Analysis of thermal expansion properties of PTFE matrix composites

PTTE (polytetrafluoroethylene) and its composites as excellent self-lubrication material both in industry and aerospace fields are widely used, the thermal expansion characteristics and linear expansion coefficient as a very important physical parameters on the products design and use effect is large. Application of PTFE material temperature range is very wide, but there are changes at room temperature, while accompanying changes in structure and size. Because PTFE material bigger than linear expansion coefficient of metal materials, and large temperature changes, it is generally only larger temperature ranges of average linear expansion coefficient. Considering the phase change process of PTFE and composites of precision mechanical structure clearance and the use of a larger impact performance, the author analyzes the pure PTFE and aramid fiber reinforced PTFE matrix composites in thermal expansion between the - 100 ℃~ + 250 ℃.

Room temperature phase transition of PTFE

PTFE material with special spiral chain structure, along the main chain of C - C plane trans position, reverse for about 17 ° Angle. Under normal pressure, there are two reversible transitions in PTFE crystals at about 19 ℃ and 30 ℃. Under 19 ℃, the repeat unit contains 13 CF2, repeat distance of 1. 68 nm, the repeat distance chain be reversed in 180 ℃, unit cell belongs to triclinic crystal system. As shown in figure 1 in 19 ℃ PTFE material part through a crystal phase diagram type transformation, in 19 ℃ above spiral slightly spread, repeat unit contains 15 CF2, repeat distance of 1. 95 nm, is within the repeat distance chain turn 180 ℃, molecular accumulation into nearly hexagonal cylinder, unit cell of hexagonal system. As shown in figure 1, PTFE material in normal temperature zone in the phase diagram to mutually Ⅱ under 19 ℃, mutually Ⅳ between 19 ~ 30 ℃, PTFE has other phase transformation under high pressure.
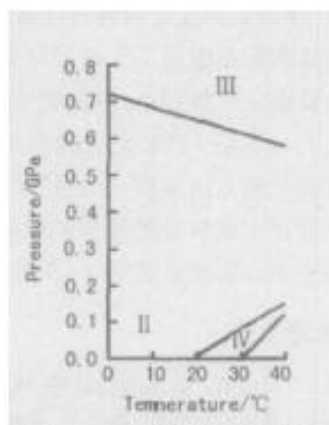

Figure 1   The partial phase diagram of PTFE material

PTFE crystals in triclinic crystal system into a crystal structure transition of hexagonal system, volume increased about 1. 2%. At 30 ℃, PTFE crystal crystallization relaxation, the helix of the chain becomes irregularly wound, when 30 ℃ volume change about 10% of the 19 ℃.Due to the crystal transformation and crystallization temperature point in common temperature range, the relaxation of almost all application condition will override this temperature range. In the process of crystal transformation and crystallization relaxation, PTFE volume changes obviously, corresponding to the application performance of PTFE and its composites have an impact.

The preparation of PTFE matrix composites

PTFE matrix composites using powder blending, cold pressing molding and sintering temperature control of preparation process. PTFE powder produced by light chemical industry research institute, the particle size of 20 ~ 40 microns, density of 2. 2 g/cm3.Enhancement for commercially available with aramid fiber, fiber diameter of 10 ~ 12 mu m, length is about 100 microns, the density of 1.45 g/cm3. Strengthening agent quality percentage adopts 15% and 15% respectively. Reinforcing fiber with PTFE matrix after mechanical mixture, under pressure from 60 M P a pressure maintaining 10 min molding, then in sintering furnace control of sintering temperature, sintering temperature of 380 ℃, 300 min sintering time, l/cooling rate of 20 ℃ / M in, along with the furnace cooling. The cooled sintered specimen is machined to produce the required test piece.

Measurement and Analysis of Linear Expansion

Linear expansion coefficient of characterization of objects caused by temperature rise 1 ℃ which affects the ratio of growth and its original length. Set an initial length of an object as L0, L is the length of the increment when the object temperature T, the cable expansion coefficient alpha α_L is:

$$\alpha_L = \frac{1}{L} \lim_{\Delta T \to 0} \frac{\Delta L}{\Delta T}$$

With German D IL 402 c type thermal expansion instrument measuring the linear expansion coefficient of PTFE matrix composites, measure the direction parallel to the direction of specimen molding pressure. Sample 5 mm in diameter, length of about 25 mm. Experimental analysis temperature range: - 100 ~ + 250 ℃, low temperature zone by liquid nitrogen for evaporative cooling way, after - 100 ℃ keep 3 min began to heat up. Adopted in 0 ~ + 50 ℃ temperature zone in the heating rate of 2 ℃ / m, other zones are used in the heating rate of 5 ℃ / m.

PTFE material and adding 15% and 25% respectively of aramid fiber thermal expansion of PTFE composites curves as shown in figure 2 ~ 4, respectively. Abscissa is temperature, ordinate is amount for sample linear expansion. According to the definition, the linear expansion

coefficient curve 2 ~ 4 by differential and linear change corresponding linear expansion coefficient curve, as shown in figure 5 ~ 7, respectively.

From figure 2 ~ 4, aramid fiber reinforced PTFE matrix composites show almost consistent with pure PTFE material thermal expansion characteristics, below 0 ℃ and 50 ℃ above sample length increase are almost linearly with the temperature, the turning point between 0 ~ 50 ℃.After adding aramid fiber materials of the thermal expansion amount is reduced, and the reduction increases with the increase of additive content. Three kinds of material in different temperature range of the average linear expansion coefficient values as shown in table 1, in - 100 ~ 0 ℃ interval linear expansion coefficient of value only half of the 50 ~ 250 ℃ range value, within the range of the two interior expansion coefficient with the increase of the filler content reduced slightly, and within the range of 0 ~ 50 ℃ insider expansion coefficient increases slightly with increasing filler content.

Table 1   The average linear expansion coefficient of PTFE composite materials $\times 10^{-5} K^{-1}$

Temperature range	PTFE	PTFE+15% aramid	PTFE+25% aramid
-100~0℃	8	7.8	6.9
0~50℃	17.8	18.3	18.9
50~250℃	16.7	15.5	13.8
-100~250℃	14.6	13.7	12.5

As can be seen from figure 5 ~ 7, linear expansion of aramid fiber reinforced PTFE matrix composites curve profile consistent with that of pure PTFE material. Under 0 ℃, three kinds of linear expansion coefficient of material all showed increasing trend with the increase of temperature, linear expansion coefficient of the material is pure PTFE under 10 x 11-5 K - 1, after adding 15% and 25% of aramid fiber linear expansion coefficient are reduced to 10 x 10-5 and 9 x 10 K - 1-5 K - 1 the following, and expansion curve flattens. In 50 ~ 250 ℃ range, linear expansion coefficient of the same with the temperature increasing, the pure PTFE for linear expansion coefficient (7. 4 ~ 27. 5) x 10 - K - 1, 5 and add respectively 15% and 25% after aramid fiber linear expansion coefficient (6. 3 ~ 26. 2) x 10-5 K - 1 and 6. 3 ~ 23. (1) x 10-5 K - 1.In 0 ~ 50 ℃ range, due to containing PTFE material phase transition point, linear expansion curve changes appear several twists and turns, but the 3 kinds of materials are at 25. 5 ℃ at its highest point, near a crystallization relaxation near 30 ℃.Crystal structure transition temperature point of the three kinds of materials have some deviation, pure PTFE material appeared in the vicinity of 17 ℃ crystal structure transformation, and transformation point after adding 15% and 25% of aramid fiber are reduced to around 13 ℃.And after adding filler PTFE material general tendency of lower linear expansion coefficient, high coefficient of linear expansion of PTFE material is from low to high in turn, PTFE + 15% aramid fiber composites, PTFE + 25% of

aramid fiber composite materials. In the case of phase change can achieve maximum linear expansion coefficient average linear expansion coefficient of 3 ~ 5 times.
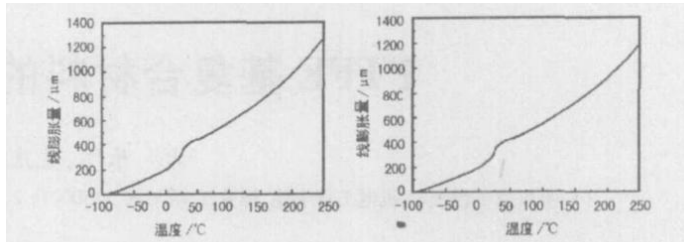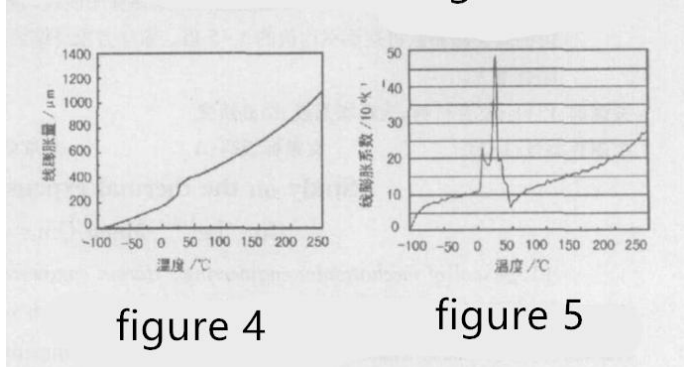

figure 2

figure 3

figure 4

figure 5

Generally, adding graphite in PTFE and inorganic fillers such as glass fiber filler does not participate in the crystallization of the PTFE molecular chains, crystal transition temperature of PTFE is not having an impact. Aramid fiber made of PTFE crystal transition temperature the temperature offset, peak temperature relaxation of crystallization temperature and expansion is essentially the same, description of aramid fiber in a certain degree of participation in the crystallization of the PTFE molecule chain, copolymer copolymer results makes grain size small, Crystal changes are more prone to swelling, and reflects the crystalline transition region line expansion coefficient becomes larger.
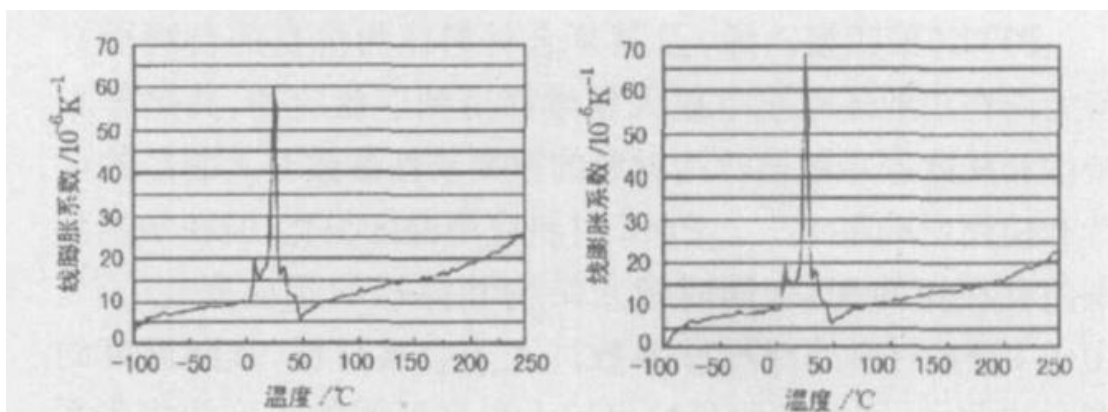

figure 6

figure 7

Conclusion

The linear expansion coefficient of PTFE matrix composites with the temperature change is bigger, linear expansion coefficient is far less than that of low temperature zone high value. With aramid fiber as reinforcing agent, the decrease of average linear expansion coefficient, the filler content is higher, the smaller the average linear expansion coefficient. After adding filler PTFE composites compared with pure PTFE material crystal structure transition temperature drift in the direction of low temperature, crystallization temperature relaxation has not big change, but in the crystal type of filler content in the transformation process, the more the linear expansion coefficient, the greater the maximum linear expansion coefficient is 3 ~ 5 times the average linear expansion coefficient.