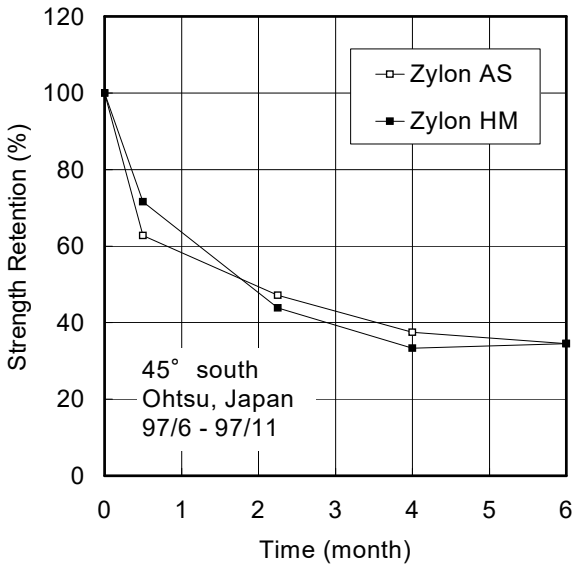
mg/g

Decomposition gases at 500°C were also measured. In the process of glass molding or aluminum extrusion, cushion materials such as felt are heated sometimes up to about 500°C. The amount of toxic gases from ZYLON® was also small at that temperature.

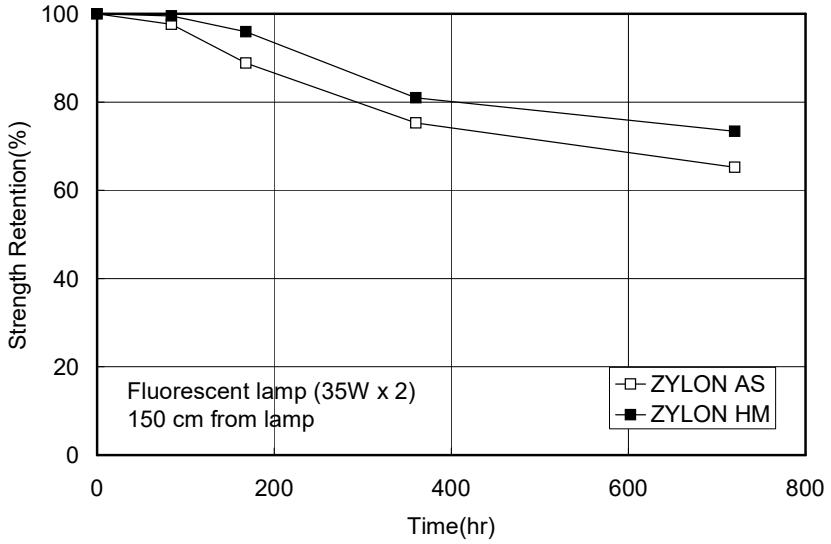
6. Light resistance

The strength of ZYLON® decreases with exposure to sunlight. Light resistance of ZYLON® was evaluated using Xenon light weather-ometer. As shown below, the strength decreases sharply at the initial stage of exposure. End products of ZYLON for outdoor use have to be protected by covering materials. The residual strength of ZYLON® after 6 months exposure to daylight is about 35%.





ZYLON® should be protected not only from ultraviolet light but also from visible light. These data show strength retention after exposure to fluorescent lamp.



7. Chemical resistance

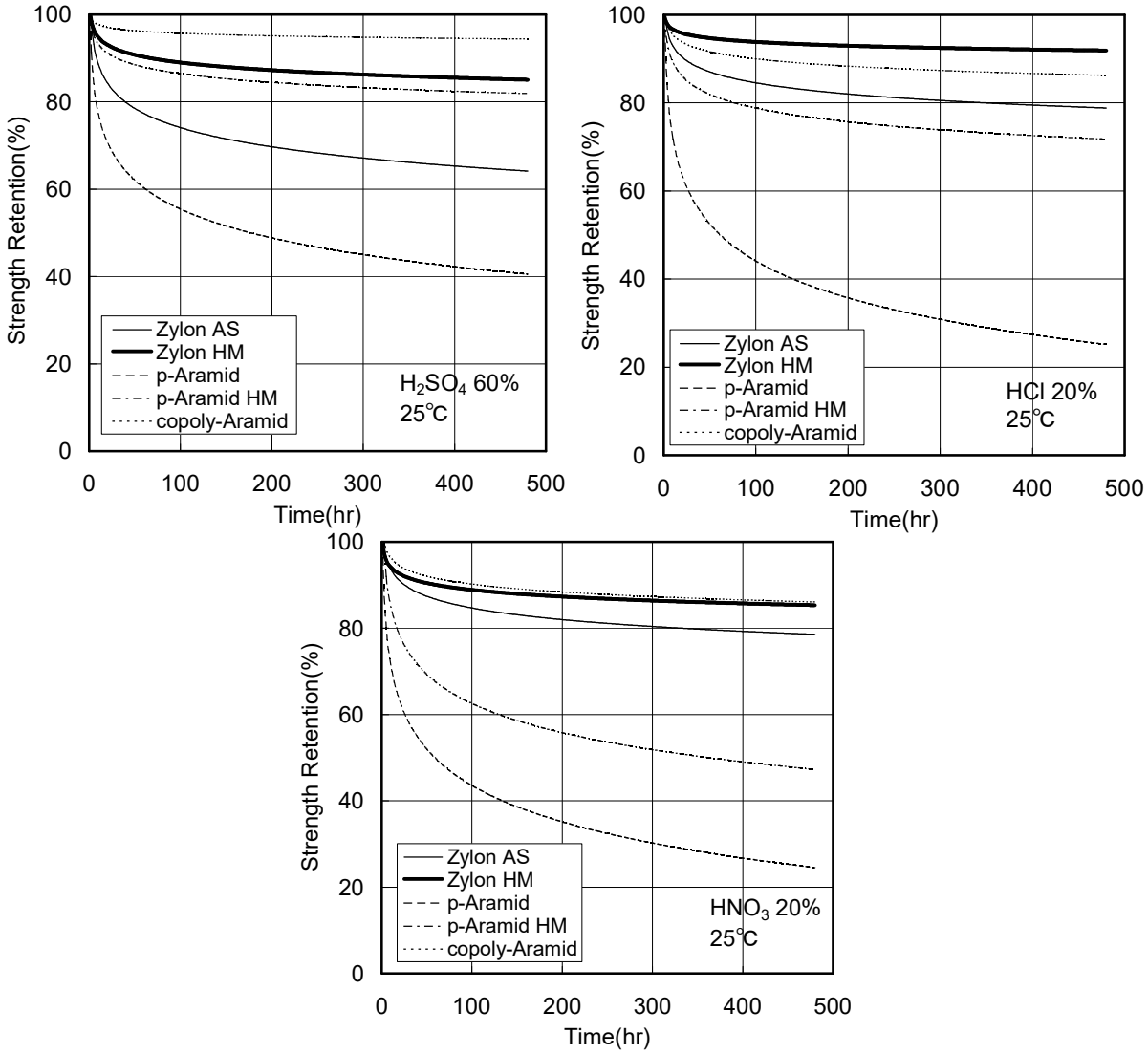
7.1 Organic mediums

ZYLON® is stable with most of organic mediums.

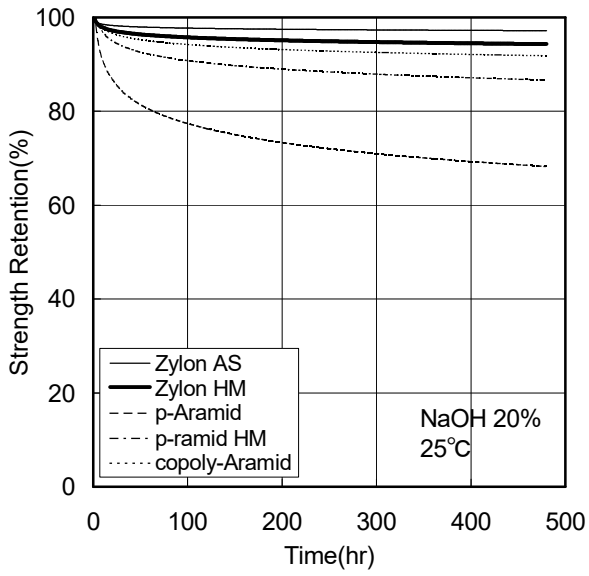
	Strength retention(%) after immersion for 500 hrs at room temperature	
Chemicals	Zylon AS	Zylon HM
Methylethylketone	100	99
Dimethylformamide	100	97
Methanol	100	99
Gasoline	100	95
Brake Fluid	100	96

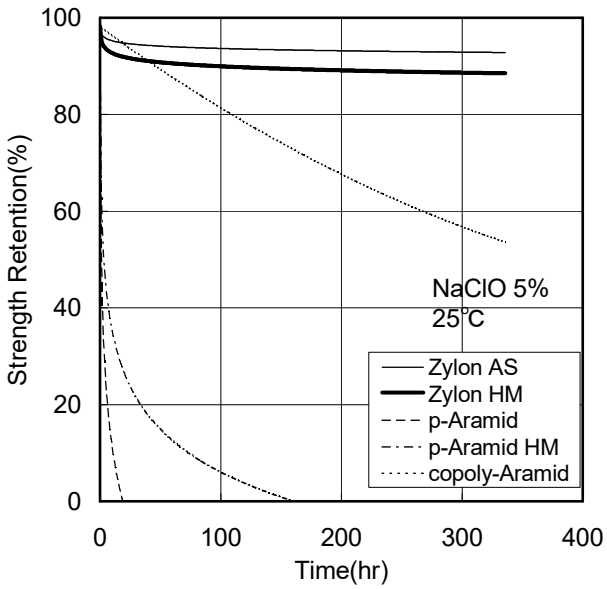
7.2 Inorganic mediums

Exposure to strong acids causes strength losses. However, ZYLON® is more stable than p-Aramid.

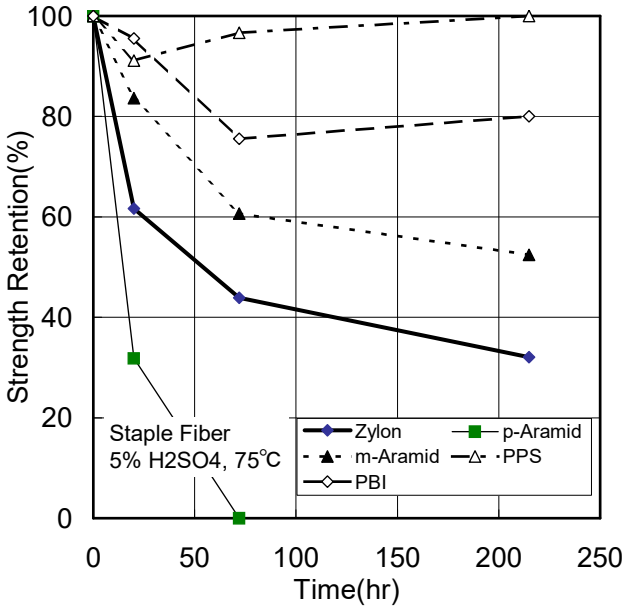


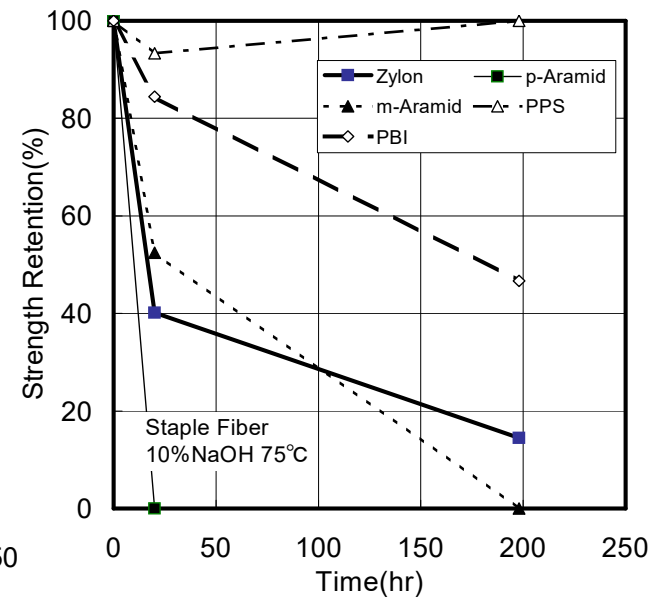
ZYLON® is stable to alkaline at room temperature. NaClO (bleach) does not cause strength loss for ZYLON® at room temperature.





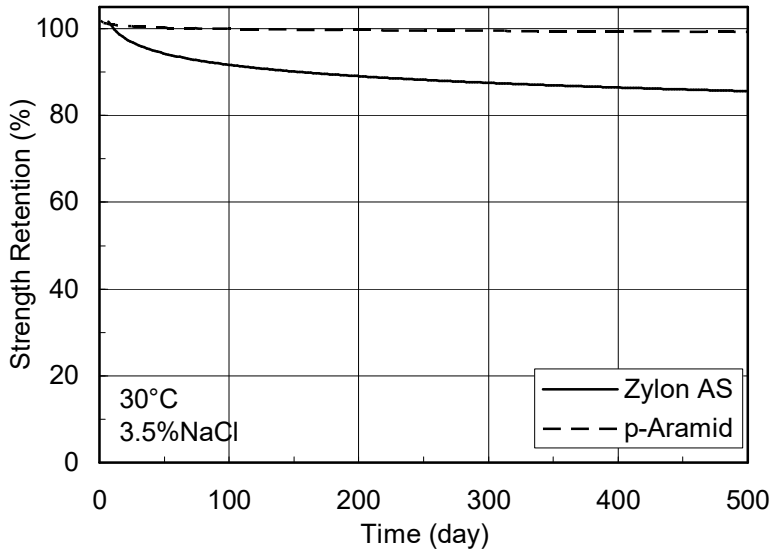
At higher temperatures, the strength of ZYLON® AS staple fiber decreases in acid and also in alkaline.





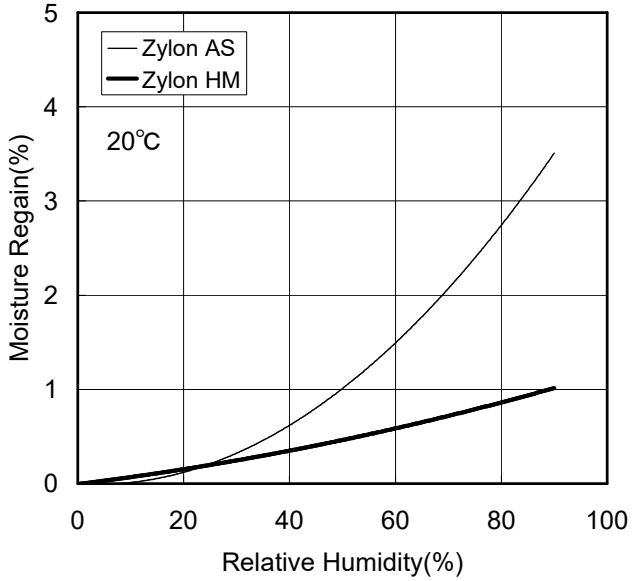
7.3 Seawater resistance

Seawater simulation shows a similar strength loss to high humidity condition.



8. Moisture pick-up

The moisture regain of ZYLON® at 20°C, 65%RH is 2.0% for AS and 0.6% for HM. The moisture regain of ZYLON® HM is far less than p-Aramid.



9. Miscellaneous

9.1 Compressive strength

The compressive strength of ZYLON® is much less than the tensile strength same as para-Aramid fiber.

Sample	Critical Strain	Tensile Modulus	Compressive Strength
	(%)	(GPa)	(GPa)
ZYLON AS	0.217	216	0.469
ZYLON HM	0.227	247	0.561
Aramid HM	0.633	118	0.749

(Bending Beam Method)

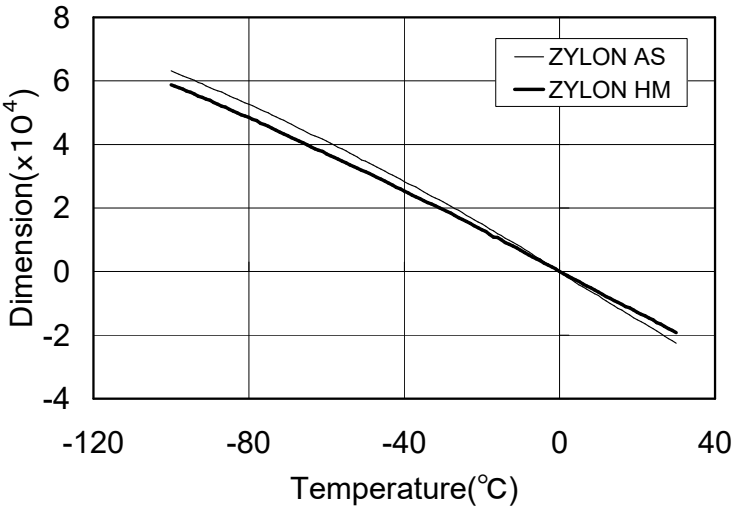
9.2 Knot and loop strength

Knot and loop strength of ZYLON® is 30-40% of its tensile strength. This is almost the same as p-Aramid fiber.

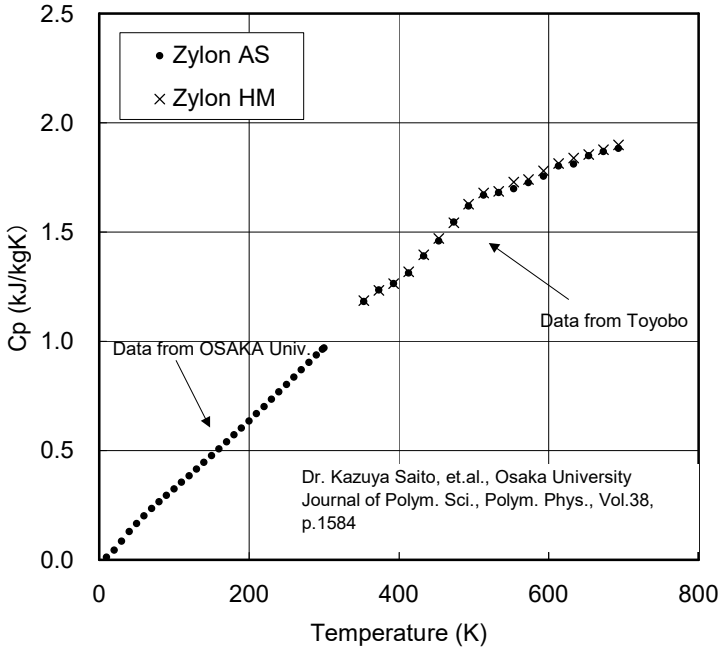
	Yarn dtex	Knot strength	Loop strength
		percentage(%) of tensile strength	
ZYLON AS	1110	32	45
ZYLON HM	1090	26	34

9.3 Thermal expansion coefficient

Coefficient of thermal expansion of ZYLON® is negative. The dimension along fiber direction decreases with increasing temperature. CTE of ZYLON®HM is around –6ppm/°C.

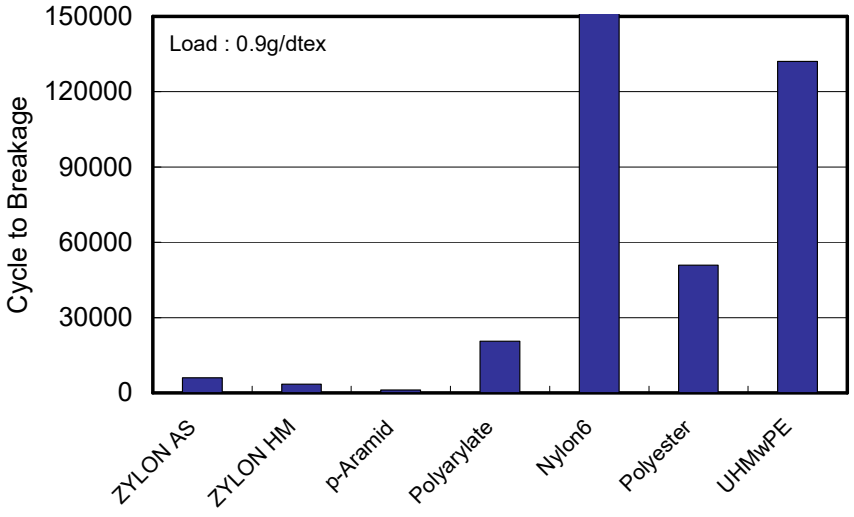


9.4 Heat capacity



9.5 Abrasion resistance between fiber and metal

Abrasion resistance of ZYLON® is higher than p-Aramid fiber under the same load, but much lower than Nylon or high molecular weight polyethylene fiber.



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The materials are to be stored free from exposure to light, high temperature and humidity.

ZYLON is a registered trademark of Toyobo Co., Ltd. in Japan.

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