EFFECT OF COMPRESSIVE PRESTRESS ON THE THERMAL CONDUCTIVE PROPERTIES OF CARBON MATERIALS

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Introduction

It is well known that an application of compressive prestresses to carbon materials brings about decreases in Young's modulus and bending strength [1-3]. Since the thermal conductivity of carbon materials contains the same parameter (sound velocity) as Young's modulus, it is believed that it also decreases due to compressive prestresses. These properties changes should be taken into account in the structural design of components made of carbon materials. This paper describes changes in thermal conductivity of carbon materials due to compressive prestresses and a correlation of thermal conductivity with Young's modulus.

Experimental

Materials tested were a nuclear grade fine-grained isotropic graphite (IG-430U) and a C/C composite (CX2002U) which were made by Toyo Tanso Co. Ltd.. Typical properties of tested materials are shown in Table 1. The original specimen geometry was 18x18x30 mm. After about 90% of the compressive strength were applied to the direction of 30 mm of the specimen., the Young's modulus change was examined by the ultrasonic propagation method. After that a disk specimen (10mm dia.x2mm thick.), which was used for the thermal diffusivity measurement, was cut out of the original specimen.

The thermal diffusivity was measured over a temperature range from room temperature to 1300K by the laser flush type thermal property measurement apparatus (TC-7000S, Shinku Riko Co.). Temperature dependence of the specific heat was evaluated by using the Butland equation. The thermal conductivity λ was calculated by the equation, $\lambda = \rho c \kappa$, where ρ is density, c specific heat and κ thermal diffusivity.

Results and Discussion

Table 2 and Table 3 show the effects of compressive stresses on the Young's modulus and electrical resistivity of IG-430U and CX-2002U materials, respectively. The Young's modulus decreased more than 10% in the direction of the stress applied. In the case of IG-430U it is noted that the Young's modulus decreased in the perpendicular direction of the stress applied too. The specific resistivity increased slightly in the direction of the stress applied. Figure 1 shows that the thermal conductivity of IG-430U decreases about 10% due to prestress. The thermal conductivity of CX-2002U in the direction of the stress applied decreases slightly due to stress, which was applied to the axial direction of carbon fiber, as shown in Figure 2.

Thermal conductivity of nonmetallic solid, λ is expressed by the equation, $\lambda = \frac{1}{3} c v \ell$, where c is specific heat, v the sound velocity and ℓ the mean free path of phonon. If we apply the above equation to the carbon materials, thermal conductivity should be related to the sound velocity except for the change in the other parameters. Decrease in thermal conductivity of carbon materials due to compressive prestresses is correlated to that in Young's modulus.

Conclusions

The thermal conductivity of carbon materials decreases due to compressive prestresses. It is related to the sound velocity of the materials as well as decrease in Young's modulus. The changes in the thermal conductivity and the Young's modulus of the carbon materials should be taken into account in the structural design of carbon components.

References

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Table 1 Materials tested.

Tested Materials	Bulk Density (g/m3)	Electrical Resistivity ($\mu\Omega \cdot m$)
IG-430	1.82	9.7
CX-2002U (XX, YY, ZZ)	1.67	1.7(XX) 3.4(YY) 5.1(ZZ)

Table 2 Changes in Young's modulus and electrical Resistivity of IG-430U. (stress axis:L)

Specimen	Changes in E ΔE/E0(L) (%)	Changes in E ΔE/E0(T) (%)	Changes in Electrical Resistivity $\Delta\rho/\rho$(%)
No.3-1	-12.0	-3.6	+1.2
No.3-2	-13.8	-4.9	+1.7

L: parallel to the stress axis

T: perpendicular to the stress axis

Table 3 Changes in Young's modulus of CX-2002U XX-direction (parallel to the stress axis).

Specimen	E0 (Gpa)	Prestressed To 0.9σc E(Gpa)	Changes in E(%) ΔE/E0	Changes in Density (%)	Changes in Velocity Δv/v (%)
No.1	14.3	11.6	-18.8	-0.1	-7.7
No.2	10.9	9.88	-11.1	0	-3.5

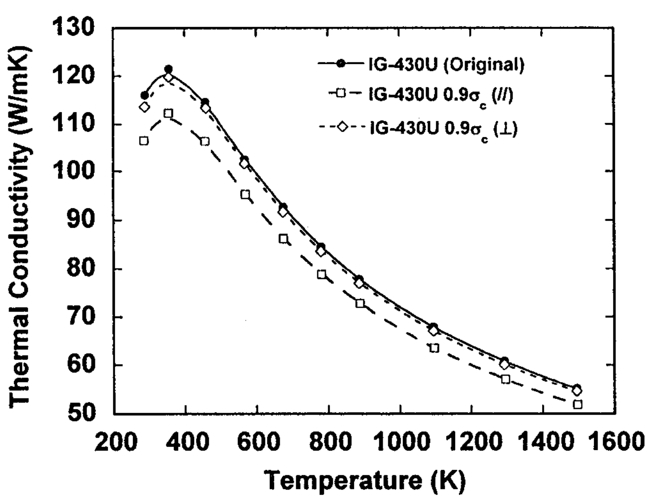

Figure 1 Thermal conductivity of nonstressed compressive prestressed IG-430Uas a function of temperature.

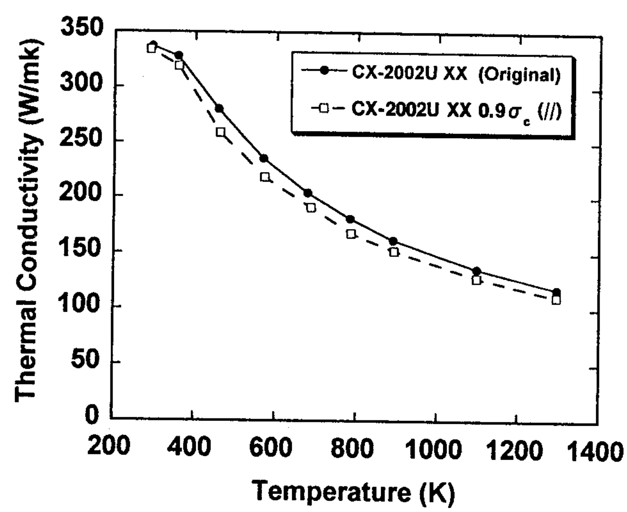

Figure 2 Thermal conductivity of nonstressed and compressive prestressed CX-2002U as a function of temperature.