10/1-16-90 JS (1)

UCID--21860

DE90 004484

COEFFICIENTS OF THERMAL EXPANSION FOR A CARBON-CARBON COMPOSITE

William W. Feng
Materials Test & Evaluation Section
Thomas H. Hoheisel
Engineering Measurements & Analysis Section
ENGINEERING SCIENCES DIVISION

November 17, 1989

Lawrence Livermore National Laboratory

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.
Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

This report has been reproduced
directly from the best available copy.

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information
P.O. Box 62, Oak Ridge, TN 37831
Prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd.,
Springfield, VA 22161

Price Code	Page Range
A01	Microfiche
Papercopy Prices	
A02	001–050
A03	051–100
A04	101–200
A05	201–300
A06	301–400
A07	401–500
A08	501–600
A09	601

COEFFICIENTS OF THERMAL EXPANSION FOR A CARBON-CARBON COMPOSITE

William W. Feng

Materials Test and Evaluation Section

Thomas H. Hoheisel

Engineering Measurements & Analysis Section

Engineering Sciences Division

Introduction

From the published data, carbon-carbon composites possess many unique properties at high temperature. They retain their room temperature strength in excess of 2200 °C. The low coefficients of thermal expansion (CTE) and the property of non-wetting by molten metals make carbon-carbon composites excellent candidates for applications in the LIS program.

Among these unique properties, CTE is the most important factor for the LIS program. In seeking to evaluate typical CTE's, we obtained complementary samples of selected carbon-carbon specimens from Carbon-Carbon Advanced Technologies (C-CAT), a fabricator located in Fort Worth, Texas. These samples were laminates with $[0_2]_s$, $[0_2,90_2]_s$ and $[\pm 45]_s$ orientations. The definition of orientation of a lamina and the longitudinal and transverse directions are shown in Fig. 1.

The results indicated that the selected carbon-carbon composites are almost isotropic in thermal expansion. The CTE's are slightly negative at low temperature and become positive at high temperature. The exact values are shown in the Figures.

In order to determine the outgassing of carbon-carbon composites, two samples were tested in vacuum. The results have shown that the outgassing can not be neglected.

Apparatus and Method

Differential dilatometry is a method in which the thermal expansion of a sample is measured relative to that of a National Bureau of Standards reference material. The Theta Differential Dilatometer we employed in testing is a horizontal unit constructed of a sintered alumina tube and push rods. The Theta's Diaflex Module provides independent, frictionless linear motion of both core and coil. The relative motion is measured by a linear variable differential transducer. The temperature in

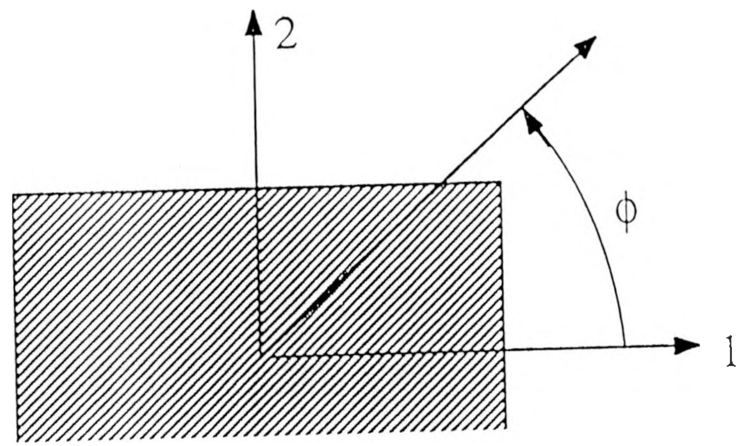

Fig. 1. The lamina orientation angle ϕ and the longitudinal (1-axis) and transverse (2-axis) directions.

the measuring head is controlled by circulating a fluid from a temperature controlled bath and is kept at 40 $^{\circ}C$. A 1600 $^{\circ}C$ silicon carbide furnace is used to supply the thermal environment.

Procedures

A tungsten reference specimen and the carbon-carbon specimen were installed in the dilatometer. A protection tube was placed over the dilatometer system in order to maintain an argon atmosphere throughout the test. The oven was ramped up to 600 $^{\circ}C$ under continuous pumping at approximately 8 mtorr then cooled down to 50 $^{\circ}C$, and back filled with argon and allowed to equilibrate to room temperature. The first cycle should be regarded as necessary for specimen conditioning in accordance with the recommendations of ASTM. This is desired in order to eliminate certain effects which may introduce length changes not associated with thermal expansion of the material.

Test Conditions and Results

Linear thermal expansion measurements were made in the Theta Differential Dilatometry unit. Data were taken at 100 $^{\circ}C$ intervals from 25 to 1150 $^{\circ}C$. All specimens were tested in an argon atmosphere. The first temperature points had some shifting due to the specimen and measuring system adjustment in attaining a stable mechanical condition. Hence, these data points were deleted from this report. The data from subsequent temperature points are reported here.

The results of these measurements are shown in Figs. 2 to 8. The specimens producing the results shown in Figs. 2, 3, 4 and 5 were $[0_2]_s$ laminates. The results shown in Figs. 2 and 3 were obtained on samples tested in an argon atmosphere. In contrast, the results shown in Figs. 4 and 5 represented those tested under vacuum condition. A comparison shows that the CTE's obtained in an argon atmosphere are different than those found in vacuum. We believe this is mainly due to the induced outgassing of the carbon-carbon composite when tested in vacuum.

In testing for the effects on CTE of the layer orientations of a laminate, three specimens with various orientations were selected. The results are shown in Figs. 6, 7 and 8. The specimen represented in Fig. 6 was a $[0_2,90_2]_s$ laminate. The specimen for Figs. 7 and 8 was a $[\pm 45]_s$ laminates. From the standpoint of geometric symmetry, the longitudinal and transverse CTE's for a $[\pm 45]_s$ laminate should be the same. We tested both, in order to demonstrate the repeatability of the tests. The test results shown in Figs. 7 and 8 demonstrated that they are indeed the same.

Conclusions

The test data shown in Figs. 7 and 8 were found to be repeatable. We also evaluated the procedures on some standard materials. All results agreed with the published data. Hence, we concluded that our tests were accurate.

The test results indicated that the average CTE for the selected carbon-carbon composites in the range between room temperature and 1150 $^{\circ}C$ is $1.5x10^{-6}/^{\circ}C$.

The CTE is almost isotropic and does not depend on the orientations of the composites. This was not what we expected. Unfortunately, the processing of the carbon-carbon composite was not known. For future tests the processing history of the specimens should be known.

It was noted that two of the specimens were run in a vacuum of 8 mtorr. The deformations associated with the specimen outgassing was sufficient to initiate a release of strains. The outgassing problem should be solved before carbon-carbon composites can be considered in the LIS program.

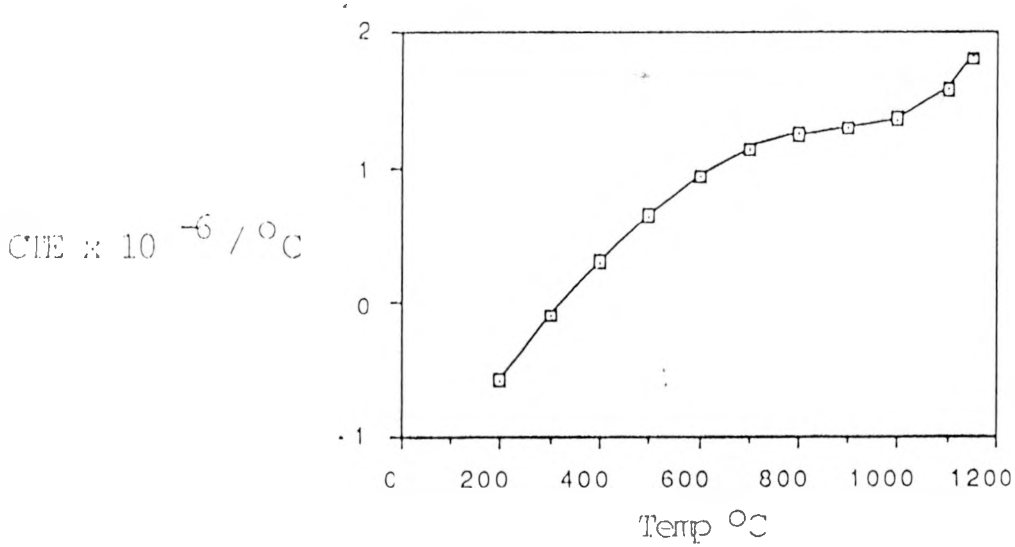

Fig. 2. The longitudinal CTE for a [0,], laminate.

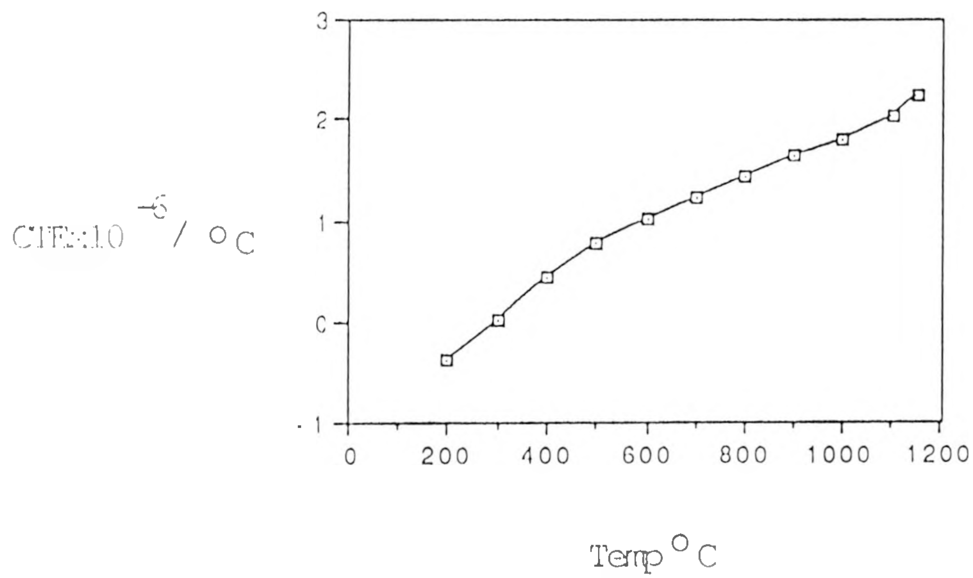

Fig. 3. The transverse CTE for a $[0_2]_s$ laminate.

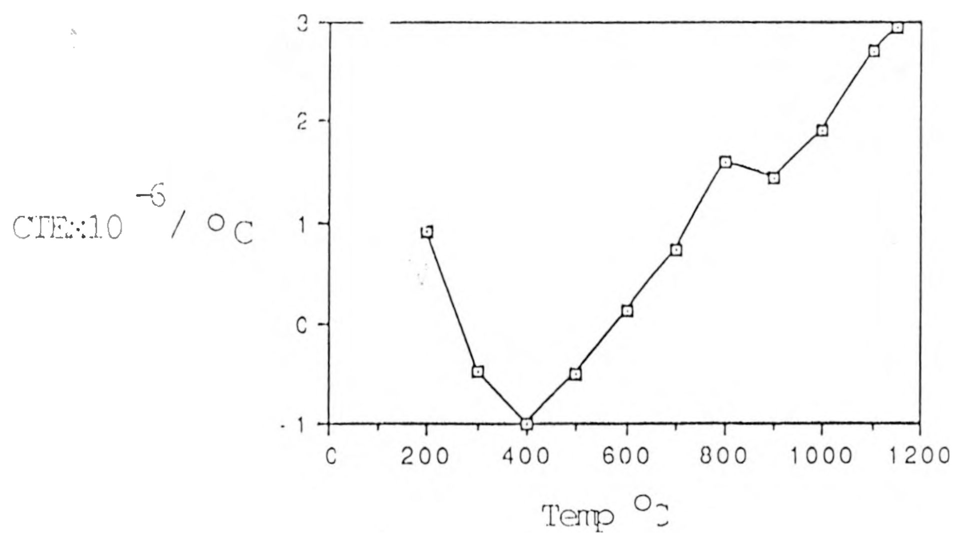

Fig. 4. The longitudinal CTE for a $[0_2]_s$ laminate in vacuum.

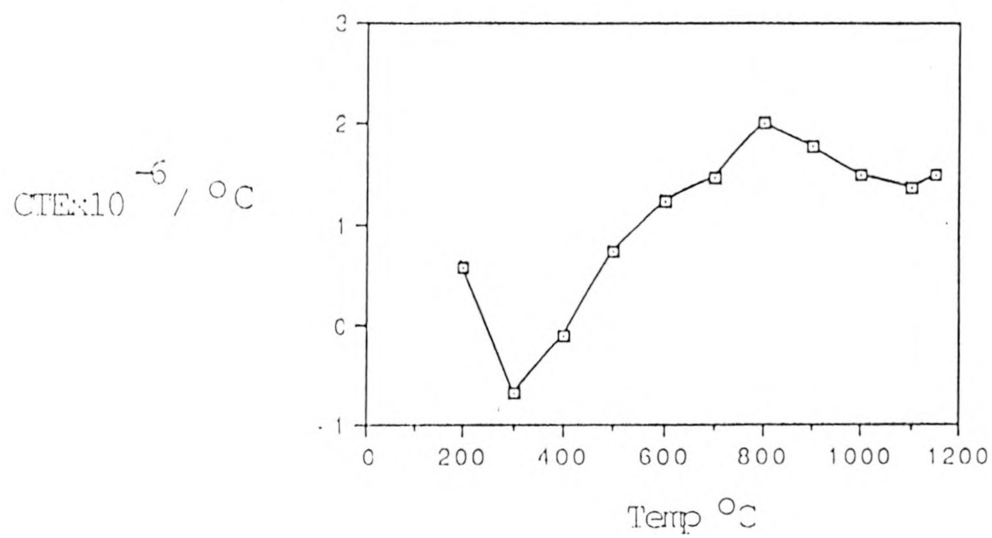

Fig. 5. The transverse CTE for a $[0_2]_s$ laminate in vacuum.

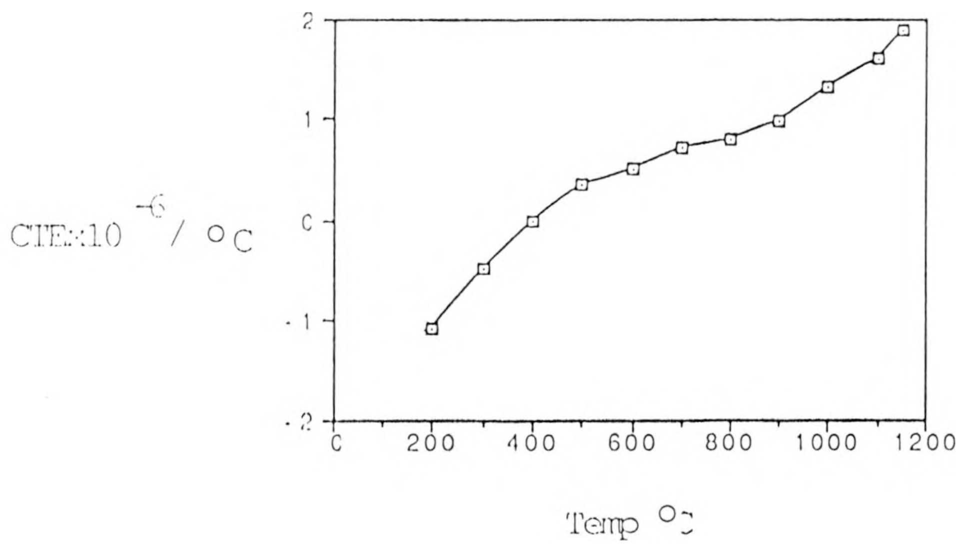

Fig. 6. The longitudinal CTE for a $[0_2, 90_2]_s$ laminate.

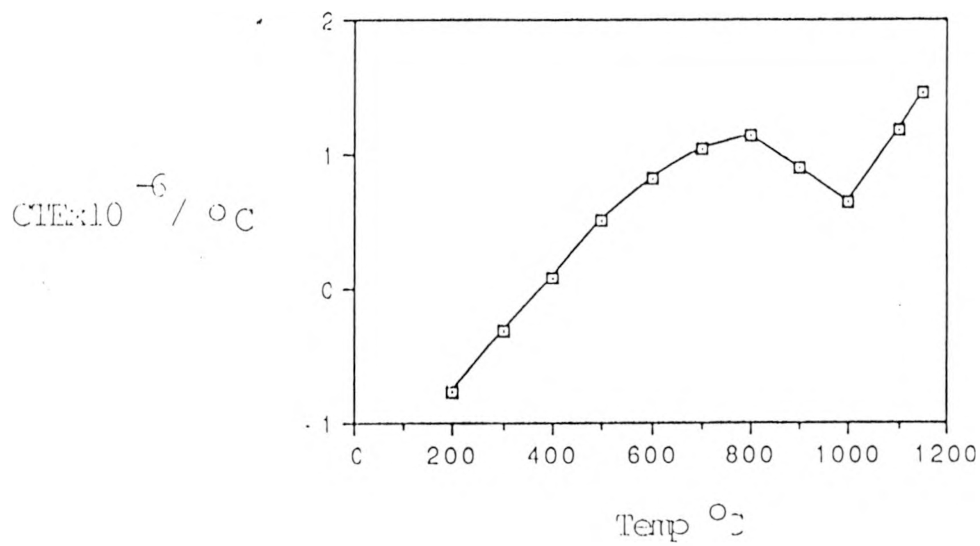

Fig. 7. The longitudinal CTE for a $[\pm 45]_s$ laminate.

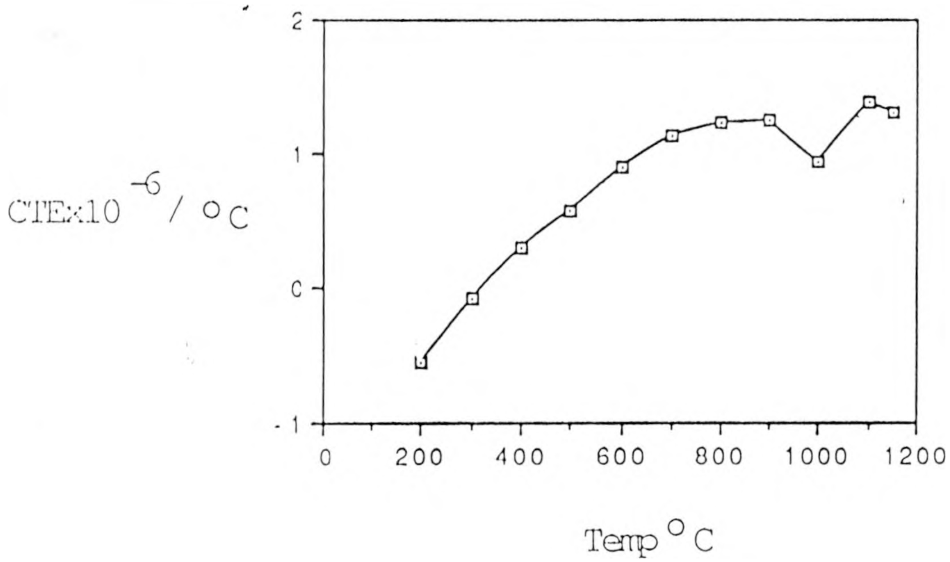

Fig. 8. The transverse CTE for a $[\pm 45]_s$ laminate.

DISTRIBUTION

Robert L. Brady, L-342
Kerry L. Cadwell, L-342
Elane C. Flower, L-342
Alfred Goldberg, L-342
Scott E. Groves, L-342
Russel A. Jandrisevits, L-342
David H. Lassila, L-342
Donald R. Lesuer, L-342
Joseph C. Long, L-460
Steven C. Lu, L-571
William McLean, L-460
Daniel J. Nikkel, L-342
Clement A. Tatro, L-342
Howard H. Woo, L-571
TID (24)

EXTERNAL DISTRIBUTION

Dr. Wendell Kawahara
Org. 8243, Bldg. 912
Sandia National Laboratory
Livermore, CA 94550