Study on Modified Polytetrafluoroethylene Composites Filled with Inorganic Nanoparticles

Polytetrafluoroethylene (PTFE) has excellent antifriction and self lubrication, but dimension stability is poor, the poor wear resistance, usually adopts the micron grade graphite, molybdenum disulfide, copper powder, glass fiber and other inorganic particles are filled and modify PTFE. Micron structured particle filling modification of PTFE, however, there are still some limitations, such as the contradiction between products softness, toughness and wear resistance, the improvement of the performance of the products processing is also limited.

Nanometer material is the excellent performance new material and developed quickly in recent years, it has the good physical and chemical properties which many micron-grade materials do not have, such as high particle strength, high specific surface area and high surface energy, etc., composite with plastic, will produce very strong interface function and good modification effect. This paper studies modification effect of inorganic nanometer particle on PTFE, focuses on the nanometer SiO2 and Al2O3 effect on the improvement of PTFE wear-resistance, results obtained excellent comprehensive properties of modified PTFE composites, the material is very suitable for the preparation of automobile engine crankshaft oil seal and other seals.

1 The experiment part

1.1 raw materials

PTFE: JF - 4TM suspended powder, particle size of 10 ~ 50 microns. Nanometer SiO2, Al2O3:30 ~ 40 nm particle size, specific surface area is equal or greater than 20 g/m2.

1.2 Modified PTFE material production process:

$$\left.\begin{matrix} PTFE \\ nanometer\ \text{meterial} \end{matrix}\right] \rightarrow checkout \rightarrow pretreatment \rightarrow sieving \rightarrow mixture \rightarrow proforming \rightarrow sintering \rightarrow machining \rightarrow checki$$

1.3 Main instrument

Universal testing machine: UH - I, Friction and wear testing machine: the MM - 200, Shaw hardness tester model: LX - D.

1.4 The performance test

The tensile strength and elongation at break: according to HG/T 2902-1997 to test; Abrasion and friction coefficient, according to GB/T 3960-1983 to test; Shaw hardness: according to GB/T 2411-2411 to test.

2 Results and discussion

2.1 The selection of dispersion mode of Inorganic Nanoparticles

The most important problem of nano-materials modified polymer is the nano-materials evenly dispersed in the polymer. For ordinary polymer, dispersion method includes solution blending method, melt blending method, melt intercalation method, etc. But PTFE almost has no solvent, the melt viscosity in the molten state is also high, the above dispersion method can not be used. Therefore, in this paper, the use of mechanical mixing, ultrasonic mixing and other decentralized way. The experimental results are shown in table 1. Table 1 shows that scattered in various ways, mechanical mixing and airflow crushing combination is the best way to disperse. In mechanical and ultrasonic mix combination way of dispersion, the modification effect is changed with the change of ultrasonic intensity, when the intensity of ultrasonic is 300 mA, the modification effect is better.

Table 1 inorganic nanoparticles dispersion effect on the properties of modified PTFE material

Scattered way	Tensile strength /MPa	Elongation at break / %	Shao D hardness	Abrasion quantity / g	Coefficient of friction
Mechanical blending	24.4	271.7	56.8	0.002 0	0.2
Mechanical blending + Ultrasonic mixing (The intensity of ultrasonic 200mA)	25.4	291.3	57.8	0.002 0	0.21
Mechanical blending + Ultrasonic mixing (The intensity of ultrasonic 300mA)	25.5	292.3	58	0.002 0	0.2
Mechanical blending + Ultrasonic mixing (The intensity of ultrasonic 400mA)	24	272.3	57.8	0.001 9	0.2
Mechanical blending + Airflow pulverization	26.5	306.9	57.6	0.001 7	0.2

Dispersing the inorganic nanopowders dispersed by mechanical mixing and airflow comminution of the modified PTFE composites, the state of the blended structure was measured by atomic force microscopy (AFM), the results are shown in figure 1. Figure 1 shows that inorganic nanoparticles is basically in the form of a single nanoparticles dispersion in the modified PTFE material, It is described that the dispersion effect of the dispersion method using the mechanical mixing and the airflow pulverization combination is good; and the dispersion method has the advantages of simple operation and stability and very conducive to industrial production.

Figure 1 Atomic Force Microscopic Morphology of Nano - particle Modified PTFE Composites

2.2 Effect of airflow crushing process on properties of PTFE modified by Inorganic Nanoparticles

The specific conditions were experimented on the dispersion process of mechanical mixing and airflow comminution, the results are shown in Table 2 and figure 2. Table 2 results show that when the air is pulverized, the choice of feed pressure 0.50 MPa, air crushing pressure of 0.75 MPa process conditions, which is advantageous for improving the performance of the modified PTFE material. If the feed pressure, airflow crushing pressure is too low, the mixing is not sufficient; If the feed pressure, air flow crushing pressure is too high, then PTFE will have a certain degradation, will result in modified products, tensile strength and hardness decreased too fast. Figure 2 shows that the wear amount of the modified PTFE material decreases with the increase of the number of times of air flow crushing, this is because with the increase of the number of airflow pulverization, nanoparticles with PTFE mixed more evenly, the effect of the nanoparticles modified is better, reflected in the wear of PTFE composite materials to further reduce.

Table 2 Effect of Airflow Crushing Pressure on Properties of Modified PTFE Material

Combination of air pressure	Tensile strength /MPa	Elongation at break / %	Shao D hardness	Abrasion quantity / g	Coefficient of friction
Feed pressure 0.25 MPa、Airflow smashing pressure 0.50 MPa	24.4	281.7	61.8	0.0025	0.22
Feed pressure 0.50 MPa、Airflow smashing pressure 0.75 MPa	26.4	297.3	60.8	0.0022	0.22

Feed pressure 0.75 MPa、Airflow smashing pressure 1.0 MPa	25.5	292.3	58	0.0022	0.22

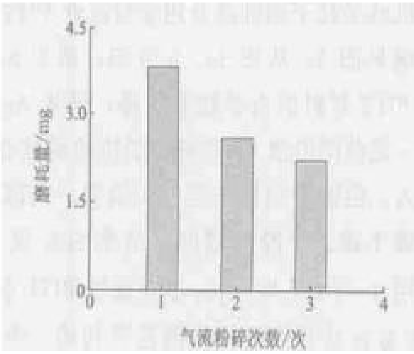

Figure 2 Effect of the number of times of airflow crushing on wear performance of PTFE composites

2.3 Effect of Inorganic Nanoparticles on Mechanical Properties of Modified PTFE Materials

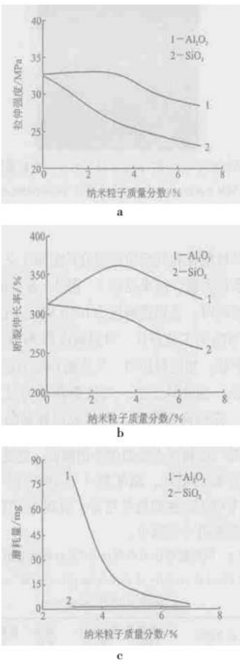

Figure 3 Effect of Nanometer Particle Type and Dosage on Mechanical Properties of PTFE Composites

The effect of the kind and amount of inorganic nanoparticles on the properties of modified PTFE is shown in Figure 3. As can be seen from a and b of Fig. 3, the addition of nano-SiO2 reduces the mechanical properties of PTFE, The addition of nano-Al2O3 increases the tensile strength and elongation at break of PTFE in a certain range, but with the further increase in the amount of PTFE material, the mechanical properties of PTFE materials decreased, and the decrease is smaller than that of the nano-SiO2. Therefore, filling the modified PTFE with 0 ~ 3% nano-Al2O3 is beneficial to improve the mechanical properties of PTFE composites. It can be seen from Figure 3c, Adding nano-SiO2 and nano-Al2O3 into PTFE, have significantly improved the wear resistance of PTFE materials, especially a small amount (3%) of nano-SiO2 modification, the PTFE material on the wear resistance has greatly improved, further increase the amount, the improvement in abrasion resistance is not significant. When the amount of nano-Al2O3 is more than 7%, the same effect can be achieved by nano-SiO2 modification.

Single nano-particles filling modification of PTFE material has certain limitation, it can only improve the performance of PTFE material in one aspect. In order to get excellent properties of modified PTFE material, nanometer Al2O3 and nano - SiO2 composite filling modification of PTFE experiment, the experimental results are shown in table 3. Experimental results showed that nano Al2O3 tensile strength, elongation at break of PTFE material, nano - SiO2 significantly improve the abrasion resistance of PTFE material, two aspects to improve effectively together, add 2% SiO2 and 3% nano Al2O3, the modified PTFE composite having excellent tensile properties of tensile strength of 27.4 MPa, elongation at break of 306.7%, Shao D hardness of 60.0, abrasion of 0.001 g and coefficient of friction of 0.20.

Table 3 Effect of Nano - particle Composite Filling on Properties of PTFE

Modified material and dosage	Tensile strength /MPa	Elongation at break / %	Shao D hardness	Abrasion quantity / g	Coefficient of friction
5 % Glass fiber	28	295.6	58.8	0.072 0	0.15
5 % nano SiO2	24.5	273.1	59.7	0.001 7	0.18
5 % nano Al2O3	30	343.1	59.2	0.012 0	0.2
3 % nano SiO2+2 % nano Al2O3	25.6	286.5	60	0.000 9	0.2
2 % nano SiO2+3 % nano Al2O3	27.4	306.7	60	0.001 0	0.2
3 % nano SiO2+3 % nano Al2O3	25.8	286	60	0.000 8	0.2

2.4 Application test

After the nano-particles modified PTFE composite materials made of automotive oil seal, the bench durability tests have been carried out. Test condition: test oil 15w / 40; Test oil temperature (120 + 3) ℃; Shaft beating 0.38 mm; Sitting holes eccentric 0.38 mm; Shaft speed 3400 r/min; Test period 120 ℃ x 20 h x 3 400 r/min + x 4 h * 0 r/min at room temperature. The test results show that There was no leaking oil in any form in 240 hours, far more than 150 hours of time required by CES10599; After the test by the demolition, the oil seal on the axis almost no wear. In the ordinary PTFE oil seal test, found that the shaft has obvious wear; From test after two main oil seal lip piece of wear, wear resistance of PTFE is better than the ordinary contrast samples. Therefore, with the experimental nano-particles modified PTFE composite made of oil seal, can better meet the needs of the automotive industry.

3 Conclusions

A. The inorganic nanoparticles can be uniformly dispersed in PTFE by a combination of mechanical mixing and airflow comminution.

B. The tensile strength and elongation at break of modified PTFE were improved by the addition of 0 ~ 3% nano -Al2O3; When the dosage is increased, the mechanical properties of the modified PTFE are decreased, but the rate of decrease is slower.

C. 3% of the amount of nano-SiO2 significantly improved the wear resistance of modified PTFE materials.

D. Nano-Al2O3 and nano-SiO2 composite modified PTFE, obtained a comprehensive performance of PTFE wear-resistant materials; the tensile strength of 27.4 MPa, the elongation at break 306.7%, shao (D) 60.0 hardness, abrasion quantity 0.001 g, 0.20 friction coefficient, the modified material is very suitable for the preparation of automobile engine shaft oil seal.