Types and Application of Filler-added PTFE Materials

1. Introduction

Among plastic-based materials, PTFE offers diverse benefits including heat resistance, chemical resistance, insulation, non-stick, and low friction. Its scope of application is broad: it is used in various fields including semiconductor devices, chemical plants, automobiles, office equipment, and home appliances.

However, PTFE suffers from inadequate abrasion resistance and creep resistance, which are serious disadvantages leading to severe self-damage in the case where PTFE is used in sliding parts like shaft bearings and large deformation in the case where one is used in load-bearing parts. The addition of a different material, namely, filler, can alleviate these problems.

This report described the types, features, and applications of typical fillers.

2. Features

2-1) Modifiable Features

The addition of filler can modify features including abrasion resistance, creep resistance, thermal conductivity, and coefficient of linear expansion. Modified PTFE has approximately 1000 times stronger abrasion resistance, twice the creep resistance, and up to twice the thermal conductivity of pure PTFE. The optimal filler should be selected depending on the desired modification.

2-2) Types of Filler

Typical fillers include inorganic fillers such as glass fiber, graphite, molybdenum disulfide, and bronze. Organic fillers are also used.

The features of each filler-added PTFE are described below.

○ Inorganic fillers

● Glass fiber

Glass fiber has little effect on chemical and electrical properties. Glass fiber-added PTFE has approximately twice the compression creep resistance and approximately 1000 times better abrasion resistance than pure PTFE. These features make glass fiber-added PTFE ideal for improving abrasion resistance. The color is white, which makes it easy to use. However, it might break a counterpart shaft when used for shaft bearings.

● Graphite

Graphite improves creep resistance and reduces initial wear and starting resistance of PTFE. Graphite-added PTFE has excellent thermal conductivity and chemical resistance. It is less abrasive to the counterpart material, so it is economically efficient, although its abrasion resistance is not excellent.

● Carbon fiber

Carbon fiber-added PTFE has excellent compressive

Table1 Types and features of fillers [3)]

Filler type	Identifying symbol	Characteristics
Glass fiber	15%…2K0 20%…2N0 25%…2T0	Excellent abrasion resistance Excellent electrical characteristics Attached by alkali Poor abrasion resistance in water
Glass fiber + graphite	20%+5%…2N1	Excellent creep resistance Improves sliding properties
Glass fiber + MoS_2	15%+5%…2K7	Excellent creep resistance and compression strength Improves sliding properties Excellent electrical insulation
Graphite	15%…1K0	Excellent sliding properties Does not attach to soft opposite materials
Bronze	60%…3M0	Excellent creep resistance and compression strength Excellent heat conductivity
Bronze + carbon fiber	3U8	Excellent sliding properties in oil
Carbon graphite	25%…6T0 33%…6P0	Excellent creep resistance and load bearing properties at high temperatures
Carbon fiber	10%…8H0	Excellent sliding property in water Excellent creep resistance
Organic filler	9A1 9A2 9B1	Does not attach to soft opposite materials Stable sliding properties Excellent creep resistance and compression strength

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Table2 List of filler-added PTFE properties [3)]

Item	Unit	ASTM measuring method	Filler identifying symbol										
			Pure PTFE	2K0	2N0	2T0	2N1	2K7	1K0	3M0	6T0	6P0	8H0
Filler content	Amount %	−		Glass fiber 15%	Glass fiber 20%	Glass fiber 25%	Glass fiber 20% Graphite 5%	Glass fiber 15% MoS2 5%	Graphite 15%	Bronze 60%	Carbon/ graphite 25%	Carbon/ graphite 33%	Carbon fiber 10%
Specific gravity		D792	2.1	2.23	2.24	2.26	2.23	2.29	2.17	3.91	2.10	2.05	2.09
Tension	MPa	D638	30.9	23	20.6	18.6	14.7	18.5	16.0	18.5	17.5	13.5	20.0
Stretch	%	D638	400	320	300	280	235	280	230	215	55	15	200
Compression creep 60min MD	%	D621 (23℃ 13.7MPa)	−	6.6	6.0	5.2	5.8	4.6	5.2	3.2	3.4	1.9	6.8
Compression creep 60min CD			−	10.3	9.4	8.3	7.0	5.4	5.8	3.5	3.6	2.6	9.0
Compression creep 24h MD			14.3	9.6	8.7	7.9	8.0	6.5	6.9	4.5	4.5	3.7	9.4
Compression creep 24h CD			16.7	14.3	13.1	12.4	9.8	7.8	8.0	4.9	4.9	3.7	13.2
Compression creep Permanent deformation (after 24 hours) MD			7.9	5.3	4.9	4.5	3.9	3.0	3.3	2.0	2.0	1.7	5.1
Compression creep Permanent deformation (after 24 hours) CD			8.4	7.6	7.5	7.5	5.2	4.0	4.5	2.3	2.3	1.8	7.1
Compression creep 60min MD		(150℃ 19.6MPa)	51.8	52.4	51.3	50.7	36.8	45.5	43.0	40.4	35.0	32.4	33.7
Compression creep 60min CD			−	−	−	−	−	−	−	−	36.1	35.6	38.7
Bending strength 0.2% offset CD	MPa	D790	5.6	3.9	4.1	4.2	8.3	8.5	6.0	8.0	9.6	−	8.3
Bending strength Modulus of elasticity CD			340〜620	1,550	1,730	1,900	1,540	1,690	−	1,380	1,190	−	1,030
Compression strength 0.2% offset MD	MPa	D695	7.6	11.6	12.3	13.1	10.0	12.9	10.2	11.9	11.2	−	8.7
Compression strength 0.2% offset CD			−	8.9	8.9	8.9	10.1	12.7	10.7	12.2	8.4	−	9.6
Compression strength Modulus of elasticity MD			410	690	760	830	980	970	−	770	1,050	−	770
Compression strength Modulus of elasticity CD			−	600	650	700	960	830	−	800	840	−	770
Hardness	Durometer "D"	D2240	55	60	62	63	64	65	61	70	67	68	64
Impact strength (izod)	J/m	D256	155	144	129	117	154	159	140	10.5	−	−	168
Heat conductivity	W/(m·K)	Cence Fitch	0.24	0.37	0.40	0.45	0.20	0.33	0.45	0.47	0.43	−	0.19
Linear expansion coefficient 25〜90℃ MD	10^{-5}/℃	D696	−	14.2	13.4	12.6	13.5	15.0	12.6	9.7	8.5	−	13.4
Linear expansion coefficient 25〜90℃ CD			12.2	10.6	10.2	8.3	9.0	6.3	7.9	7.8	7.2	−	9.9
Linear expansion coefficient 25〜150℃ MD			−	15.1	14.2	13.2	13.1	15.8	13.5	10.3	9.4	−	14.5
Linear expansion coefficient 25〜150℃ CD			12.6	10.9	10.3	8.6	9.0	6.4	8.5	7.9	7.7	−	10.0
Linear expansion coefficient 25〜200℃ MD			−	16.3	15.4	14.4	13.9	17.3	14.6	11.4	10.6	−	15.7
Linear expansion coefficient 25〜200℃ CD			13.7	12.3	11.4	9.7	9.9	6.9	9.2	9.0	8.5	−	11.1
Linear expansion coefficient 25〜260℃ MD			−	18.5	17.7	16.8	15.9	20.0	17.6	14.0	13.5	−	18.2
Linear expansion coefficient 25〜260℃ CD			16.4	14.8	13.4	11.9	11.7	8.0	10.8	10.4	9.7	−	13.1
Water absorption rate	%	D570	0	0.015	0.014	0.013	0.016	0.010	0	0	−	−	−
Limit PV value 0.1m/s	MPa·m/s		−	0.6	0.7	0.7	0.8	0.8	0.9	0.6	1.0	1.0	0.9
Limit PV value 0.5m/s			−	0.7	0.9	0.9	1.4	1.5	1.4	1.0	1.4	1.5	1.5
Limit PV value 5.0m/s			−	1.1	1.2	1.2	1.8	1.8	1.3	0.6	1.8	1.9	1.8
Coefficient of abrasion (in air, after 50 hours)	$\frac{cm \cdot s}{MPa \cdot m \cdot h} \times 10^{-5}$	Measuring with Matsubara-type test instrument	7,100	5	7	7	7	6	9.8	13	8	13	6
Coefficient of abrasion (in water, after 50 hours)				5,500	−	5,100	−	−	470	−	20	26	20
Coefficient of dynamic friction (after 50 hours)		P=0.69MPa V=0.5m/s	−	0.39〜0.42	0.29〜0.35	0.50〜0.54	0.30〜0.32	0.29〜0.31	0.22〜0.25	0.12〜0.17	0.31〜0.37	0.31〜0.35	0.27〜0.30
Coefficient of static friction		P=3.4MPa	0.05〜0.08	0.10〜0.13	0.10〜0.13	0.10〜0.13	0.08〜0.10	0.08〜0.10	0.08〜0.10	0.08〜0.10	−	−	−

strength, creep characteristics, and abrasion resistance. These features are significantly improved in the high-temperature region above 200°C. It also has excellent sliding characteristics and good chemical resistance in water. It offers excellent sliding characteristics in fluids of low lubricity including acid and alkaline fluids.

● Molybdenum disulfide

Molybdenum disulfide-added PTFE has improved creep resistance and lubrication. It does not degrade electrical insulation, so it can be used for electrical usages. However, molybdenum disulfide is rarely added to PTFE as a single filler; it is added along with glass fiber and bronze.

● Bronze

Bronze-added PTFE has significantly improved abrasion resistance, compressive strength, creep resistance, hardness, and dimensional stability. It tends to retain oil on sliding surfaces, and has excellent abrasion resistance under oil lubrication, so it can be used for oil lubrication usages. However, it is important to note that bronze-added PTFE is not suitable for electrical and chemical applications.

○ Organic fillers

● Polymide-based resin

Polymide based resin-added PTFE is beneficial in the case where soft metal moving parts that are likely to be damaged by carbon-added or graphite-added PTFE are used as a counterpart material.

● Polyphenylene sulfide-based resin

Polyphenylene sulfide-added PTFE has creep resistance and dimensional stability.

● Aromatic polyester-based resin

Aromatic polyester based resin-added PTFE has improved mechanical characteristics including compression and bending, as well as stable sliding.

Like these examples, there are many types of filler. An appropriate filler should be selected depending on the usage conditions including load, sliding speed, lifespan, frictional conditions, counterpart material, linear expansion, corrosion resistance, and electrical properties.

Although pure PTFE is white, some fillers turn PTFE black or dark brown. These conditions should be considered depending on the position of use and the application.

3. Conclusion

PTFE has excellent chemical characteristics, sliding properties and non-stick, making it suitable for shaft bearings and sliding parts. In the case where filler is added to PTFE, the PTFE gains improved frictional and creep characteristics, making it suitable for mechanical purposes.

The type of filler determines the improvement in characteristics of PTFE. We hope the above explanation of various fillers will help our readers when selecting a material.

4. Reference

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