NEW THORNEL® K-800X FIBER WITH HIGH THERMAL CONDUCTIVITY

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Introduction

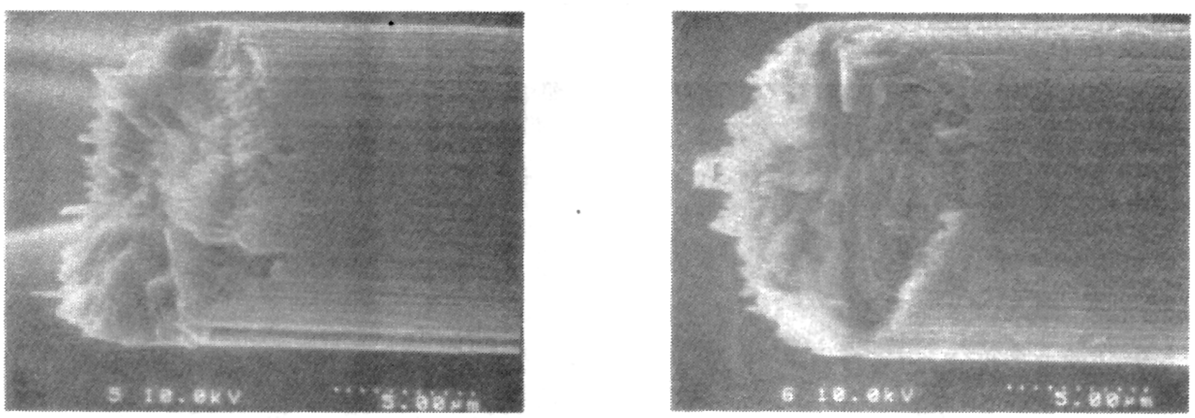
Ultra high thermal conductivity graphite fibers have been developed by BP Amoco and are protected by a strong position patent [1]. Thornel® K-1100 fiber with a thermal conductivity around 1000 W/mK is commercially available from BP Amoco. A new, lower cost Thornel® K-800X fiber with a typical thermal conductivity of 800 W/mK has been developed. BP Amoco plans to commercialize the fiber in 1999. The primary application of K-800X fiber is in the space market where high thermal conductivity is one of the major requirements. Typical K-800X properties are shown in Table 1.

During K-800X development, two variants of fiber with thermal conductivity of 800 W/mK were considered, but only variant 1 was chosen as a final product. Both variants have almost identical fiber mechanical properties identified in Table 1, but variant 2 has slightly higher thermal conductivity within the range indicated in Table 1. However, mechanical laminate properties were quite different for these variants. This paper presents the laminate properties for these two variants and discusses the difference between them.

Experimental

Two K-800X fiber variants were made using two different BP Amoco proprietary processes. The common features of both processes is that fibers were spun with pitches of high mesophase content, subjected to oxidative thermosetting treatment, and then were heat treated to achieve desirable thermal conductivity. After thermal treatment, both fiber variants were surface treated and coated with standard AP-200 sizing developed in Amoco (~ 1 wt% size pick-up). Both variants were prepared in a tow size of 2000 filaments with an average filament diameter of 10 μm.

All fiber samples were prepregged under similar conditions with a typical cyanate ester resin available commercially. Lay-up, bagging, and cure were performed per Amoco standard laboratory techniques for prepreg from high modulus fibers.



(a) (b)

Figure 1. SEM images of two K-800X fiber variants: (a) variant1; (b) variant 2.

All mechanical testing was performed in BP Amoco's laboratory. Thermal conductivity of laminates was measured by Materials Innovations Inc. (MII) using the Fourier Thermal Conductivity Method.

Results and Discussion

SEM pictures of of K-800X filaments for variant 1 and variant 2 are presented in Figure 1. Well organized graphitic structure responsible for high thermal conductivity can be seen.

Results on laminate testing are presented in Table 2. Several significant differences were observed between two K-800X variants. Among the mechanical properties evaluated, variant 2 fiber yielded higher tensile strength than variant 1, although the difference was not that great. However, variant 1 showed much superior compressive, flexural, and shear properties. Both variants had similar thermal conductivities, with variant 2 being slightly more thermally conductive.

The reason that variant 2 showed higher thermal performance and lower compressive, flexural, and shear performance is its higher degree of fiber crystallinity. It has been seen before [2] that more crystalline fiber have lower compressive, flexural, and shear performance. We explain the higher crystalline organization of variant 2 fiber by different process characteristics.

In spite of superior thermal performance of variant 2 fiber, K-800X manufactured by variant 1 process was finally decided to be commercialized due to its superior mechanical performance such as compressive, flexural, and shear strength.

References

1. Schulz DA, Nelson LC. Continuous, ultrahigh modulus carbon fiber. US Patent 5266294, 1993.
2. Kumar S., Anderson DP., Crasto AS. Carbon fibre compressive strength and its dependence on structure and morphology. Journal of Materials Science 1993;28(2):423-439.

Table 1. Typical properties of Thornel® K-800X 2K fiber after surface treatment and sizing with AP-200 size (~ 1 wt% size pick-up).

Tensile Strength (ksi)	Tensile Modulus (Msi)	Yield (g/m)	Density (g/cm^3)	Electrical resistivity (μΩm)	Thermal conductivity (W/mK)
> 300	> 125	0.325	2.20	1.2 – 1.5	800

Table 2. Laminate properties of two K-800X variants.

Properties		Variant 1 (To Be Commercialized)	Variant 2
Tensile[1,2]	Strength (ksi)	204	218
	Modulus (Msi)	75.5	74.5
Compressive[1,3]	Strength (ksi)	42.0	34.0
	Modulus (Msi)	72.4	69.3
Flexural[1,4]	Strength (ksi)	72.4	67.0
	Modulus (Msi)	59.1	56.8
Shear strength, Short Beam Method (ksi)		5.1	4.5
Thermal Conductivity[1] (W/mK)		472	498

[1] - normilized to fiber volume fraction of 60%.
[2] - tensile modulus determined as the slope of the chord between intersepts at 1000-2000 με.
[3] - compressive modulus determined as the slope of the chord between intersepts at 100-250 με.
[4] - flexural modulus determined as the slope of the chord between intersepts at 250-1000 με.