The Effect of HTT on the Physical Properties of Carbon Fibers

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Introduction

The graphite fibers are generally used in the 3D C-C. The characteristics of graphite fibers are: the high carbon content, good crystallinity, high thermal conductivity, low coefficient of thermal expansion, high purity, high modulus of elastisity, high specific heat. But the characteristics of carbon fibers are: high elongation of rupture, high specific surface, high specific electric resistance, high coefficient of thermal expansion. Obviously, the graphite fibers has more merits than the carbon fibers in manufacturing 3D C-C. This paper is intend to research the influence of the HTT on some physical properties of carbon fibers.

Experiment

The change of the properties of carbon fibers in the heat treatment process are closely concerned with HT process parameters. In this paper the following parameters of high temperature heat treatment are used:

--- The HTT studied include 1300 °C, 1800 °C, 2000 °C, 2300 °C and 2500 °C.
--- The heating cycles studied are 1hr. 3hr. 6hr. and 12hr.
--- Three kind of loads (no load, a little tensile load, tensile load) on carbon fibers are adopted.

The experiment of HT was carried out in the induction furnace at the Ar atmosphere. PAN middle-strength type-I carbon fiber, PAN high-strength carbon fiber T300 and PAN high-modulus graphite fiber M40 are used in the experiment.

The density, coefficient of thermal expansion, specific electrical resistance of carbon fibers were measured before and after their processing. In addition, their crystallite size(Lc) and mean interplanar spacing(doo2) are also measured by x-ray diffraction. Some of typical results were given in table 1.

As shown in table 1, density of PAN carbon fibers is increased from 1.73-1.76 g/cm^3 to 1.82-1.84 g/cm^3 after HT at 2000 °C and to 1.99 g/cm^3 after HT at 2500 °C. These densities are higher than that of M40 (as receipt) and are corresponding to that of HT M40 fibers at the respective HTT. The CTE of the middle-strength type-I carbon fibers after HT at 2000 °C is reduced approximately by a factor of 3 (for 1000 filaments/ply) and a factor of 4 (for 3000 filaments/ply). To compare with its value (as receipt), these CTE are corresponding to or a little lower than it of M40 fibers. After HT at 2000 °C, specific electric resistance is reduced considerably (about 50 %) for middle-strength type-I and T300 fibers but no so much (about 23 %) for M40. After HT at 2500° C specific electric resistance of all these fibers are also reduced, but their values are approximate to same. After HT at 2500 °C, the doo2 of these three fibers are in the range of 3.361 Å to 3.373 Å. It shows that the degree of their graphitization is high.

Table 1. Some physical properties of carbon fibers

fiber type		mid-strength type I		T300	M40
FILAMENT/ply		1000	3000	3000	3000
density g/cm^3	as received	1.74	1.73	1.76	1.81
	2000 °C	1.82	1.82	1.84	1.84
	2500 °C	1.99	1.99	1.99	1.99
CTE x10^6/ °c R.T.-900c	as received	0.99	0.86	1.04	0.42
	2000 °C	0.35	0.20	-	-
specific electric resistance Ω cm	as received	0.00-154	0.00-154	0.00-155	0.00-085
	2000°C	0.00-075	-	0.00-071	0.00-065
	2500°C	0.00-055	0.00-040	0.00-054	0.00-041
doo2 (Å)	as received	3.542		3.535	3.433
	2000°C	3.450		3.463	-
	2500°C	3.361		3.373	3.373
Lc (Å)	as received	12.6		14.0	31.0
	2000°C	31.62		32.28	-
	2500°C	96.67		93.20	-

Conclusion and discussion

During the HT process the microstructure of carbon fibers along axis and radial changed, mainly in the degree of graphitization and orientation etc. It is reported(1) in the range of 1000-1500 °C the process of crystallite polymerization and rearrange is slow, but at the temperature about 2000 °C, it becomes rapid, at 2500 °C it reaches saturation state. It is the structural variation that causes change of physical properties of carbon fibers in a wide range. With increasing HTT, the change on the graphitization degree of the PAN middle-strength type-I carbon fibers, the density, the specific electric resistance, Lc, doo2, CTE is caused obviously. By high temperature HT (above 2000-2500 °C) the physical properties of middle-strength type-I fiber could reach the level of graphite fibers (as M40). According to our experiments, the HTT is the main factor effected on the physical properties of carbon fibers. This study also shows, it is possible to use PAN carbon fibers(including the middle-strength type) as raw material in manufacturing 3D C-C.

Reference

1. D.J. Johnson, Chemistry and Industry p.692. 18. sep. 1982