Characterization of Composites Response at High Rates of Deformation

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1. BACKGROUND

The objective of the proposed research is to experimentally study the effect of strain rate on mechanical response (deformation and failure) of IM-7/977-2 carbon fiber/epoxy matrix composites. The experimental data will provide the information needed for the development of a nonlinear, rate dependent deformation and strength model for this material that can subsequently be used in design.

2. EXPERIMENTAL SETUP

Tensile tests at strain rates of approximately 5×10^{-5}, 1, and 400 s^{-1} were conducted. The low strain rate tests (5×10^{-5} and 1 s^{-1}) were done on a hydraulic Instron machine, and the high strain rate tests were done using the tensile split Hopkinson bar apparatus. In tests with the Instron machine, force was measured by the load cell of the machine, and strain was measured with strain gages cemented to the specimen. In each test two strain gages (Measurements Group EA-06-125BZ-350) were cemented on the specimen's surface on opposite sides.

The tensile split Hopkinson bar apparatus, shown schematically in Fig. 1, is made up of two 0.5 in. diameter aluminum bars. The specimen is placed (cemented) between the bars. The specimen is loaded by a tensile wave that is generated in the incident bar by clamping a tensile force in the end section of the bar, and then releasing the clamp. Upon loading, part of the loading wave reflects back to the incident bar, and part propagates on to the transmitter bar. The incident and transmitter bars remain elastic throughout the test. In the standard technique, the history of stress and strain in the specimen is determined from the recorded elastic waves in the bars. In this determination it is assumed that the specimen is under a state of uniform uniaxial tension stress and deformation. In the present research the split Hopkinson bar technique was also modified such that strain could also be measured directly on the specimen. This was done by attaching two strain gages on opposite sides of the specimen, as in the low rate tests. Approximately half of the high strain rate tests were done with strain gages attached to the specimen.

3. SPECIMENS

The specimen is a short dog-bone shape coupon cut from a plate. The coupon is glued to two slotted cylindrical adapters. The specimen's geometry and the adapters are shown in Fig. 2. For use in the split Hopkinson bar the unit is cemented between the input and output bars. For use in the hydraulic testing machine the assembly is pinned to double universal joints which are connected to the grips of the machine. The double universal joint connection reduces the possibility of introducing a bending moment resulting from a possible eccentric load line in the testing machine.

4. RESULTS

Tests were conducted with specimens made of the resin material and with 90^o, 10^o, 45^o, $[\pm 45^o]_S$, IM-7/977-2 carbon fiber/epoxy laminates. Each type of specimen was tested at strain rates of approximately $5x10^{-5}$, 1, and 400 s^{-1}. In tests with the split Hopkinson bar apparatus, the strain in about half of the tests was also measured with strain gages attached to the specimen.

The tests are summarized in table 1. For each test, the stress, strain, and strain rate (in the split Hopkinson bar tests), all as a function of time, and the stress-strain curve for the test are given in the Appendix (in the order listed in table 1). The stress-strain curves from all the tests for each material tested are given in Figs. 3 – 7. The results show that the material is very sensitive to the strain rate. In all of the specimens tested the initial modulus and the maximum stress increases with strain rate.

4.a. Use of Strain Gages in the Split Hopkison Bar Tests.

In the standard split Hopkinson bar technique the strain in the specimen is determined from the elastic waves on the bars. The determination is based on the assumption that the state of stress and deformation is uniform in the specimen. This assumption is valid only when the specimen is short such that the time for the waves to

travel through is short. The gage length of the specimens used in the present tests (Fig. 2) is 0.375 in., which is relatively long for this technique. In addition, the rounded ends of the specimen add to the length between the two bars. Under these circumstances it was decided to cement strain gages to half the specimens tested with the split Hopkinson bar apparatus and then to compare their readings with the strain obtained from the elastic stress waves recorded on the bars. The effect of the strain gage itself on the measurements was examined by comparing results from tests with and without strain gages. As described in the next two sections the strain gages that were attached to the specimens affected the response of the resin, but had no effect on the response of the composite specimens.

4.a.1 Tests of the epoxy resin.

Data recorded in a typical test (EXP 99-4) is shown in Fig. 8. The upper three diagrams show the wave profiles from the three strain gage stations *A*, *B*, and *C*, on the split Hopkinson bars (see Fig. 1). The bottom two diagrams show the strain measured by the strain gages on the specimen. Using elastic wave theory, the stress and strain-rate in the specimen are determined from the signals from the three gage stations. The strain is obtained by integrating the strain-rate. These quantities as a function of time are shown in Fig. 9. The figure shows that following the rise time, the strain rate is about 900 1/s, and the strain reaches a value of 0.032 at the end of the test. In addition, this figure shows also the strain measured by the strain gages that are attached to the specimen. The strain experienced by the two strain gages is almost identical, which indicates that the specimen is loaded in nearly pure tension without bending. The strain at the end of the test is about 0.02. The slope of the strain gage strain versus time curve gives the strain rate. Figure 9 shows that this slope is nearly a constant, with a value of 405 1/s, during the test.

The strain rate and subsequently the strain determined from the recorded wave profiles on the split Hopkinson bars are larger then measured directly on the specimen because of the geometry of the specimen. The portion that is between the bars is the middle section (a prism with a cross section of 0.12 in. by 0.18 in. and 0.375 in. long),

and the rounded sections in both ends. The strain rate is determined from the difference in the velocities of the ends of the bars. The difference is due to the deformation in the portion that is between the bars which includes the middle section (the prism) and the rounded ends. In processing the data, however, a gage length has to be defined and substituted in the equation. The curves in Fig. 9 are obtained by taking the gage length as 0.375 in., which is the length of the middle section. Obviously, this gives a larger strain rate since it assumes that all the deformation between the bars including the deformation in the rounded ends occurs only in the middle section.

Stress-strain curves from all of the split Hopkinson bar tests with the resin are shown in Fig. 10. In this figure two curves are shown for each of the tests in which strain gages were placed on the specimen. In one curve the strain determined by the SHB equations was used, and in the other the average strain recorded by the strain gages on the specimen was used. Comparison of the results from split Hopkinson bar tests with and without strain gages on the specimen shows that specimens with the strain gages fracture before specimens without strain gages. Examination of the fractured specimens shows that when a strain gage is glued to the specimen, the specimen fractures at the strain gage ends. It is possible that during the gluing process a layer of the resin underneath the strain gage dissolved introducing a stress concentration at the boundary of the gage. The true resin response (if the strain gage was not on) can be estimated by continuing the stress-strain curve from the tests with the strain gages to the stress level of the tests with specimens without strain gages. This is shown by the dashed line in Fig. 10.

The stress stress-strain curves of all the tests with the split Hopkinson bar on the resin show oscillations in the stress. The period of the oscillations is approximately 20 μs. The stress profile is obtained from the signal recorded with gage C, which is on the transmitter bar. The oscillations are probably due to waves that travel back and forth in the specimen. Typically, the specimen in the split Hopkinson bar test is very short (0.1 in) such that the waves in the specimen are not visible in the stress signal. In the present tests, however, the length of the resin piece between the ends of the bars is about 1.1875 in. If the time between two peaks corresponds to the time it takes for the wave to travel a round trip in the resin, the wave speed in the resin is:

$$v = \frac{1.1875 \cdot 2}{20 \times 10^{-6}} = 1.19 \times 10^5 \text{ in/s} \quad (3 \text{ mm}/\mu s)$$

The theoretical axial wave speed in a bar of elastic waves is:

Assuming:

$E = 1.61 \times 10^6$ psi (initial slope of the high strain rate stress-strain curves, Fig.)

$\rho = 0.04736$ lb/in^3 (1.31 g/cm^3)

$$v = \sqrt{\frac{E}{\rho}} = \sqrt{\frac{1.61 \times 10^6 \frac{\text{lb}}{\text{in}^2}}{0.04736 \frac{\text{lb}}{\text{in}^3} \cdot \frac{1}{386.088} \frac{\text{s}^2}{\text{in}}}} = 1.148 \times 10^5 \text{ in/s} \qquad (2.9 \text{ mm}/\mu s)$$

The observed velocity agrees quite well with the theoretical elastic wave speed.

4.a.2 Tests of 90^o, 10^o, 45^o, $[\pm 45^o]_S$, composites.

Stress-strain curves from split hopkinson bar tests with and without strain gages cemented on the specimens are shown for 90^o, 10^o, 45^o, $[\pm 45^o]_S$, laminates in Figs 11 – 14, respectively. The results from all the tests show a small difference between the strain measured by the strain gages and the strain determined by the split Hopkinson bar equations. In all the tests, however, the strain gages had no effect on the maximum stress.

TABLE 1
OSU TESTS FOR NASA
SUMMARY OF TESTS

TEST NO.	SPECIMEN'S MATERIAL	STRAIN RATE (1/s)	COMMENTS
EXP99-1	epoxy resin	980 (SHB equations)	No strain gages on specimen
EXP99-2	epoxy resin	1000 (SHB equations)	No strain gages on specimen
EXP99-3	epoxy resin	900 (SHB equations)	Strain gages on specimen Only one strain gage record
EXP99-4	epoxy resin	405 (strain gages)	Strain gages on specimen
EXP99-5	epoxy resin	356 (strain gages)	Strain gages on specimen
EXP99-6	epoxy resin	365 (strain gages)	Strain gages on specimen
EXP99-7	epoxy resin	5.7×10^{-5}	
EXP99-8	epoxy resin	5.7×10^{-5}	
EXP99-9	epoxy resin	6.3×10^{-5}	
EXP99-10	epoxy resin	1.31	
EXP99-11	epoxy resin	1.31	
EXP99-12	epoxy resin	1.31	
EXP00-1	90° composite	490 (strain gages)	Strain gages on specimen
EXP00-2	90° composite	405 (strain gages)	Strain gages on specimen
EXP00-3	90° composite	395 (strain gages)	Strain gages on specimen
EXP00-4	90° composite	930 max (SHB equations)	No strain gages on specimen
EXP00-5	90° composite	910 max (SHB equations)	No strain gages on specimen
EXP00-6	90° composite	890 max (SHB equations)	No strain gages on specimen
EXP00-7	90° composite	4.44×10^{-5}	
EXP00-8	90° composite	2.14×10^{-5}	
EXP00-9	90° composite	4.52×10^{-5}	
EXP00-10	90° composite	1.06	
EXP00-11	90° composite	1.09	
EXP00-12	90° composite	1.09	
EXP00-13	45° composite	422	Strain gages on specimen
EXP00-14	45° composite	407	Strain gages on specimen
EXP00-15	45° composite	405	Strain gages on specimen
EXP00-16	45° composite	900 max (SHB equations)	No strain gages on specimen
EXP00-17	45° composite	890 max (SHB equations)	No strain gages on specimen
EXP00-18	45° composite	920 max (SHB equations)	No strain gages on specimen

EXP00-19	10^{o} composite	228	Strain gages on specimen
EXP00-20	10^{o} composite	312	Strain gages on specimen
EXP00-21	10^{o} composite	274	Strain gages on specimen
EXP00-22	10^{o} composite	580 (SHB equations)	No strain gages on specimen
EXP00-23	10^{o} composite	480 (SHB equations)	No strain gages on specimen
EXP00-24	45^{o} composite	$4.7x10^{-5}$	
EXP00-25	45^{o} composite	$5.1x10^{-5}$	
EXP00-26	45^{o} composite	$4.75x10^{-5}$	
EXP00-27	10^{o} composite	$1.4x10^{-5}$	Specimen separated from adapter
EXP00-28	10^{o} composite	$1.8x10^{-5}$	
EXP00-29	10^{o} composite	$1.8x10^{-5}$	
EXP00-30	45^{o} composite	1.1	
EXP00-31	45^{o} composite	1.2	
EXP00-32	45^{o} composite	1.0	
EXP00-33	10^{o} composite	0.6	
EXP00-34	10^{o} composite	0.56	
EXP00-35	10^{o} composite	0.56	
EXP00-36	+- 45^{o} composite	635	Strain gages on specimen
EXP00-37	+- 45^{o} composite	517	Strain gages on specimen
EXP00-38	+- 45^{o} composite	604	Strain gages on specimen
EXP00-39	+- 45^{o} composite	$9x10^{-5}$	Specimen separated from adapter
EXP00-40	+- 45^{o} composite	$9.3x10^{-5}$	
EXP00-41	+- 45^{o} composite	2	
EXP00-42	+- 45^{o} composite	2.1	

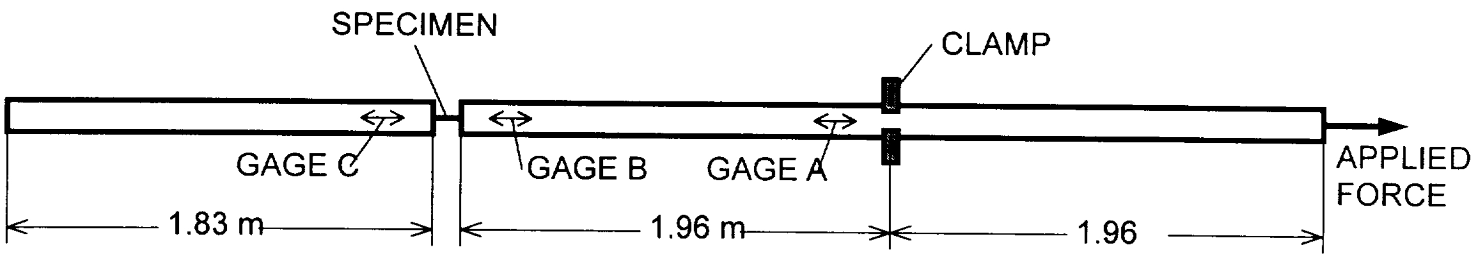


Fig. 1: Schematic of the tensile split Hopkinson bar apparatus.

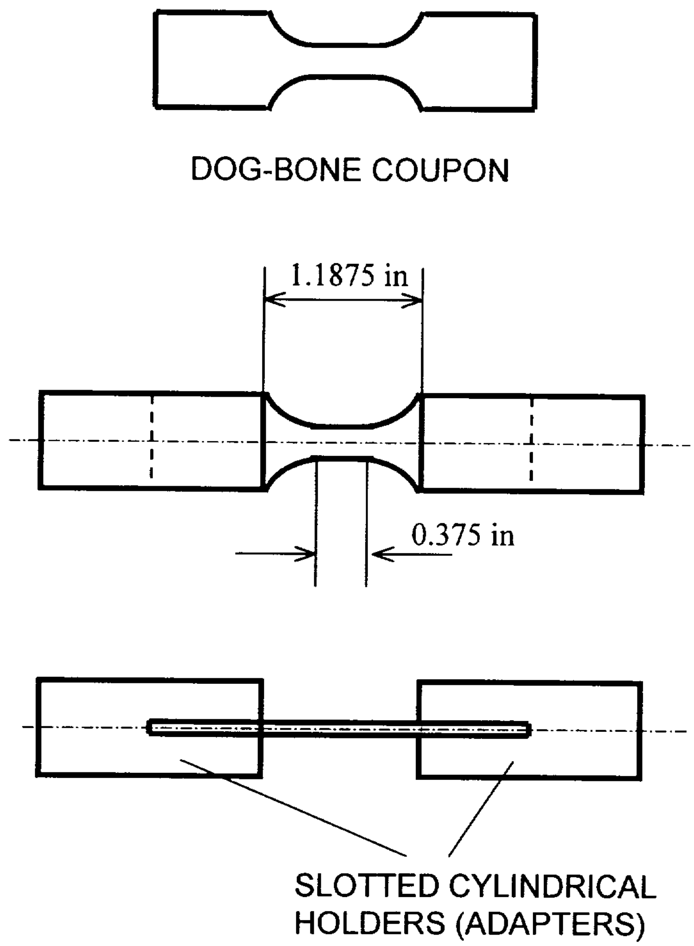


Fig. 2 Specimen and adapters.

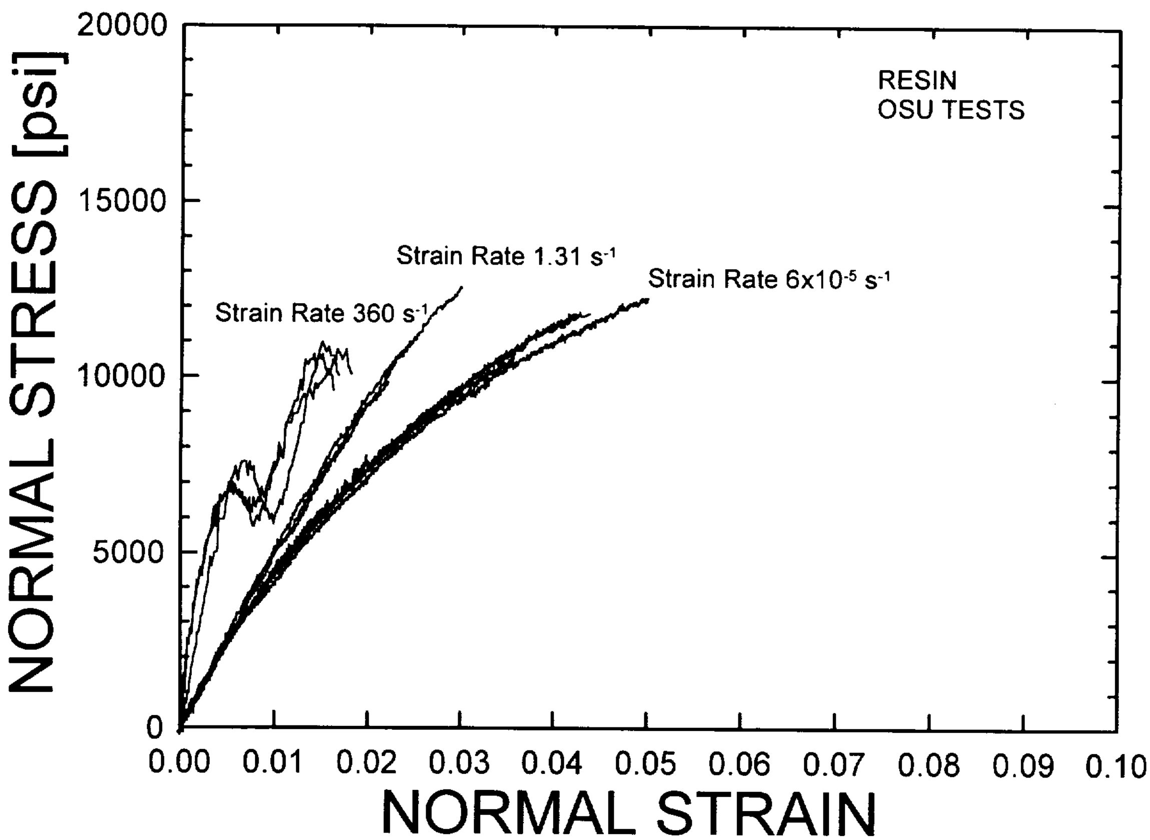


Fig. 3 Stress strain curves for the resin at different strain rates.

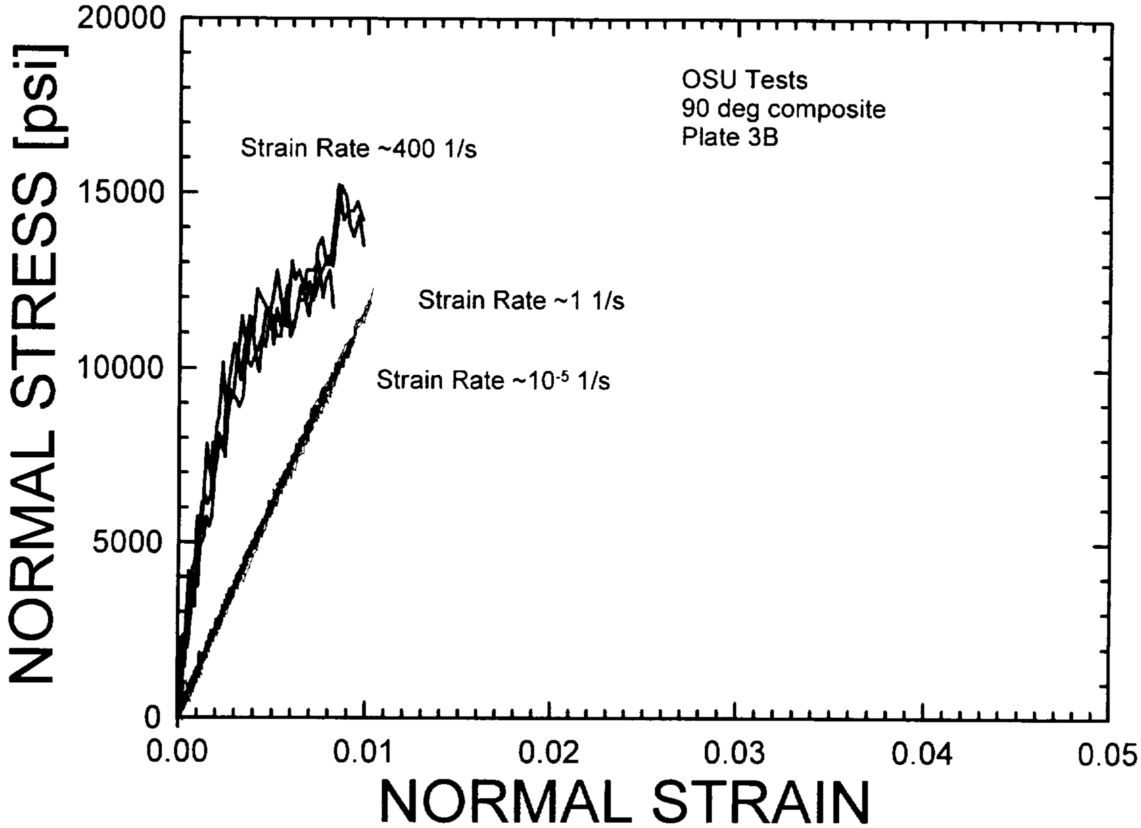


Fig. 4 Stress strain curves for the 90^{o} composite at different strain rates.

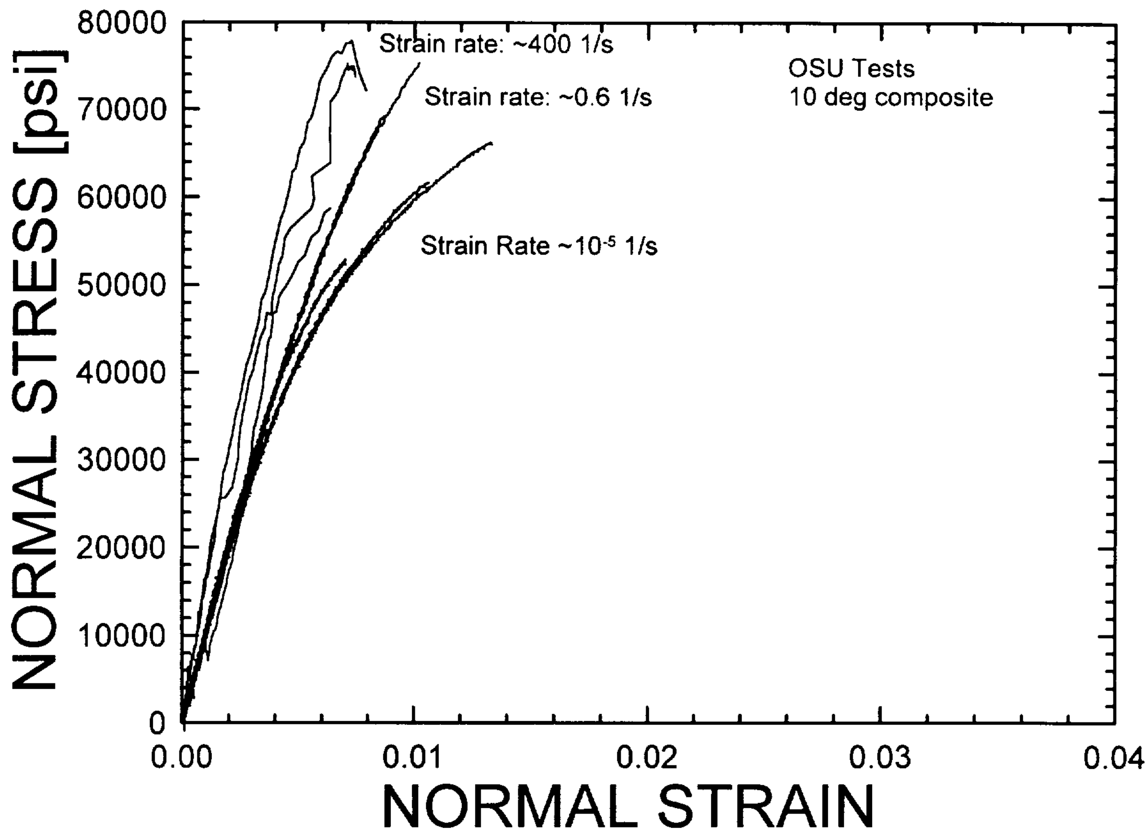


Fig. 5 Stress strain curves for the 10^{O} composite at different strain rates.

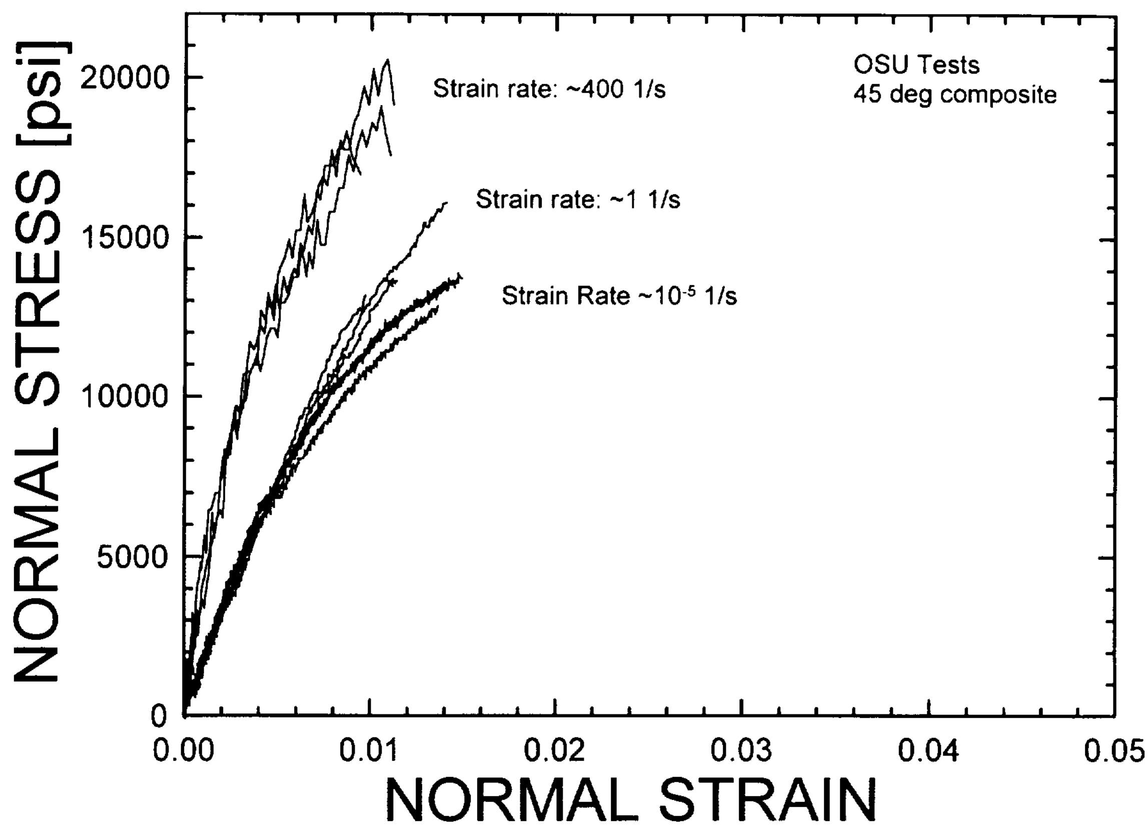


Fig. 6 Stress strain curves for the 45^{O} composite at different strain rates.

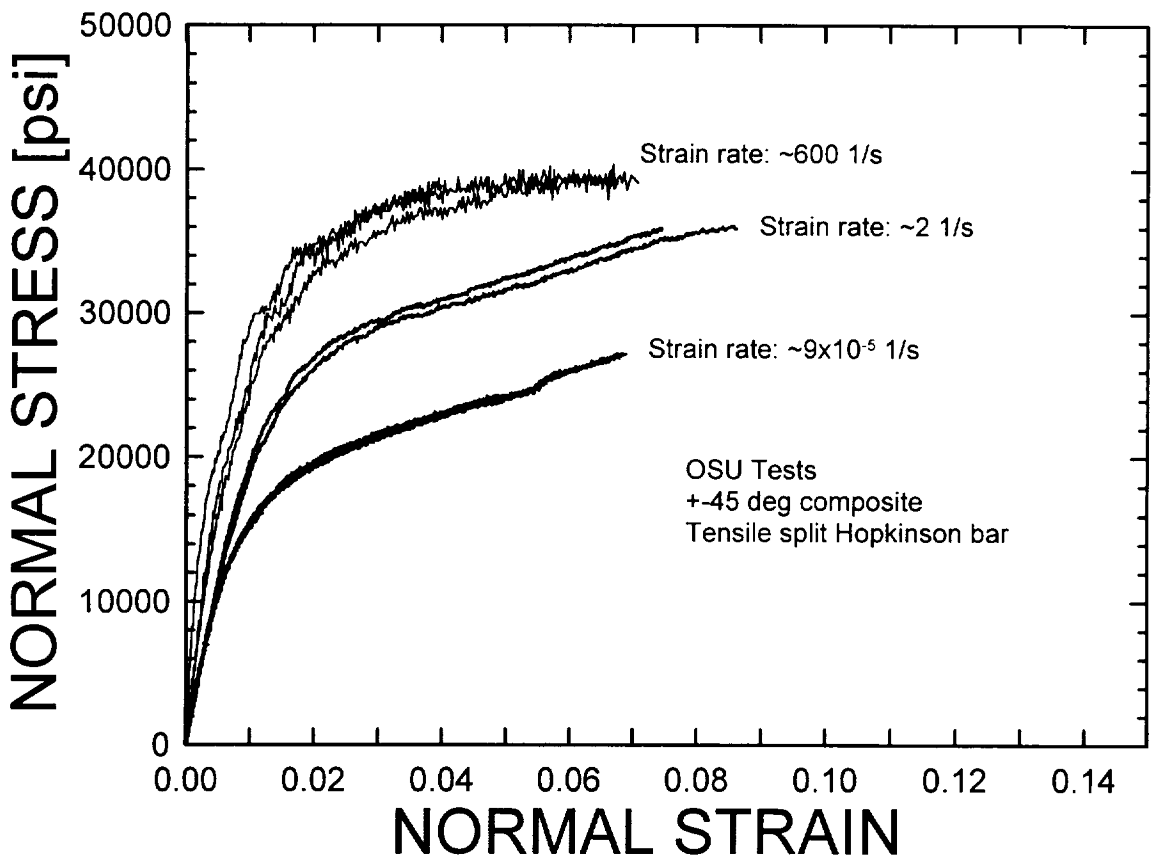


Fig. 7 Stress strain curves for the $[\pm 45^{o}]_S$ composite at different strain rates.

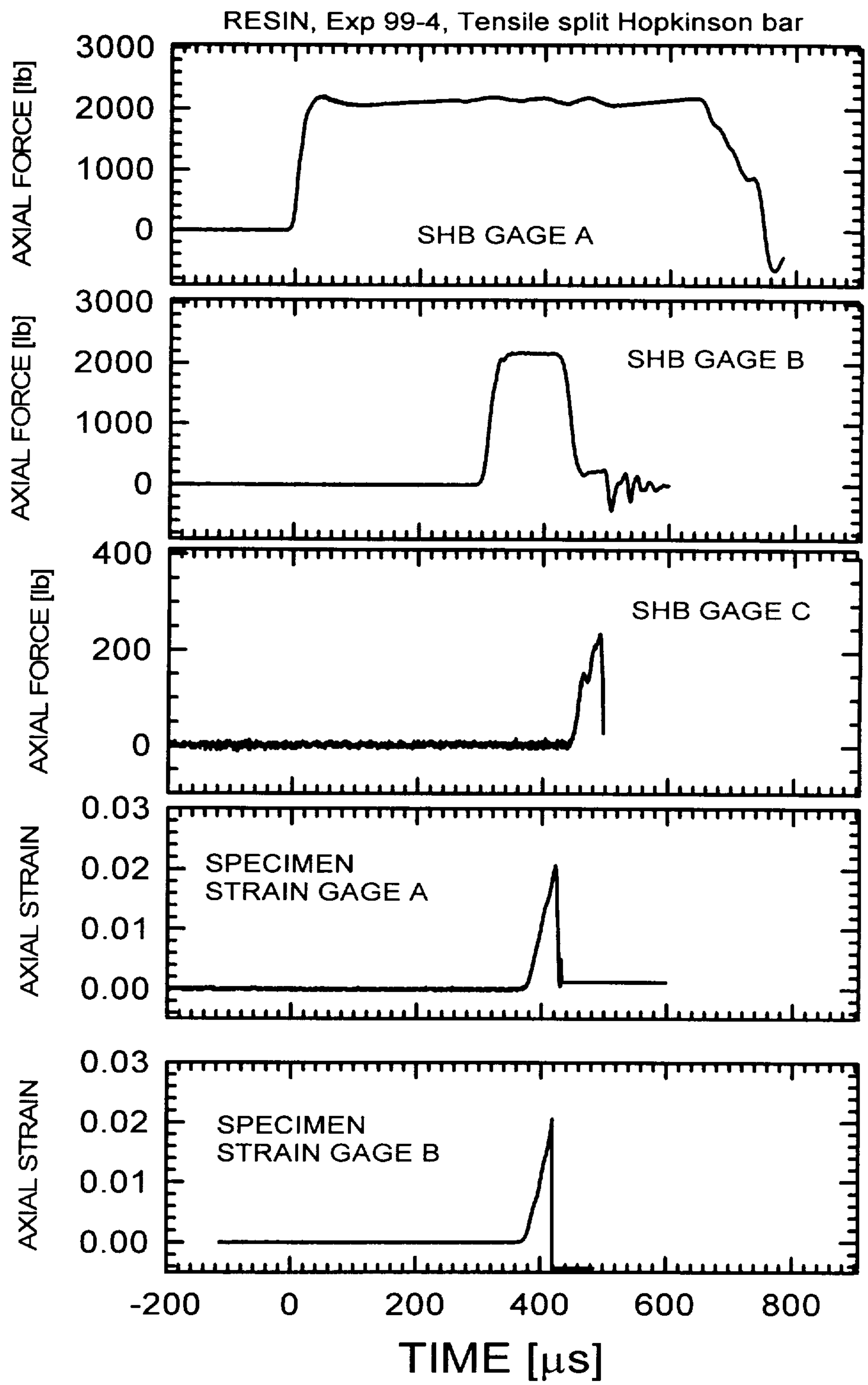


Fig. 8 Raw data recorded in test 99-4.

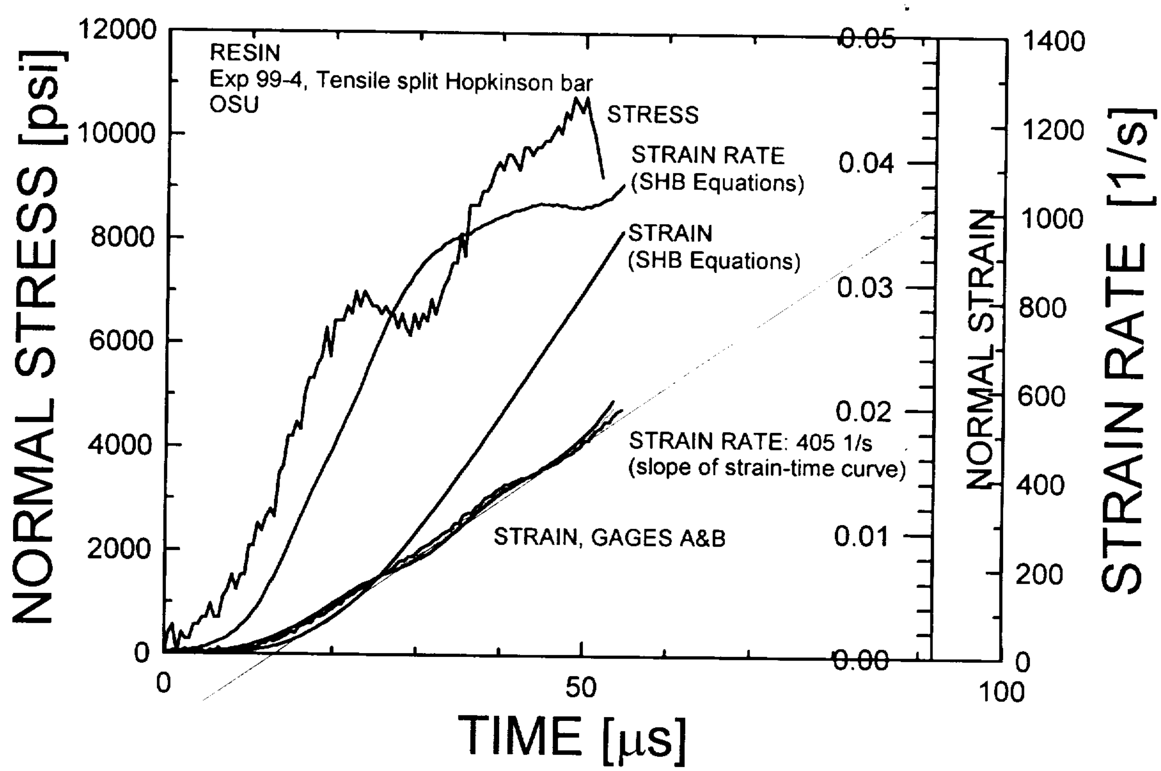


Fig. 9 Stress, strain rate, and strain vs. time in test 99-4.

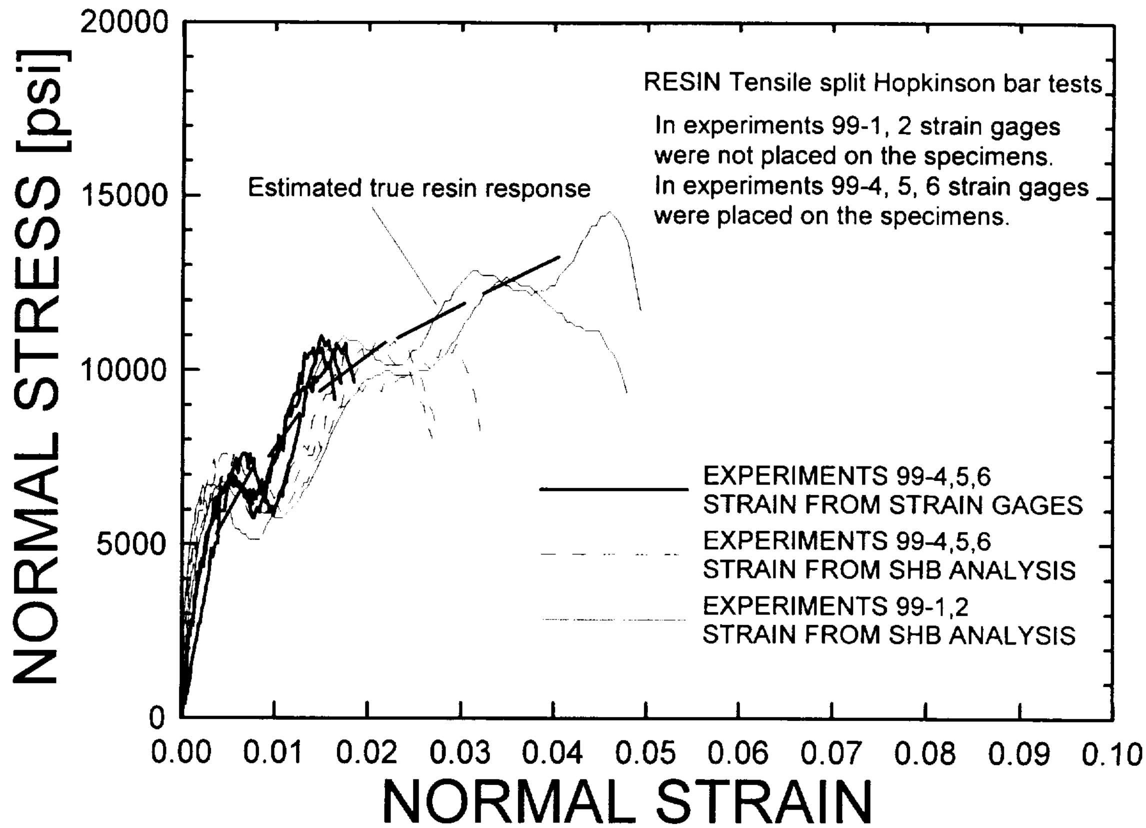


Fig. 10 Resin stress-strain curves from all split Hopkinson bar tests.

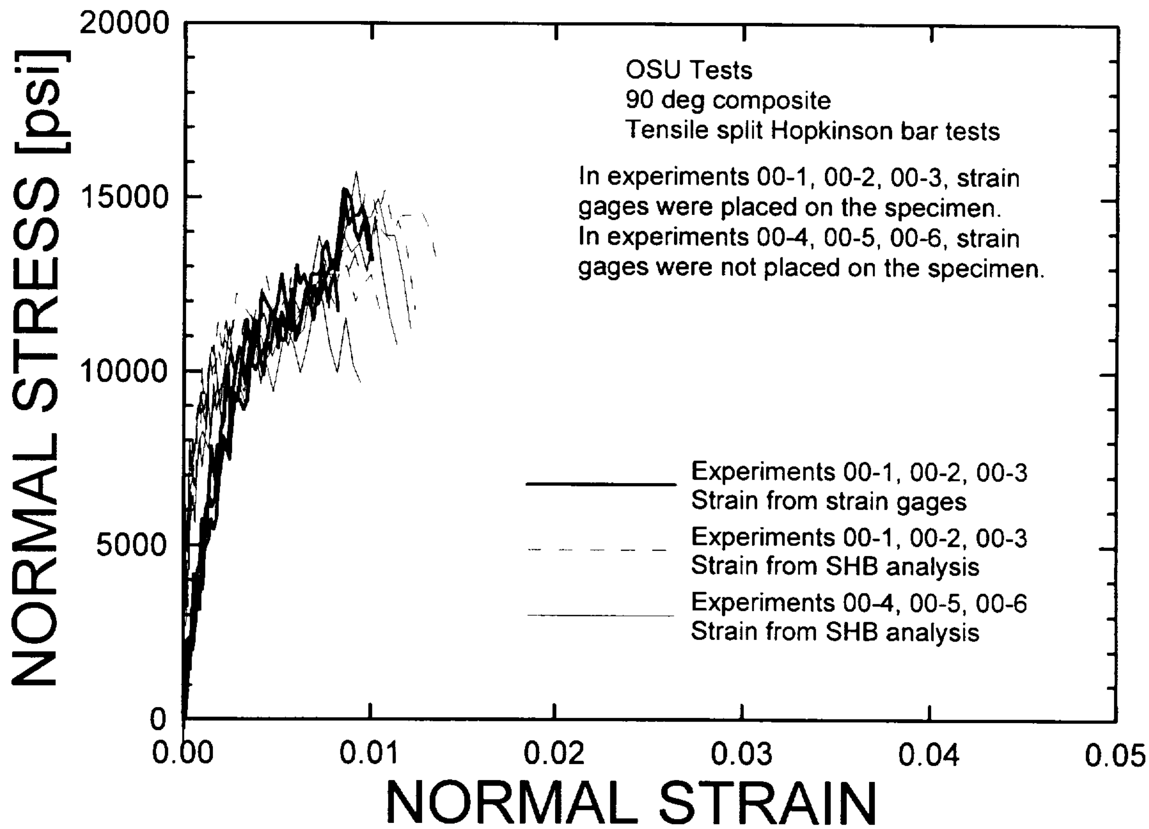


Fig. 11 Stress-strain curves for 90^{O} laminates from all split Hopkinson bar tests.

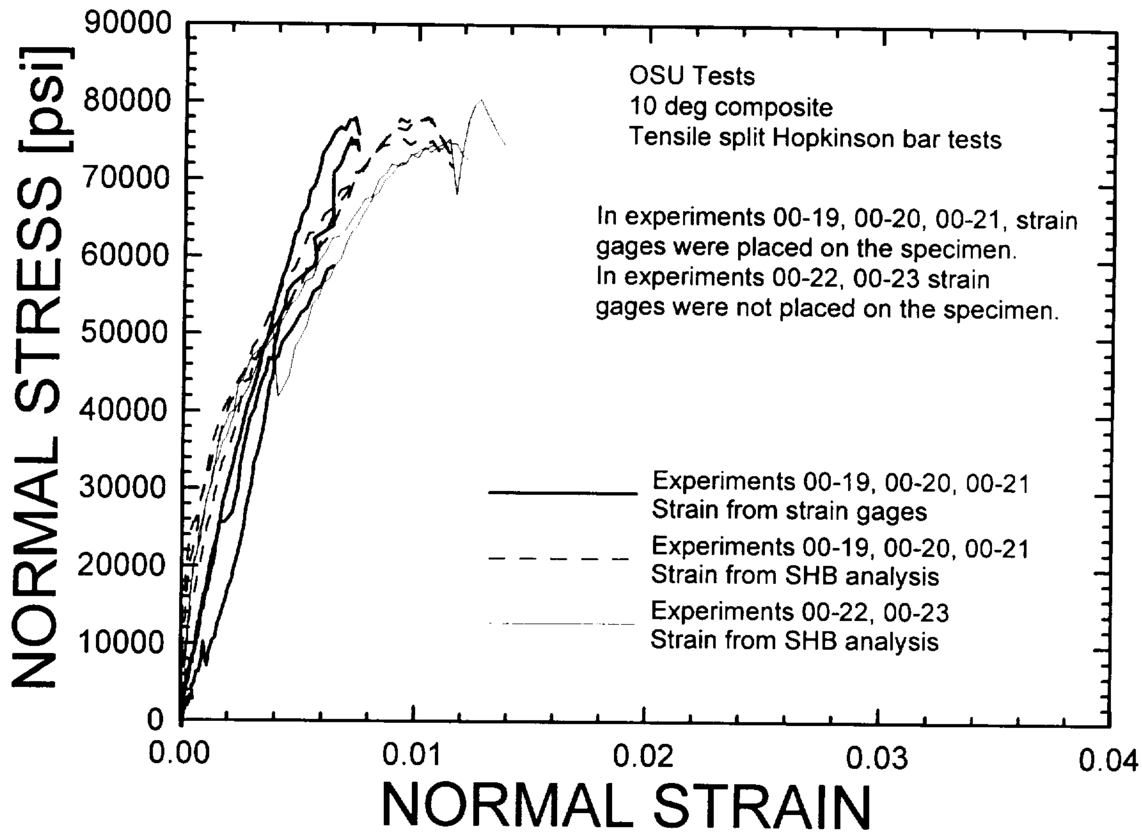


Fig. 12 Stress-strain curves for 10^{o} laminates from all split Hopkinson bar tests.

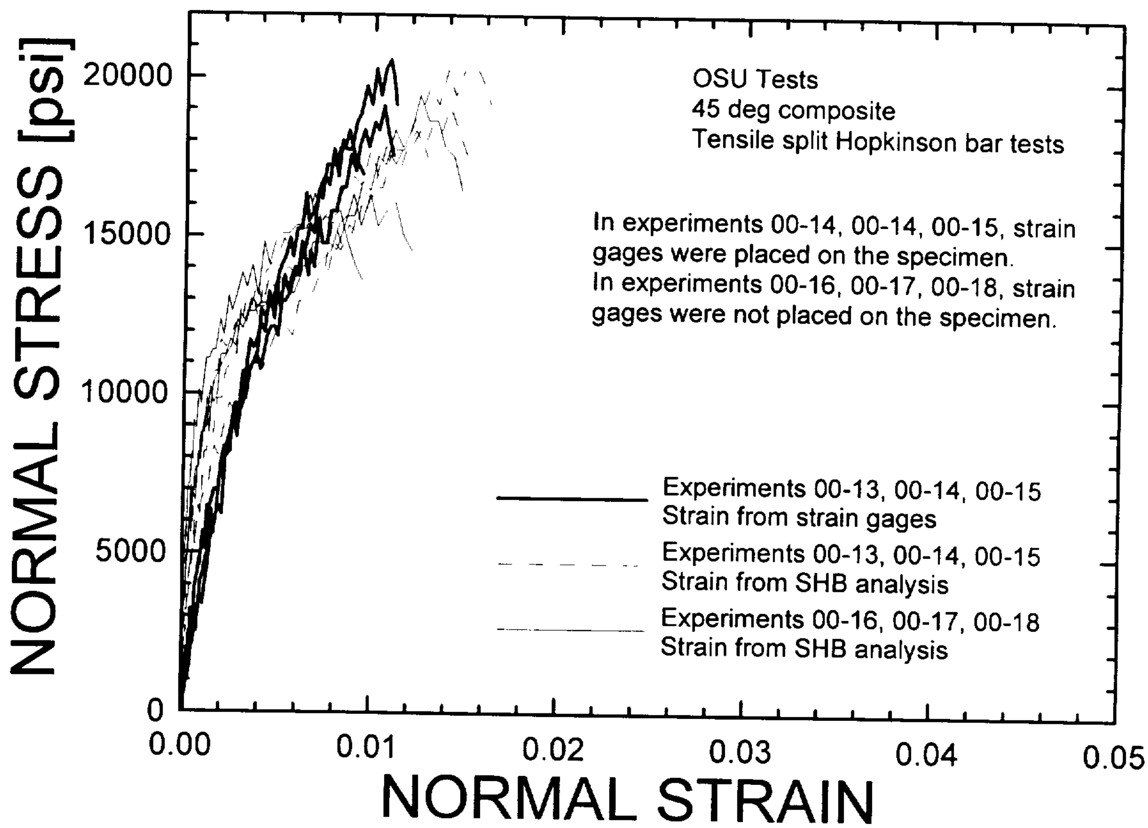


Fig. 13 Stress-strain curves for 45^{0} laminates from all split Hopkinson bar tests.

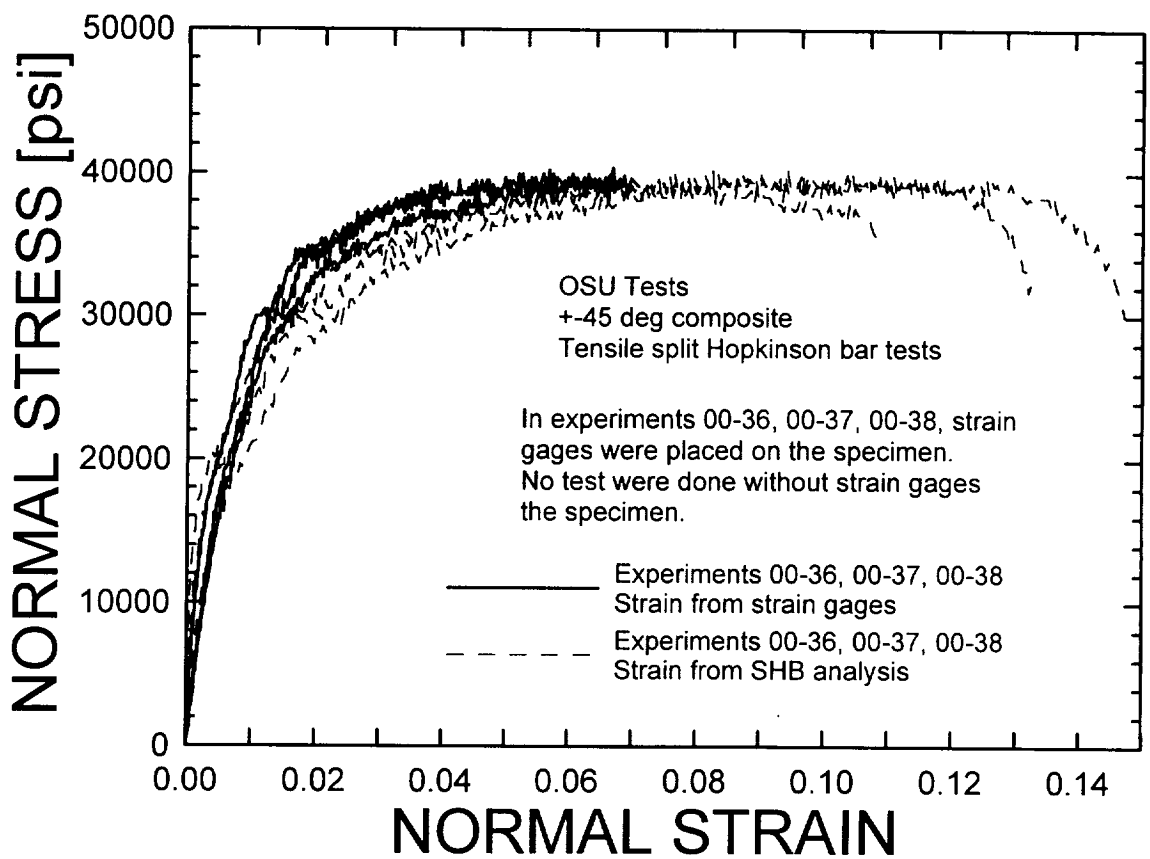
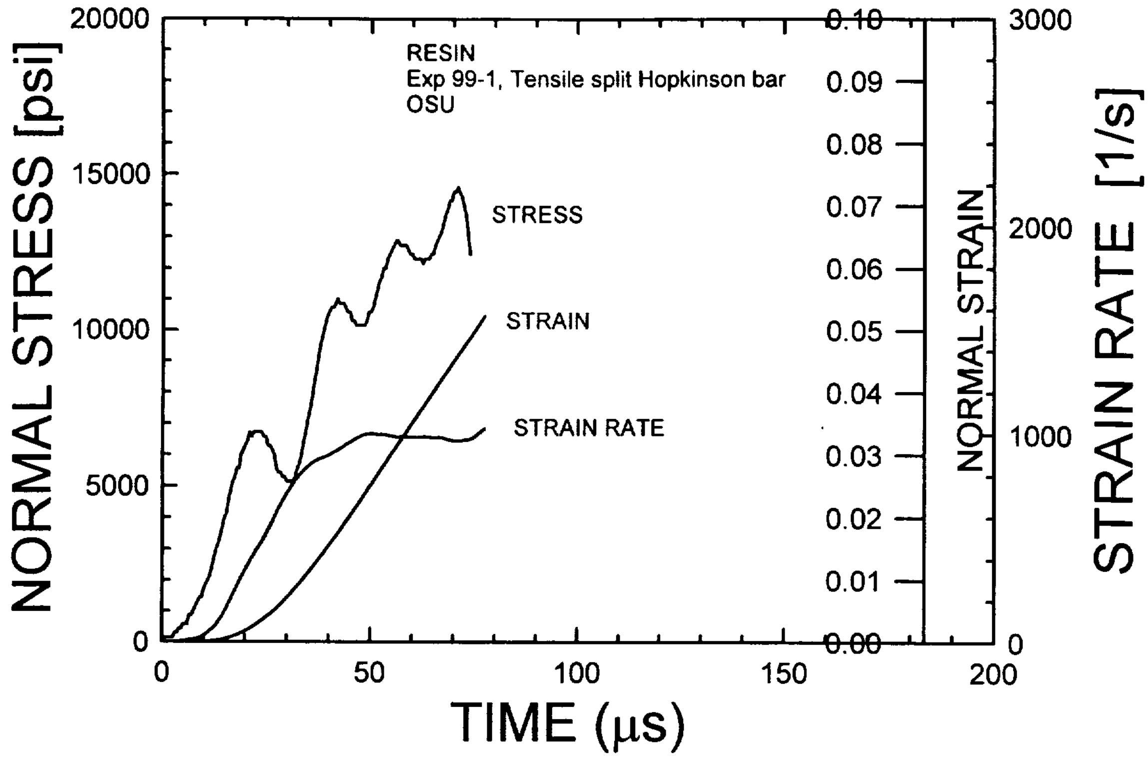


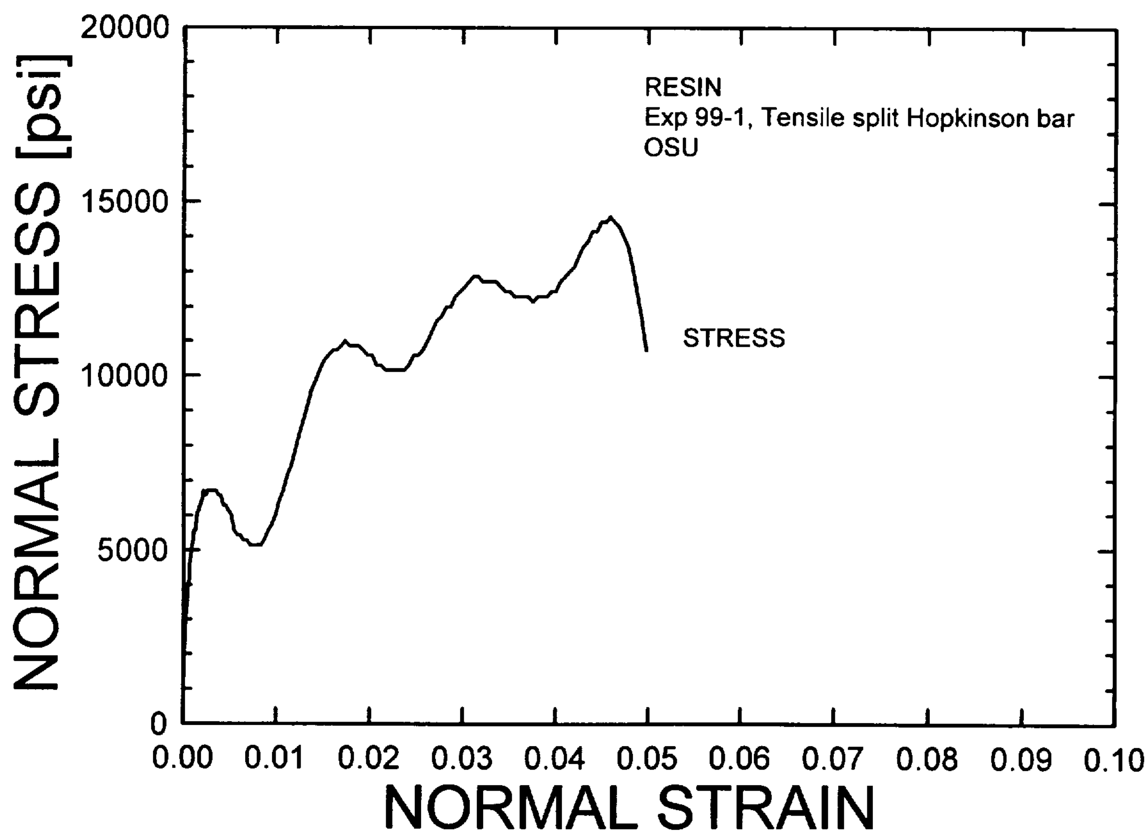
Fig. 14 Stress-strain curves for $[\pm 45^{o}]_S$ laminates from all split Hopkinson bar tests.

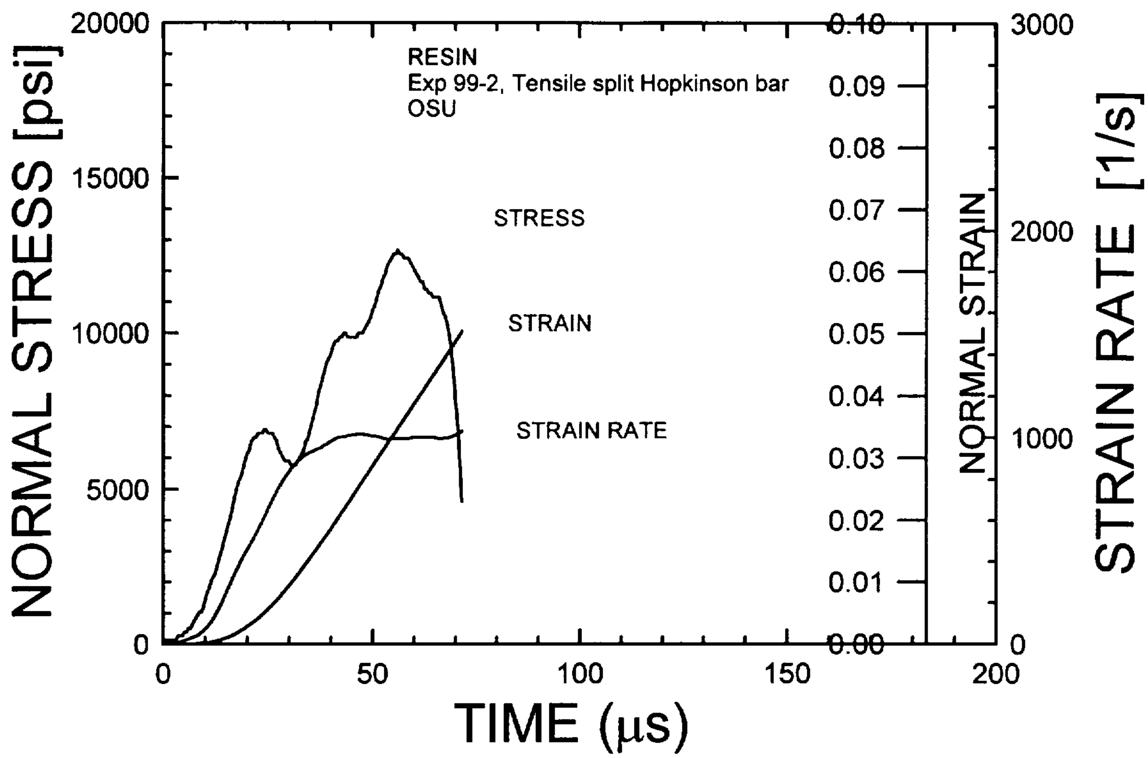
APPENDIX

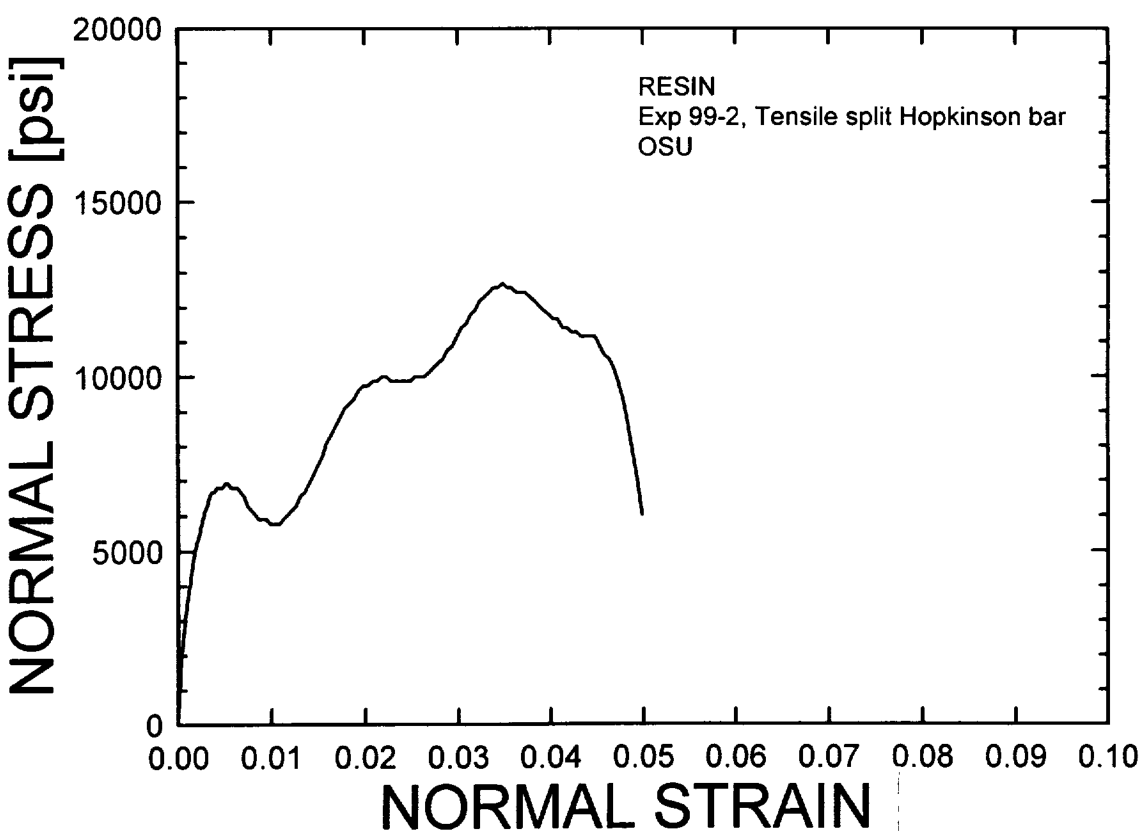
For each test two plots are presented. In one the stress, strain (measured by the strain gages when gages were attached to the specimen, and/or determined by the SHB analysis), and strain rate (in the split Hopkinson bar tests), all as a function of time. The other plot contains the stress-strain curve for the test.

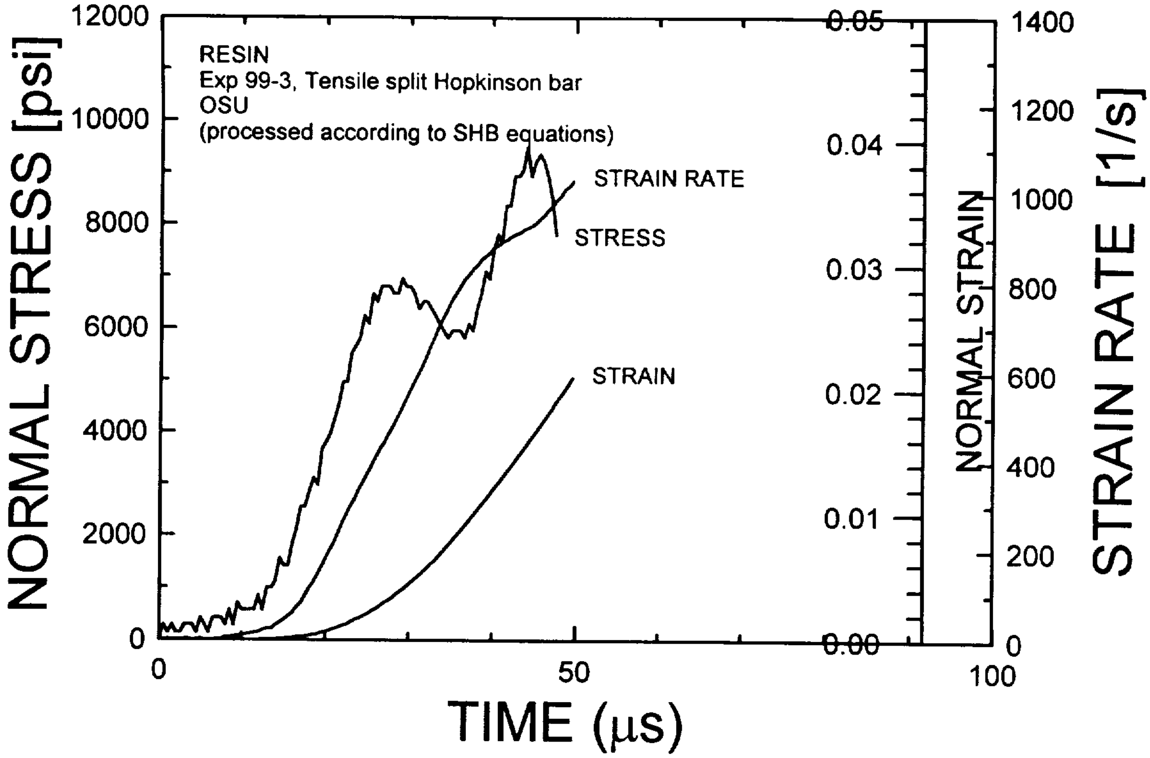
The plots are in the order listed in Table 1.

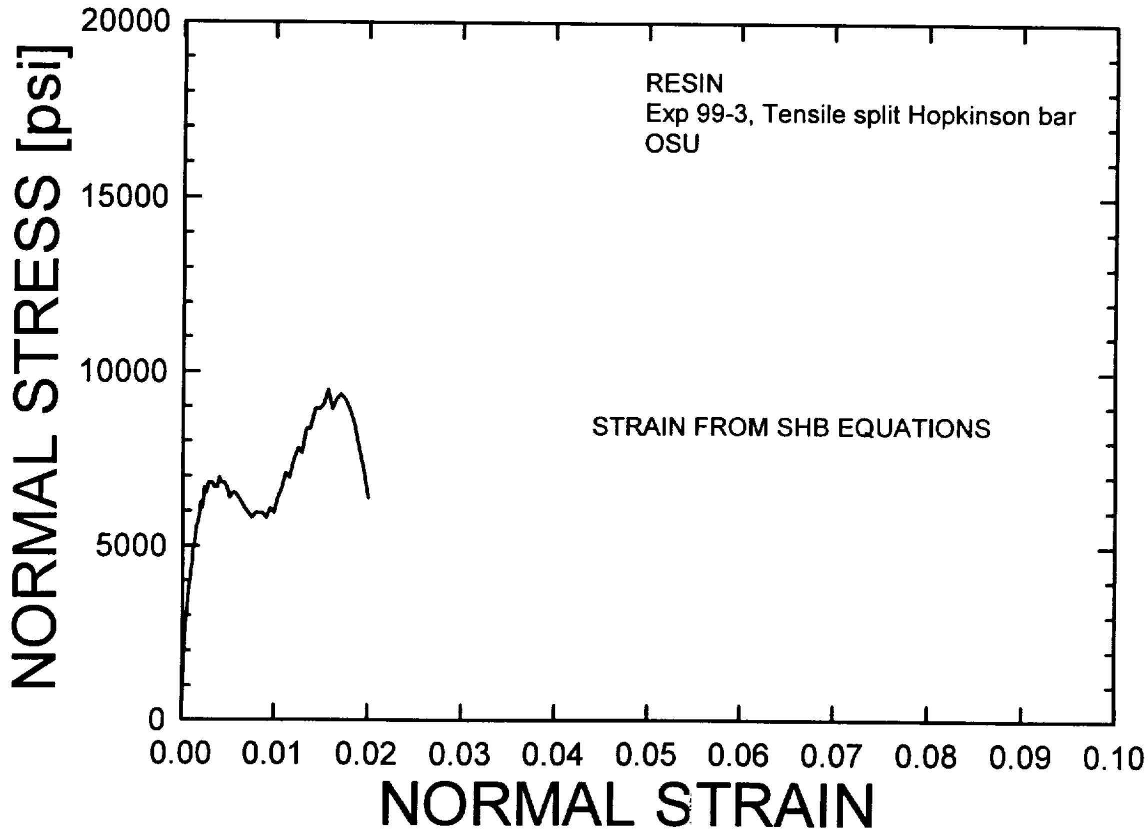

RESIN
Exp 99-1, Tensile split Hopkinson bar
OSU
STRESS
STRAIN
STRAIN RATE
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)

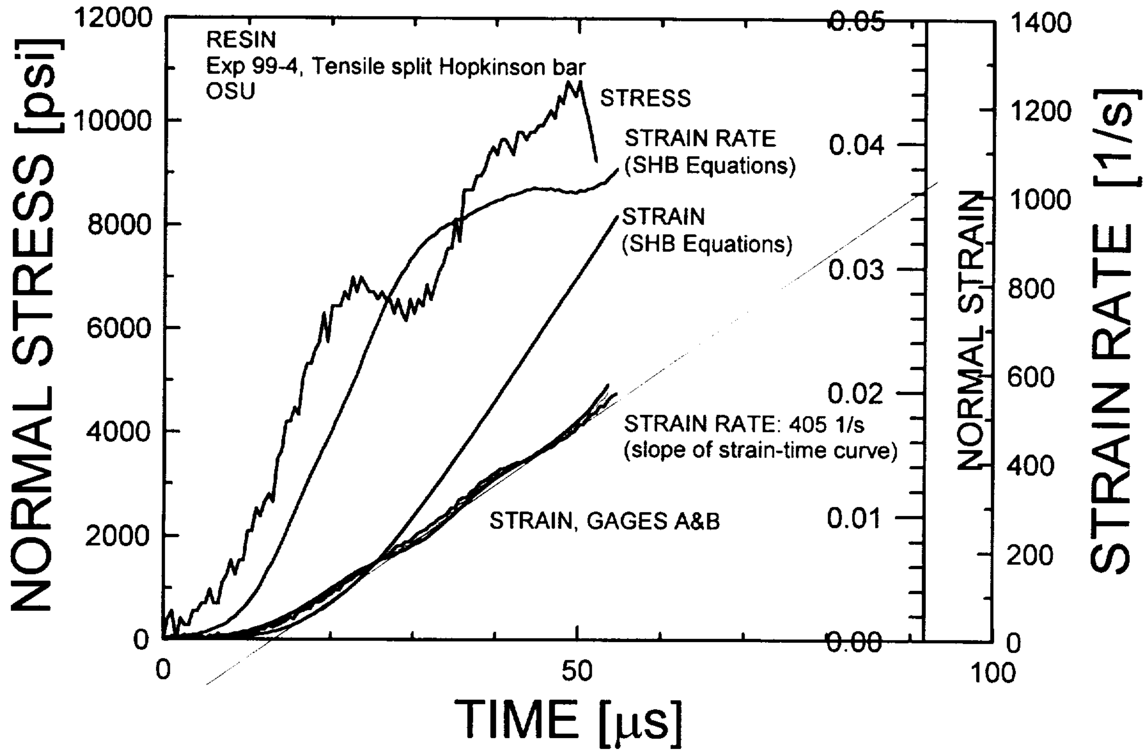

RESIN
Exp 99-1, Tensile split Hopkinson bar
OSU
STRESS
NORMAL STRESS [psi]
NORMAL STRAIN

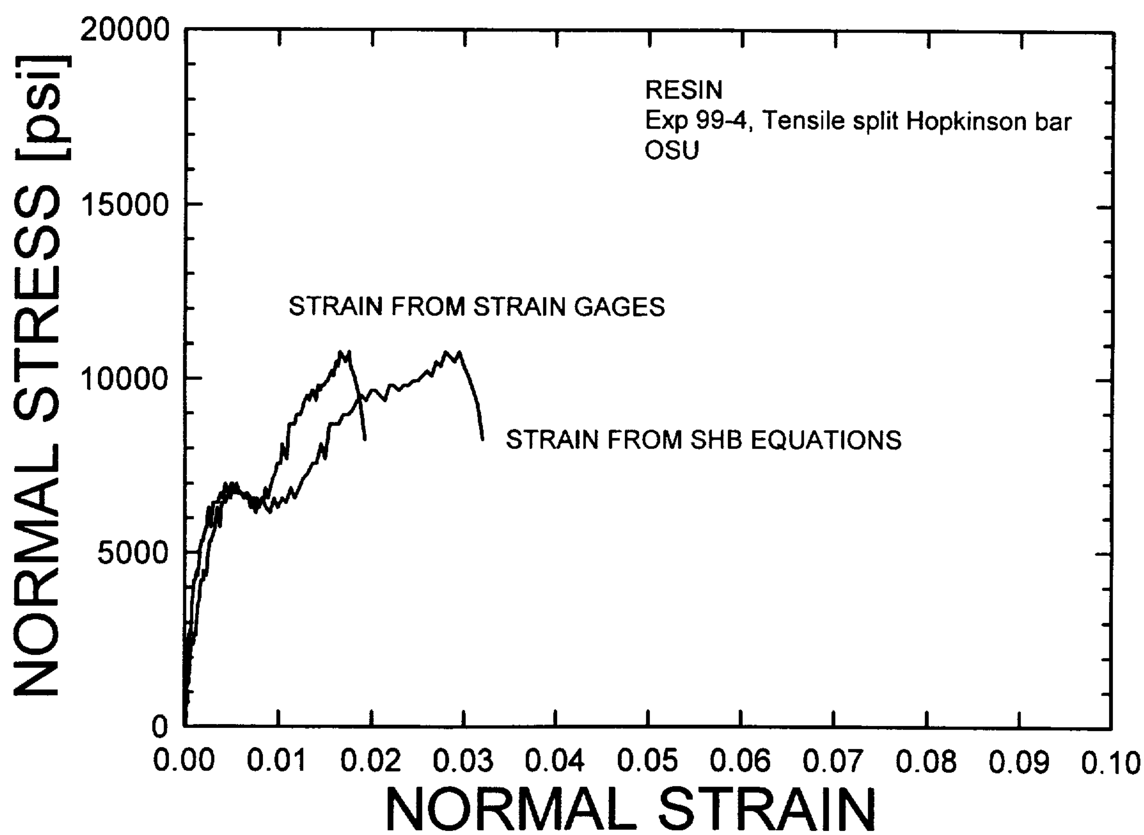

RESIN
Exp 99-2, Tensile split Hopkinson bar
OSU
STRESS
STRAIN
STRAIN RATE
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)

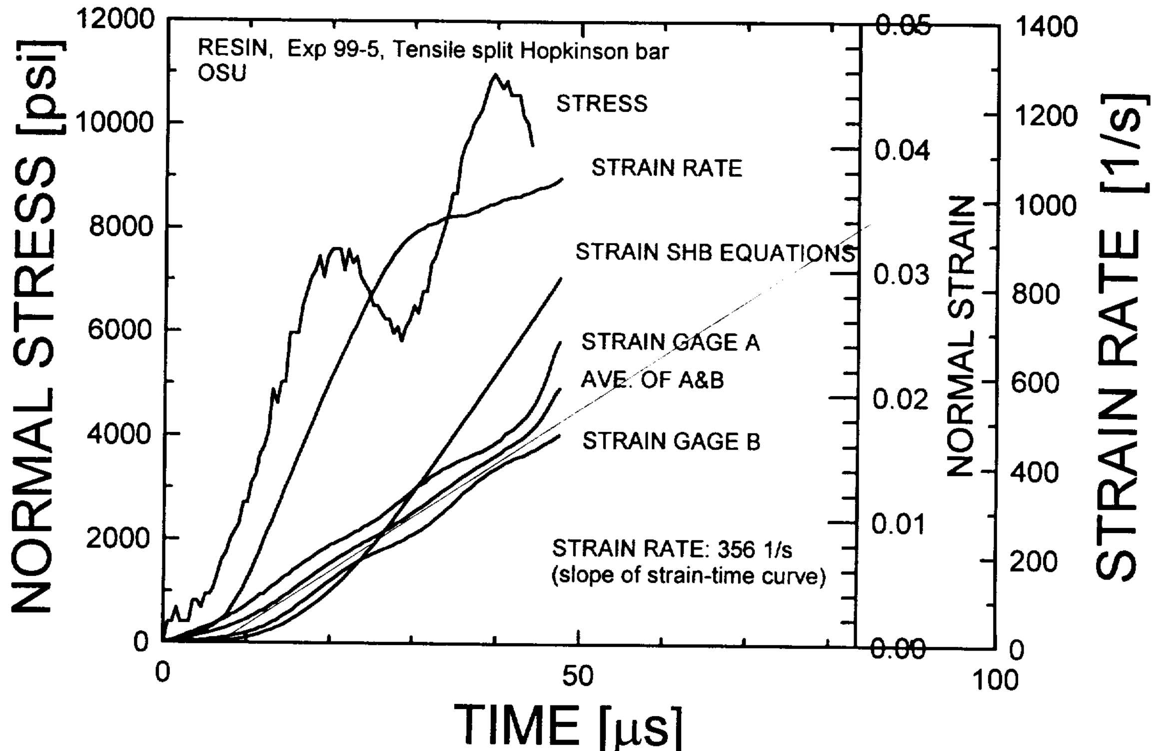

RESIN
Exp 99-2, Tensile split Hopkinson bar
OSU
NORMAL STRESS [psi]
NORMAL STRAIN

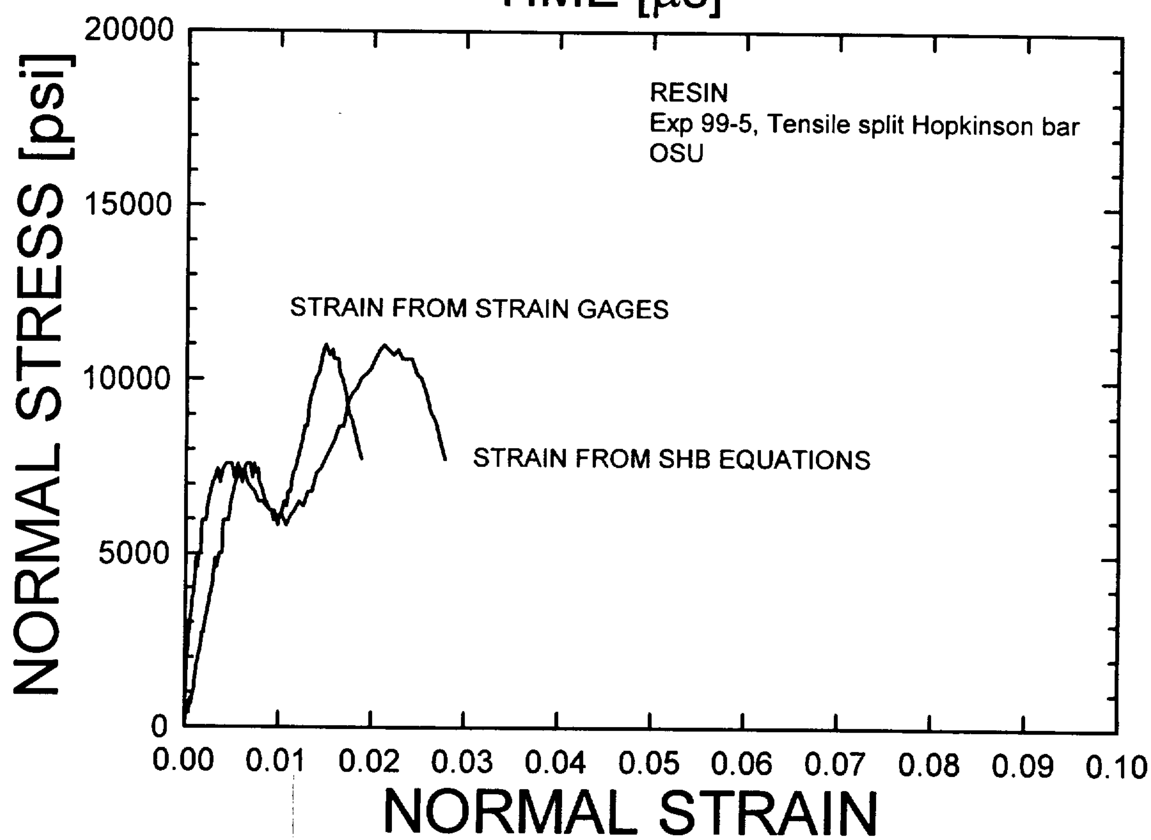

RESIN
Exp 99-3, Tensile split Hopkinson bar
OSU
(processed according to SHB equations)
STRAIN RATE
STRESS
STRAIN
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)
0
2000
4000
6000
8000
10000
12000
0.00
0.01
0.02
0.03
0.04
0.05
0
200
400
600
800
1000
1200
1400
0
50
100

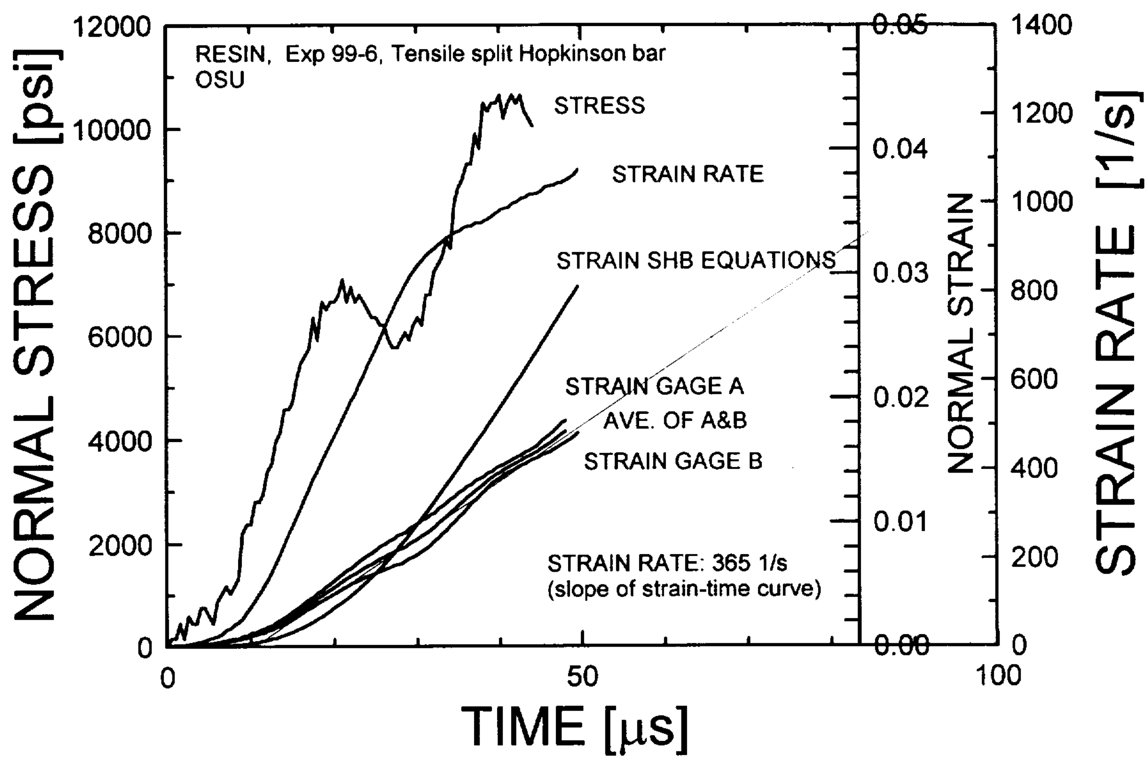

RESIN
Exp 99-3, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10

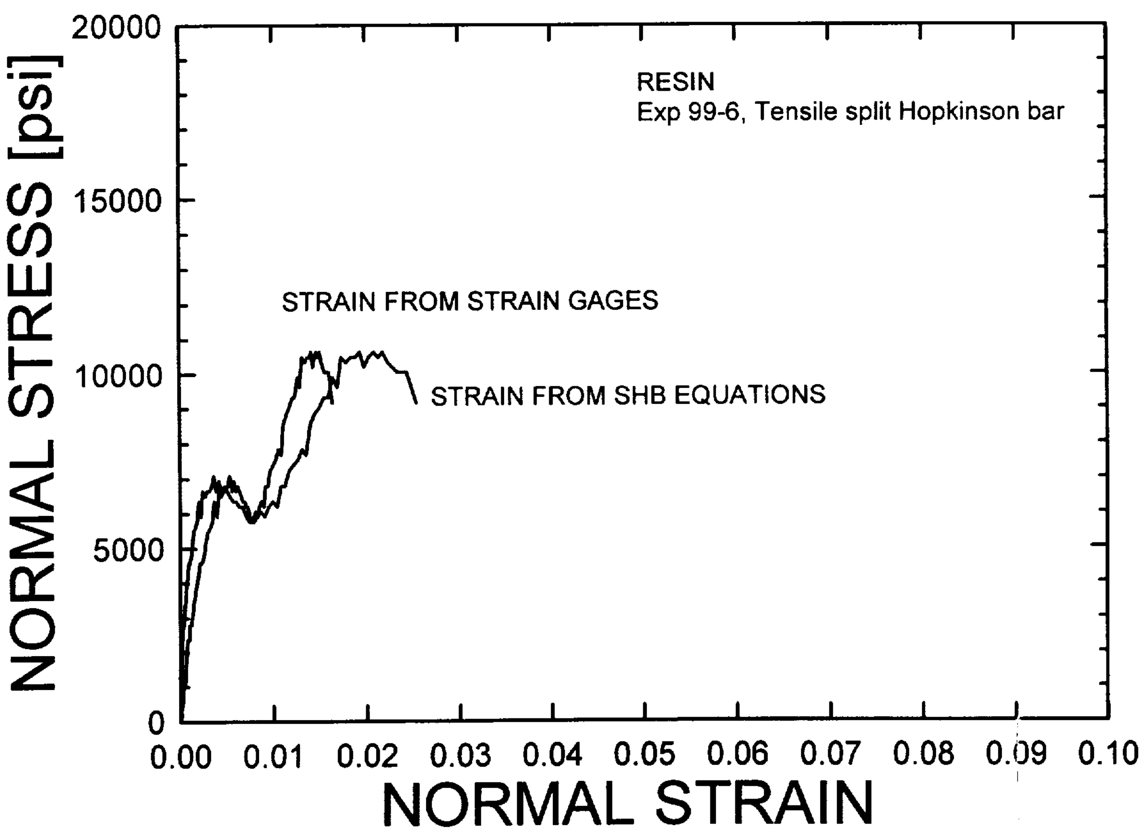

RESIN
Exp 99-4, Tensile split Hopkinson bar
OSU
STRESS
STRAIN RATE
(SHB Equations)
STRAIN
(SHB Equations)
STRAIN RATE: 405 1/s
(slope of strain-time curve)
STRAIN, GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME [μs]
12000
10000
8000
6000
4000
2000
0
0.05
0.04
0.03
0.02
0.01
0.00
1400
1200
1000
800
600
400
200
0
0
50
100

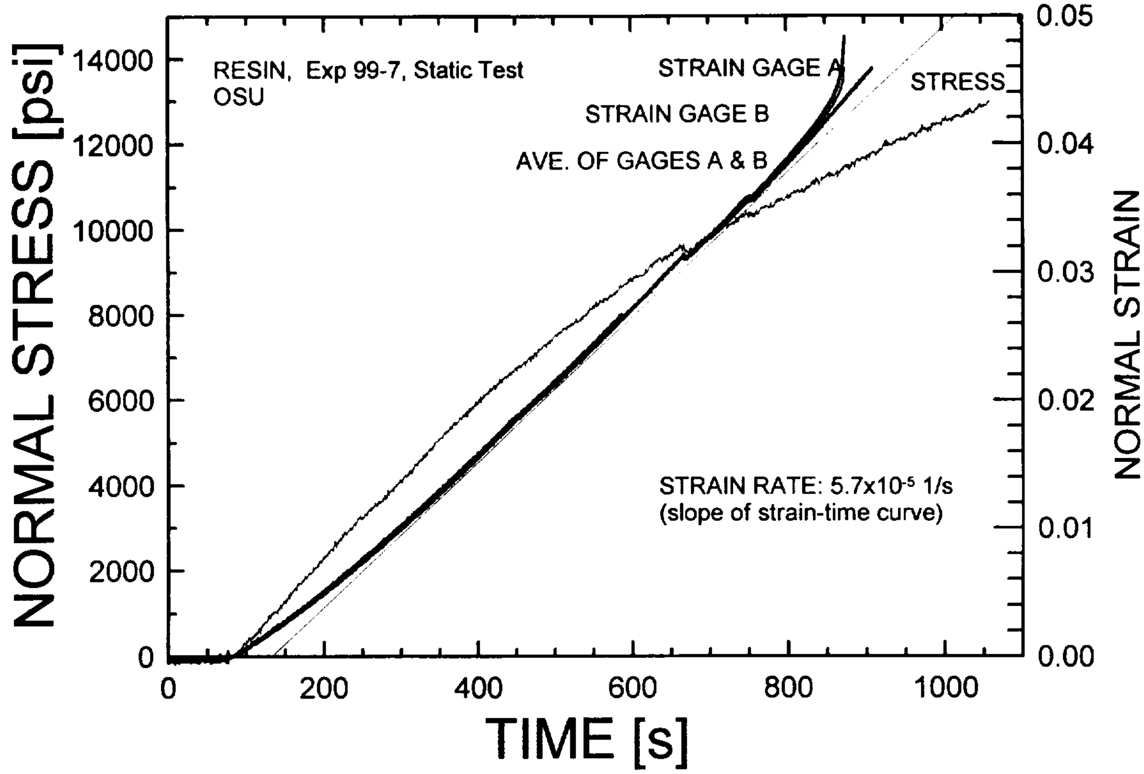

RESIN
Exp 99-4, Tensile split Hopkinson bar
OSU
STRAIN FROM STRAIN GAGES
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
20000
15000
10000
5000
0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10

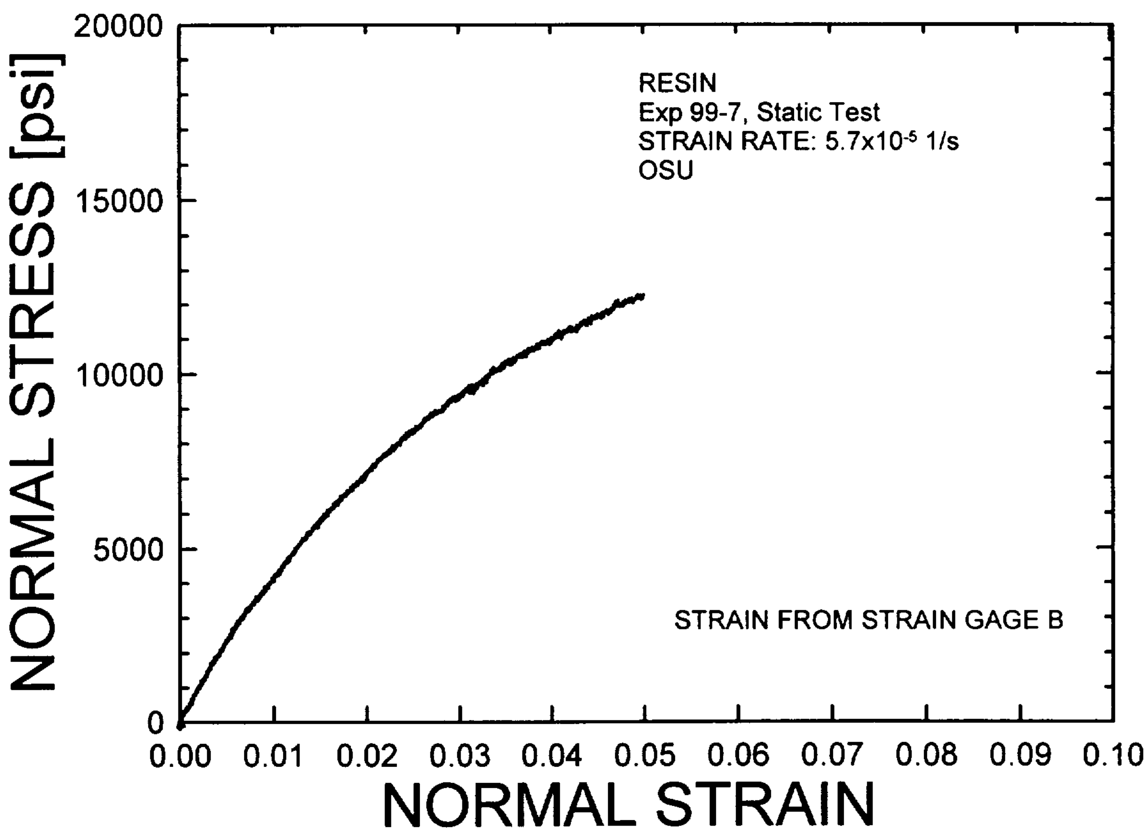

RESIN, Exp 99-5, Tensile split Hopkinson bar
OSU
STRESS
STRAIN RATE
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 356 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME [μs]
0
2000
4000
6000
8000
10000
12000
0.00
0.01
0.02
0.03
0.04
0.05
200
400
600
800
1000
1200
1400
50
100

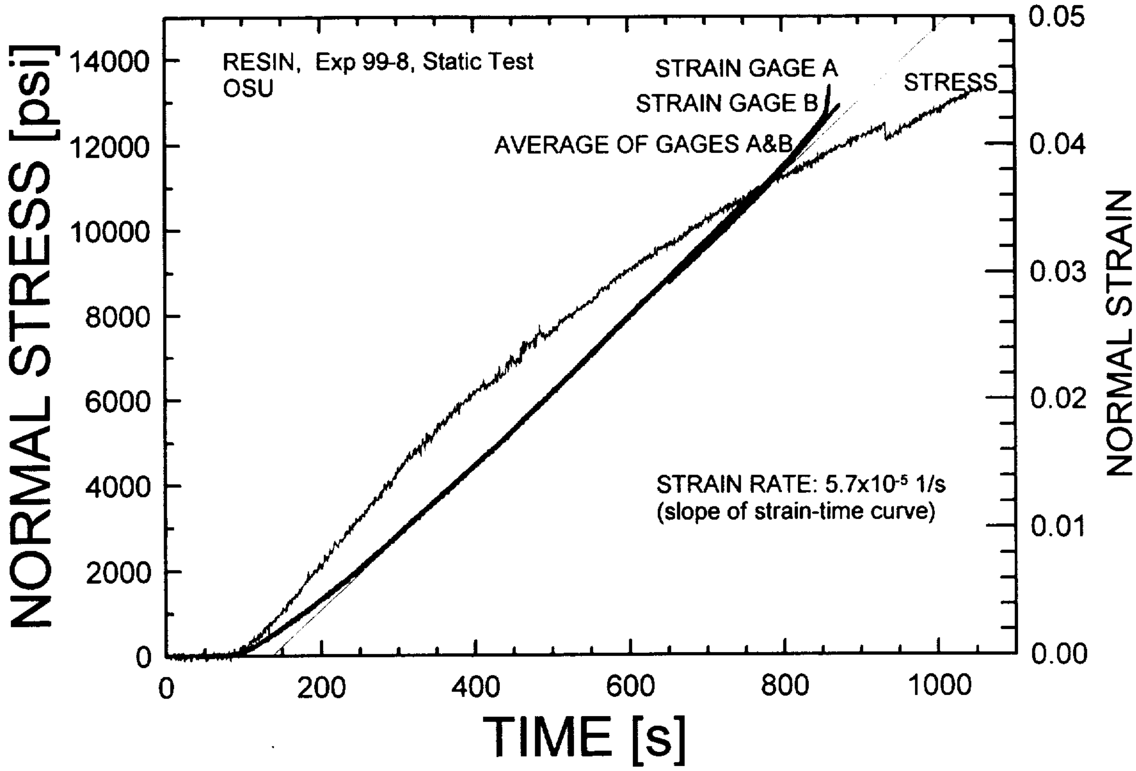

RESIN
Exp 99-5, Tensile split Hopkinson bar
OSU
STRAIN FROM STRAIN GAGES
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10

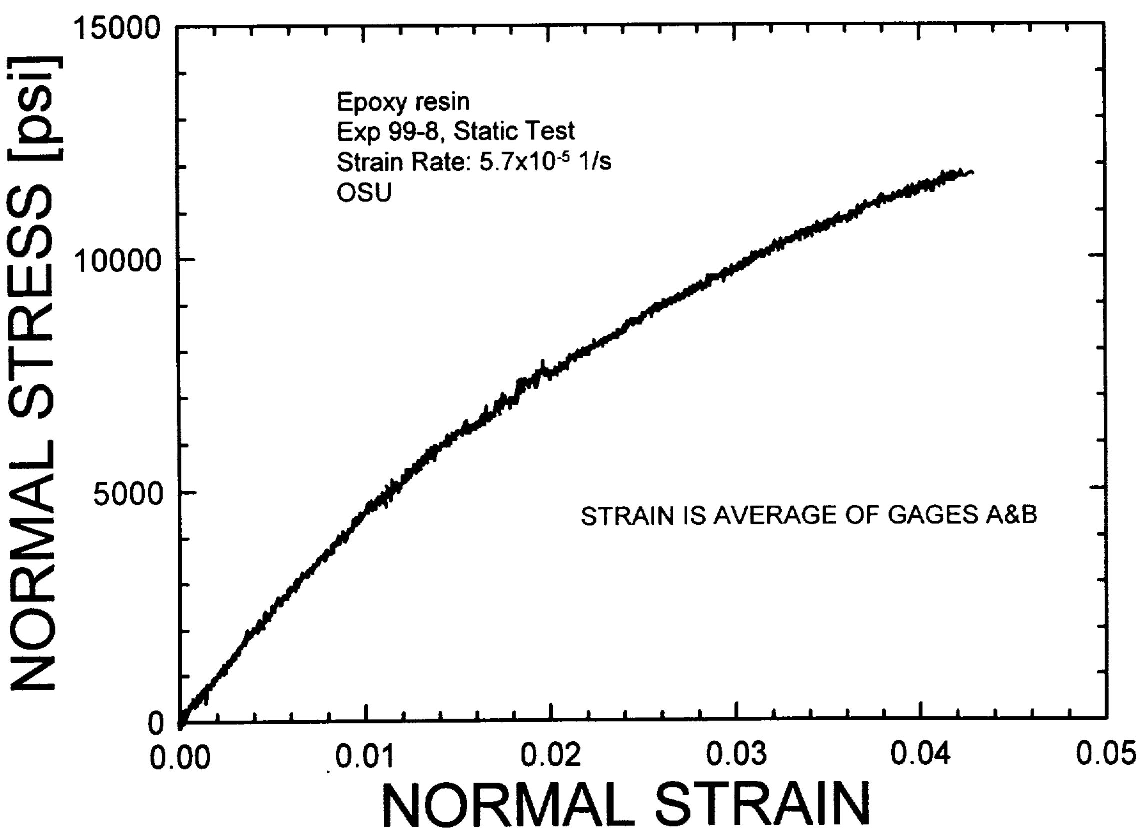

RESIN, Exp 99-6, Tensile split Hopkinson bar
OSU
STRESS
STRAIN RATE
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 365 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME [μs]
0
2000
4000
6000
8000
10000
12000
0.00
0.01
0.02
0.03
0.04
0.05
200
400
600
800
1000
1200
1400
50
100

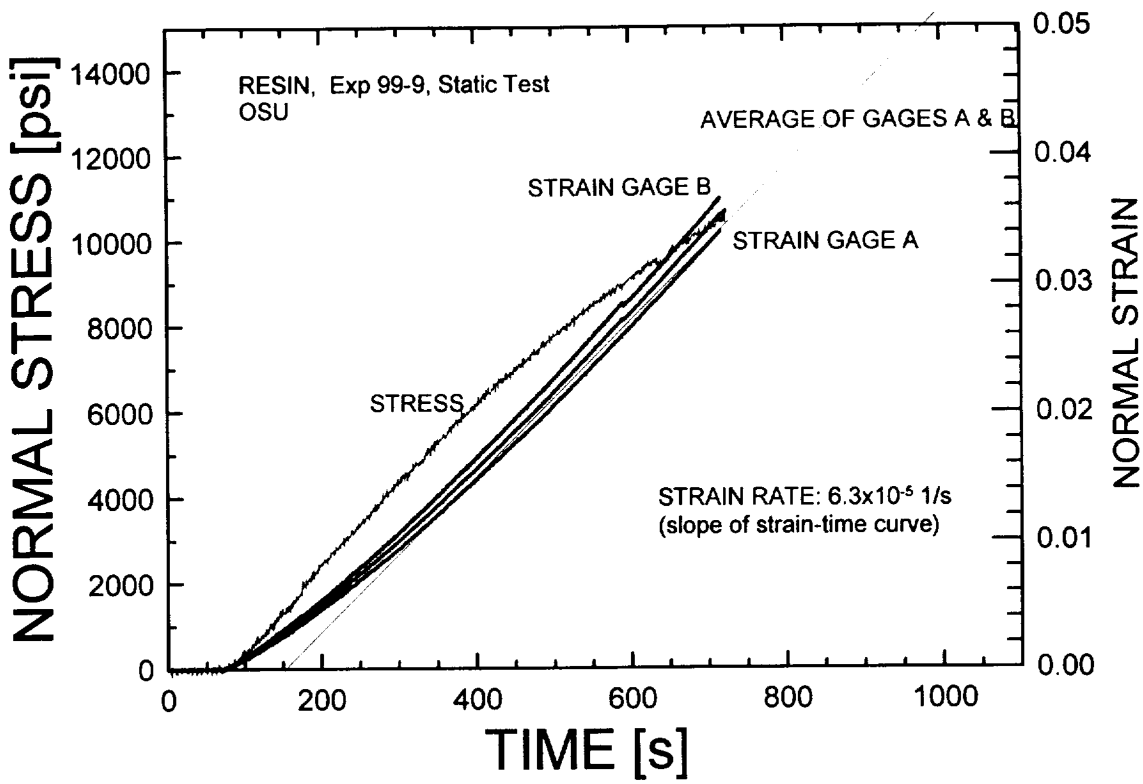

RESIN
Exp 99-6, Tensile split Hopkinson bar
STRAIN FROM STRAIN GAGES
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10


NORMAL STRESS [psi]
14000
12000
10000
8000
6000
4000
2000
0
0
200
400
600
800
1000
TIME [s]
0.05
0.04
0.03
0.02
0.01
0.00
NORMAL STRAIN
RESIN, Exp 99-7, Static Test
OSU
STRAIN GAGE A
STRAIN GAGE B
AVE. OF GAGES A & B
STRESS
STRAIN RATE: 5.7x10-5 1/s
(slope of strain-time curve)

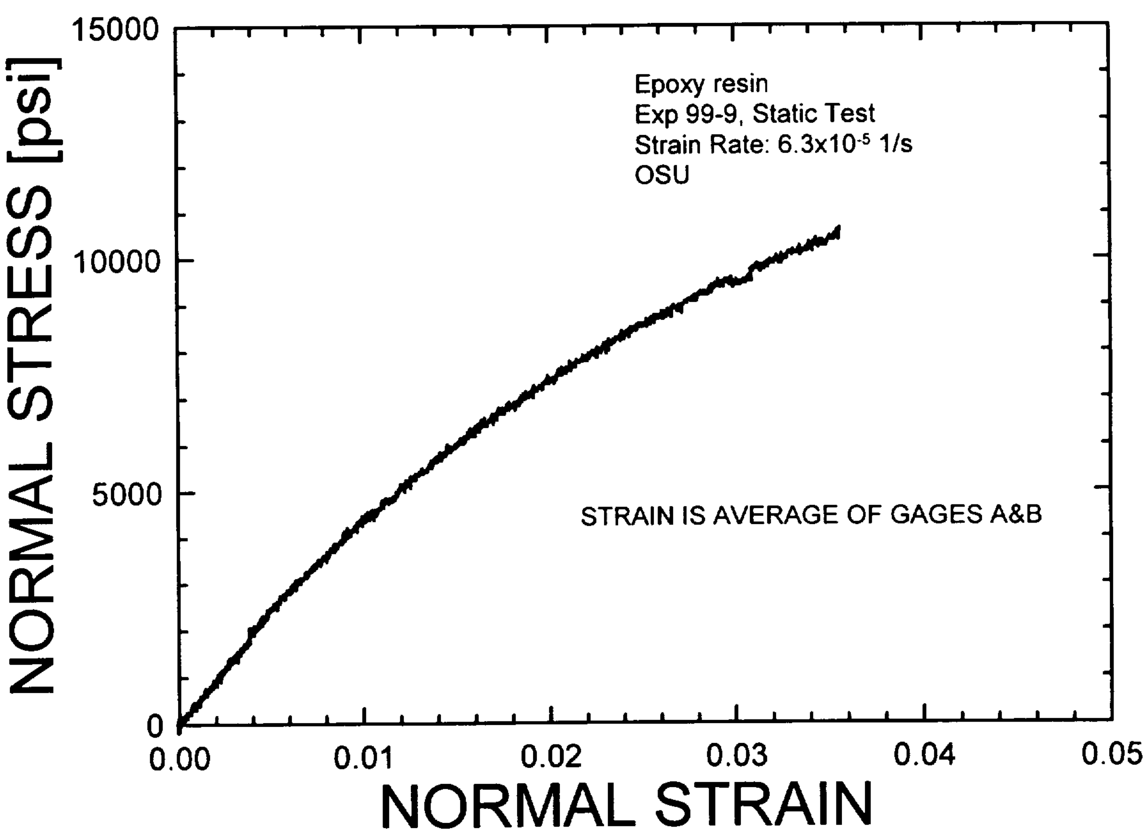

NORMAL STRESS [psi]
20000
15000
10000
5000
0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
NORMAL STRAIN
RESIN
Exp 99-7, Static Test
STRAIN RATE: 5.7x10-5 1/s
OSU
STRAIN FROM STRAIN GAGE B


RESIN, Exp 99-8, Static Test
OSU
STRAIN GAGE A
STRAIN GAGE B
AVERAGE OF GAGES A&B
STRESS
STRAIN RATE: 5.7x10-5 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
0.00
0.01
0.02
0.03
0.04
0.05
0
200
400
600
800
1000

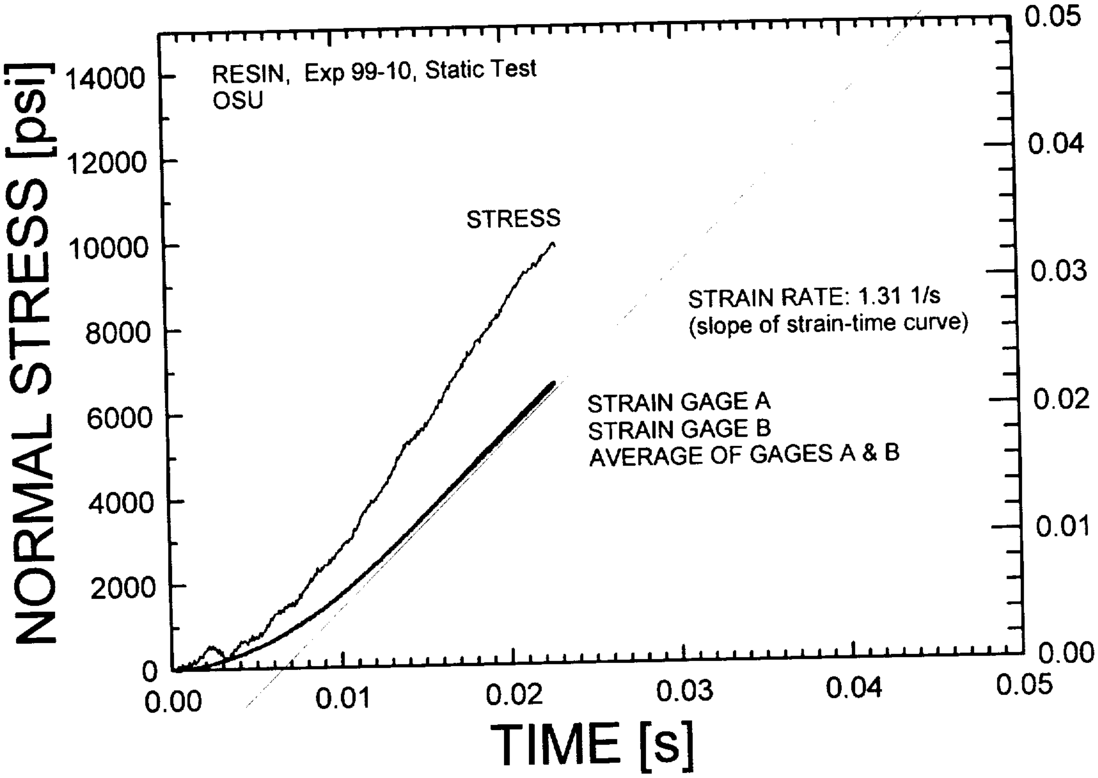

Epoxy resin
Exp 99-8, Static Test
Strain Rate: 5.7x10-5 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
0.00
0.01
0.02
0.03
0.04
0.05

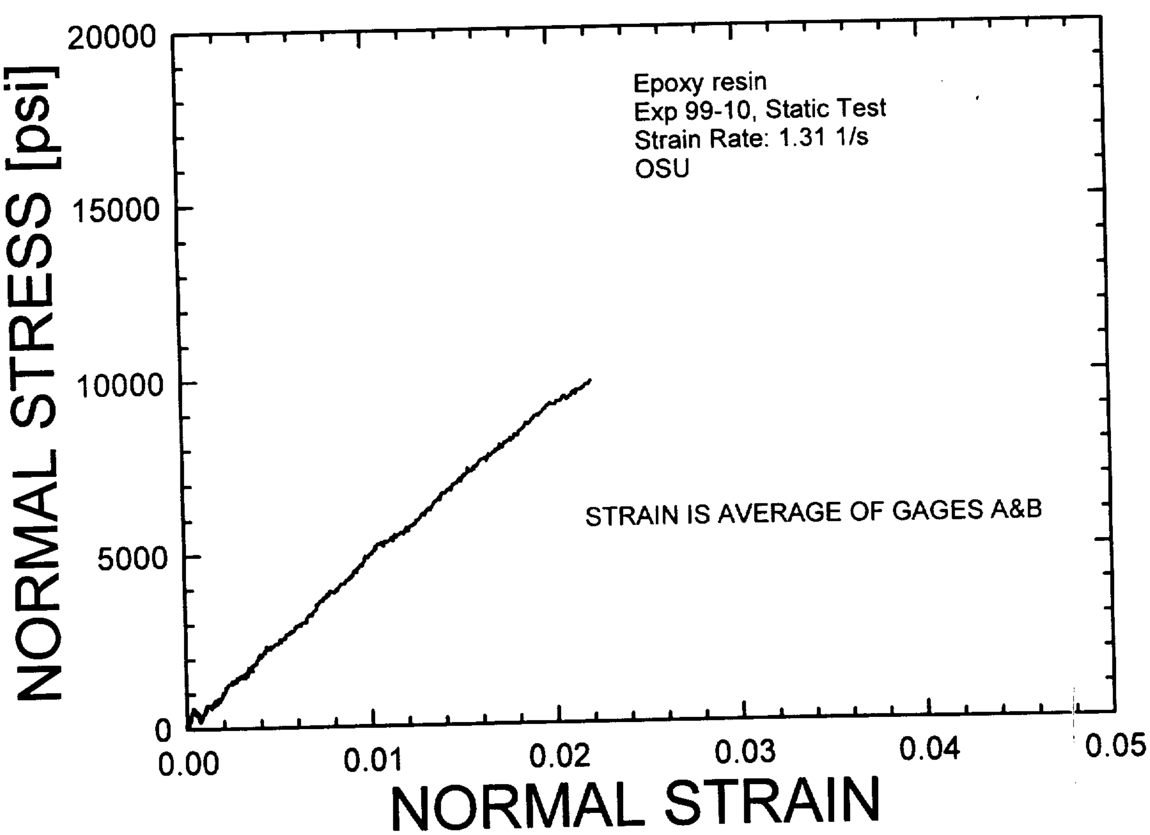


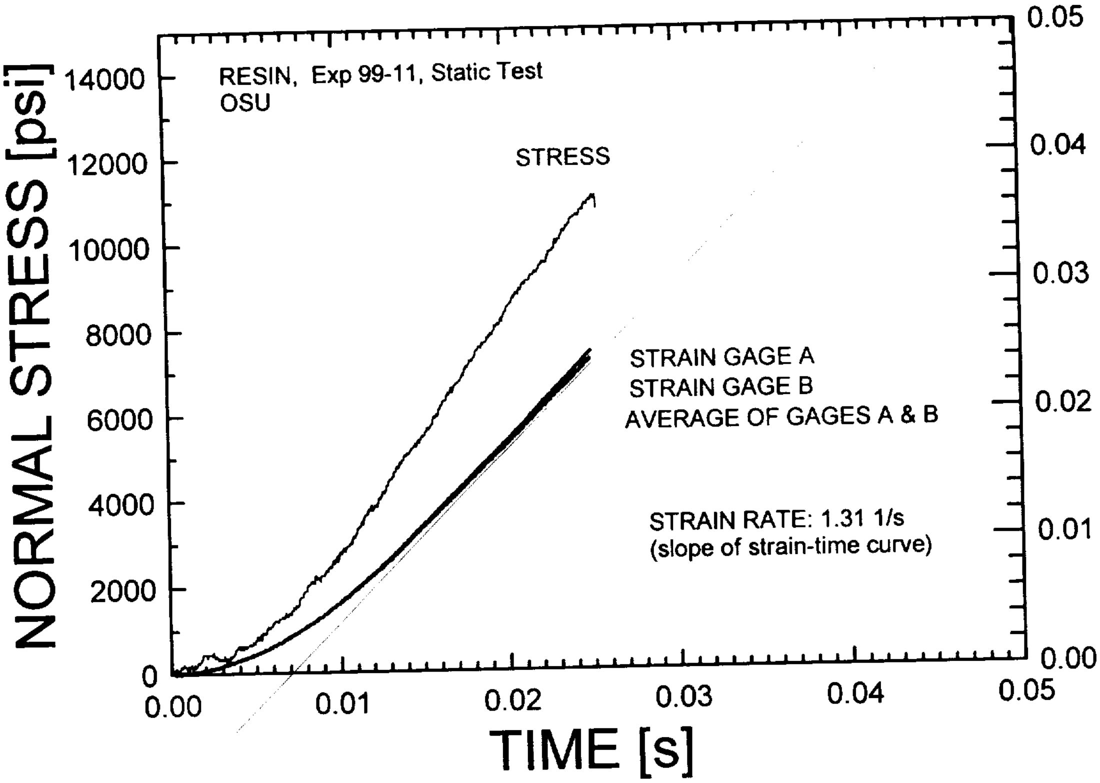
RESIN, Exp 99-9, Static Test
OSU
AVERAGE OF GAGES A & B
STRAIN GAGE B
STRAIN GAGE A
STRESS
STRAIN RATE: 6.3x10^{-5} 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]

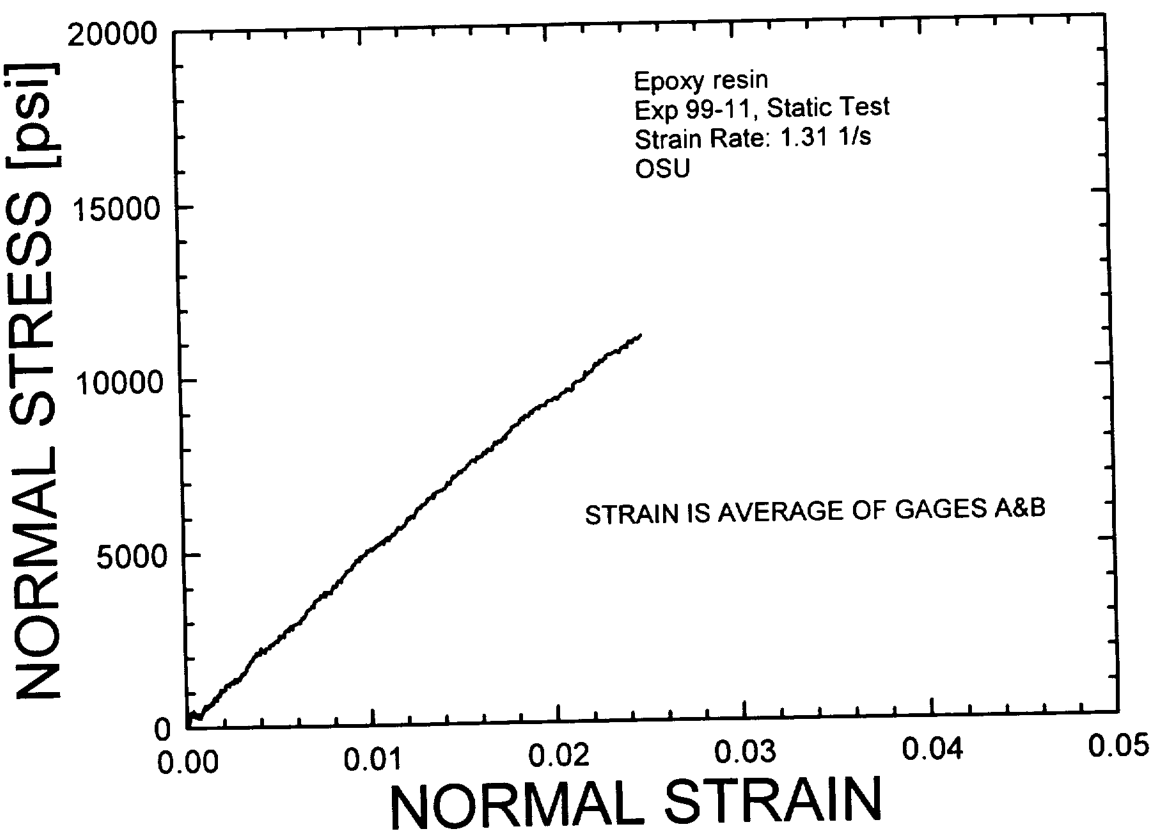


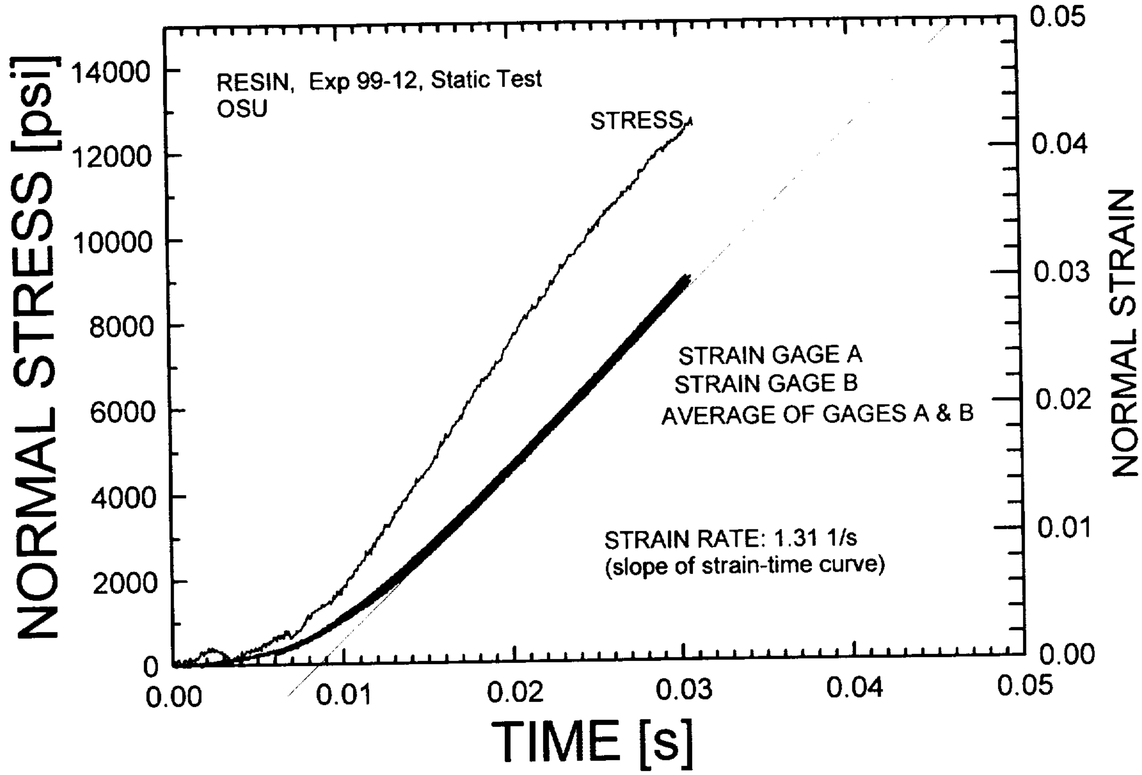
Epoxy resin
Exp 99-9, Static Test
Strain Rate: 6.3x10^{-5} 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN

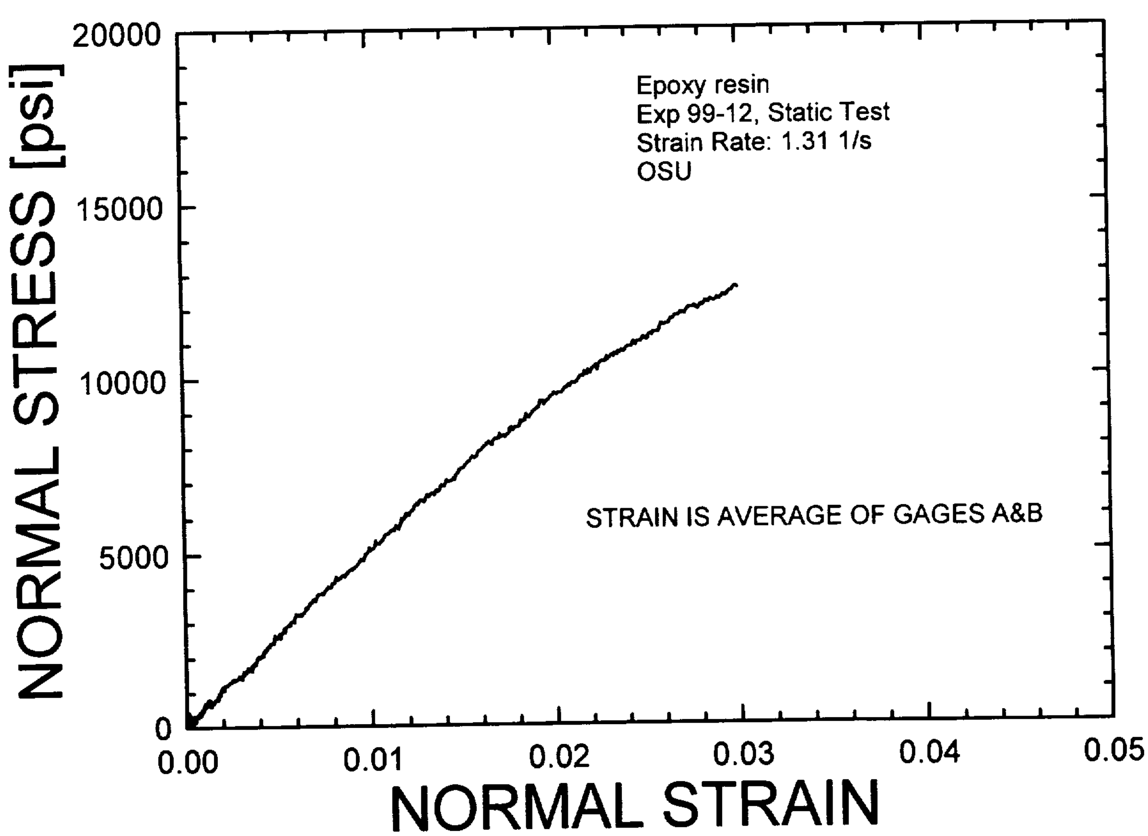

RESIN, Exp 99-10, Static Test
OSU
STRESS
STRAIN RATE: 1.31 1/s
(slope of strain-time curve)
STRAIN GAGE A
STRAIN GAGE B
AVERAGE OF GAGES A & B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]

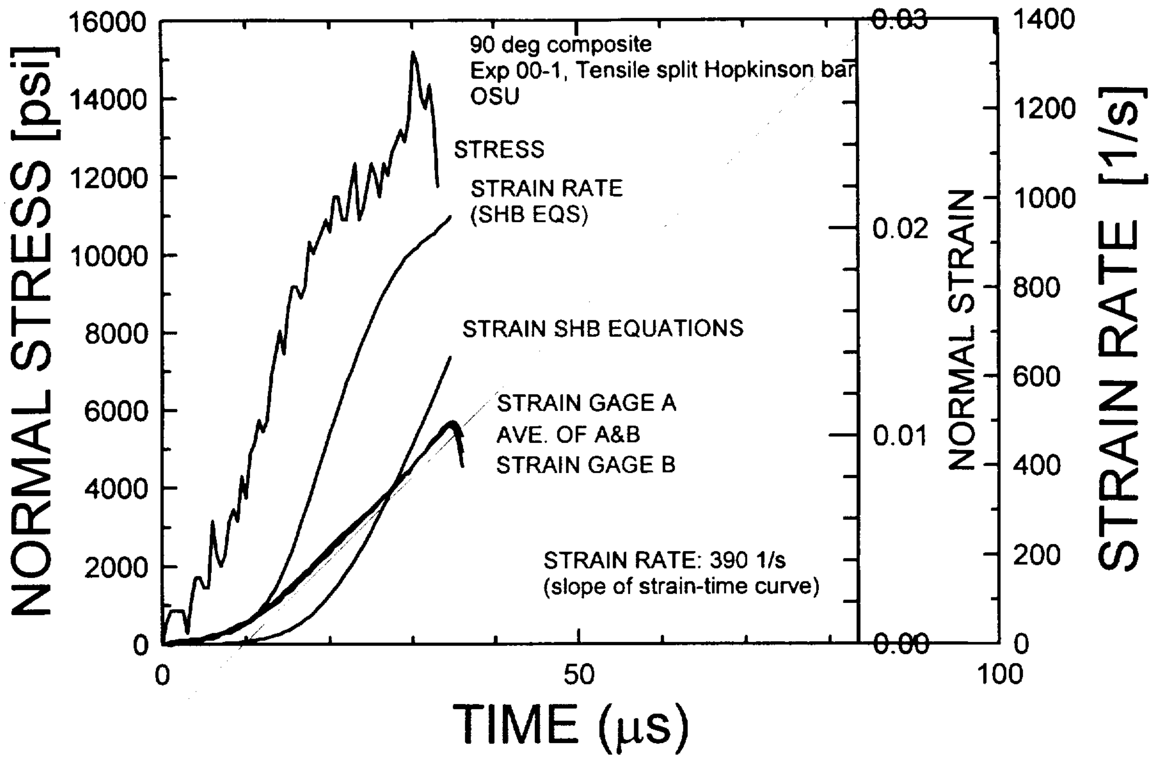

Epoxy resin
Exp 99-10, Static Test
Strain Rate: 1.31 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN


RESIN, Exp 99-11, Static Test
OSU
STRESS
STRAIN GAGE A
STRAIN GAGE B
AVERAGE OF GAGES A & B
STRAIN RATE: 1.31 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
0.00
0.01
0.02
0.03
0.04
0.05

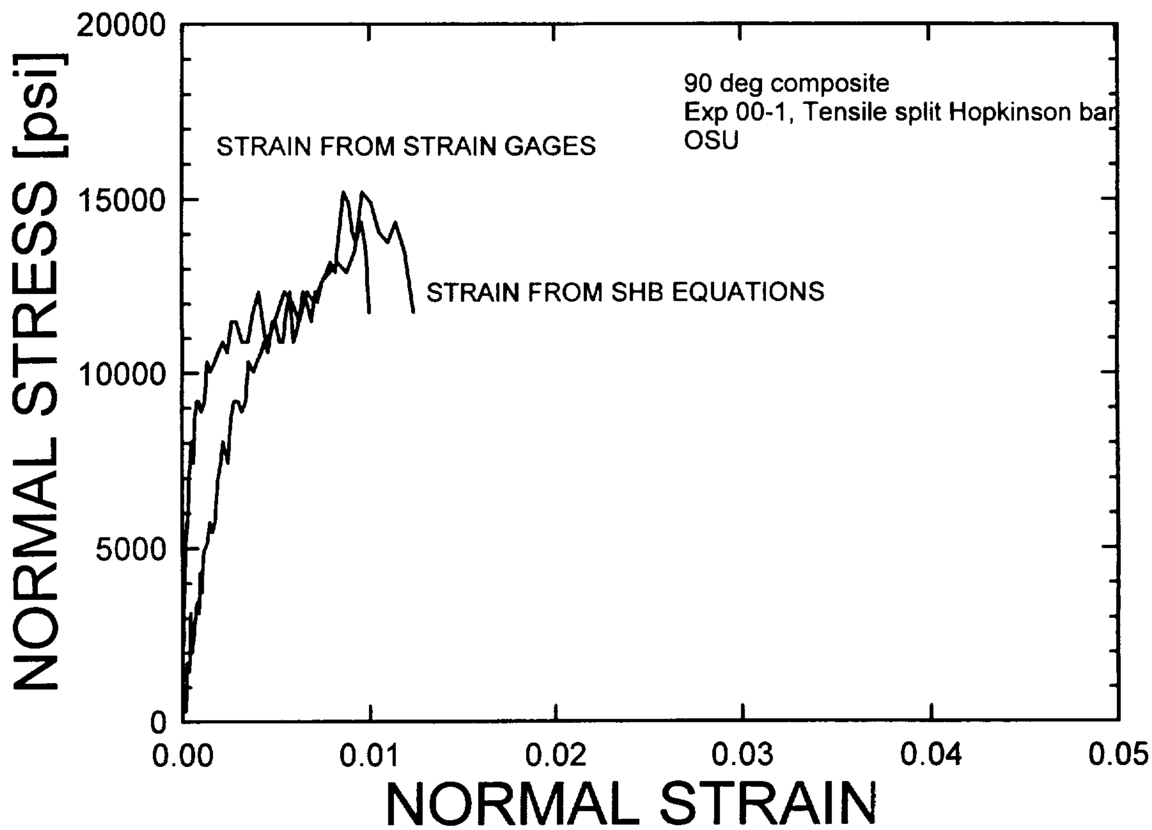

Epoxy resin
Exp 99-11, Static Test
Strain Rate: 1.31 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05


RESIN, Exp 99-12, Static Test
OSU
STRESS
STRAIN GAGE A
STRAIN GAGE B
AVERAGE OF GAGES A & B
STRAIN RATE: 1.31 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
0.00
0.01
0.02
0.03
0.04
0.05

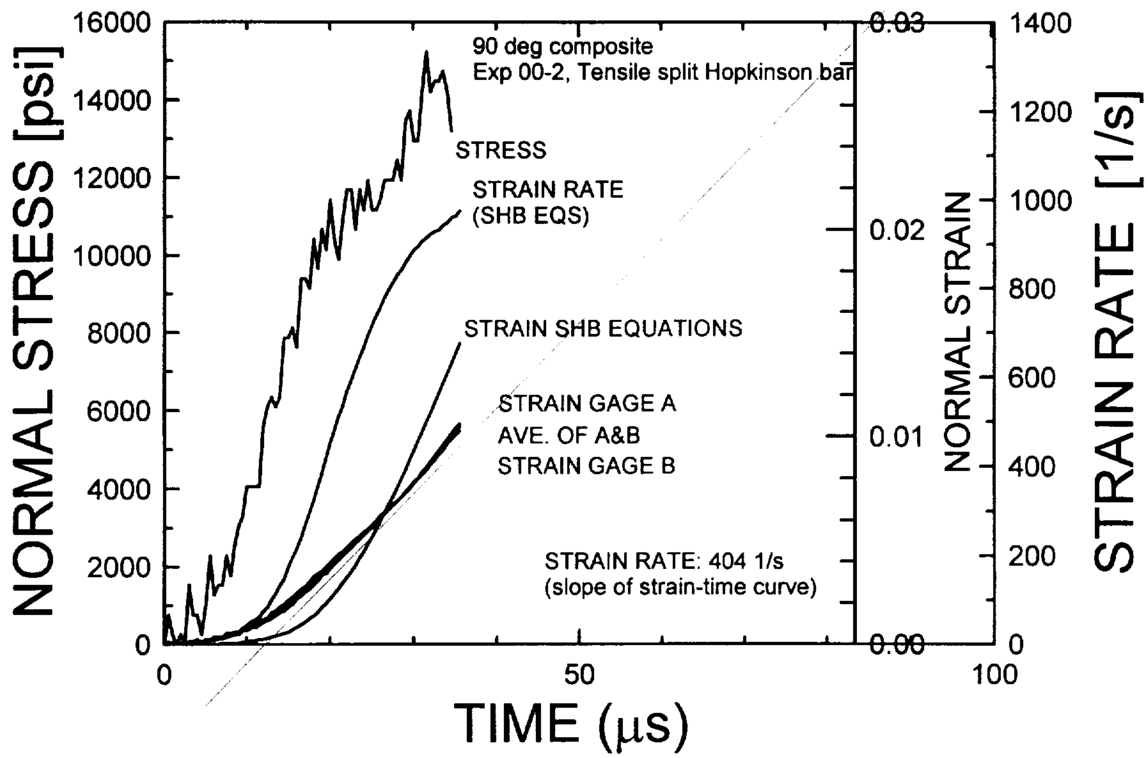

Epoxy resin
Exp 99-12, Static Test
Strain Rate: 1.31 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05



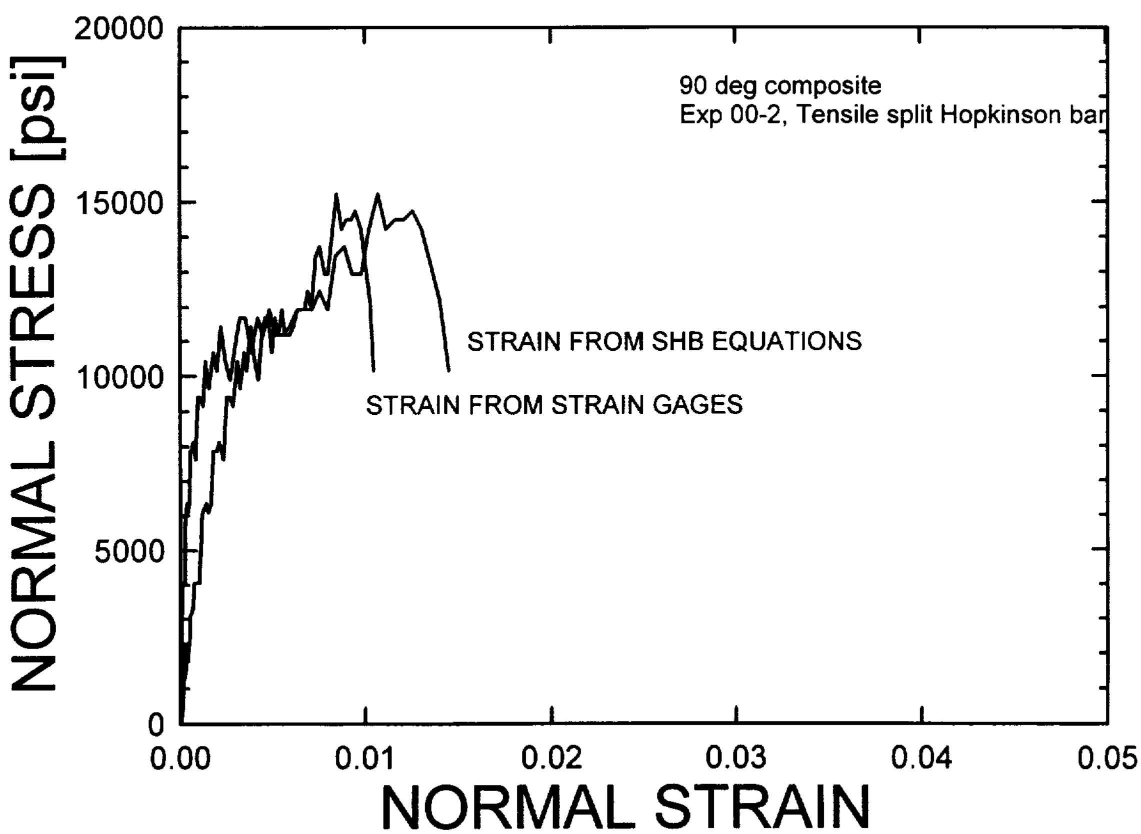
90 deg composite
Exp 00-1, Tensile split Hopkinson bar
OSU
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 390 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)
16000
14000
12000
10000
8000
6000
4000
2000
0
0
50
100
0.03
0.02
0.01
0.00
1400
1200
1000
800
600
400
200
0



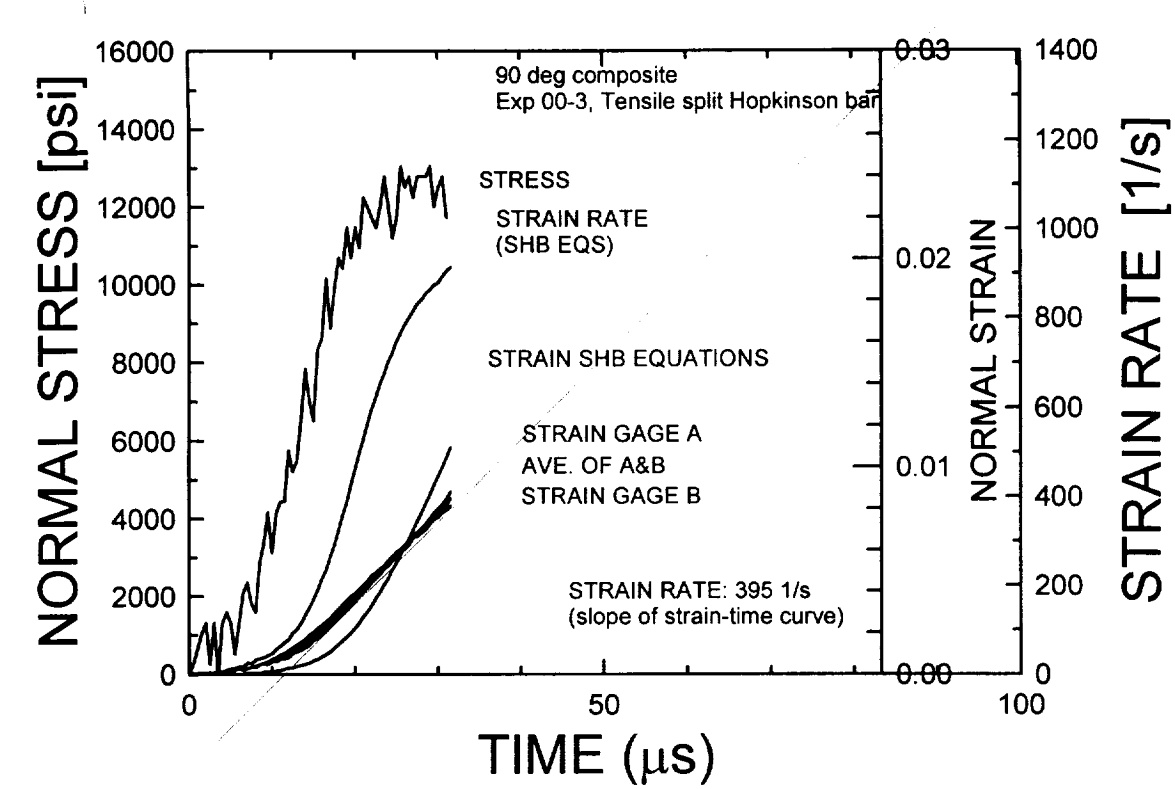
90 deg composite
Exp 00-1, Tensile split Hopkinson bar
OSU
STRAIN FROM STRAIN GAGES
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
20000
15000
10000
5000
0
0.00
0.01
0.02
0.03
0.04
0.05

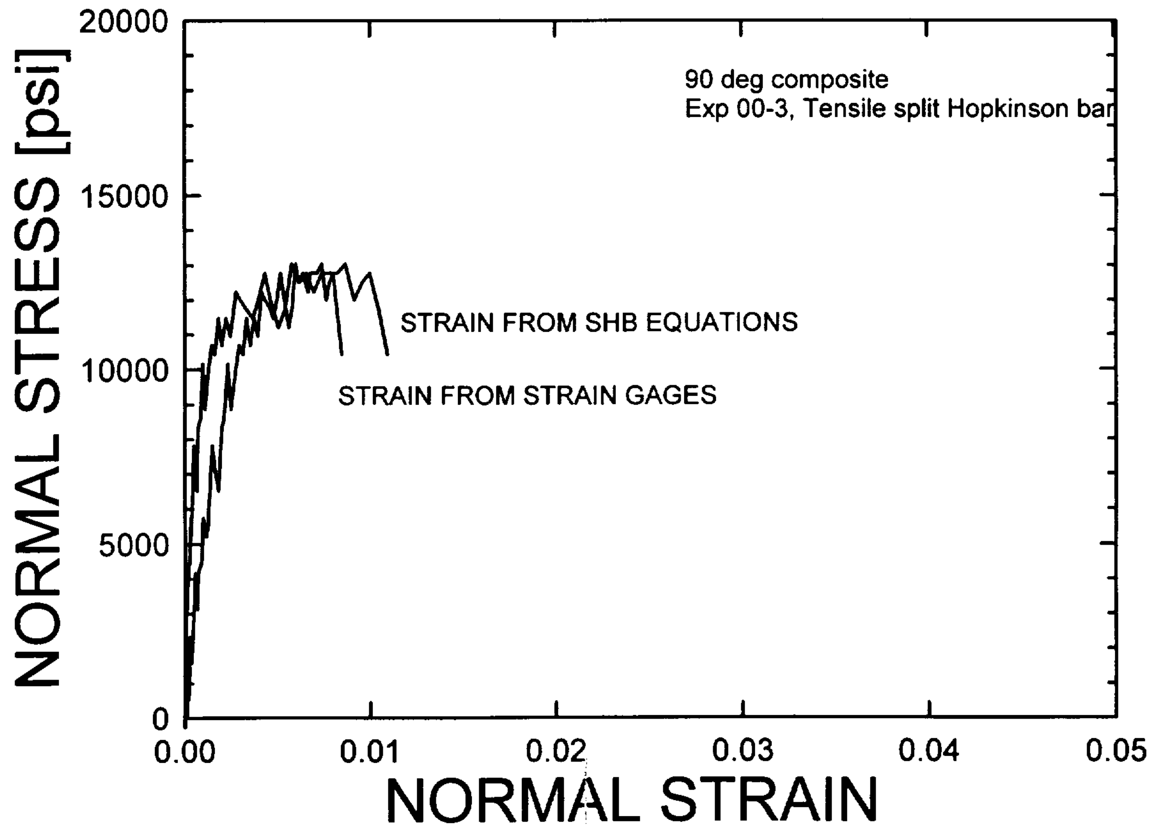


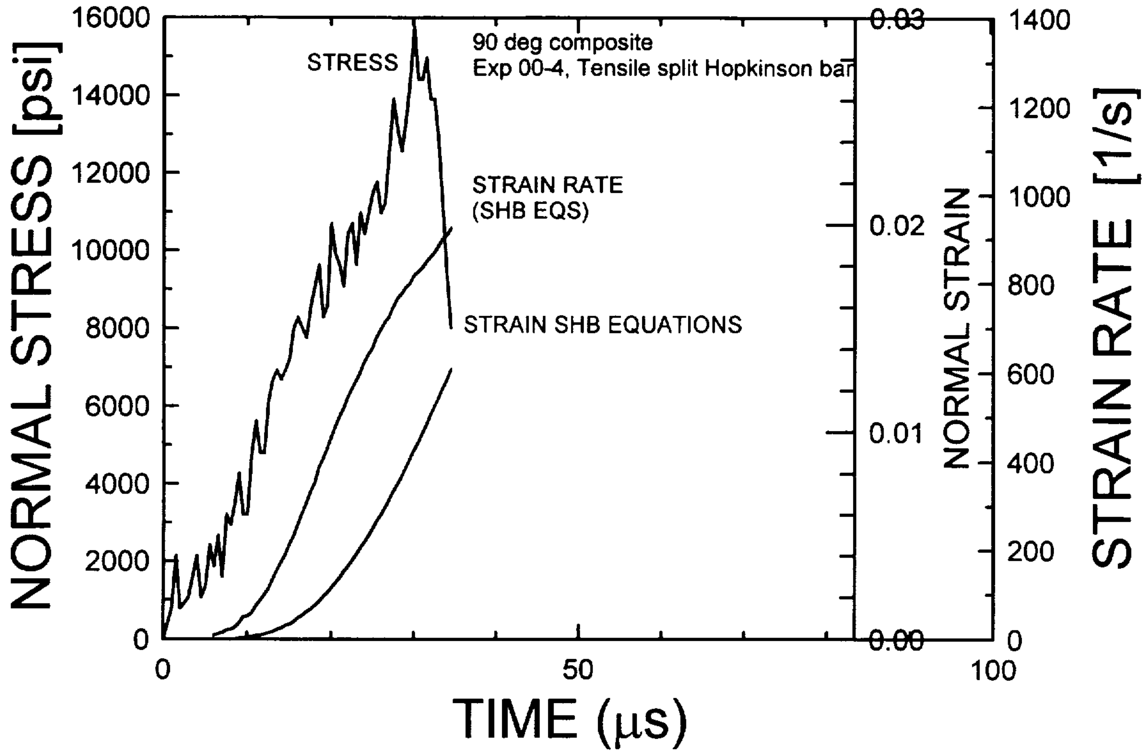
90 deg composite
Exp 00-2, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 404 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)

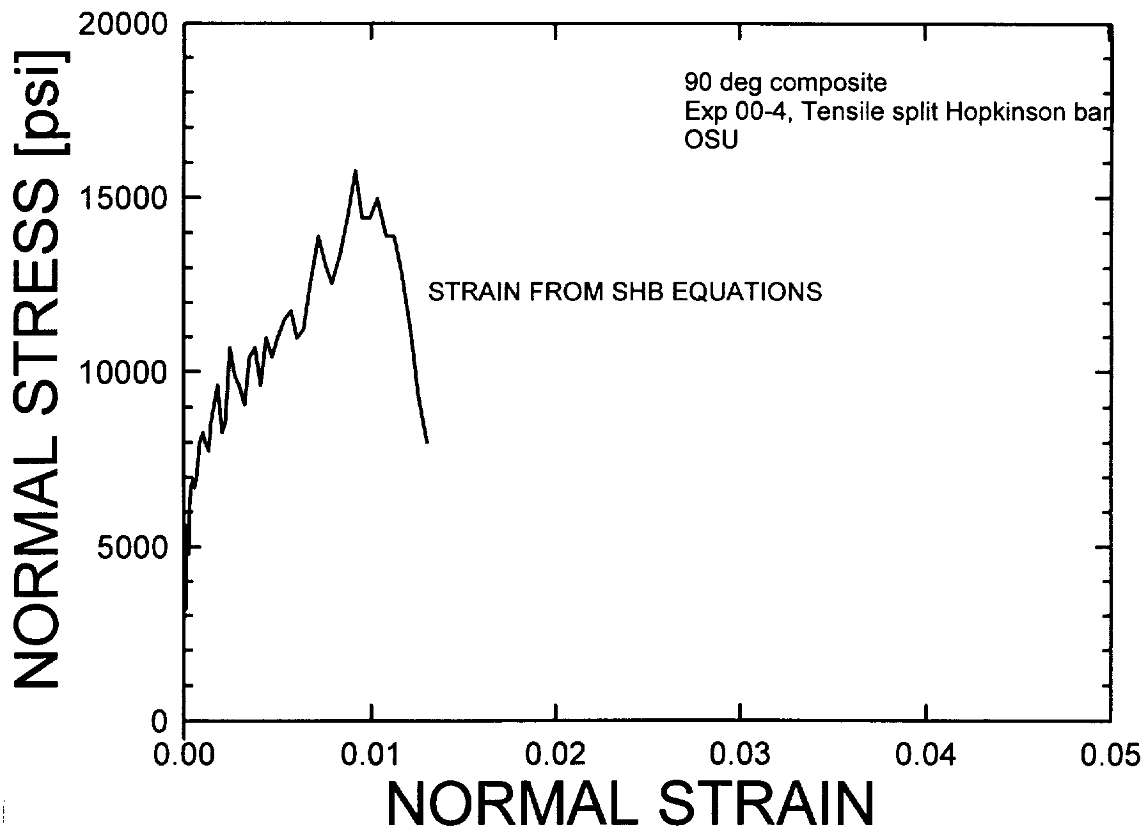


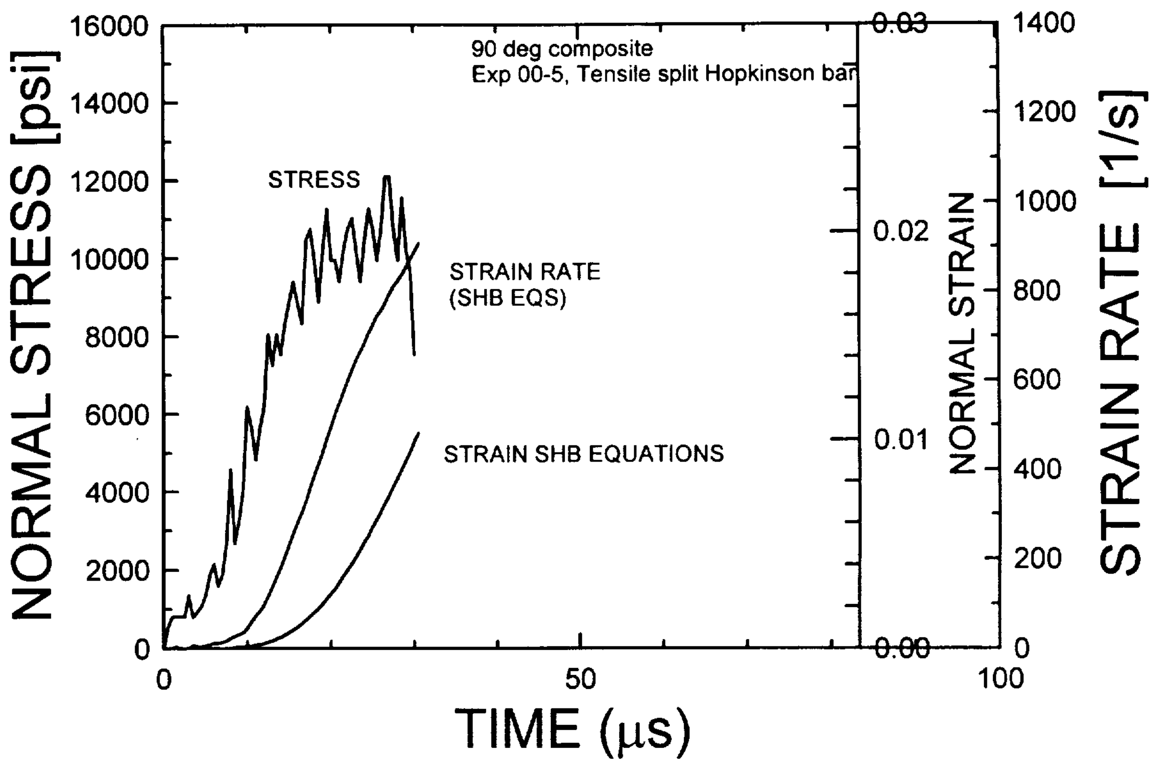
90 deg composite
Exp 00-2, Tensile split Hopkinson bar
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES
NORMAL STRESS [psi]
NORMAL STRAIN


90 deg composite
Exp 00-3, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 395 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)

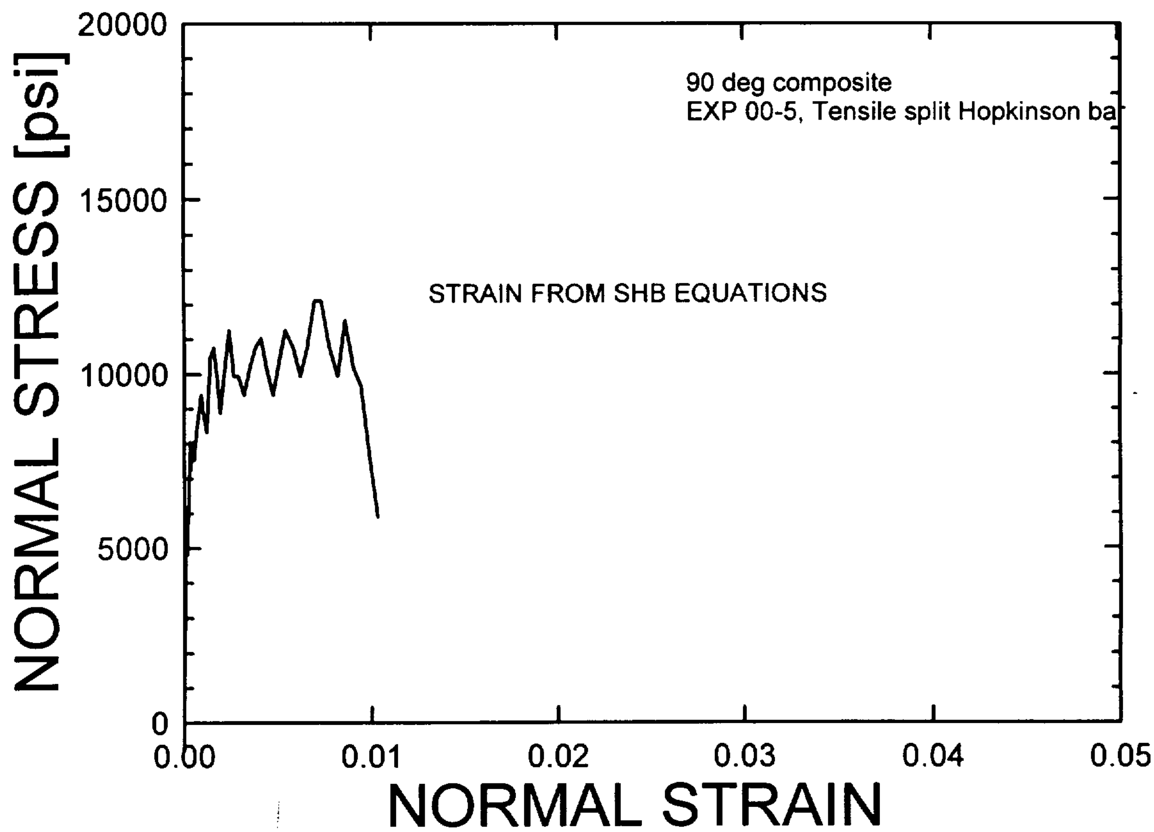

90 deg composite
Exp 00-3, Tensile split Hopkinson bar
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES
NORMAL STRESS [psi]
NORMAL STRAIN


16000
14000
12000
10000
8000
6000
4000
2000
0
NORMAL STRESS [psi]
STRESS
90 deg composite
Exp 00-4, Tensile split Hopkinson bar
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
0.03
0.02
0.01
0.00
NORMAL STRAIN
1400
1200
1000
800
600
400
200
0
STRAIN RATE [1/s]
0
50
100
TIME (μs)

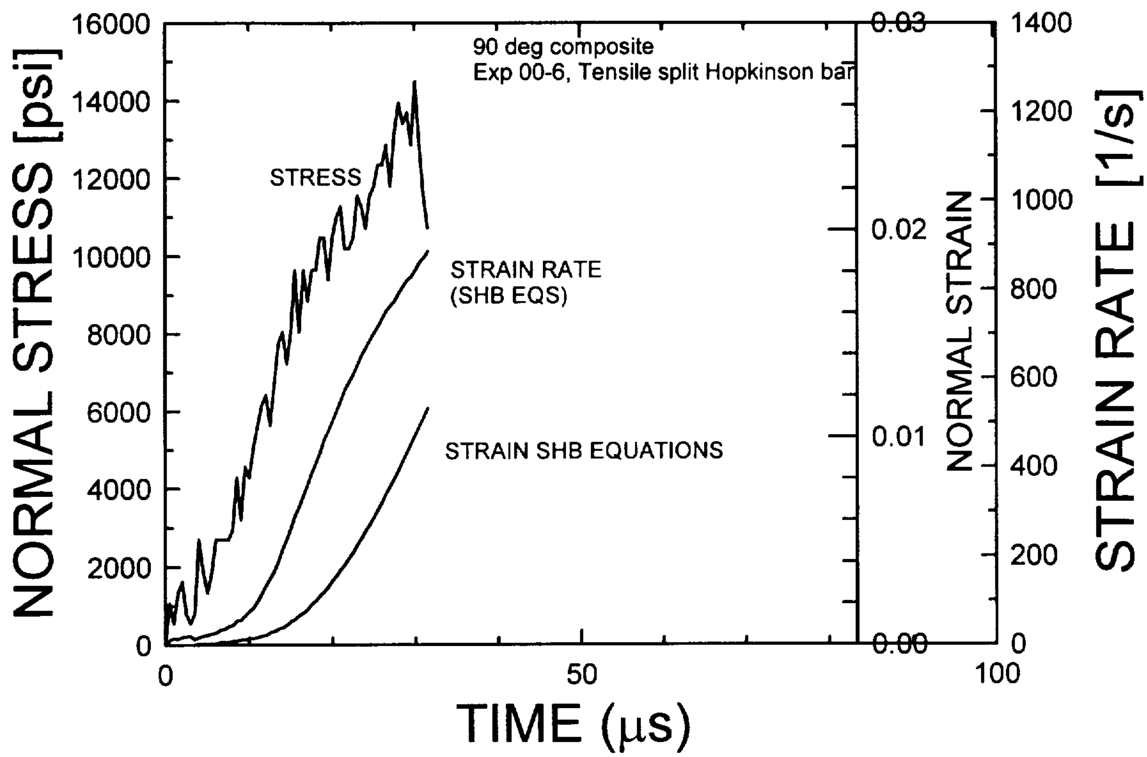

20000
15000
10000
5000
0
NORMAL STRESS [psi]
90 deg composite
Exp 00-4, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS
0.00
0.01
0.02
0.03
0.04
0.05
NORMAL STRAIN

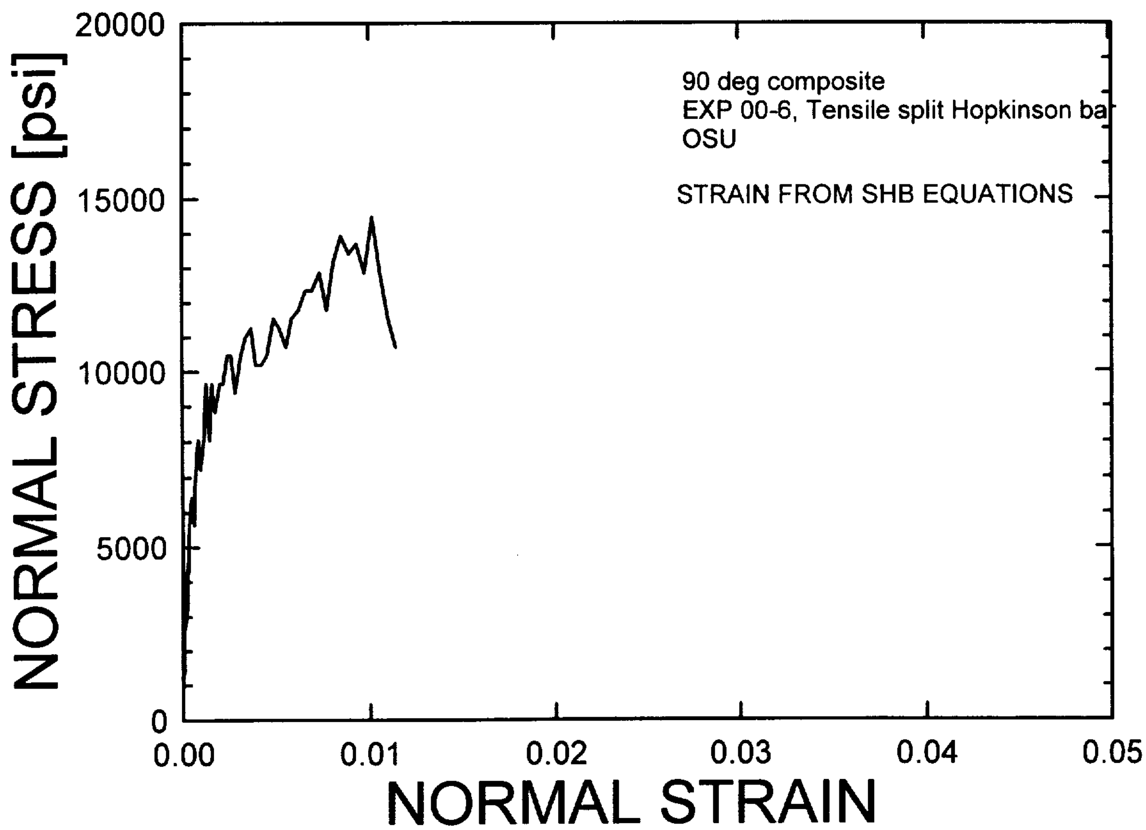


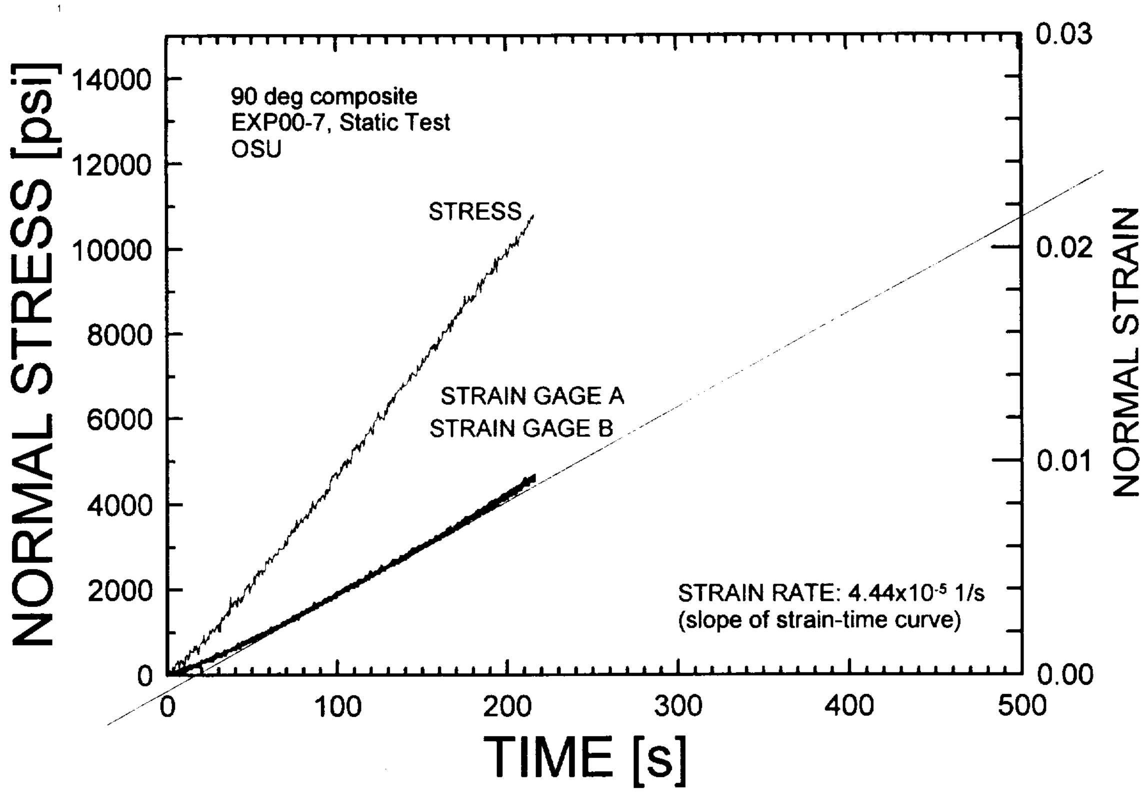
90 deg composite
Exp 00-5, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)



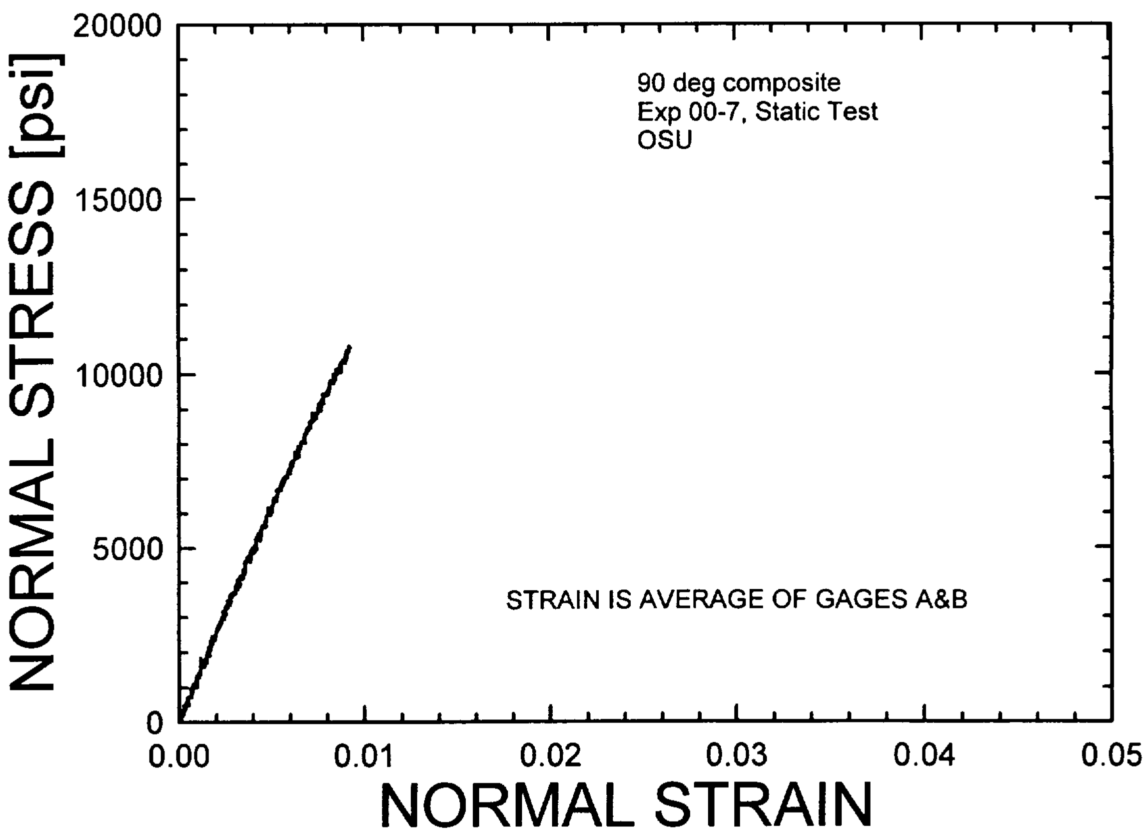
90 deg composite
EXP 00-5, Tensile split Hopkinson bar
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN


90 deg composite
Exp 00-6, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)

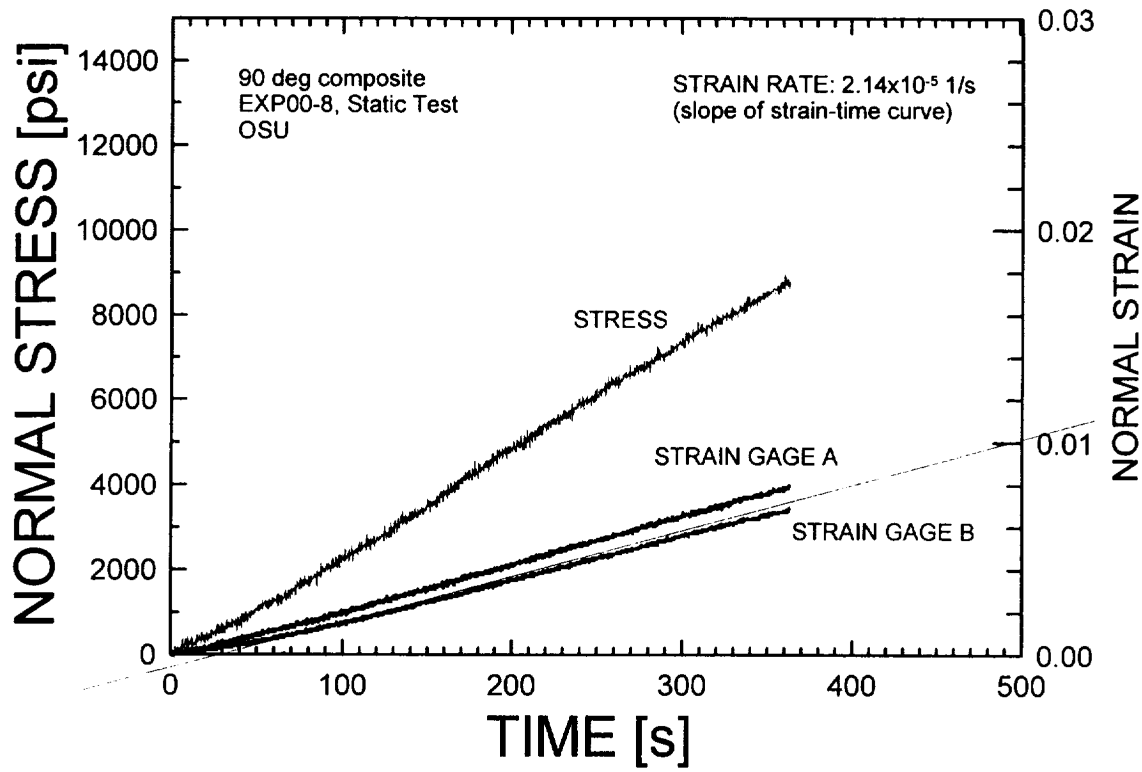

90 deg composite
EXP 00-6, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN

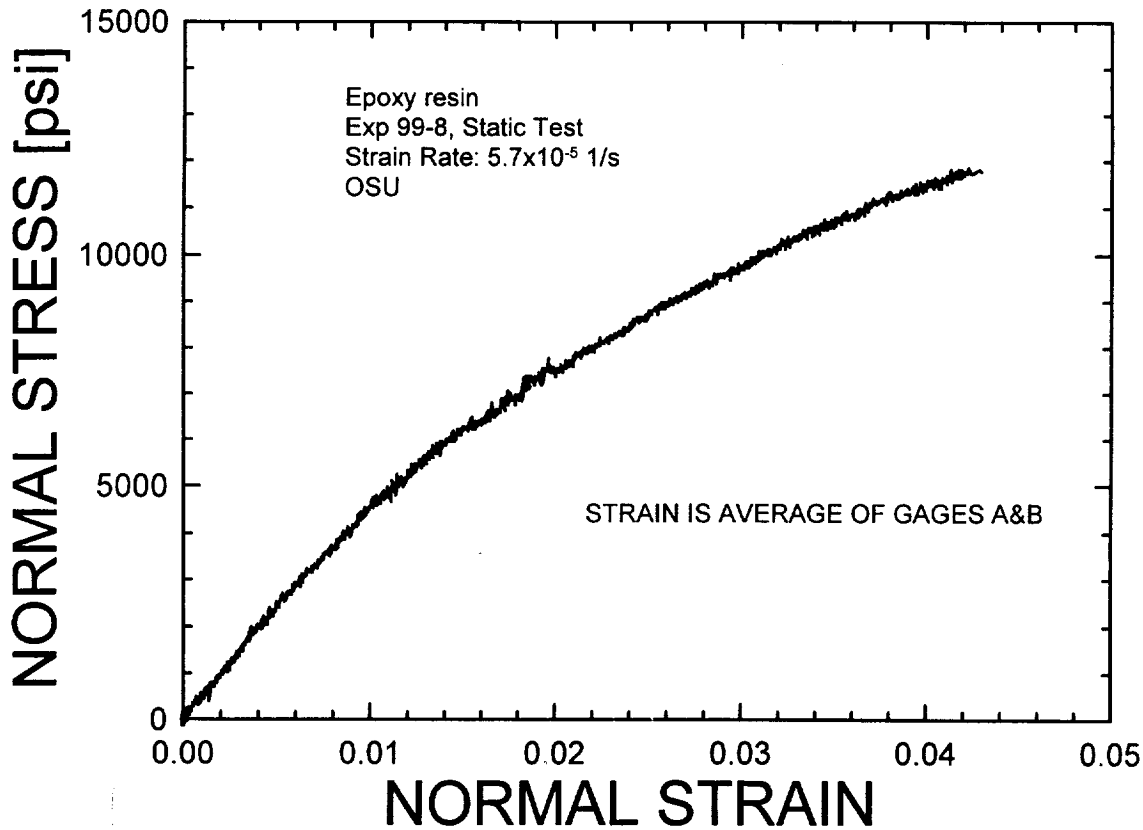


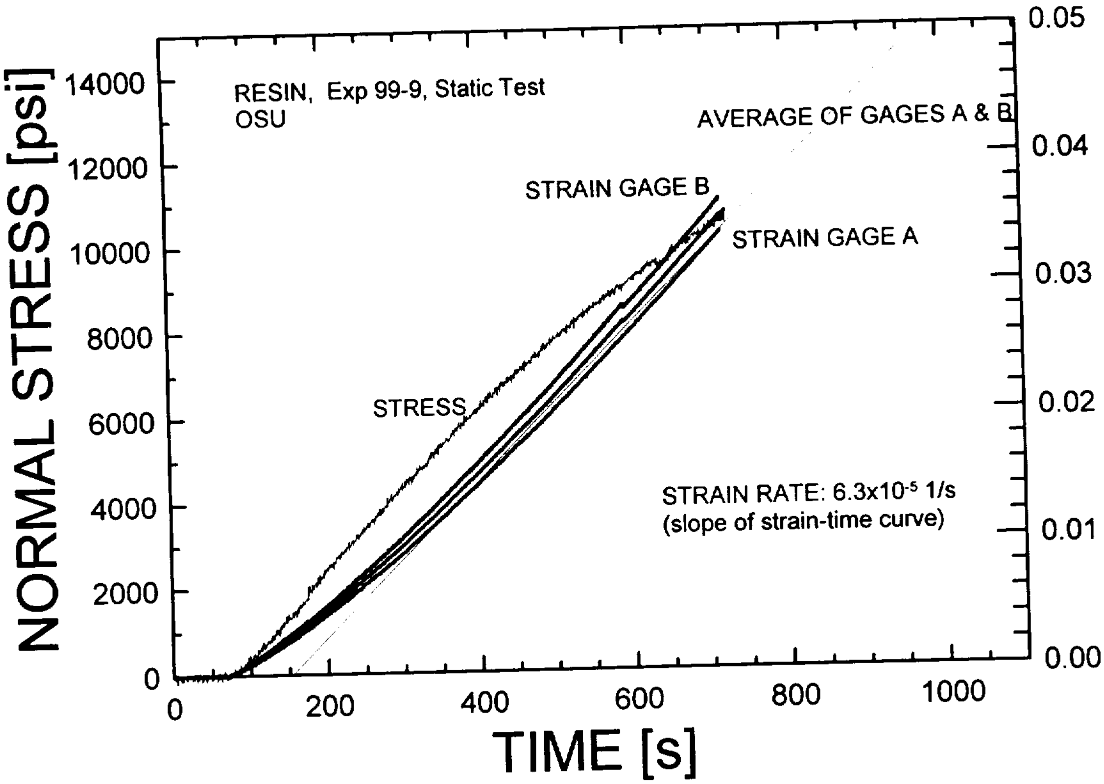
90 deg composite
EXP00-7, Static Test
OSU
STRESS
STRAIN GAGE A
STRAIN GAGE B
STRAIN RATE: 4.44x10^-5 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
0.00
0.01
0.02
0.03
0
100
200
300
400
500

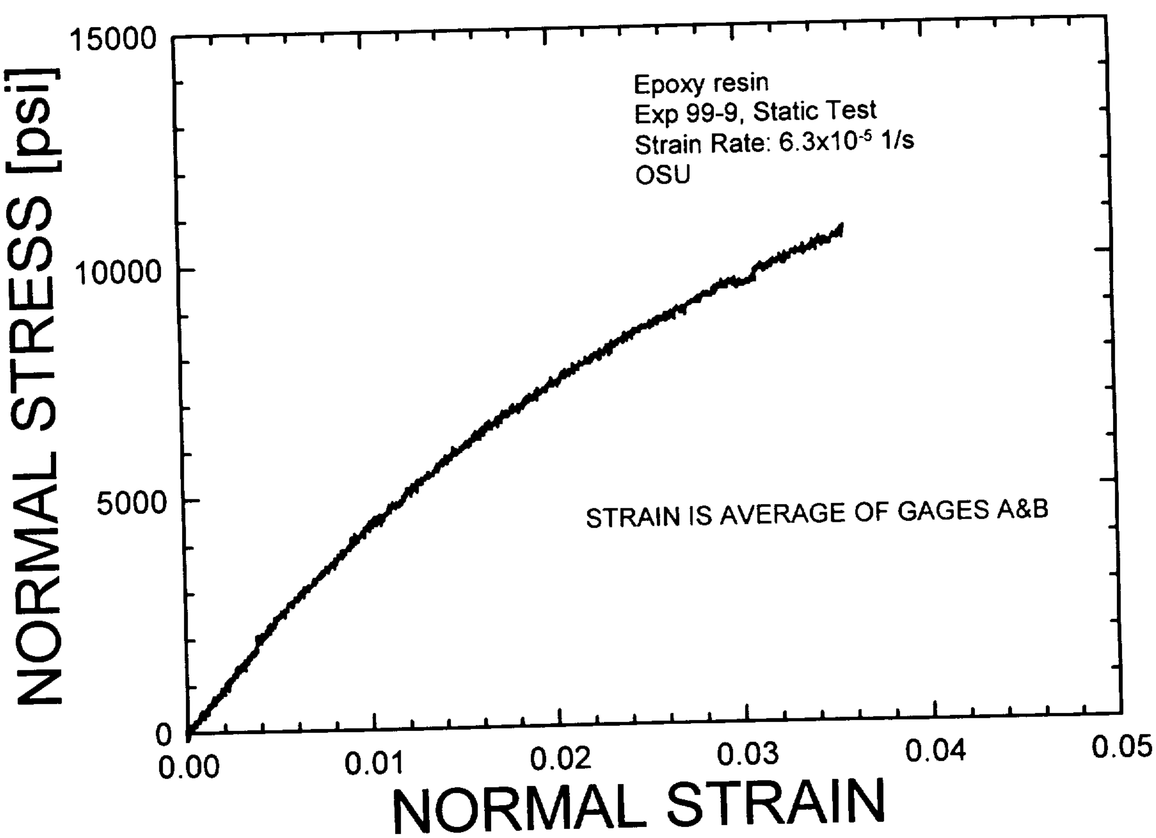


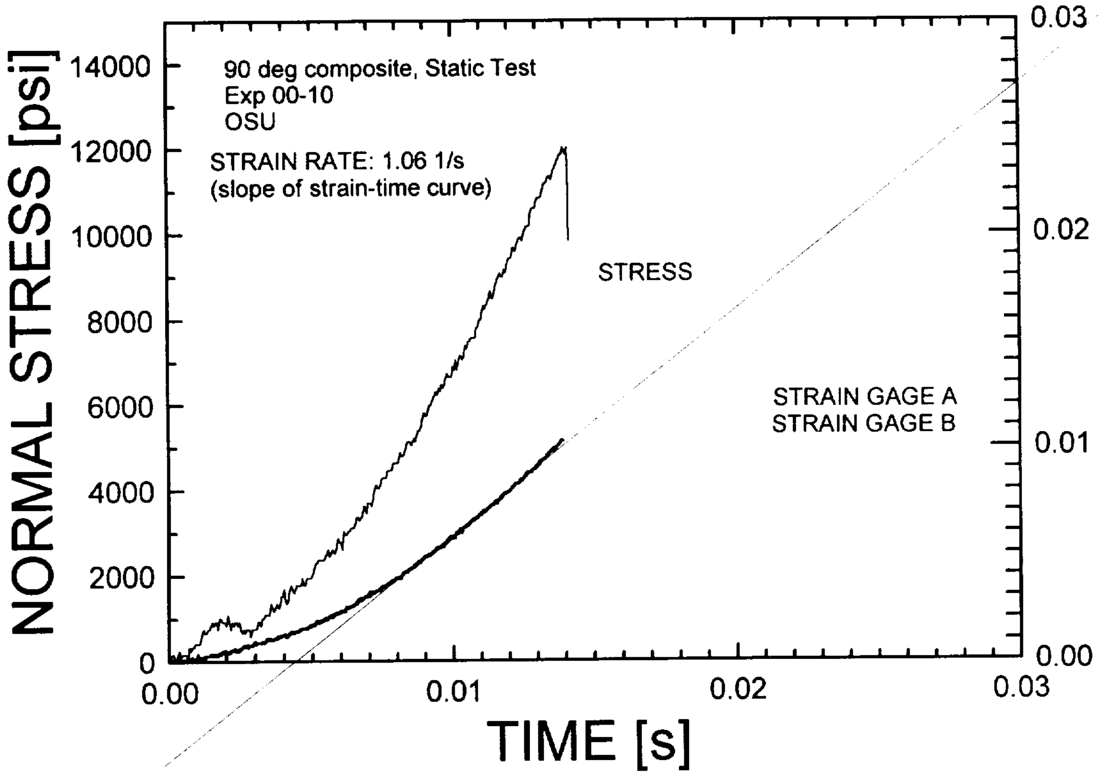
90 deg composite
Exp 00-7, Static Test
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05

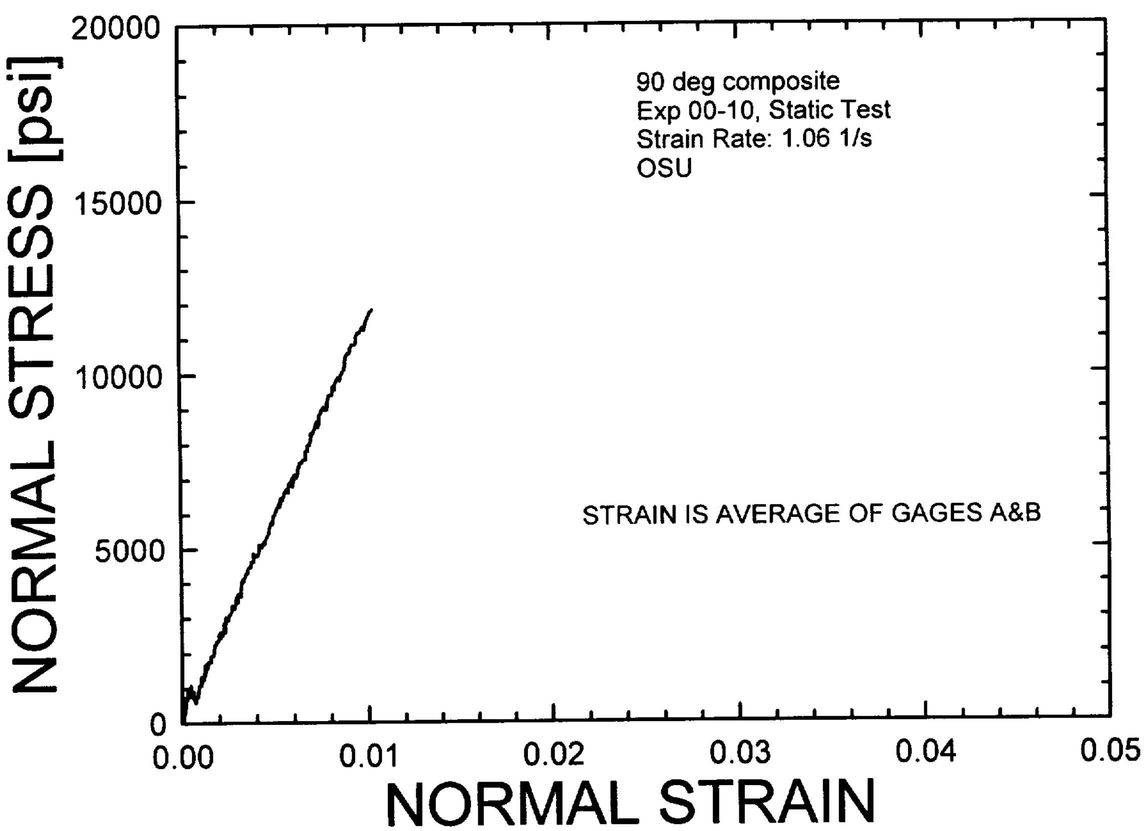

90 deg composite
EXP00-8, Static Test
OSU
STRAIN RATE: 2.14x10-5 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
0.00
0.01
0.02
0.03
0
100
200
300
400
500

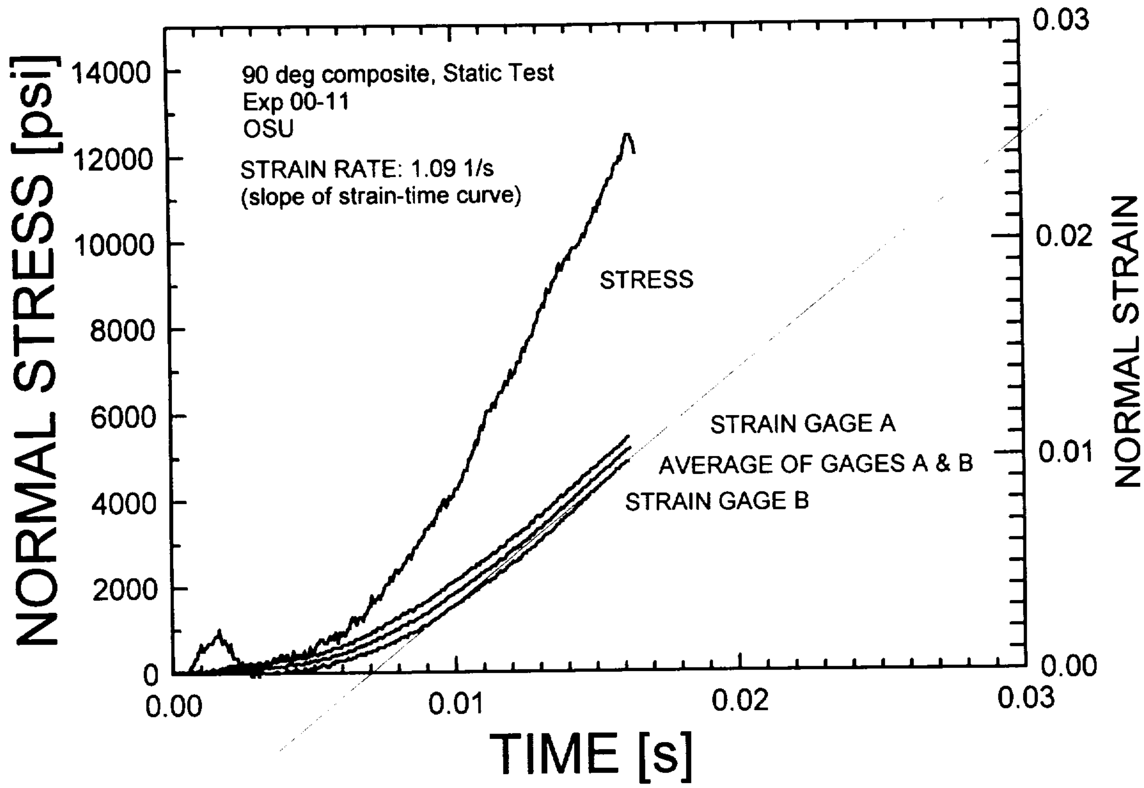

Epoxy resin
Exp 99-8, Static Test
Strain Rate: 5.7x10-5 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
0.00
0.01
0.02
0.03
0.04
0.05

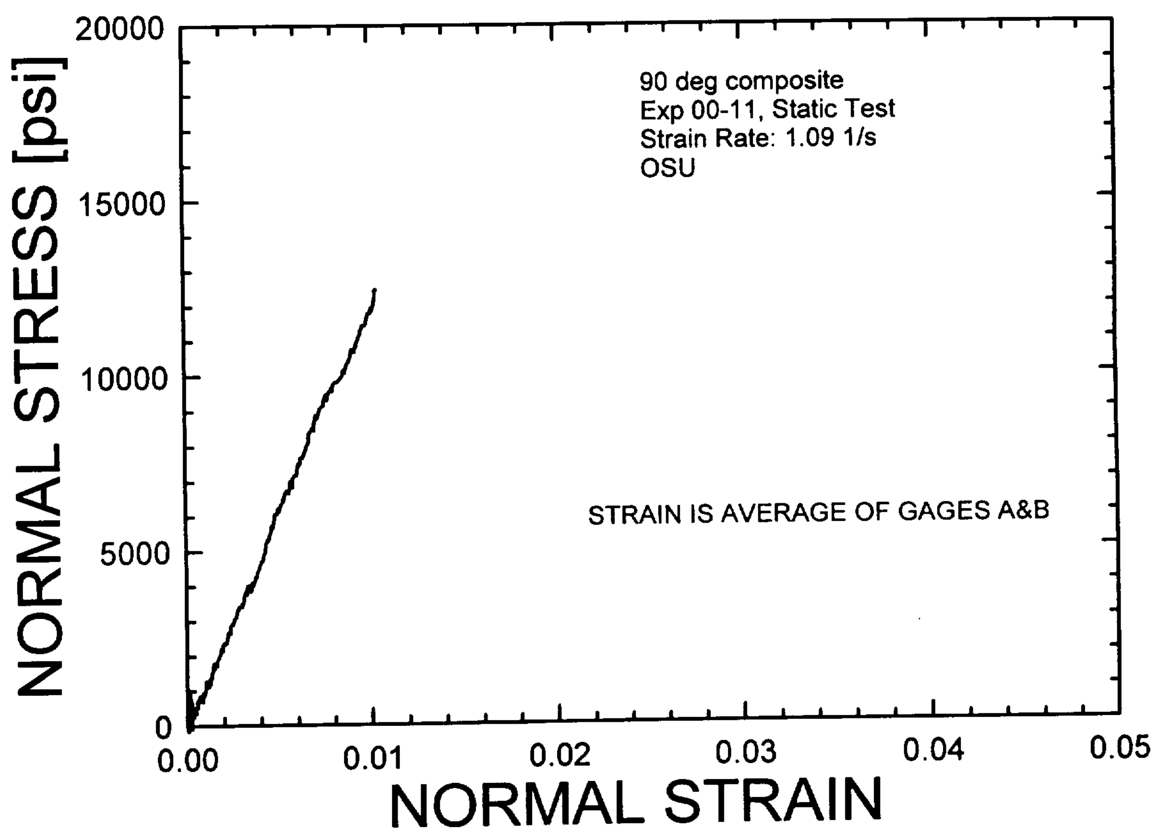

RESIN, Exp 99-9, Static Test
OSU
AVERAGE OF GAGES A & B
STRAIN GAGE B
STRAIN GAGE A
STRESS
STRAIN RATE: 6.3x10-5 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
200
400
600
800
1000
0.00
0.01
0.02
0.03
0.04
0.05

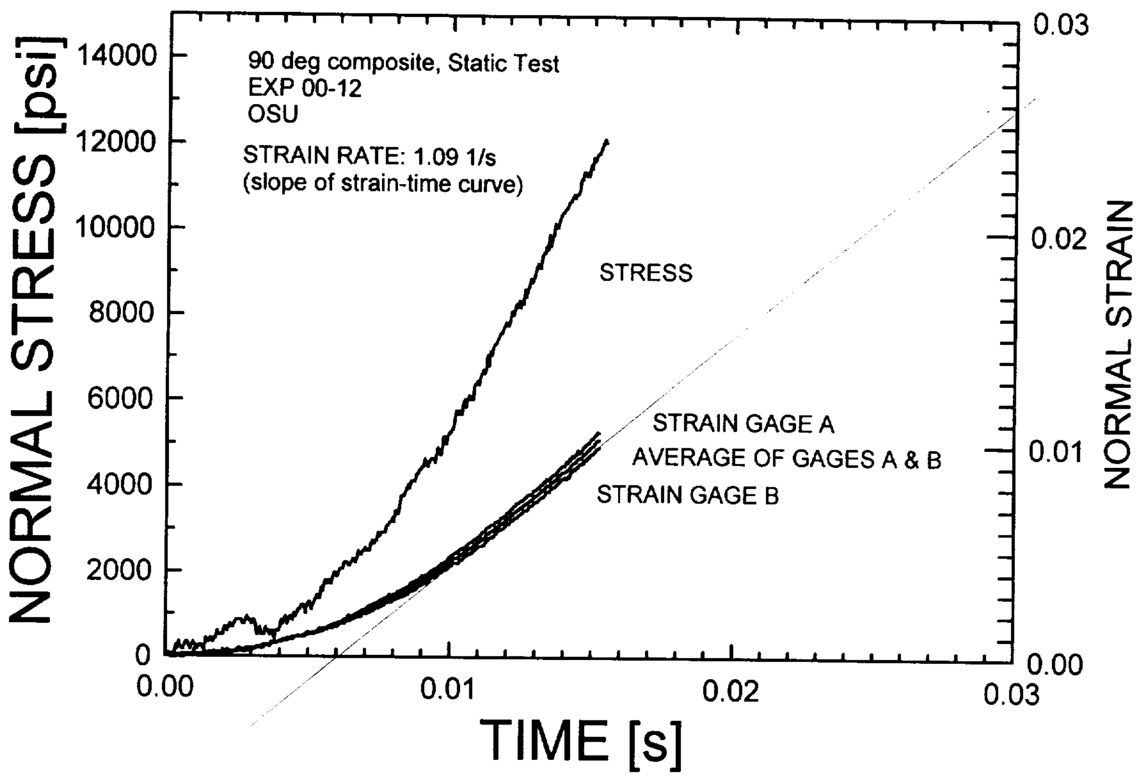

Epoxy resin
Exp 99-9, Static Test
Strain Rate: 6.3x10-5 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
0.00
0.01
0.02
0.03
0.04
0.05

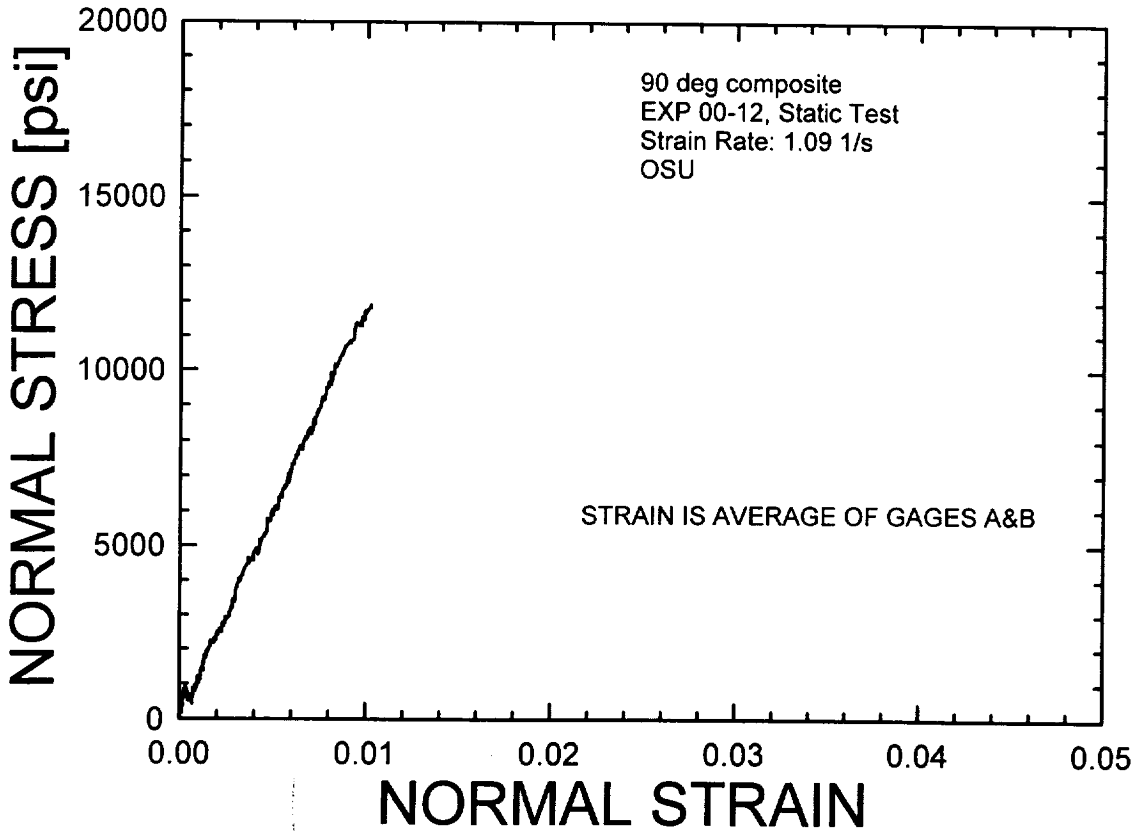

90 deg composite, Static Test
Exp 00-10
OSU
STRAIN RATE: 1.06 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
0.00
0.01
0.02
0.03

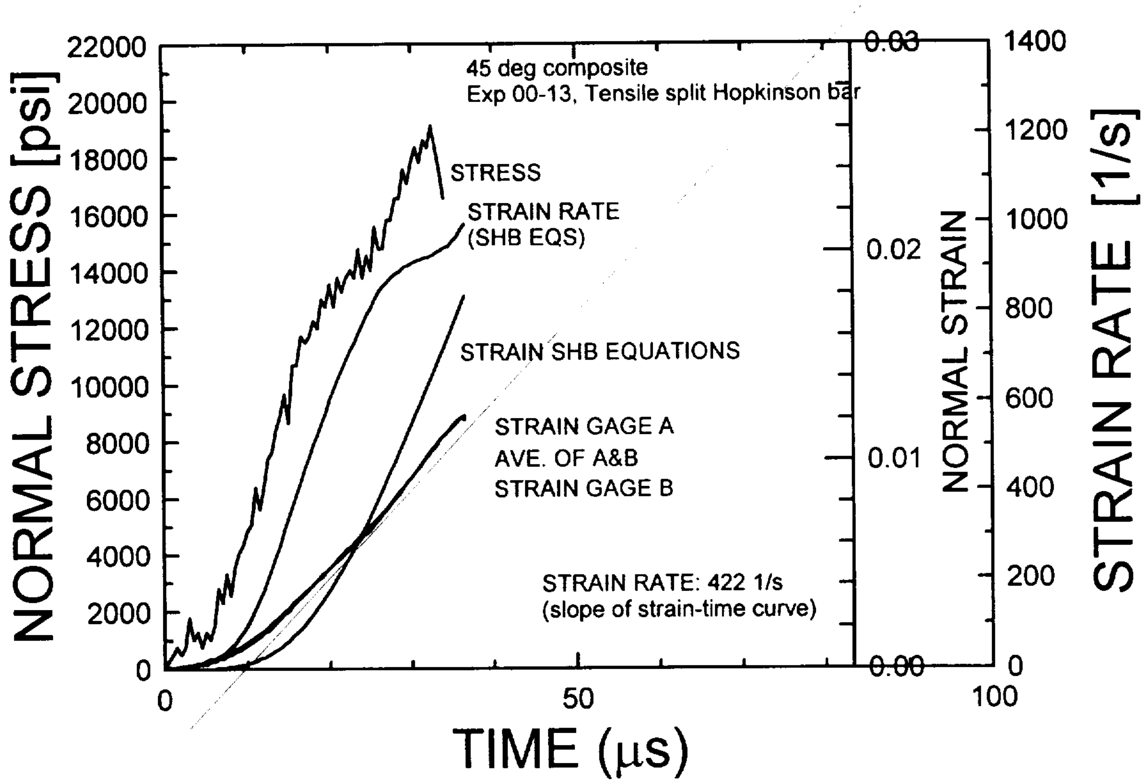

90 deg composite
Exp 00-10, Static Test
Strain Rate: 1.06 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05

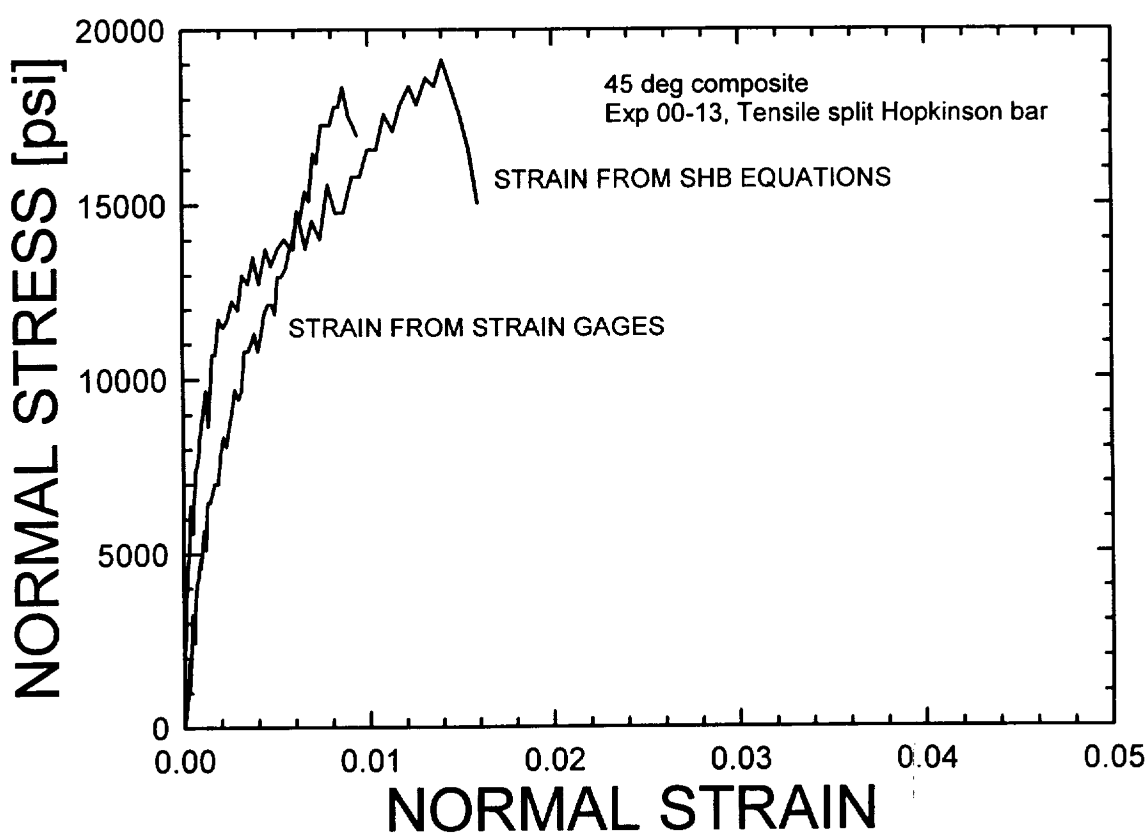

90 deg composite, Static Test
Exp 00-11
OSU
STRAIN RATE: 1.09 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
2000
4000
6000
8000
10000
12000
14000
0.00
0.01
0.02
0.03

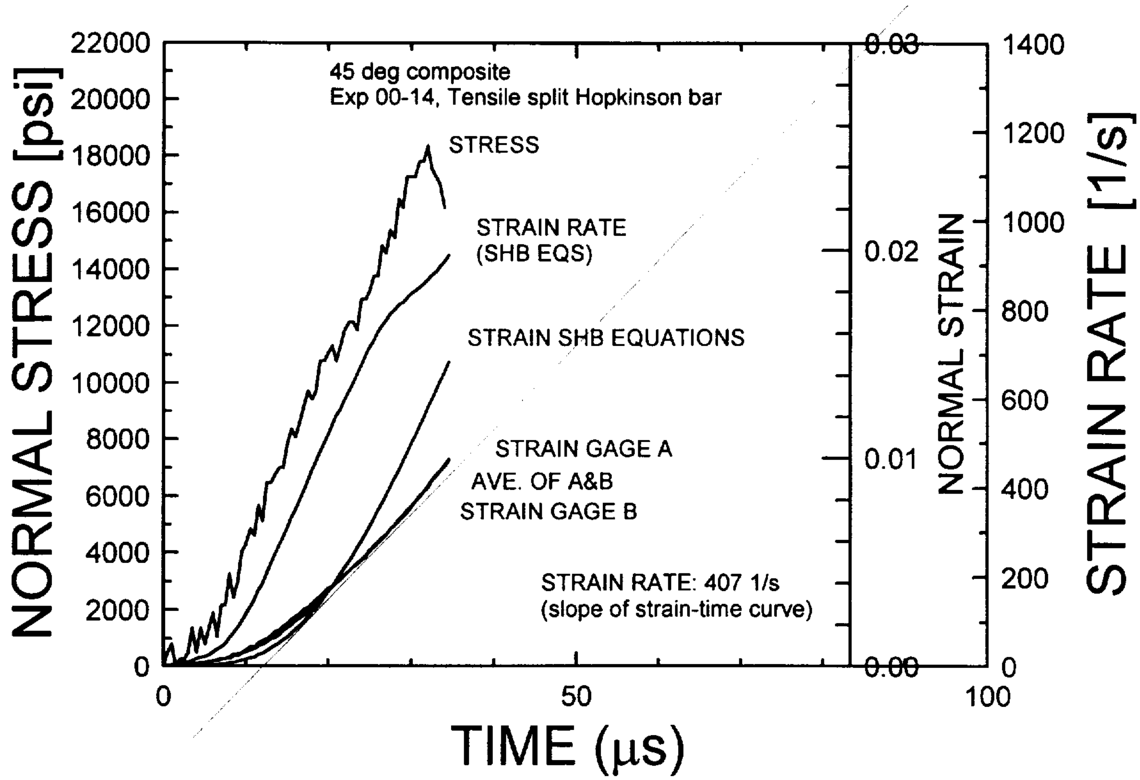

90 deg composite
Exp 00-11, Static Test
Strain Rate: 1.09 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05


90 deg composite, Static Test
EXP 00-12
OSU
STRAIN RATE: 1.09 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]

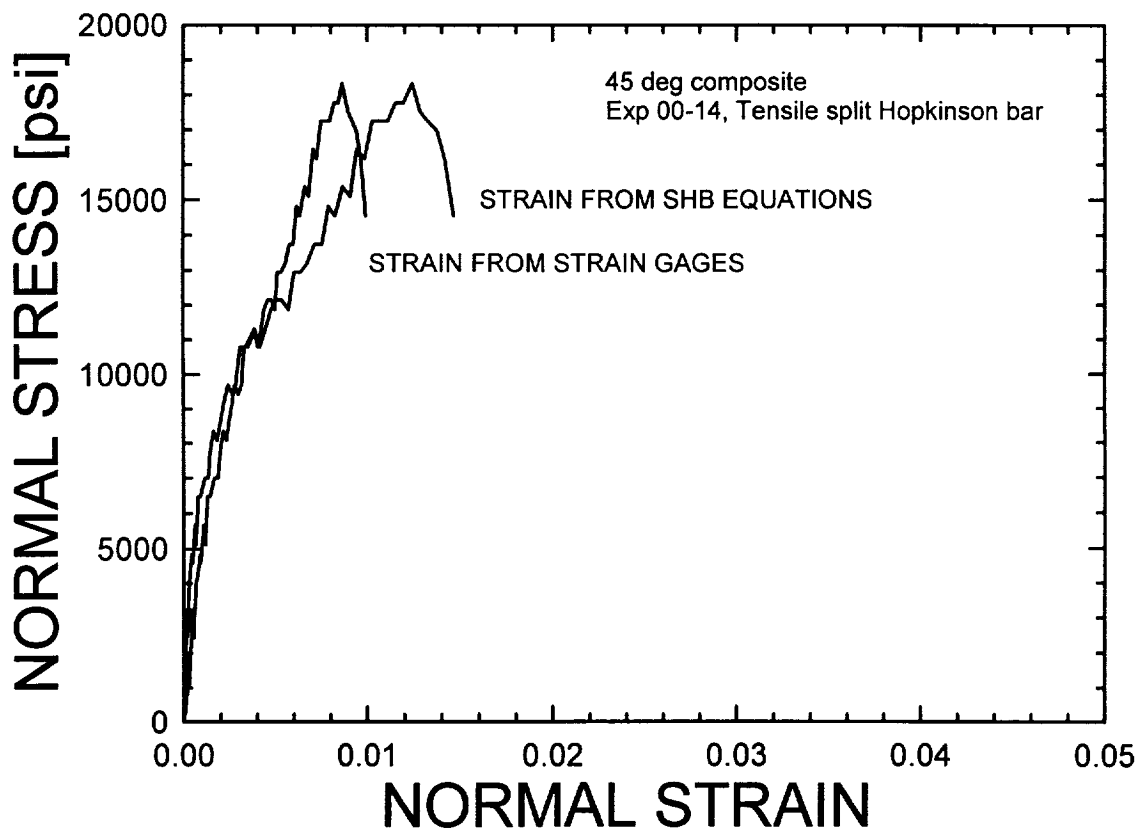

90 deg composite
EXP 00-12, Static Test
Strain Rate: 1.09 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN


45 deg composite
Exp 00-13, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 422 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
0.00
0.01
0.02
0.03
200
400
600
800
1000
1200
1400
50
100

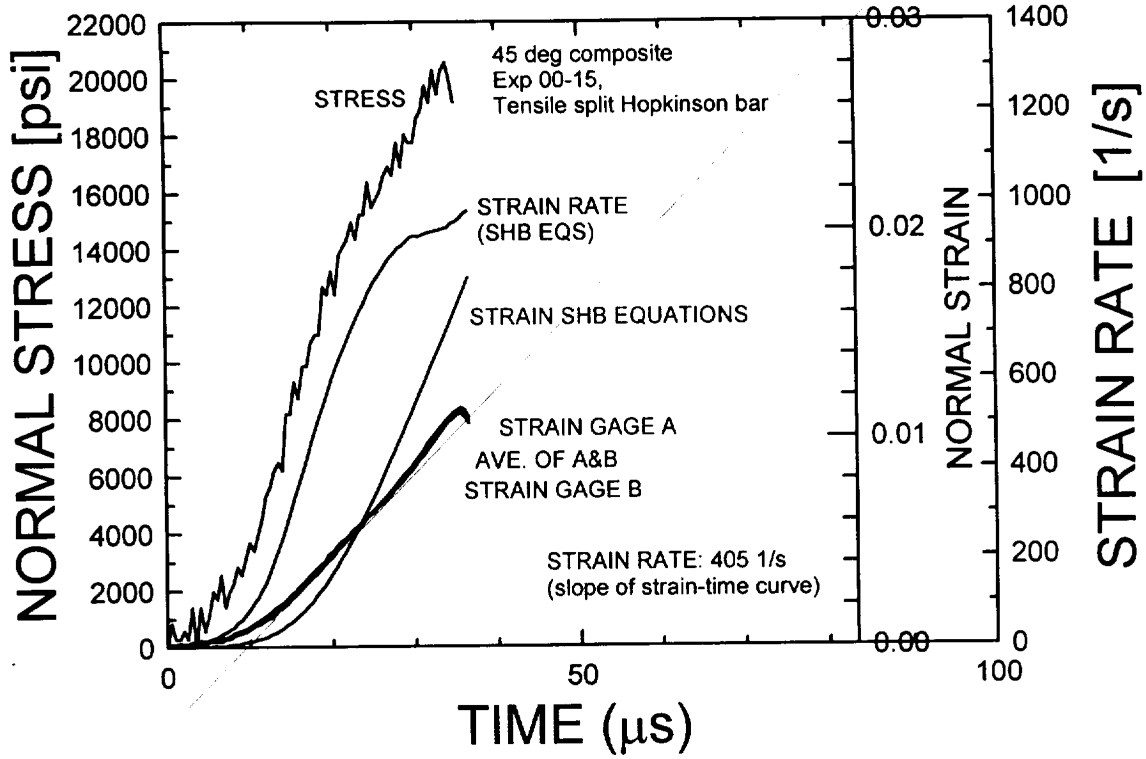

45 deg composite
Exp 00-13, Tensile split Hopkinson bar
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES
NORMAL STRESS [psi]
NORMAL STRAIN
0
5000
10000
15000
20000
0.00
0.01
0.02
0.03
0.04
0.05

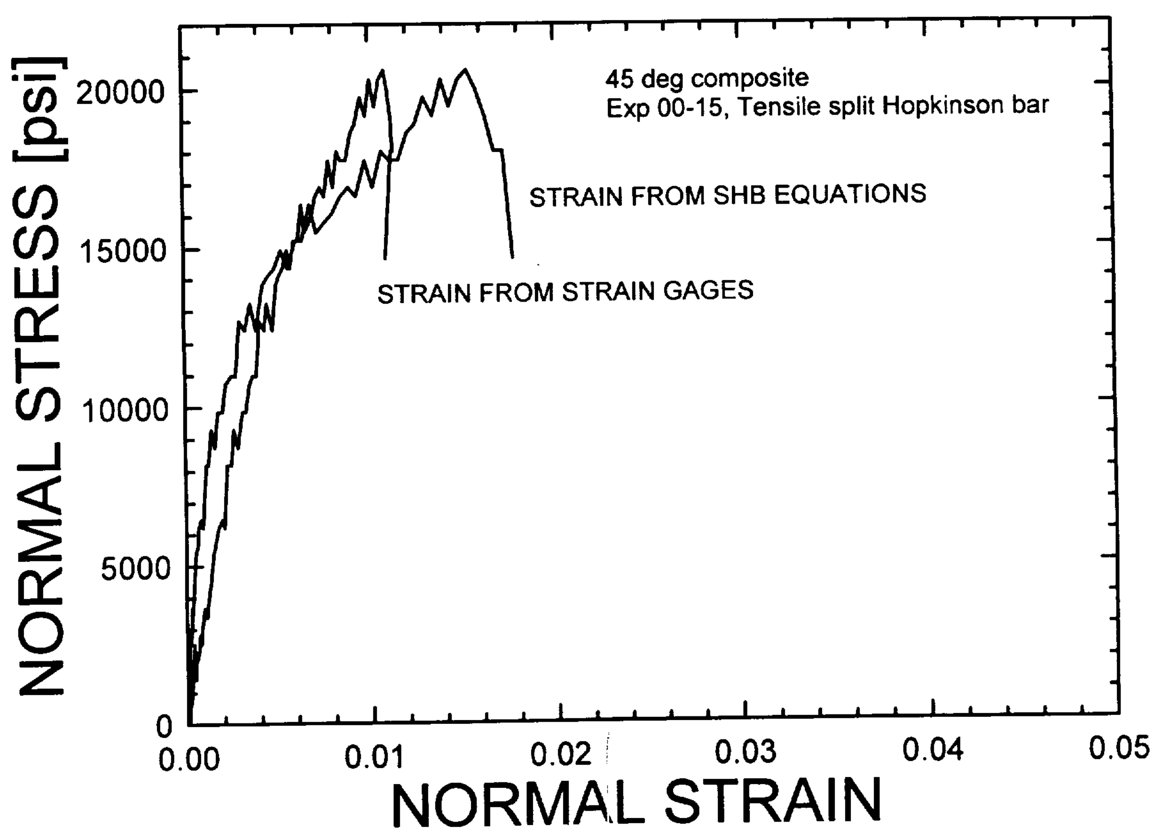


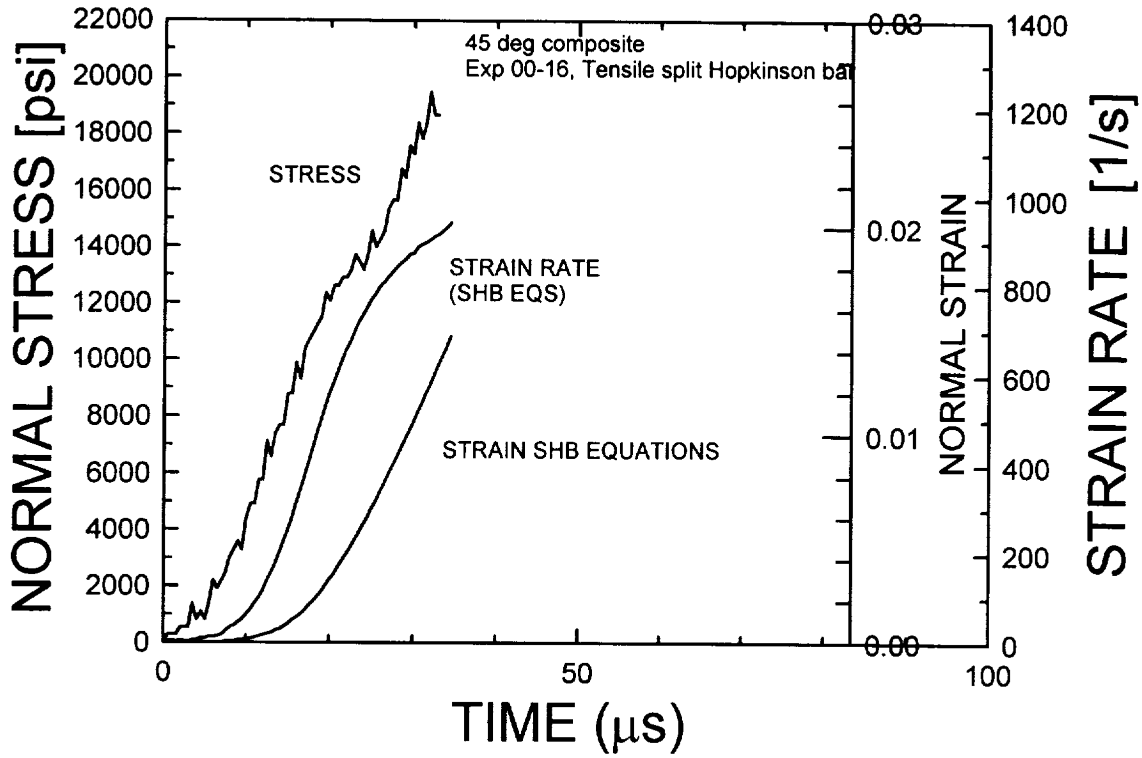
45 deg composite
Exp 00-14, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 407 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)



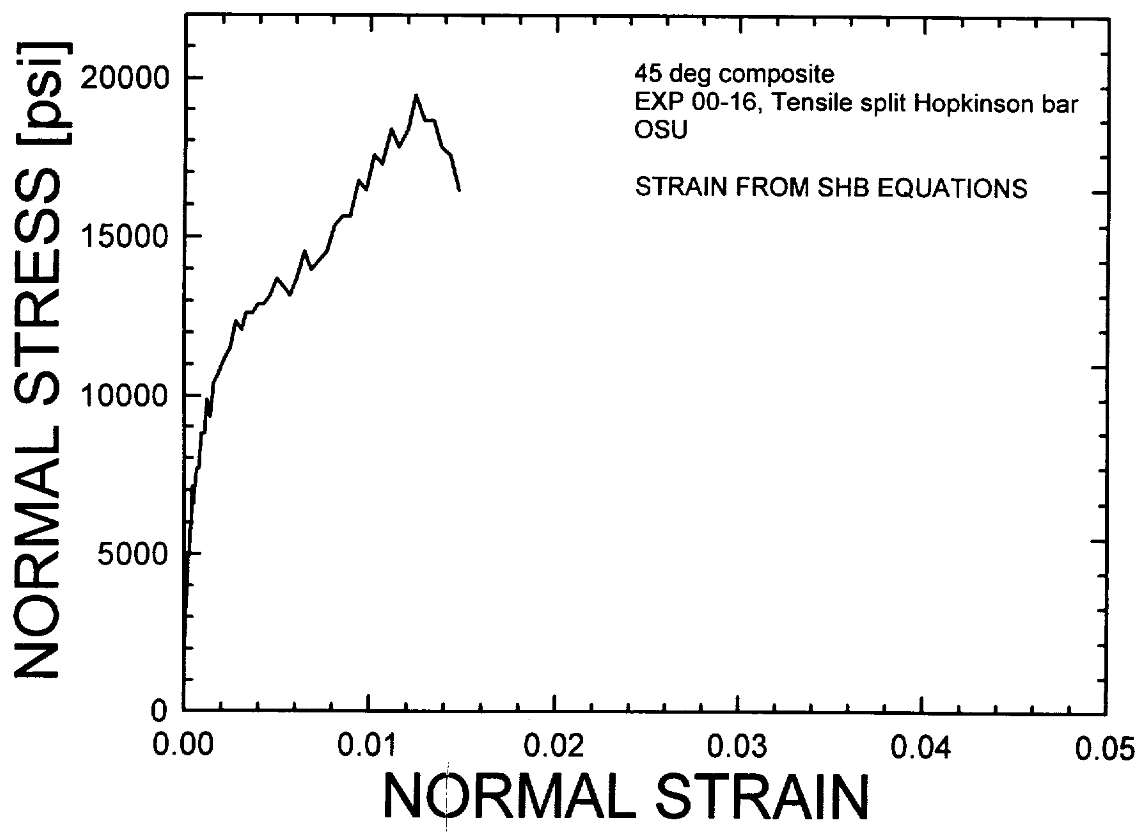
45 deg composite
Exp 00-14, Tensile split Hopkinson bar
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES
NORMAL STRESS [psi]
NORMAL STRAIN


NORMAL STRESS [psi]
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
50
100
TIME (μs)
0.03
0.02
0.01
0.00
NORMAL STRAIN
1400
1200
1000
800
600
400
200
0
STRAIN RATE [1/s]
STRESS
45 deg composite
Exp 00-15,
Tensile split Hopkinson bar
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 405 1/s
(slope of strain-time curve)

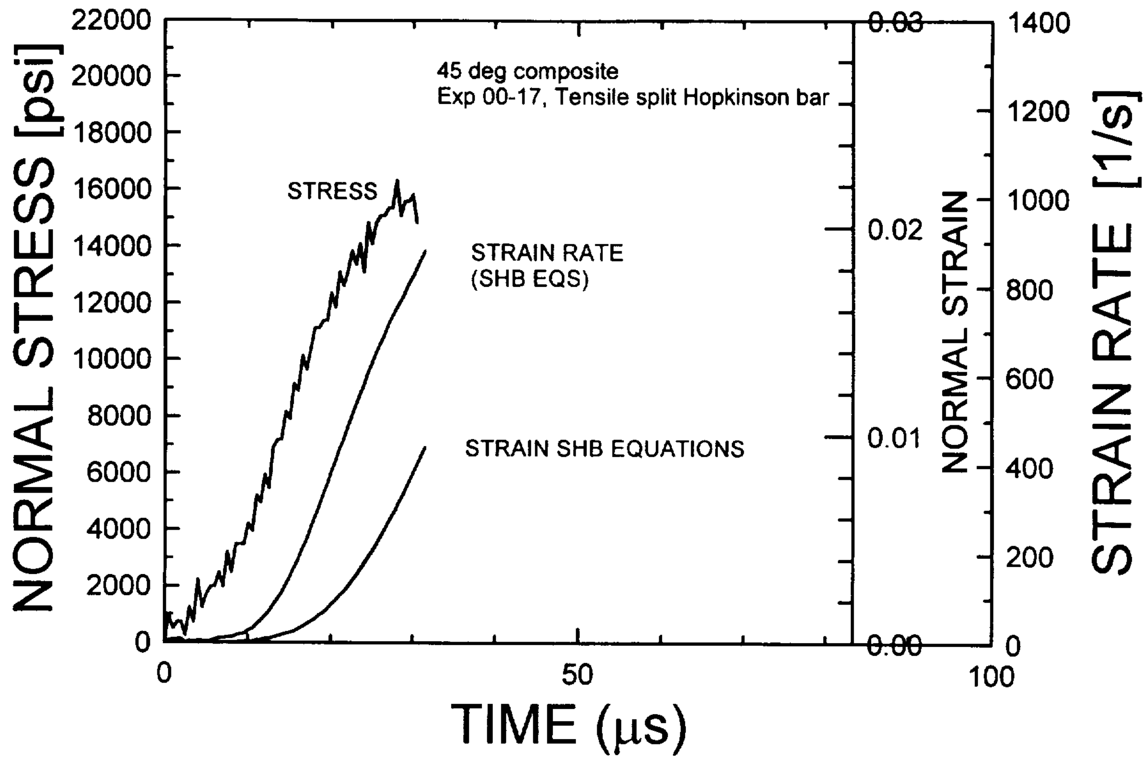

NORMAL STRESS [psi]
20000
15000
10000
5000
0
0.00
0.01
0.02
0.03
0.04
0.05
NORMAL STRAIN
45 deg composite
Exp 00-15, Tensile split Hopkinson bar
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES



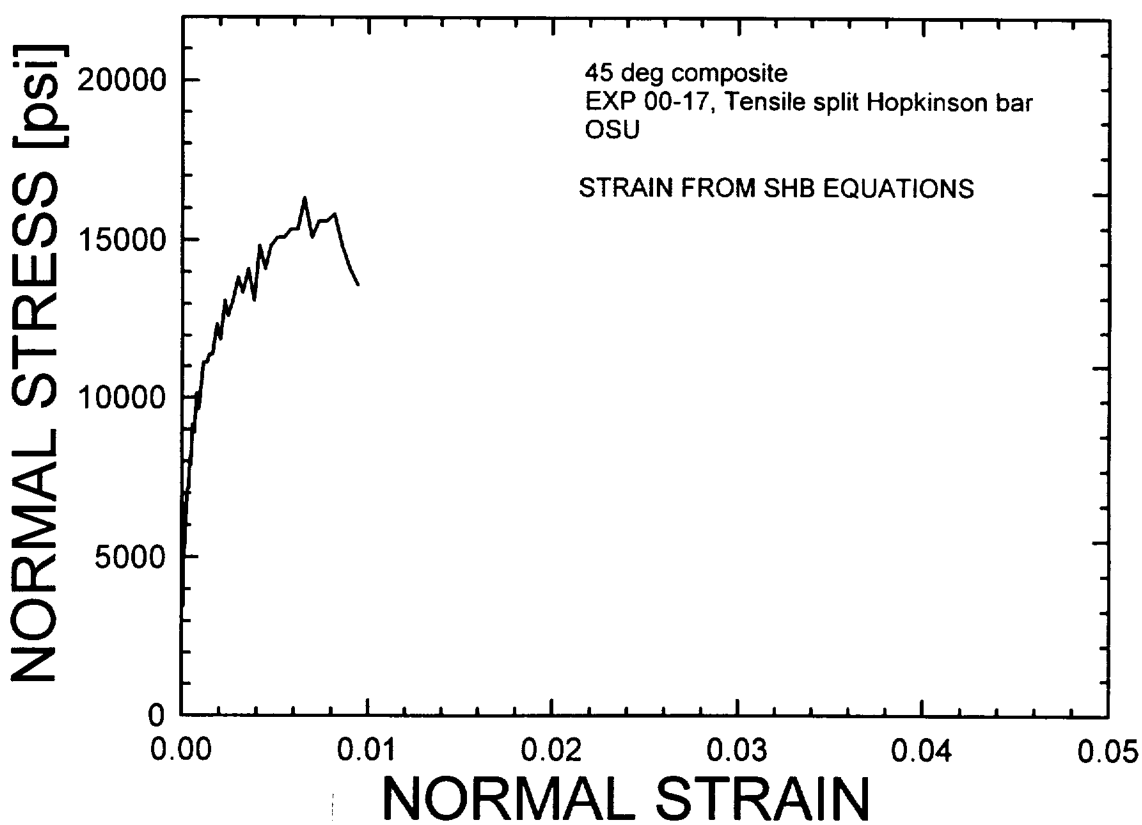
45 deg composite
Exp 00-16, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)
0
50
100
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.03
0.02
0.01
0.00
1400
1200
1000
800
600
400
200



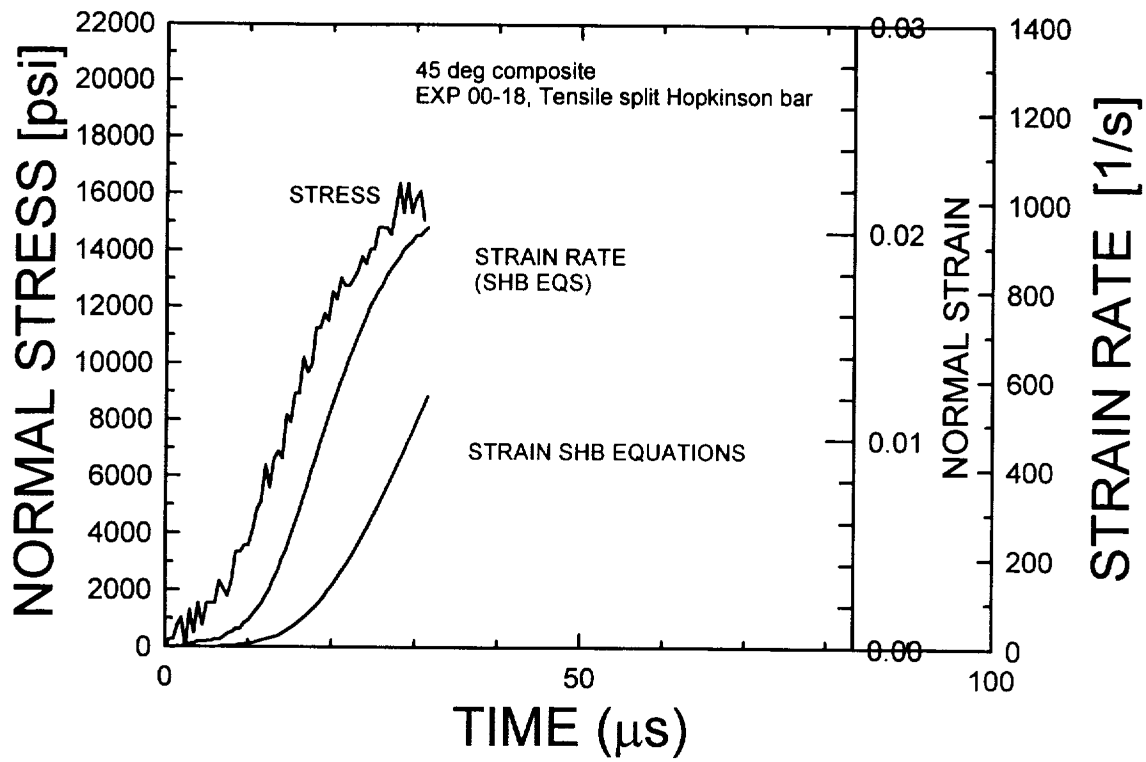
45 deg composite
EXP 00-16, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
20000
15000
10000
5000
0
0.00
0.01
0.02
0.03
0.04
0.05



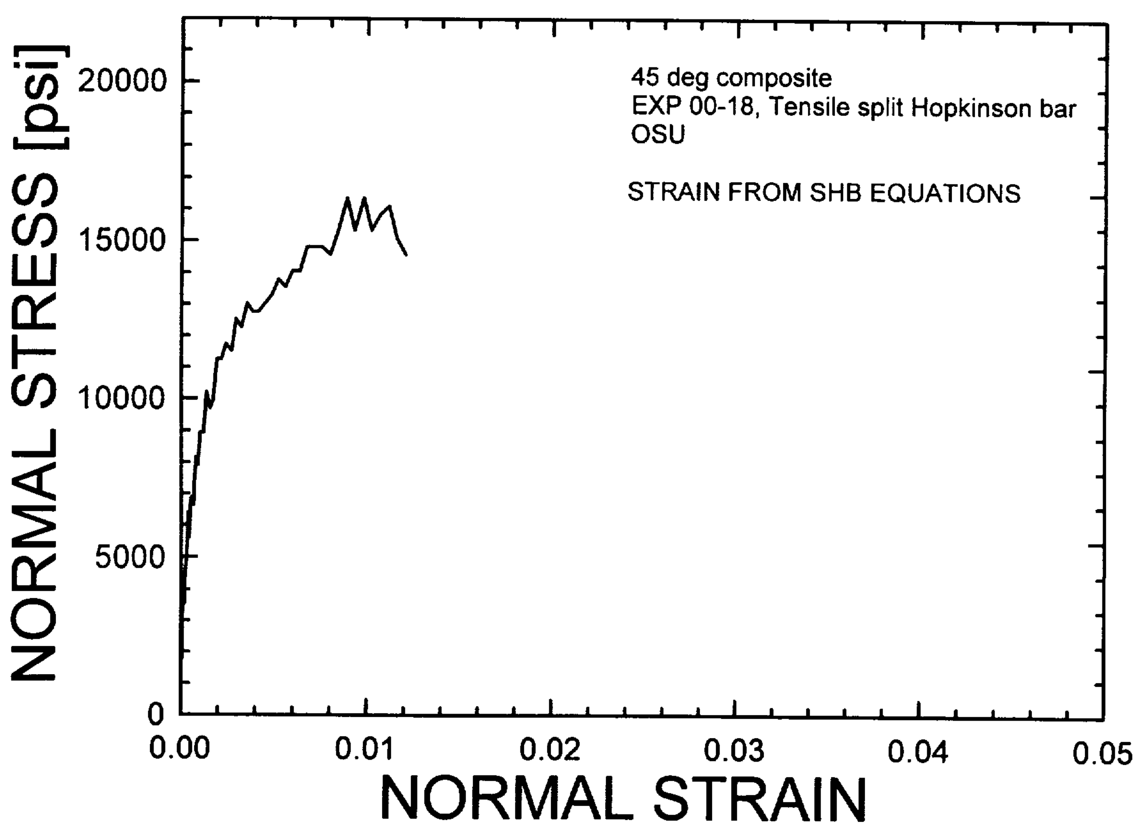
45 deg composite
Exp 00-17, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)



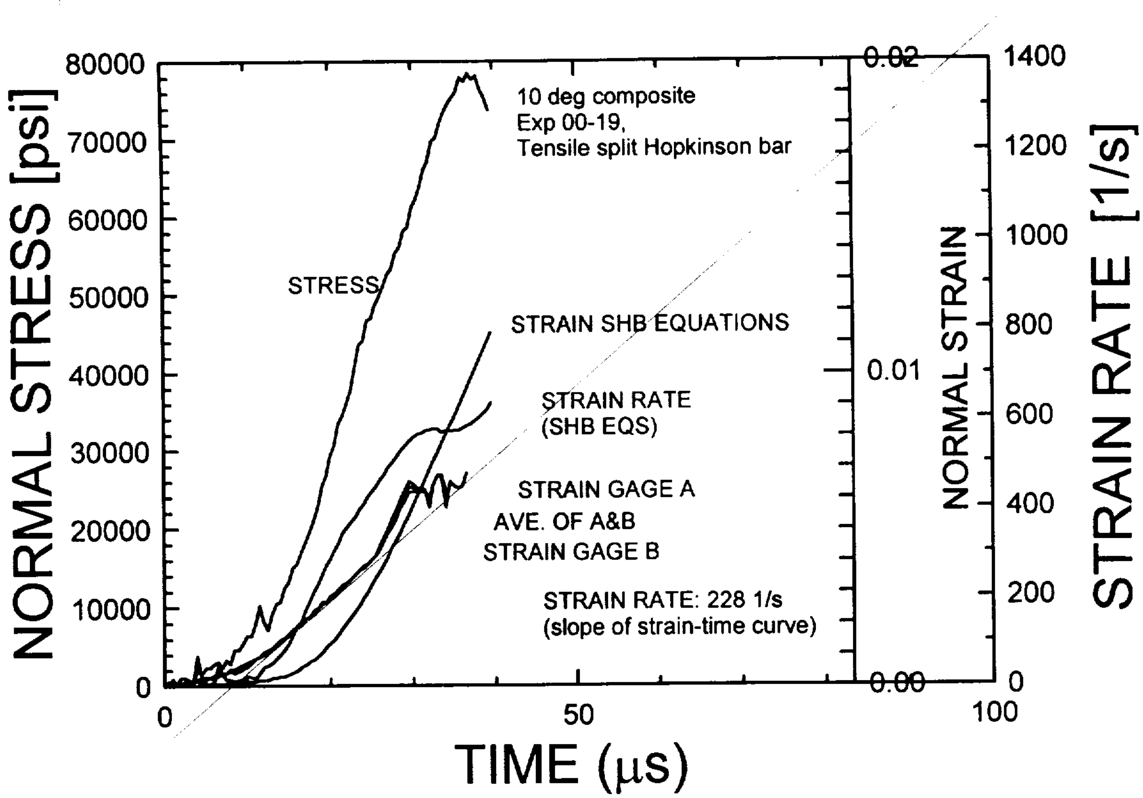
45 deg composite
EXP 00-17, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS
NORMAL STRESS [psi]
NORMAL STRAIN

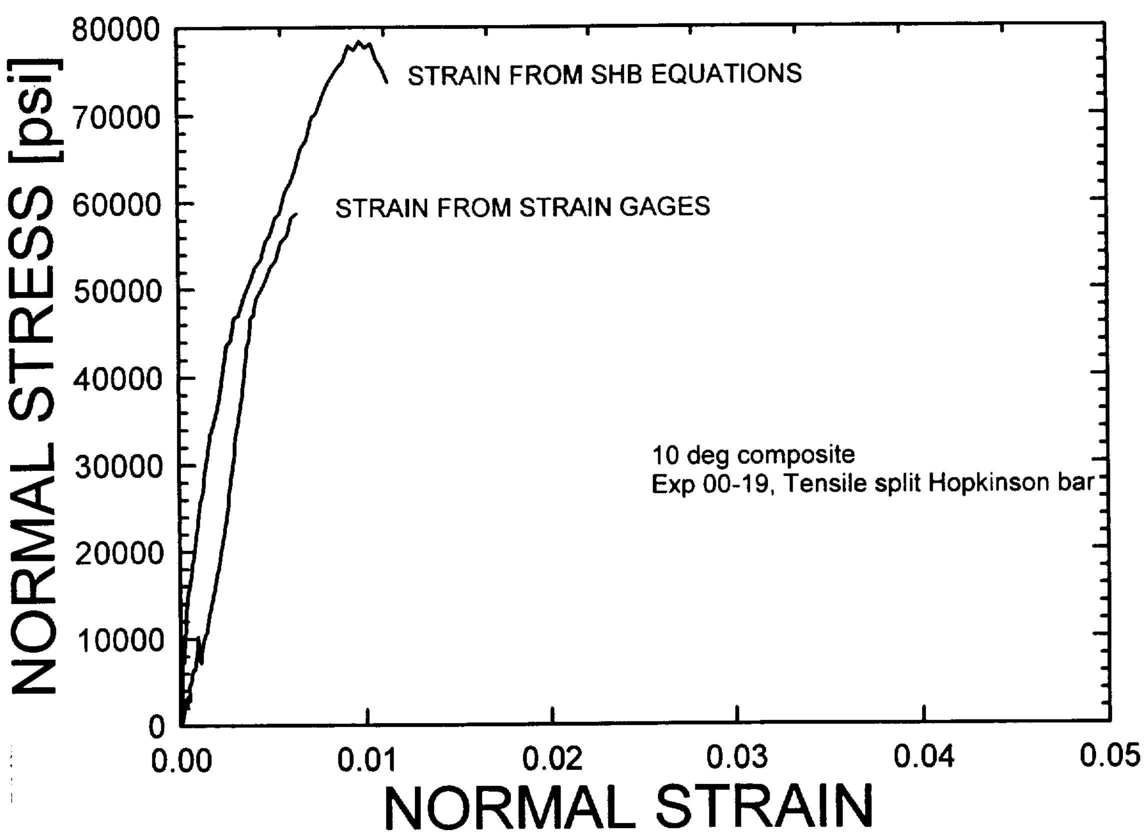


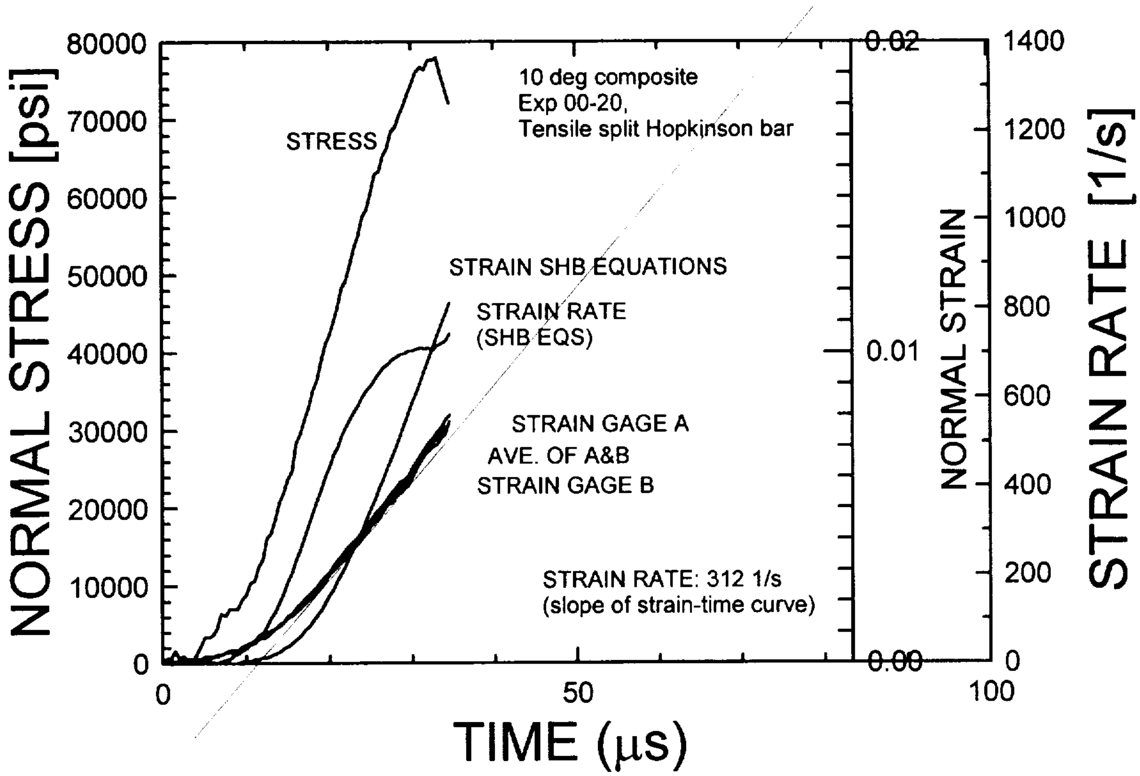
NORMAL STRESS [psi]
TIME (µs)
NORMAL STRAIN
STRAIN RATE [1/s]
45 deg composite
EXP 00-18, Tensile split Hopkinson bar
STRESS
STRAIN RATE
(SHB EQS)
STRAIN SHB EQUATIONS



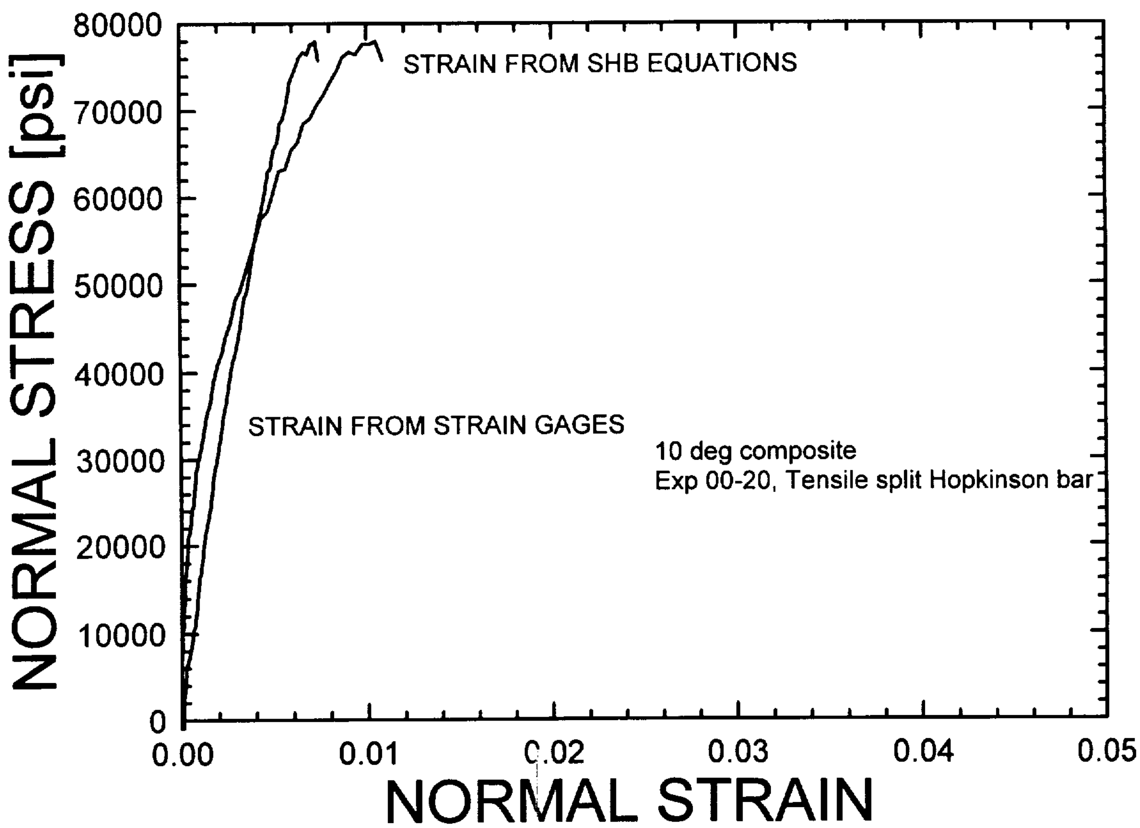
NORMAL STRESS [psi]
NORMAL STRAIN
45 deg composite
EXP 00-18, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS


80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
0
50
100
TIME (μs)
0.02
0.01
0.00
NORMAL STRAIN
1400
1200
1000
800
600
400
200
0
STRAIN RATE [1/s]
10 deg composite
Exp 00-19,
Tensile split Hopkinson bar
STRESS
STRAIN SHB EQUATIONS
STRAIN RATE
(SHB EQS)
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 228 1/s
(slope of strain-time curve)

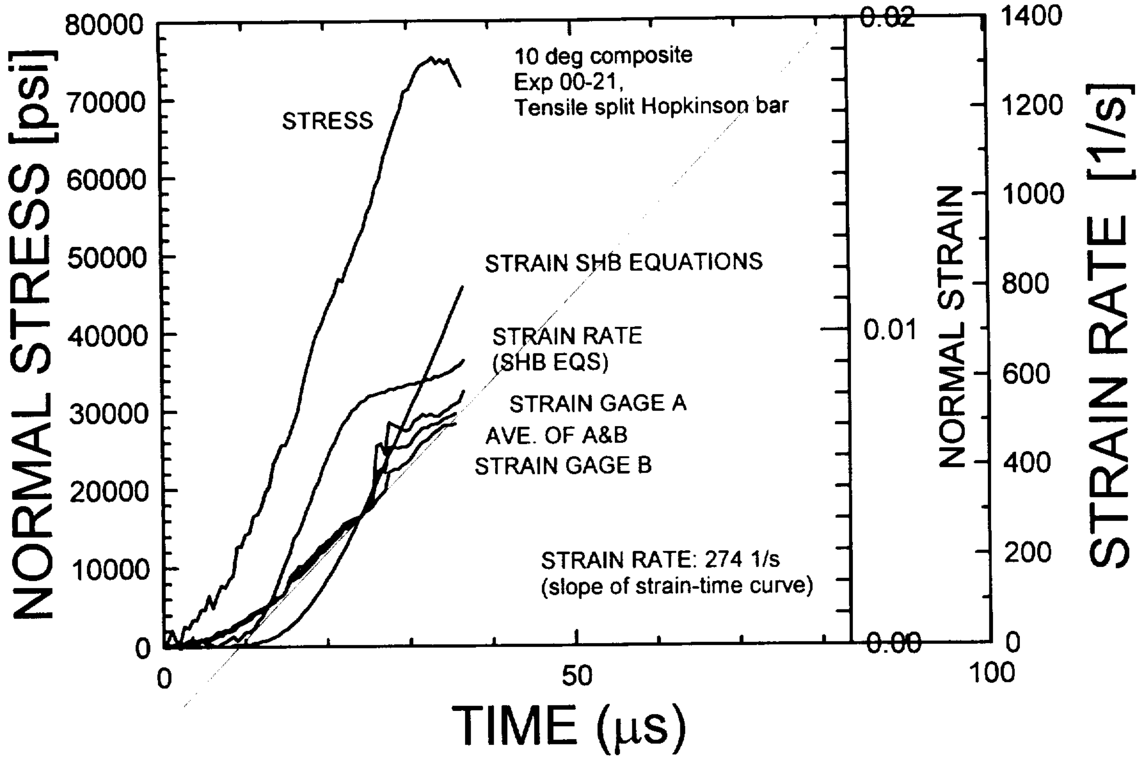

80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
0.00
0.01
0.02
0.03
0.04
0.05
NORMAL STRAIN
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES
10 deg composite
Exp 00-19, Tensile split Hopkinson bar



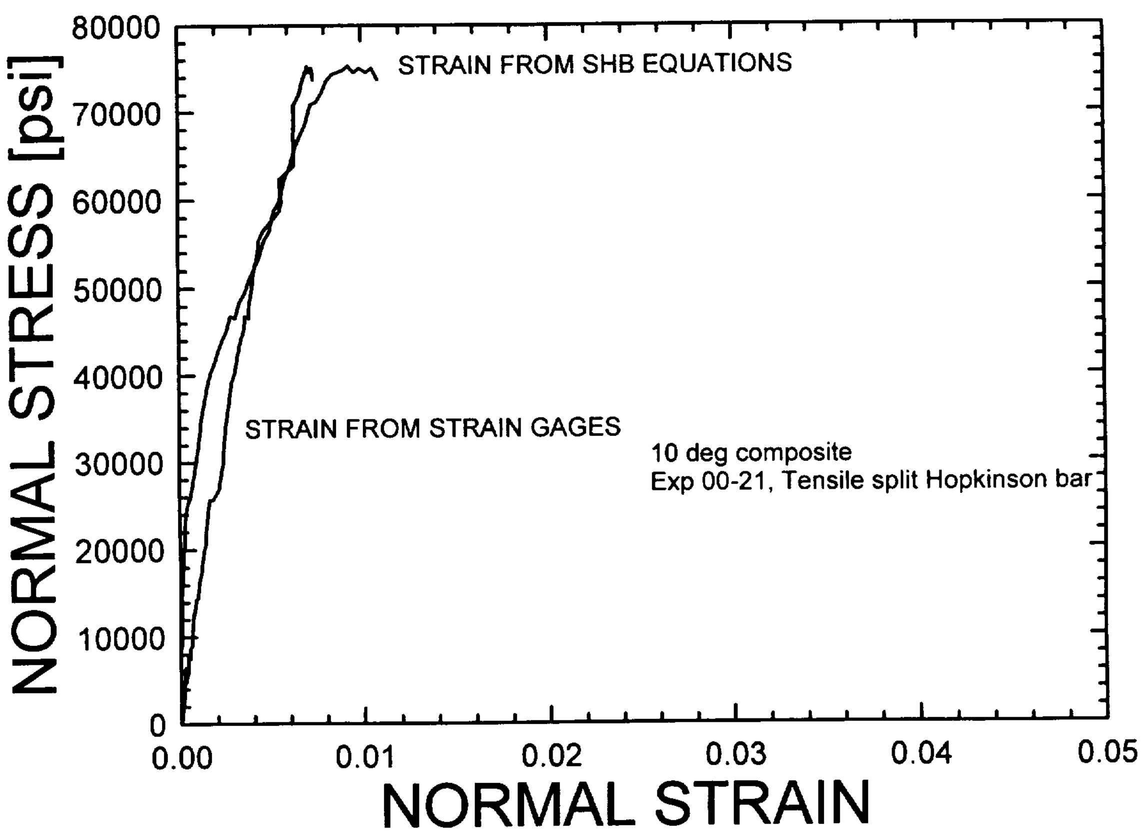
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)
10 deg composite
Exp 00-20,
Tensile split Hopkinson bar
STRESS
STRAIN SHB EQUATIONS
STRAIN RATE
(SHB EQS)
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 312 1/s
(slope of strain-time curve)



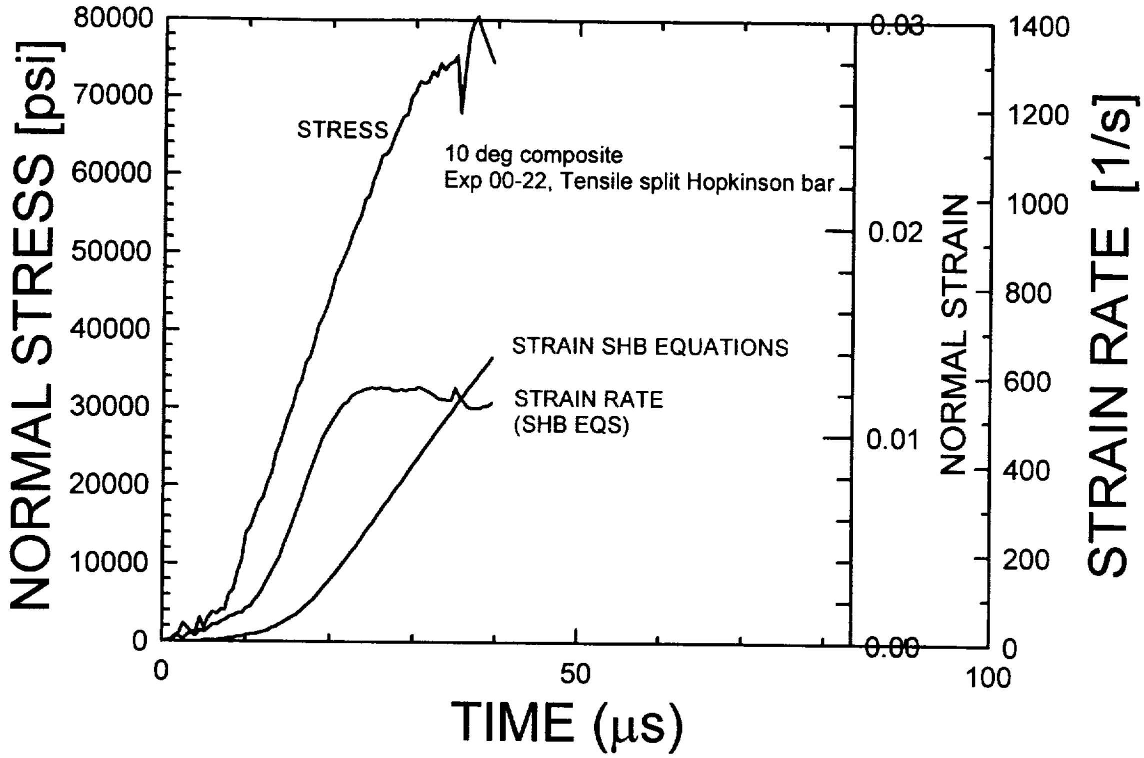
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES
10 deg composite
Exp 00-20, Tensile split Hopkinson bar

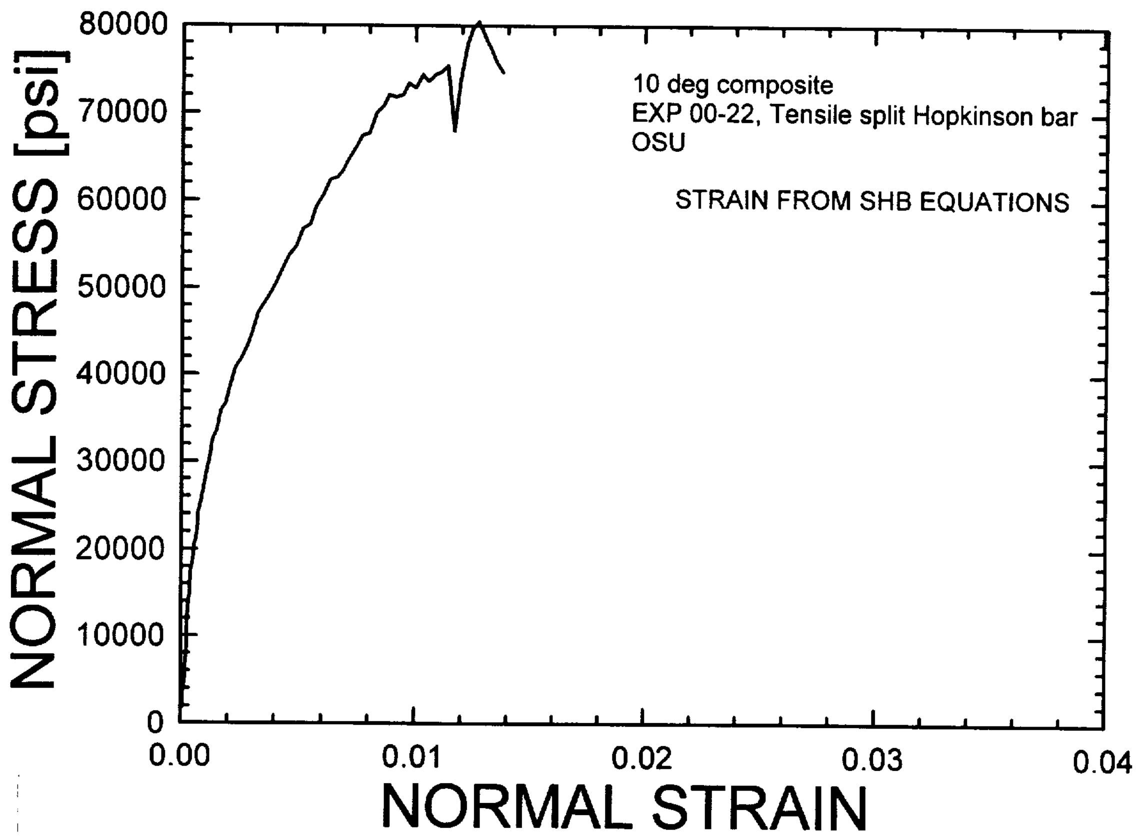


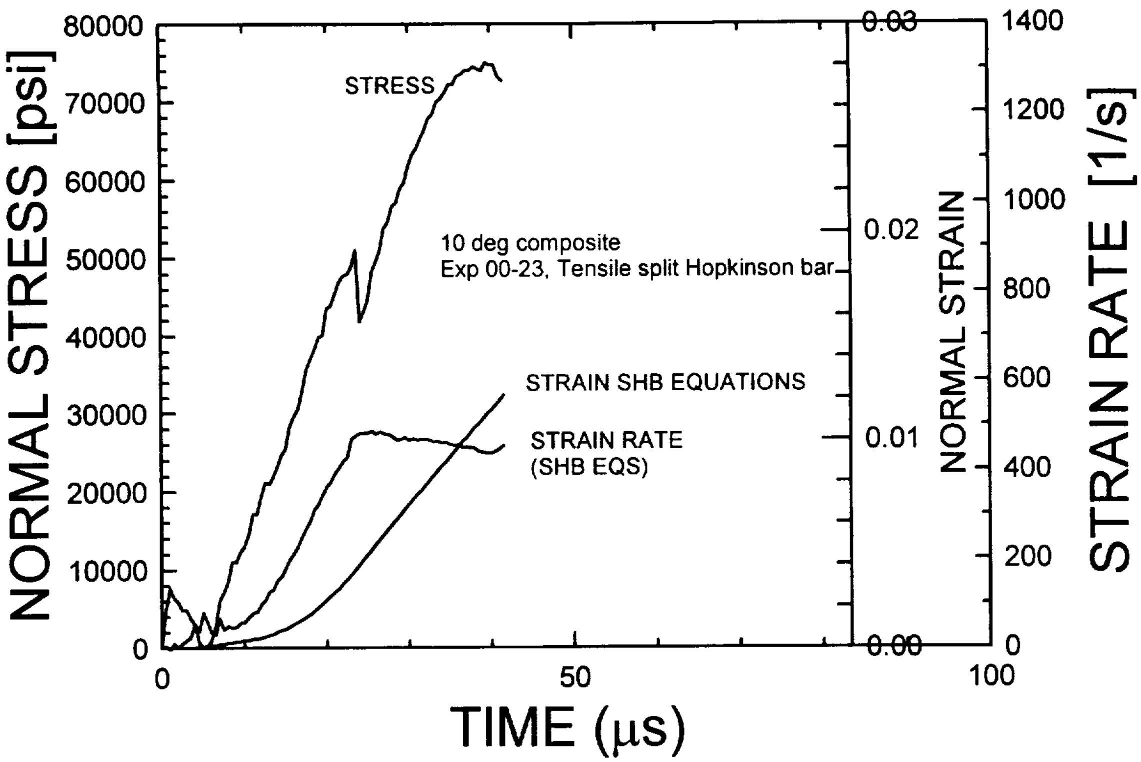
NORMAL STRESS [psi]
TIME (μs)
NORMAL STRAIN
STRAIN RATE [1/s]
10 deg composite
Exp 00-21,
Tensile split Hopkinson bar
STRESS
STRAIN SHB EQUATIONS
STRAIN RATE
(SHB EQS)
STRAIN GAGE A
AVE. OF A&B
STRAIN GAGE B
STRAIN RATE: 274 1/s
(slope of strain-time curve)

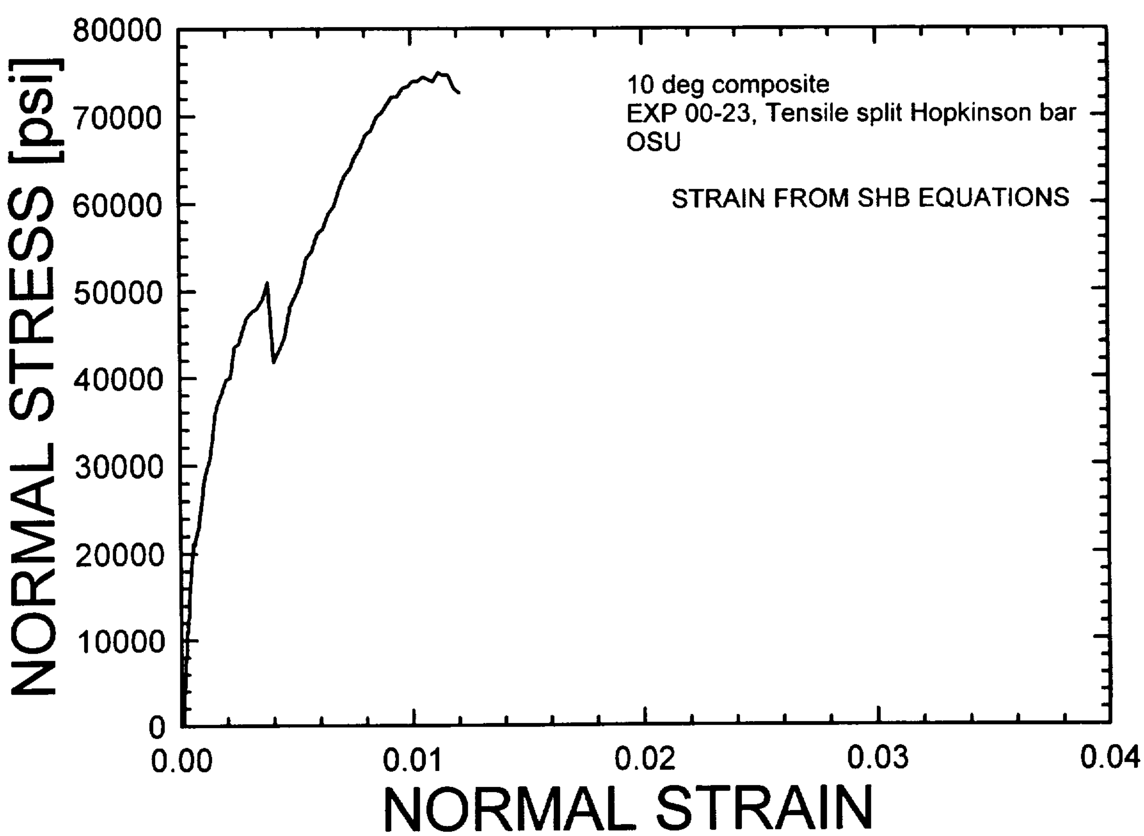


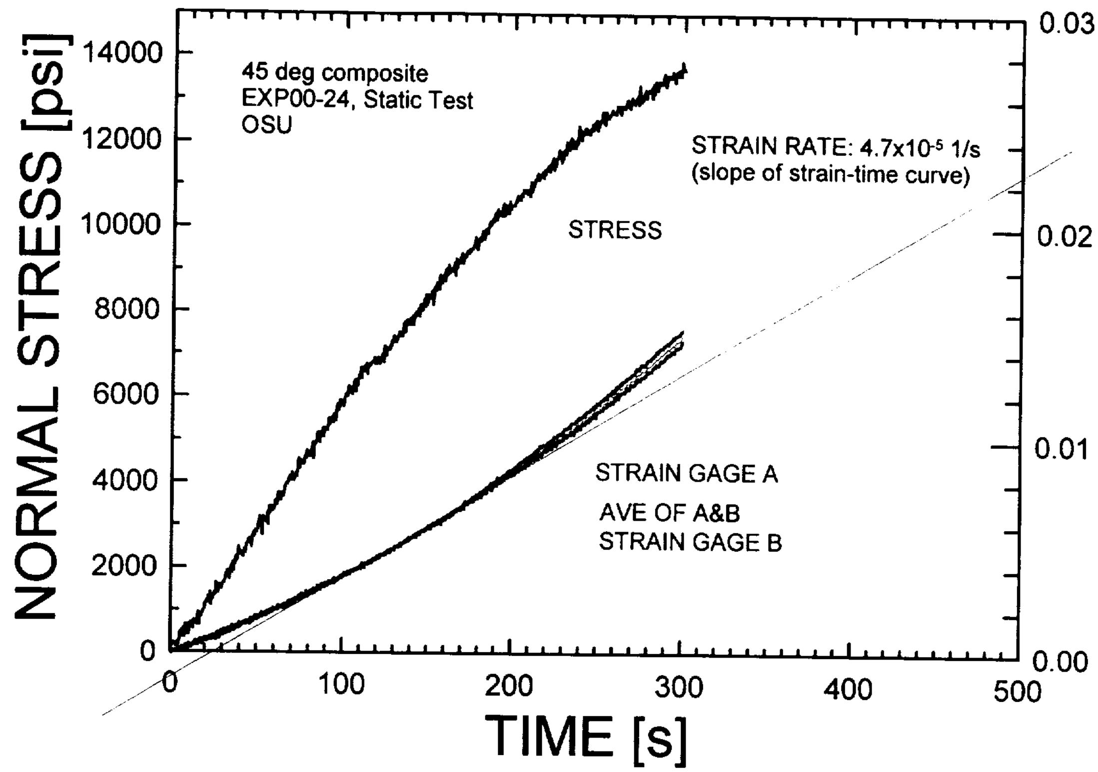
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN FROM SHB EQUATIONS
STRAIN FROM STRAIN GAGES
10 deg composite
Exp 00-21, Tensile split Hopkinson bar

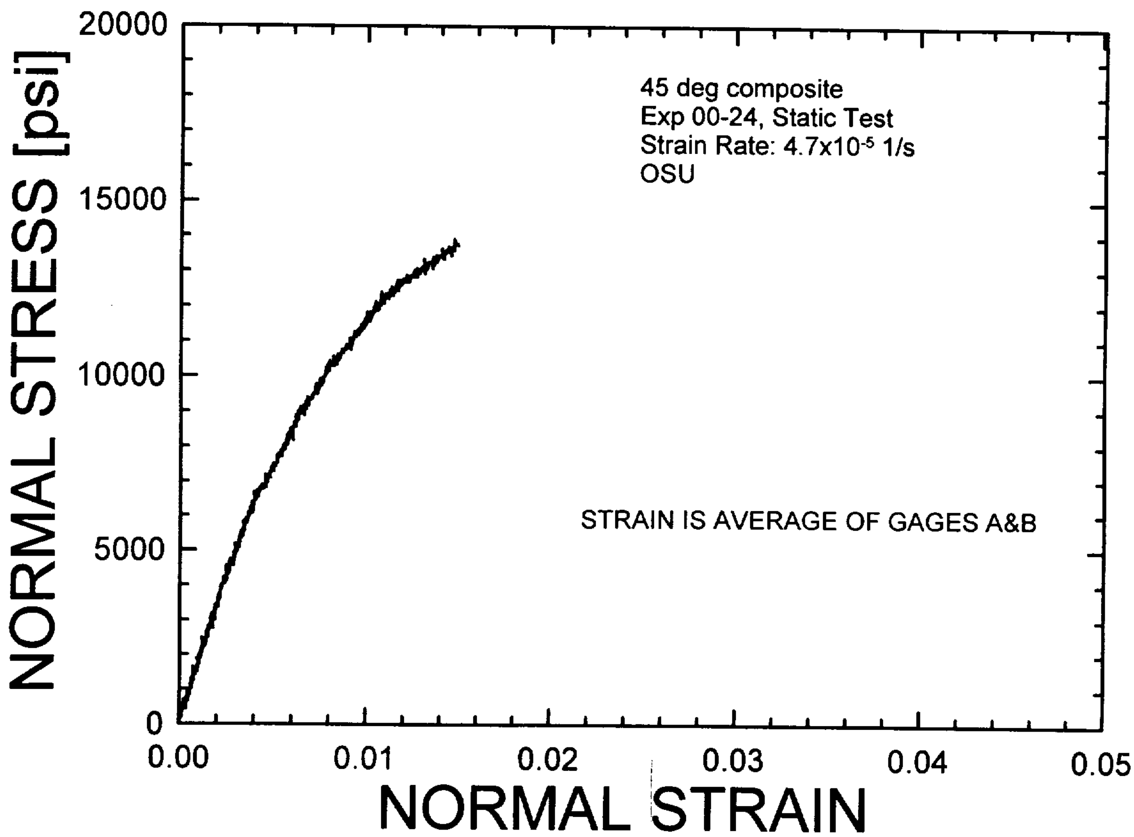

80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
STRESS
10 deg composite
Exp 00-22, Tensile split Hopkinson bar
STRAIN SHB EQUATIONS
STRAIN RATE
(SHB EQS)
0.03
0.02
0.01
0.00
NORMAL STRAIN
1400
1200
1000
800
600
400
200
0
STRAIN RATE [1/s]
0
50
100
TIME (μs)

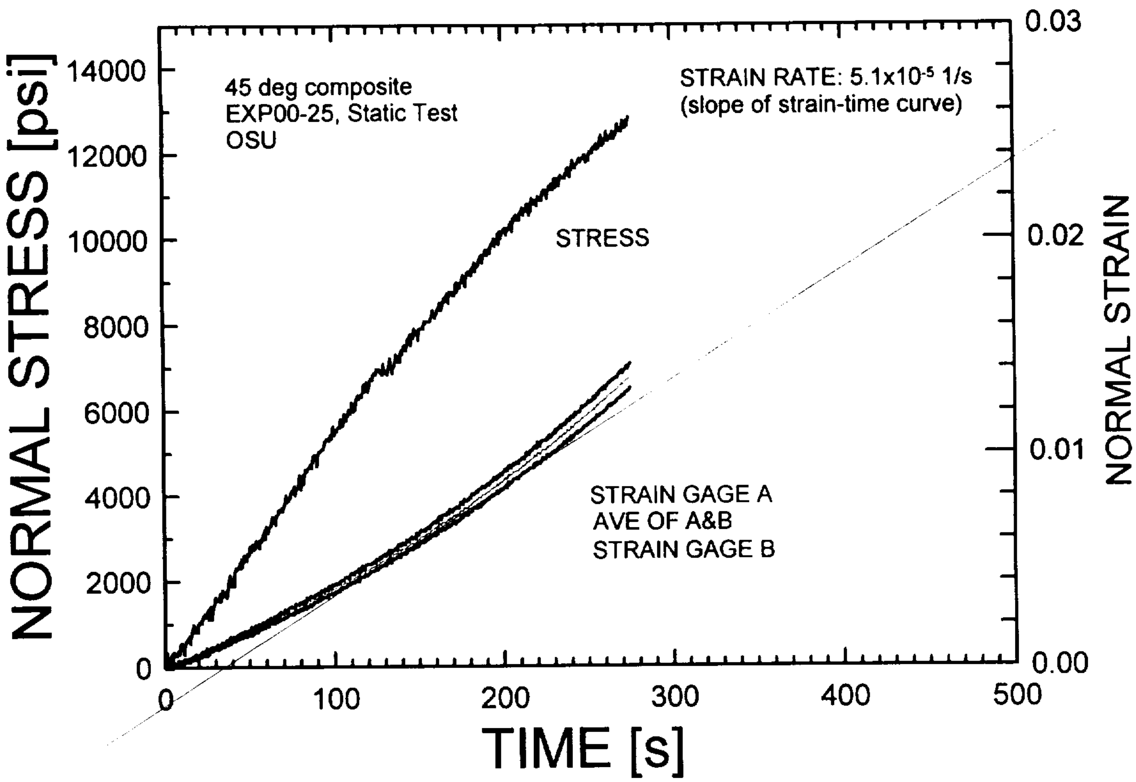

80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
10 deg composite
EXP 00-22, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS
0.00
0.01
0.02
0.03
0.04
NORMAL STRAIN

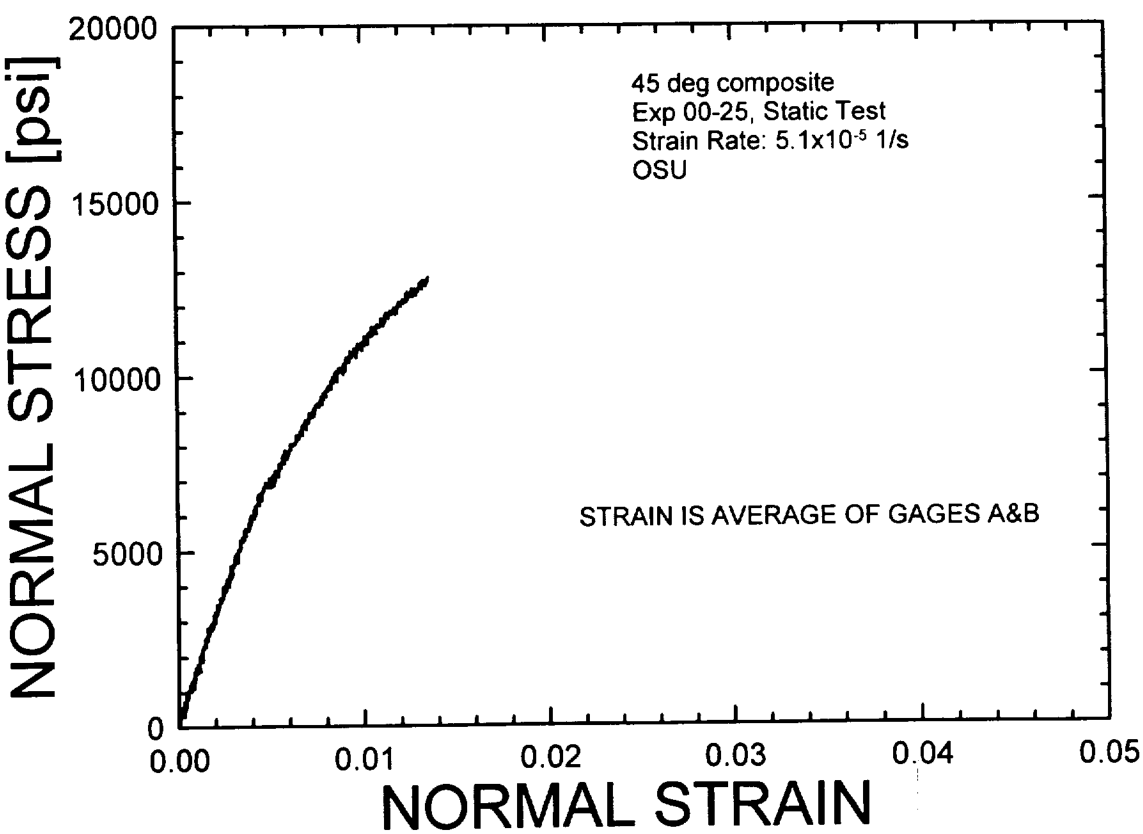

NORMAL STRESS [psi]
80000
70000
60000
50000
40000
30000
20000
10000
0
STRESS
10 deg composite
Exp 00-23, Tensile split Hopkinson bar
STRAIN SHB EQUATIONS
STRAIN RATE
(SHB EQS)
0.03
0.02
0.01
0.00
NORMAL STRAIN
1400
1200
1000
800
600
400
200
0
STRAIN RATE [1/s]
0
50
100
TIME (μs)

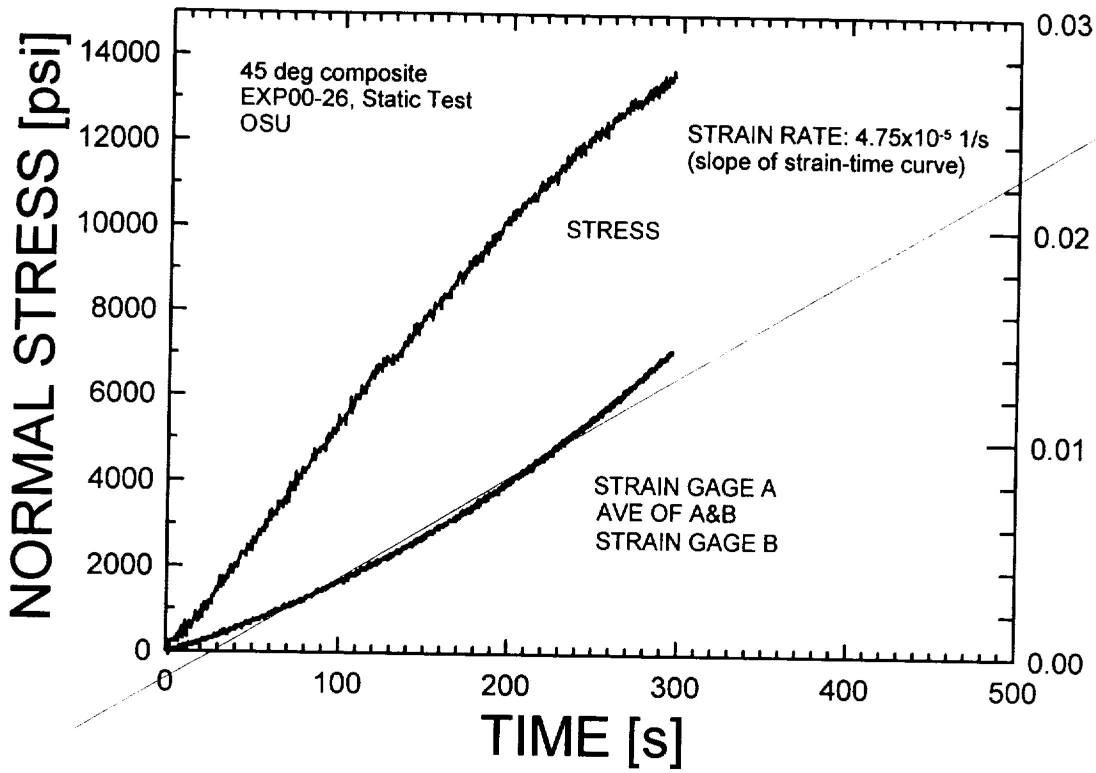

NORMAL STRESS [psi]
80000
70000
60000
50000
40000
30000
20000
10000
0
10 deg composite
EXP 00-23, Tensile split Hopkinson bar
OSU
STRAIN FROM SHB EQUATIONS
0.00
0.01
0.02
0.03
0.04
NORMAL STRAIN

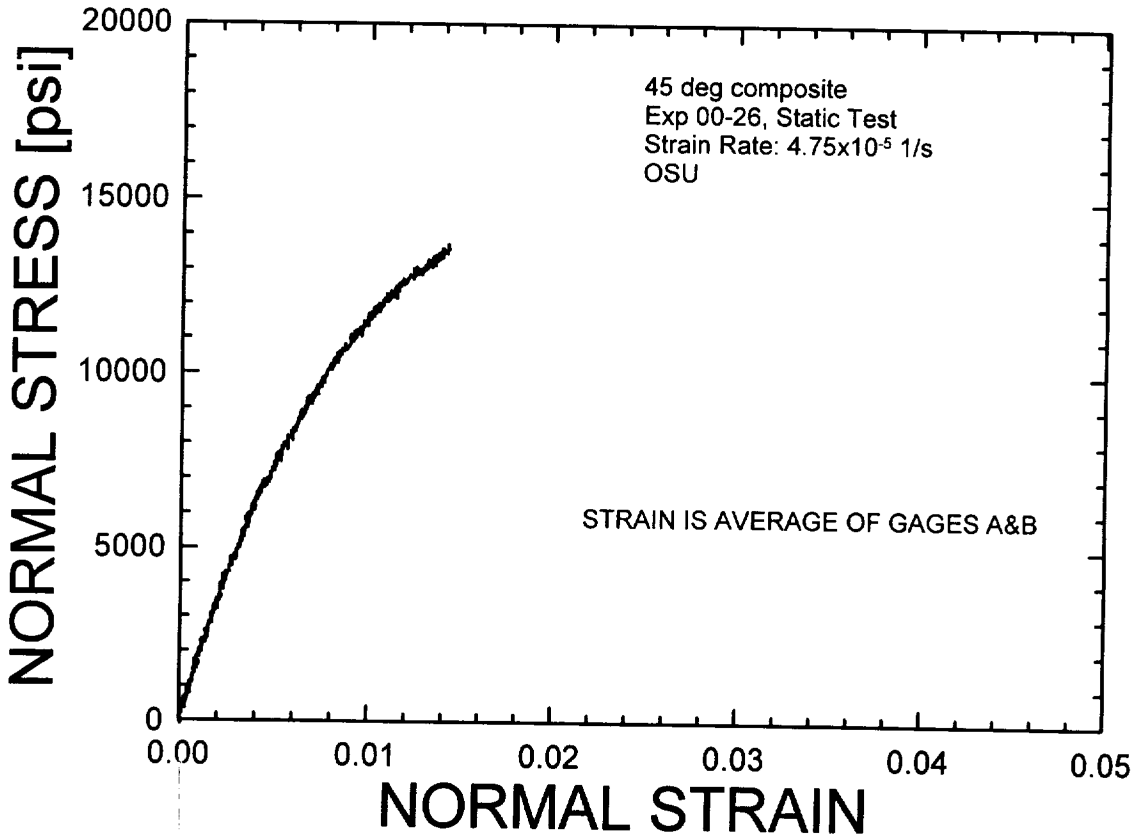

45 deg composite
EXP00-24, Static Test
OSU
STRAIN RATE: 4.7x10^-5 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVE OF A&B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]

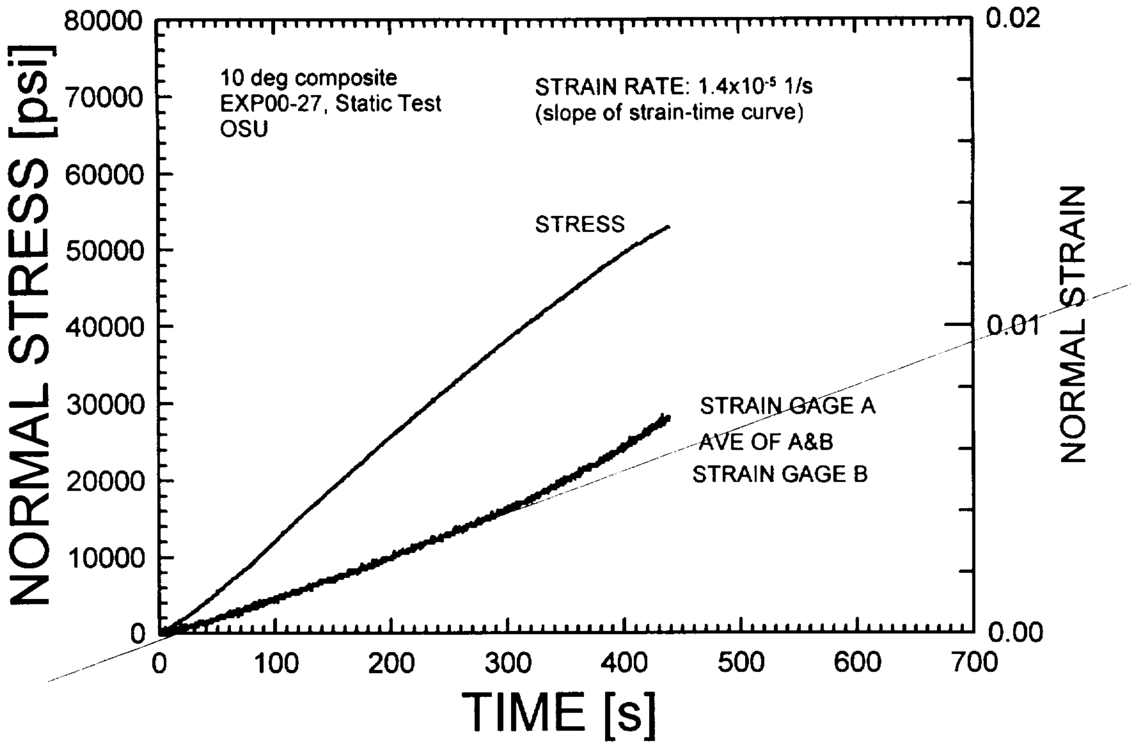

45 deg composite
Exp 00-24, Static Test
Strain Rate: 4.7x10^-5 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN


45 deg composite
EXP00-25, Static Test
OSU
STRAIN RATE: 5.1x10⁻⁵ 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVE OF A&B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]

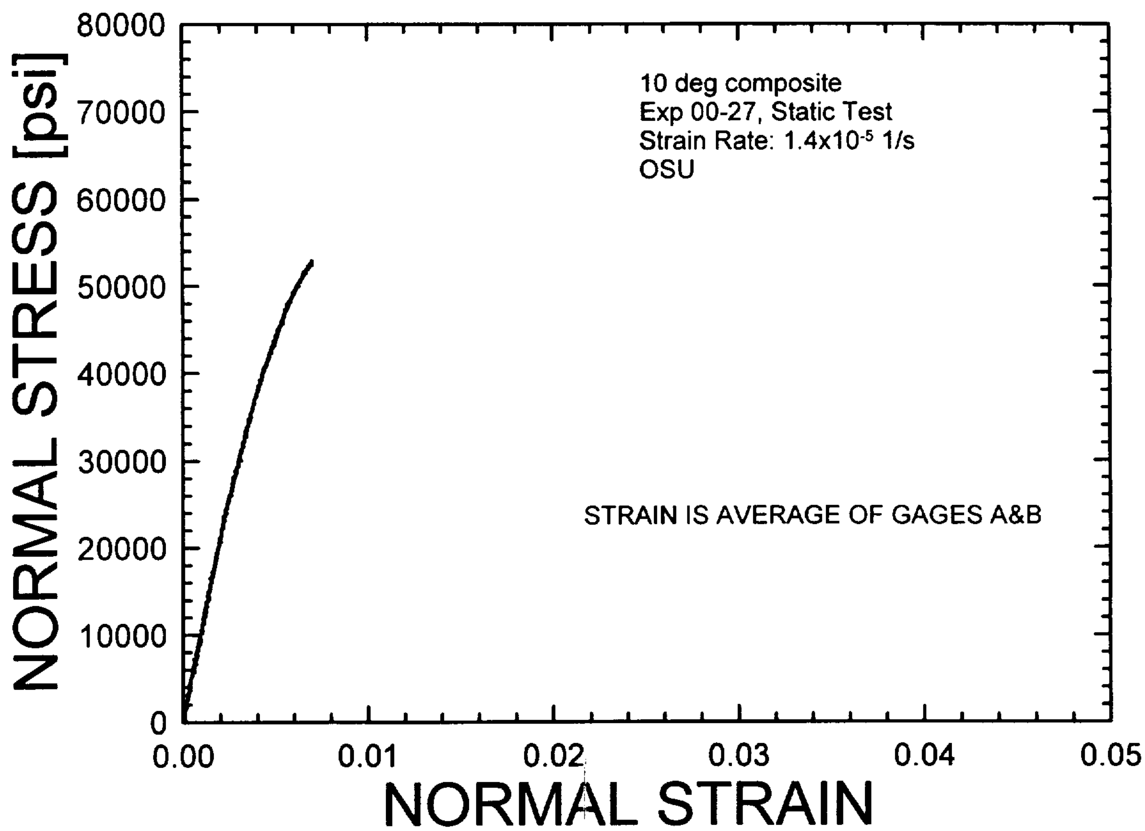

45 deg composite
Exp 00-25, Static Test
Strain Rate: 5.1x10⁻⁵ 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN


NORMAL STRESS [psi]
45 deg composite
EXP00-26, Static Test
OSU
STRAIN RATE: 4.75x10-5 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVE OF A&B
STRAIN GAGE B
NORMAL STRAIN
TIME [s]

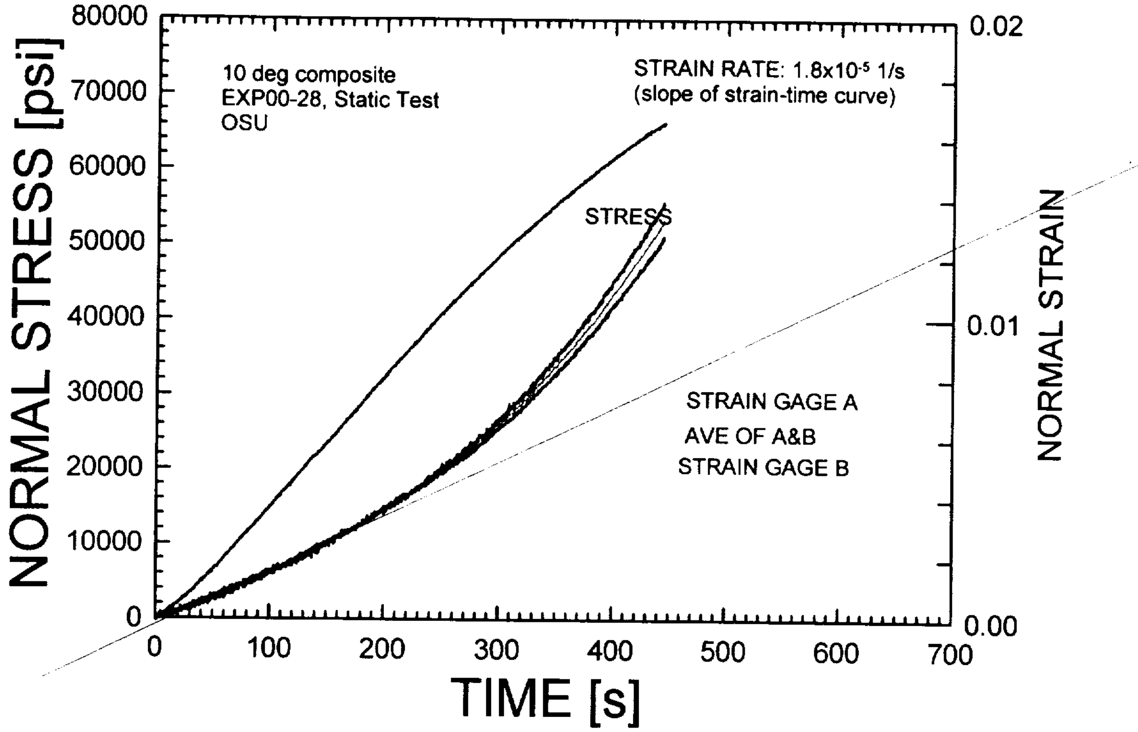

NORMAL STRESS [psi]
45 deg composite
Exp 00-26, Static Test
Strain Rate: 4.75x10-5 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRAIN

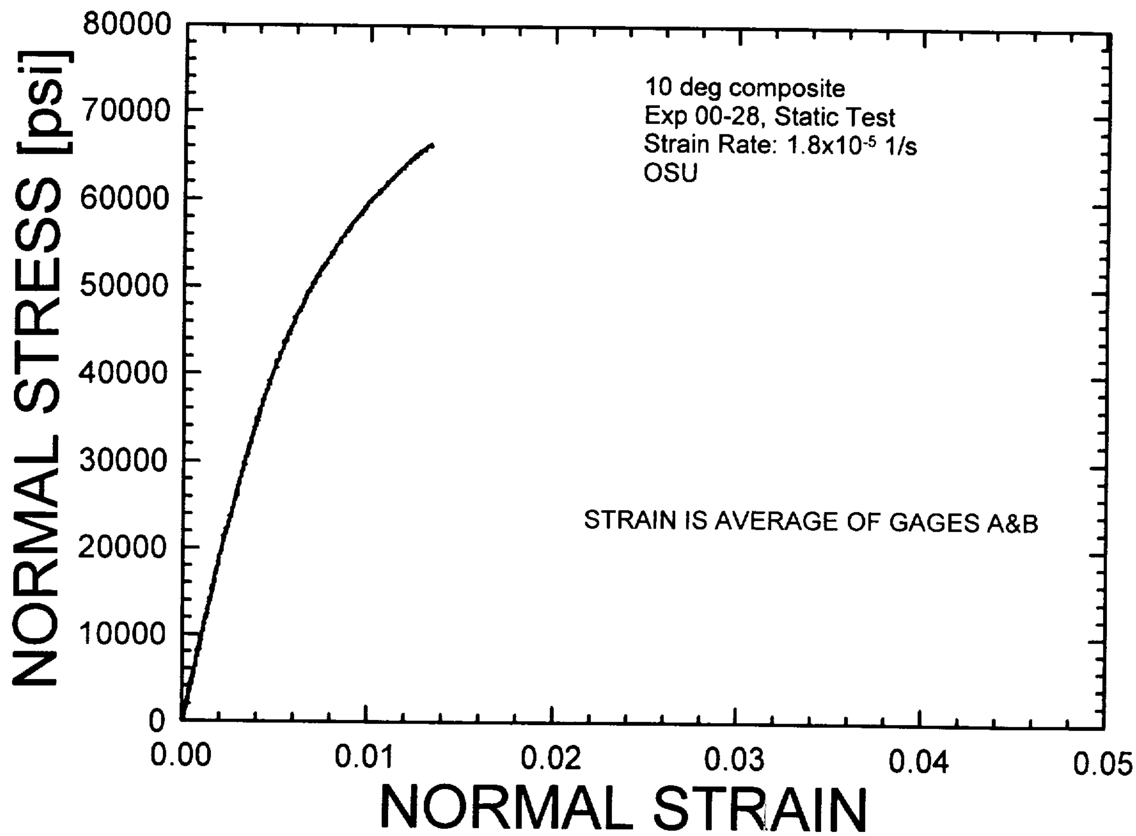


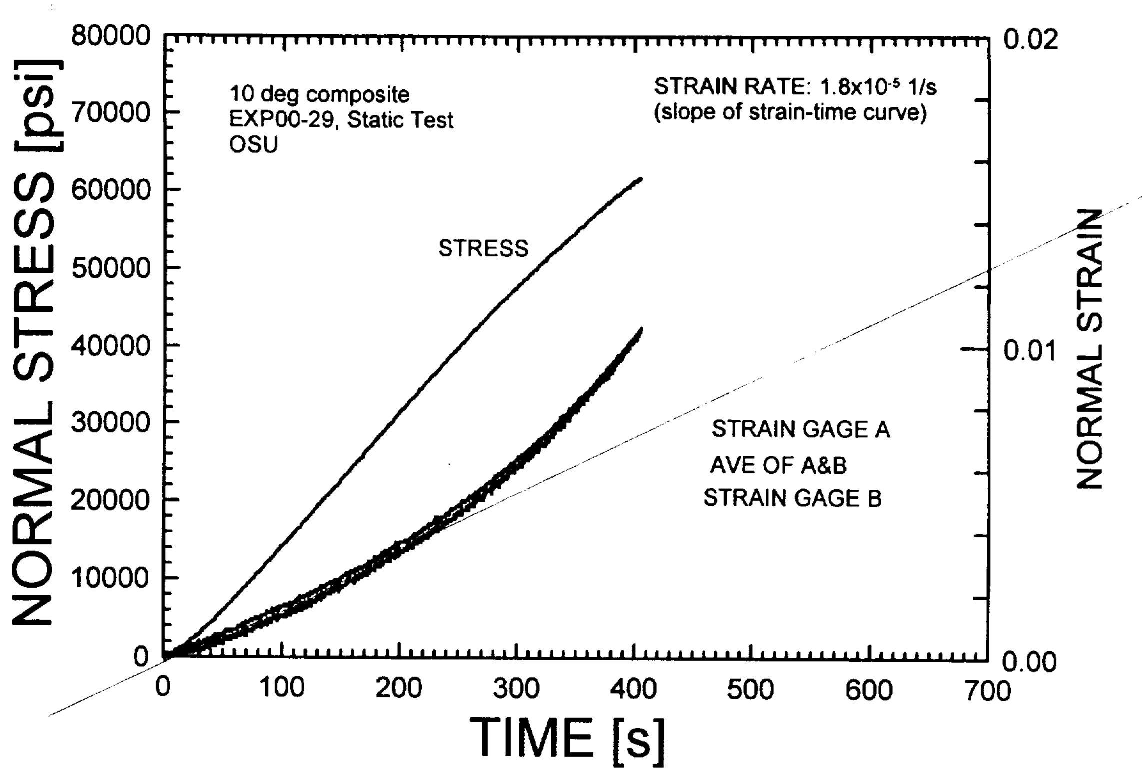
10 deg composite
EXP00-27, Static Test
OSU
STRAIN RATE: 1.4x10⁻⁵ 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVE OF A&B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]

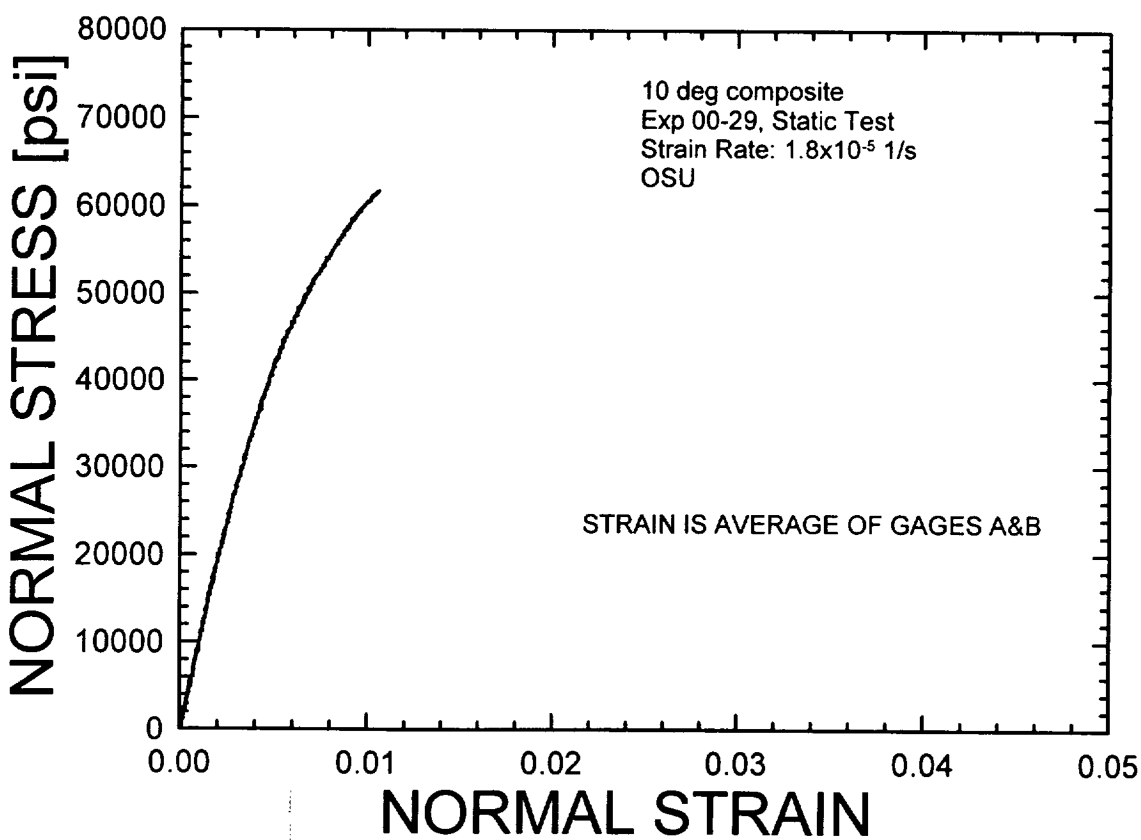


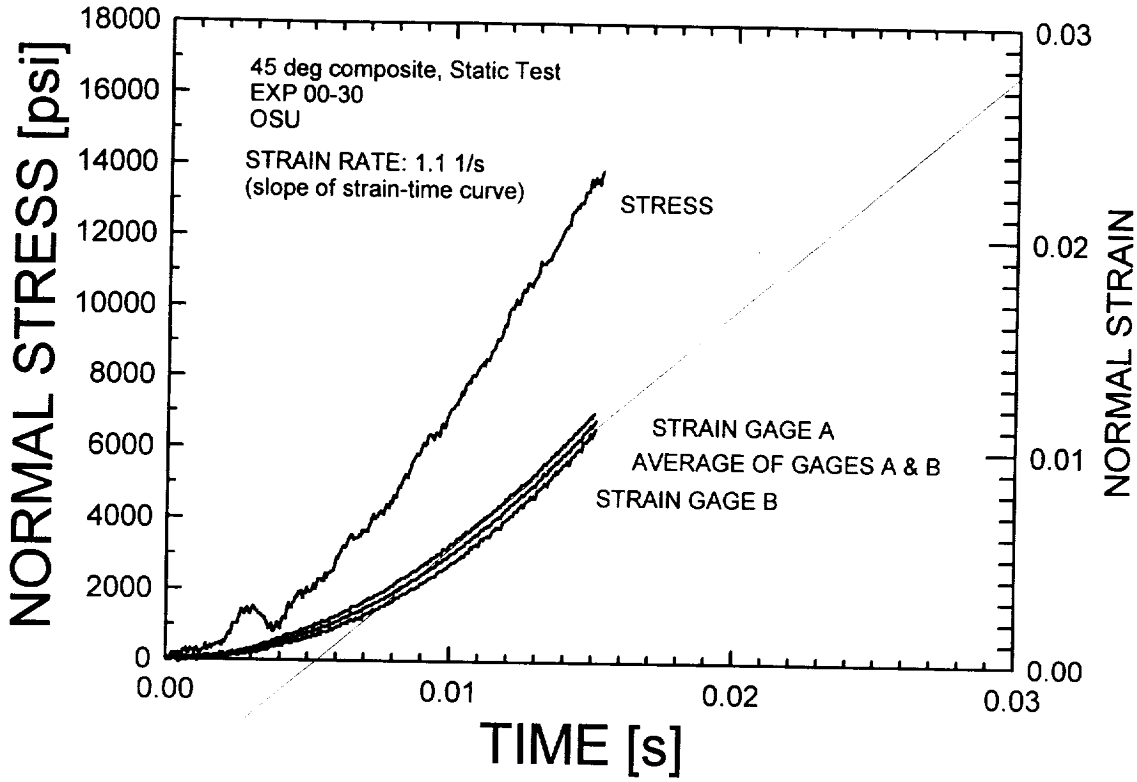
10 deg composite
Exp 00-27, Static Test
Strain Rate: 1.4x10⁻⁵ 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN

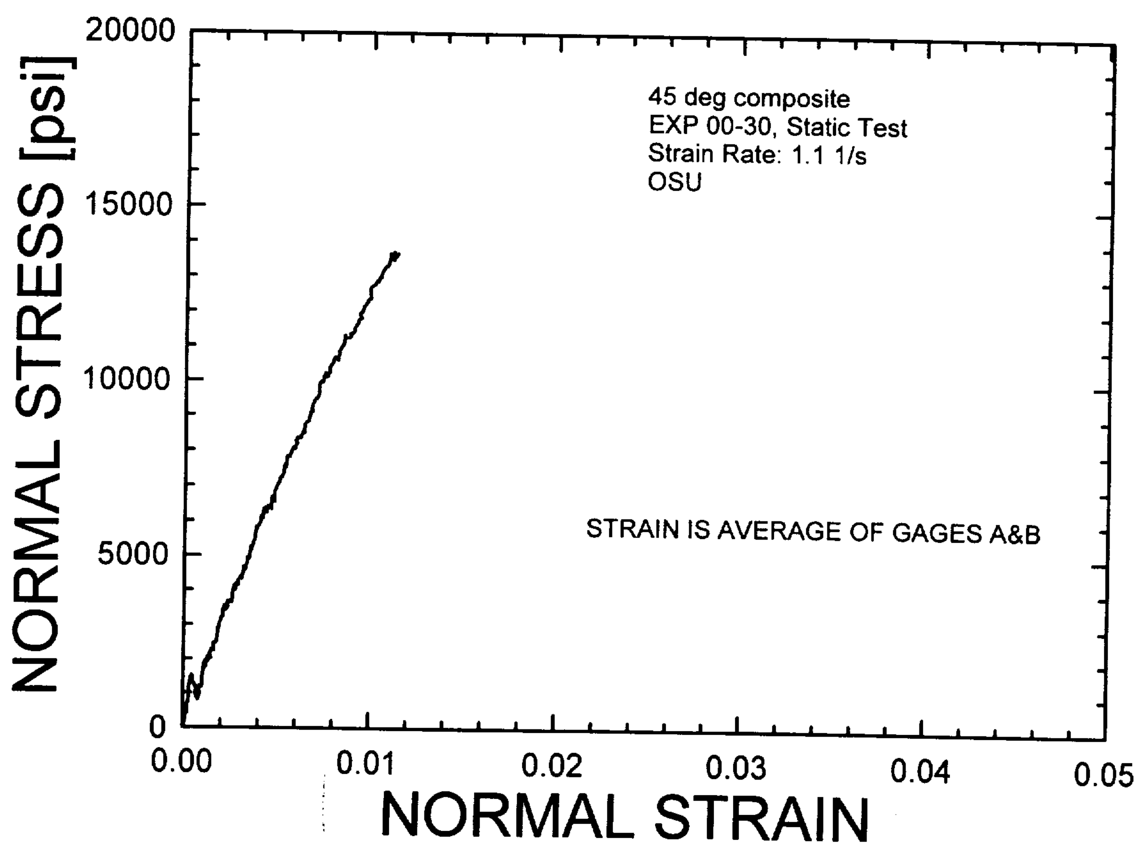

80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
0.02
0.01
0.00
NORMAL STRAIN
0
100
200
300
400
500
600
700
TIME [s]
10 deg composite
EXP00-28, Static Test
OSU
STRAIN RATE: 1.8x10-5 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVE OF A&B
STRAIN GAGE B

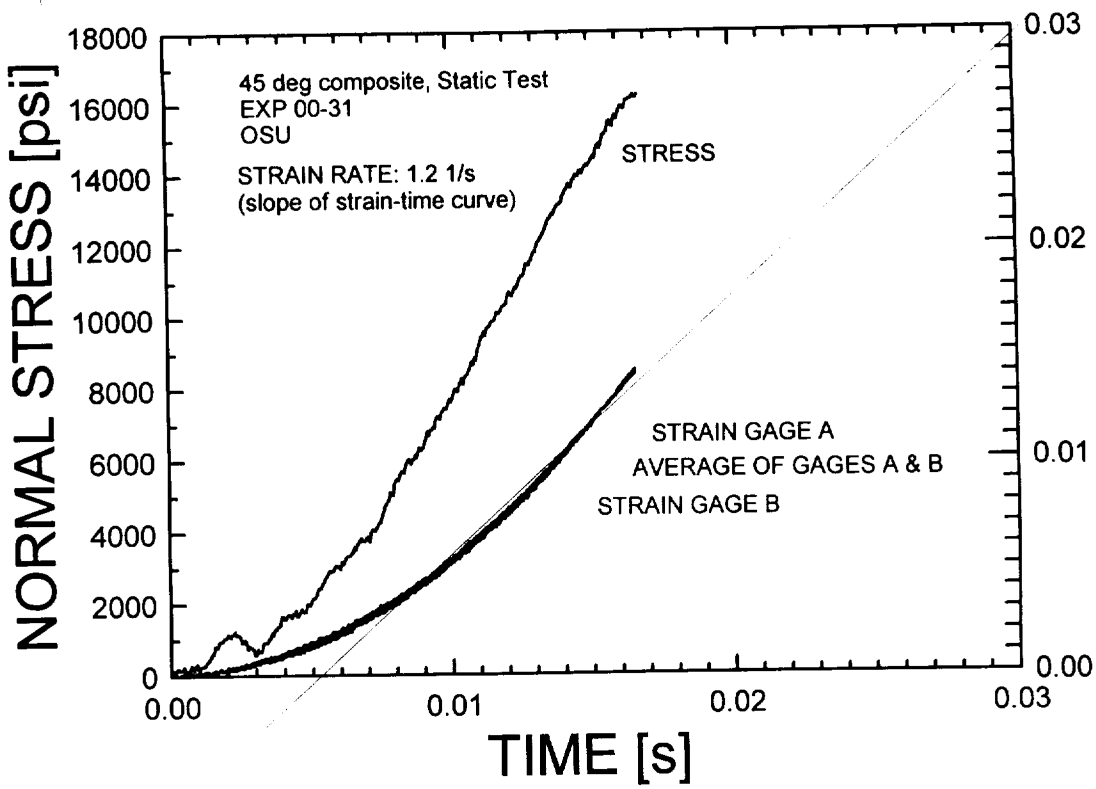

80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
0.00
0.01
0.02
0.03
0.04
0.05
NORMAL STRAIN
10 deg composite
Exp 00-28, Static Test
Strain Rate: 1.8x10-5 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B


10 deg composite
EXP00-29, Static Test
OSU
STRAIN RATE: 1.8×10^{-5} 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVE OF A&B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]

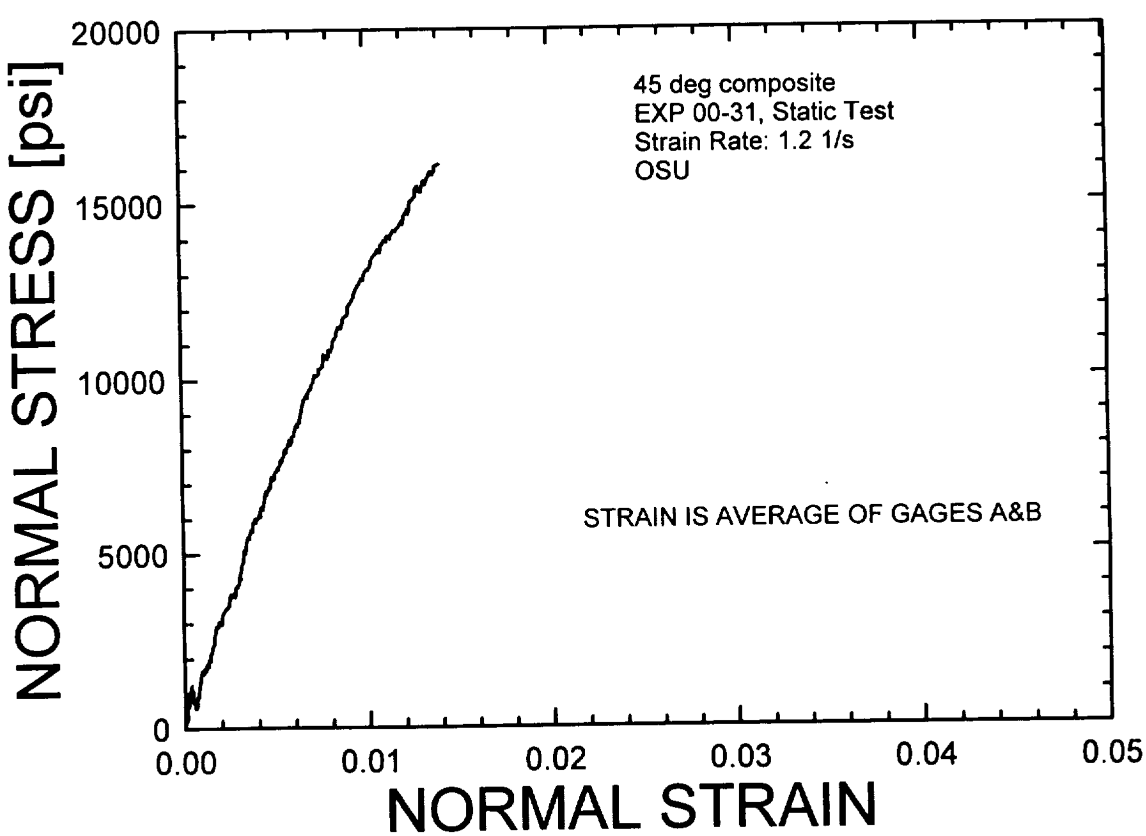

10 deg composite
Exp 00-29, Static Test
Strain Rate: 1.8×10^{-5} 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN


18000
16000
14000
12000
10000
8000
6000
4000
2000
0
NORMAL STRESS [psi]
0.03
0.02
0.01
0.00
NORMAL STRAIN
0.00
0.01
0.02
0.03
TIME [s]
45 deg composite, Static Test
EXP 00-30
OSU
STRAIN RATE: 1.1 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B

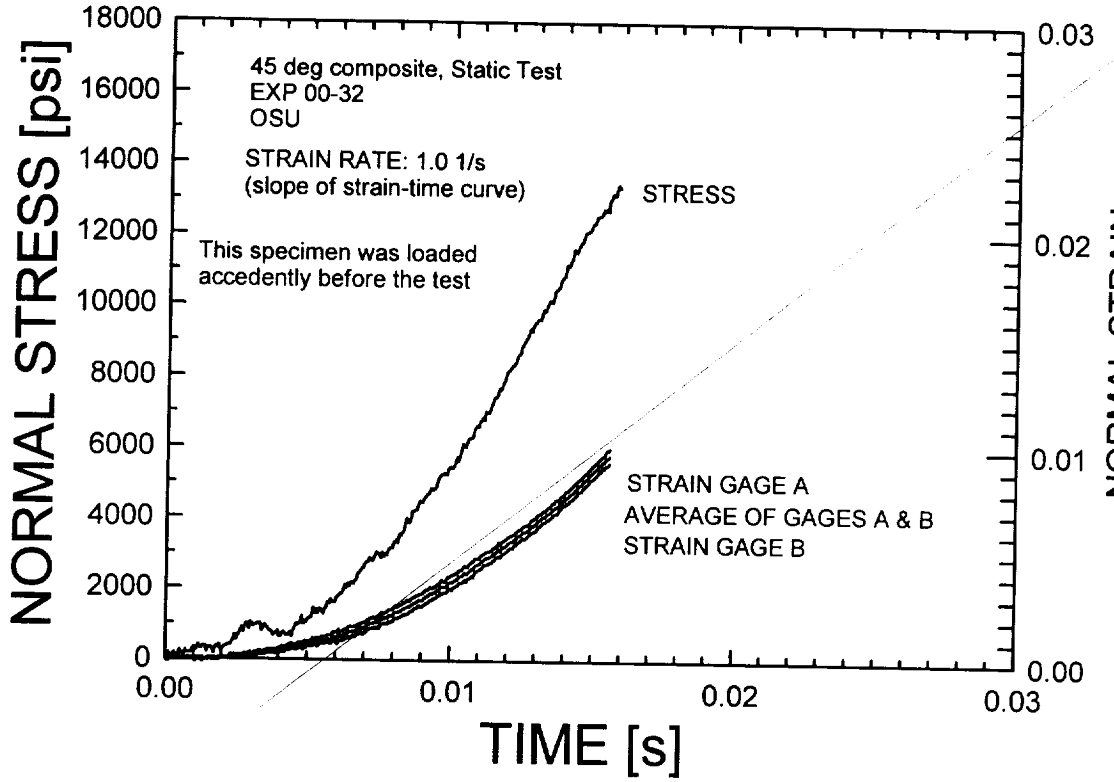

20000
15000
10000
5000
0
NORMAL STRESS [psi]
0.00
0.01
0.02
0.03
0.04
0.05
NORMAL STRAIN
45 deg composite
EXP 00-30, Static Test
Strain Rate: 1.1 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B

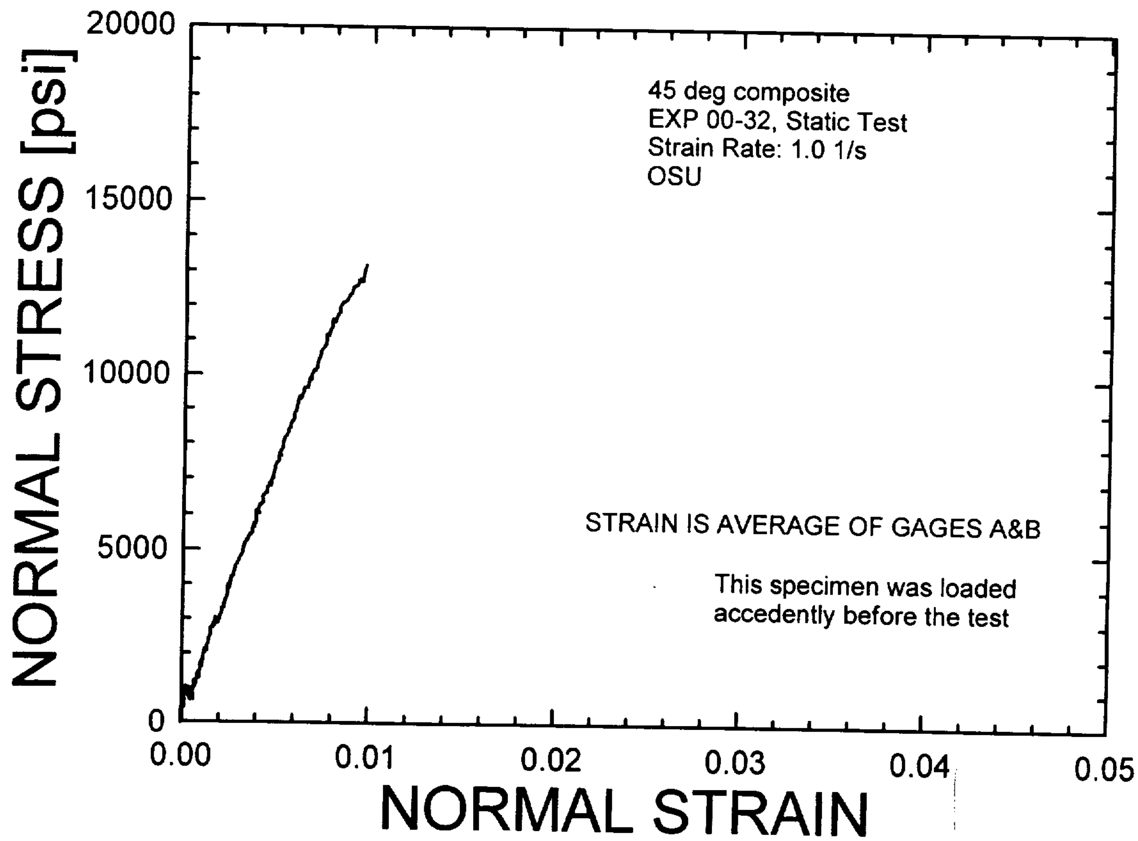


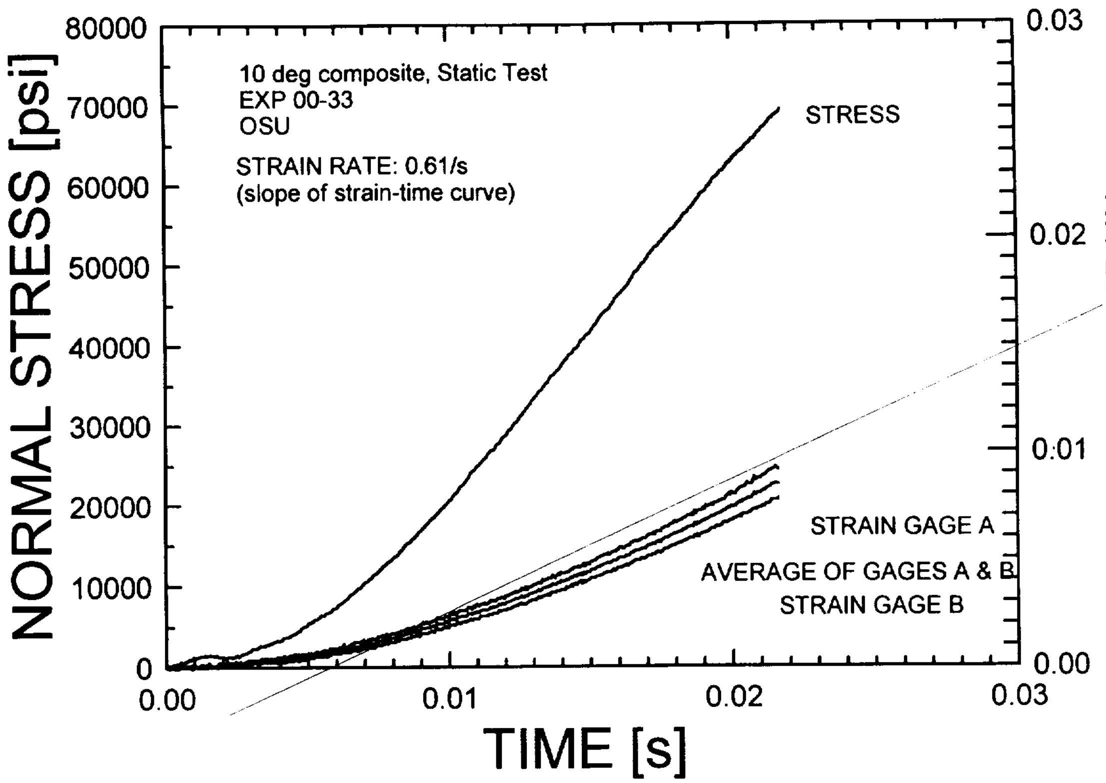
45 deg composite, Static Test
EXP 00-31
OSU
STRAIN RATE: 1.2 1/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.00
0.01
0.02
0.03
0.03
0.02
0.01
0.00

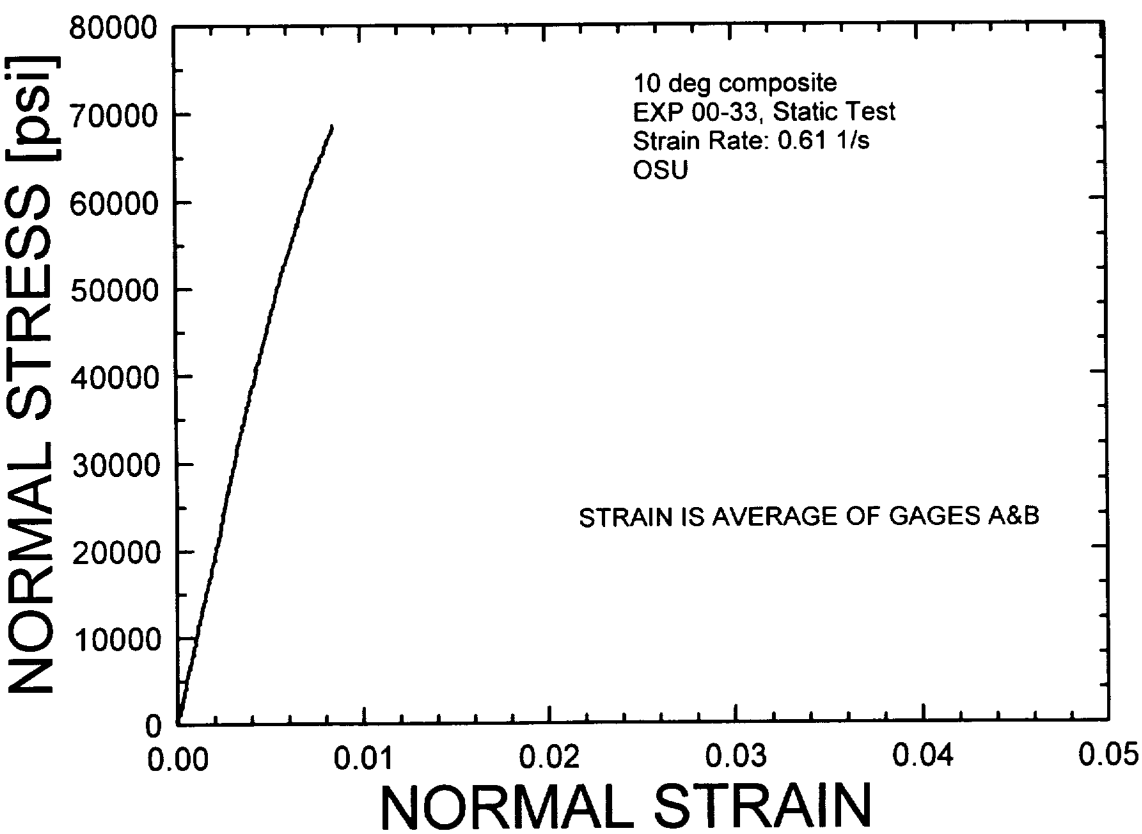


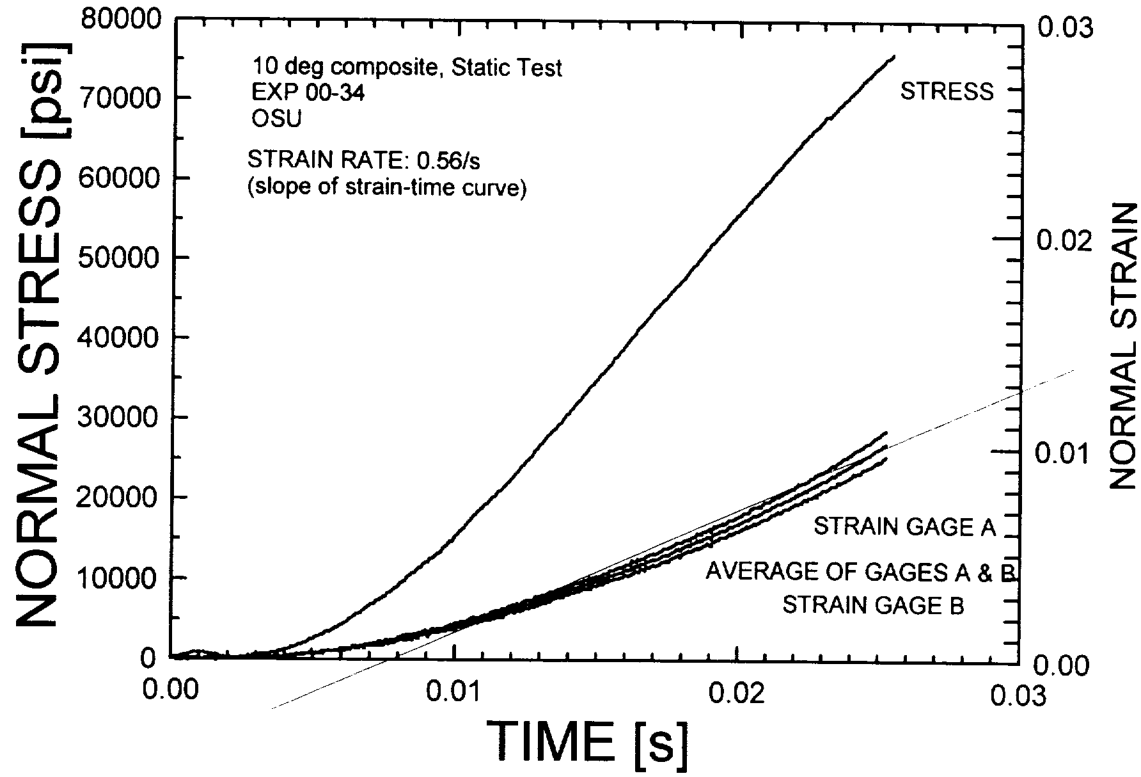
45 deg composite
EXP 00-31, Static Test
Strain Rate: 1.2 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
20000
15000
10000
5000
0
0.00
0.01
0.02
0.03
0.04
0.05

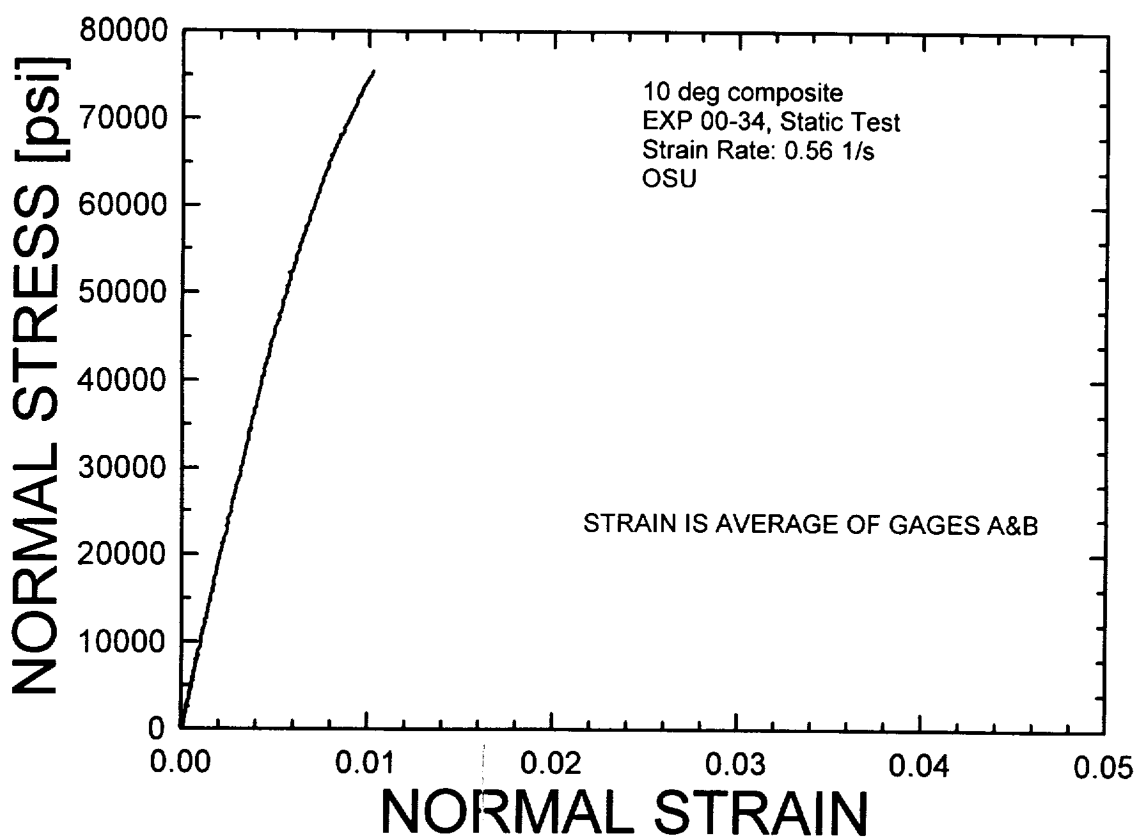

45 deg composite, Static Test
EXP 00-32
OSU
STRAIN RATE: 1.0 1/s
(slope of strain-time curve)
This specimen was loaded
accedently before the test
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.00
0.01
0.02
0.03
0.03
0.02
0.01
0.00

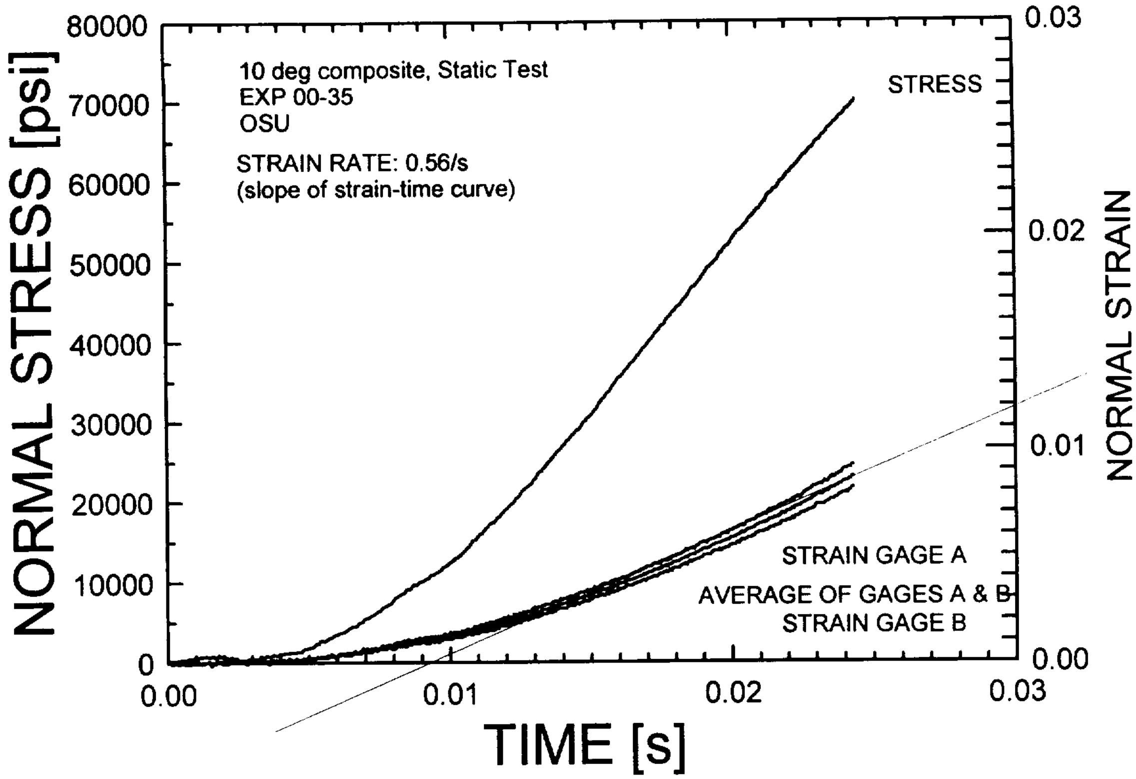

45 deg composite
EXP 00-32, Static Test
Strain Rate: 1.0 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
This specimen was loaded
accedently before the test
NORMAL STRESS [psi]
NORMAL STRAIN
20000
15000
10000
5000
0
0.00
0.01
0.02
0.03
0.04
0.05

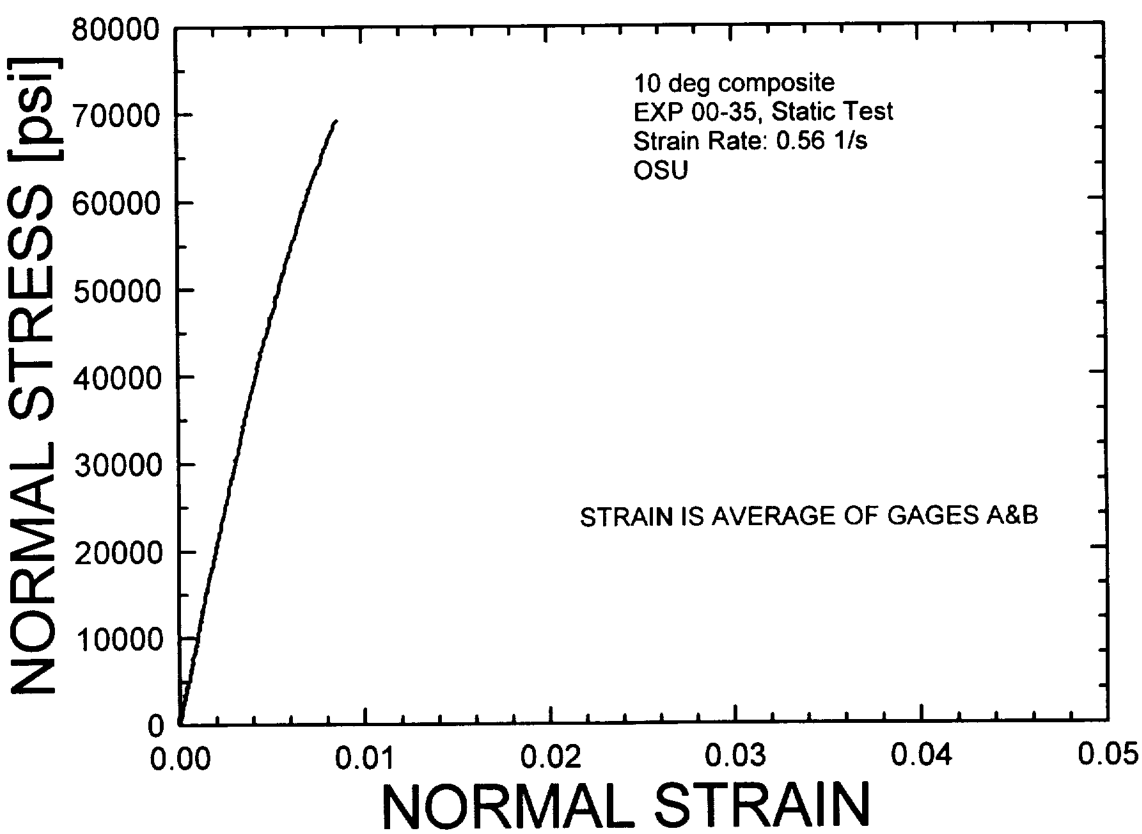

10 deg composite, Static Test
EXP 00-33
OSU
STRAIN RATE: 0.61/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
10000
20000
30000
40000
50000
60000
70000
80000
0.00
0.01
0.02
0.03

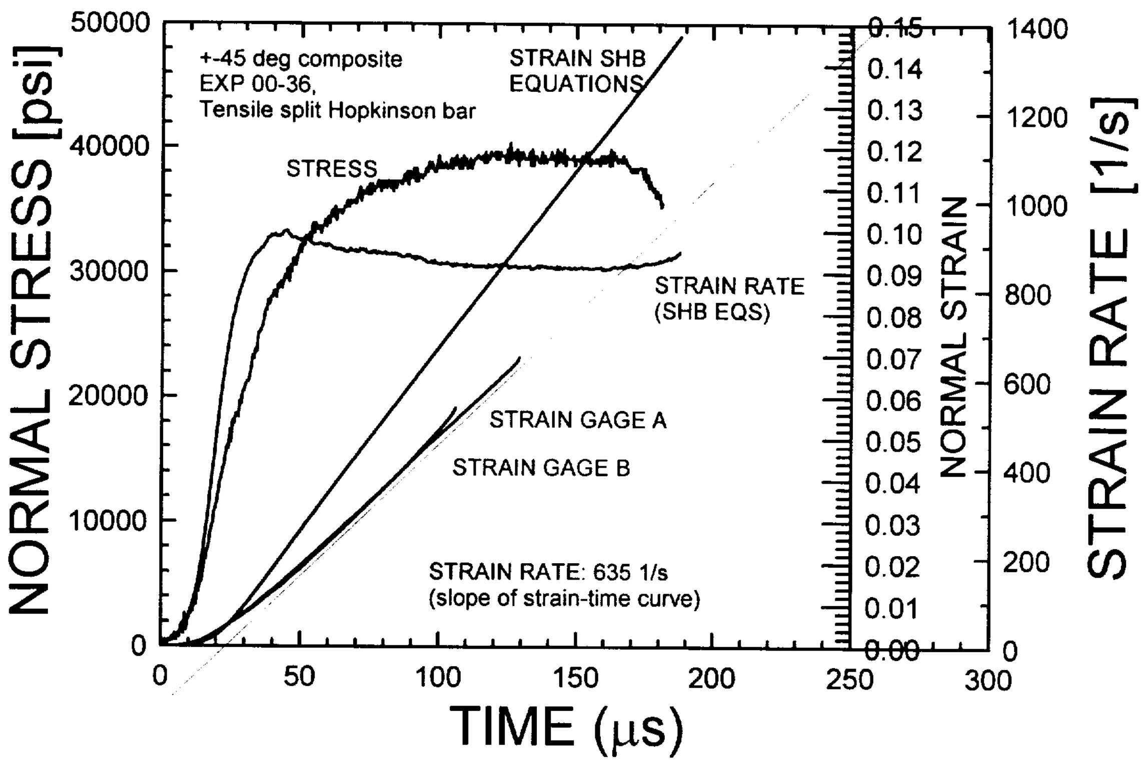

10 deg composite
EXP 00-33, Static Test
Strain Rate: 0.61 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
0
10000
20000
30000
40000
50000
60000
70000
80000
0.00
0.01
0.02
0.03
0.04
0.05


80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
0.00
0.01
0.02
0.03
TIME [s]
0.03
0.02
0.01
0.00
NORMAL STRAIN
10 deg composite, Static Test
EXP 00-34
OSU
STRAIN RATE: 0.56/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B

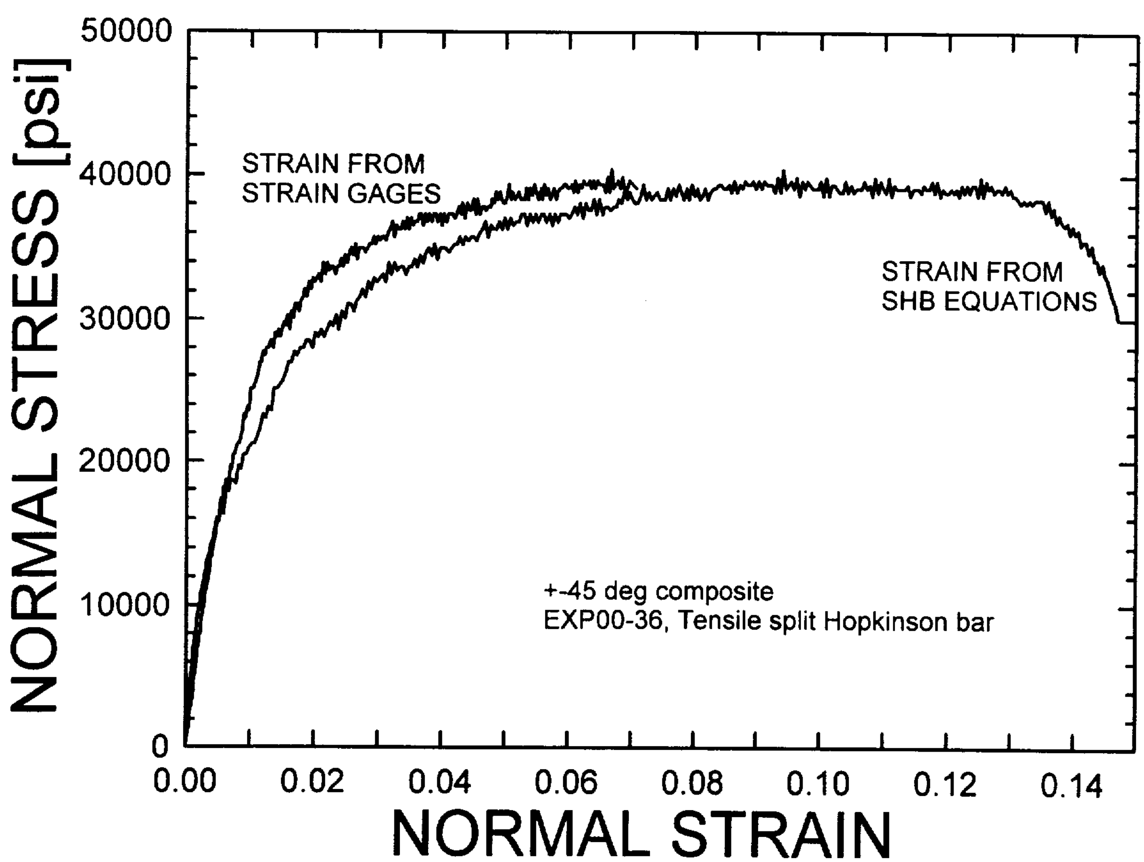

80000
70000
60000
50000
40000
30000
20000
10000
0
NORMAL STRESS [psi]
0.00
0.01
0.02
0.03
0.04
0.05
NORMAL STRAIN
10 deg composite
EXP 00-34, Static Test
Strain Rate: 0.56 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B


10 deg composite, Static Test
EXP 00-35
OSU
STRAIN RATE: 0.56/s
(slope of strain-time curve)
STRESS
STRAIN GAGE A
AVERAGE OF GAGES A & B
STRAIN GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
80000
70000
60000
50000
40000
30000
20000
10000
0
0.00
0.01
0.02
0.03

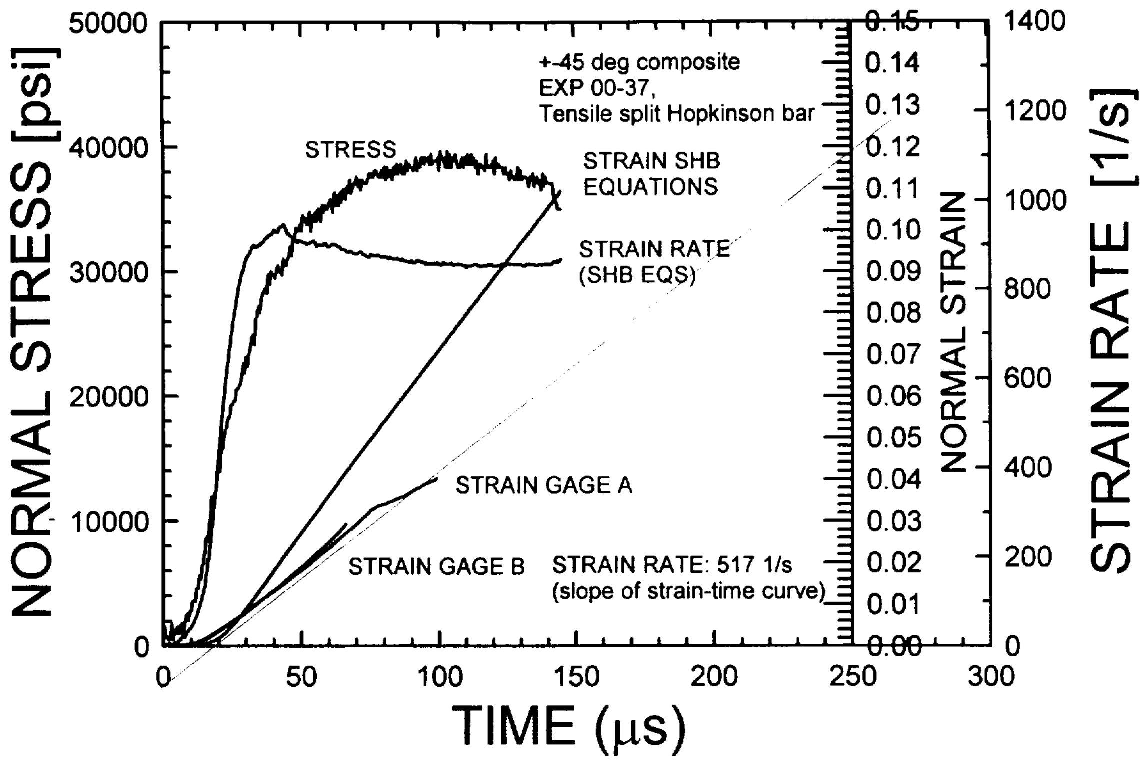

10 deg composite
EXP 00-35, Static Test
Strain Rate: 0.56 1/s
OSU
STRAIN IS AVERAGE OF GAGES A&B
NORMAL STRESS [psi]
NORMAL STRAIN
80000
70000
60000
50000
40000
30000
20000
10000
0
0.00
0.01
0.02
0.03
0.04
0.05



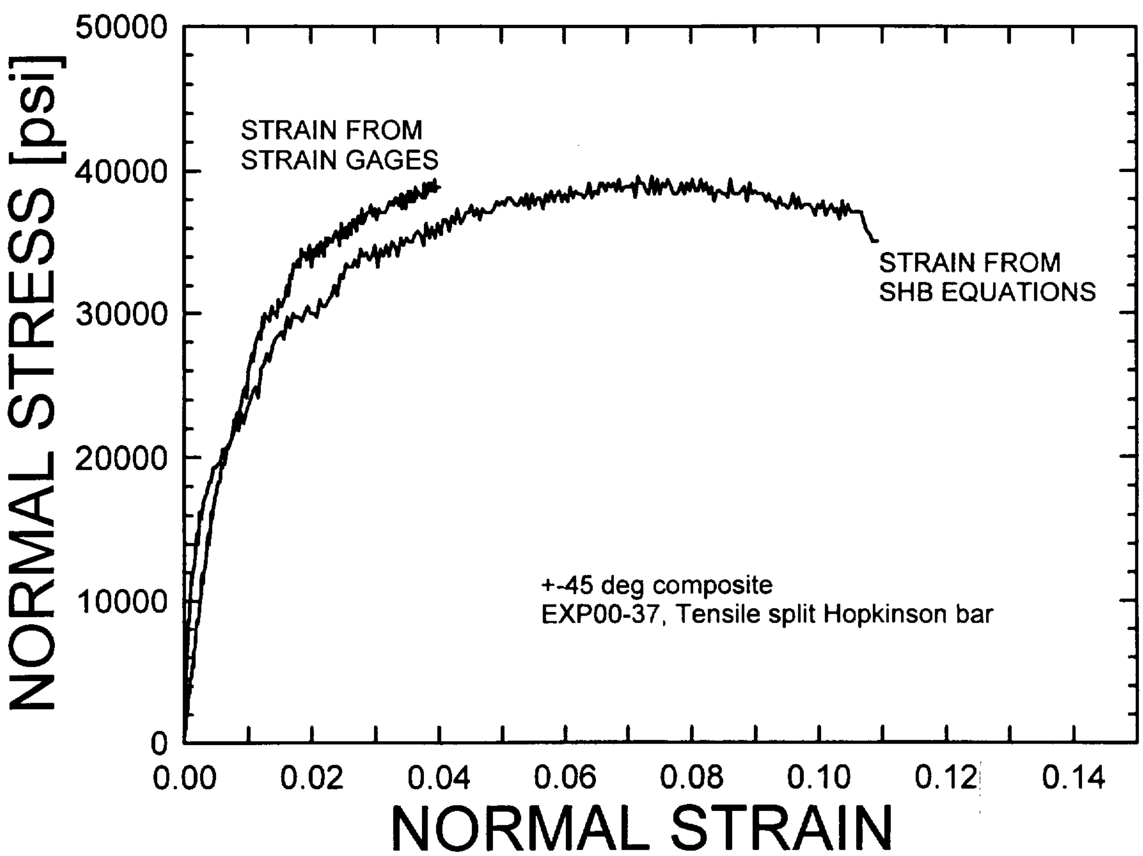
+-45 deg composite
EXP 00-36,
Tensile split Hopkinson bar
STRAIN SHB
EQUATIONS
STRESS
STRAIN RATE
(SHB EQS)
STRAIN GAGE A
STRAIN GAGE B
STRAIN RATE: 635 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)



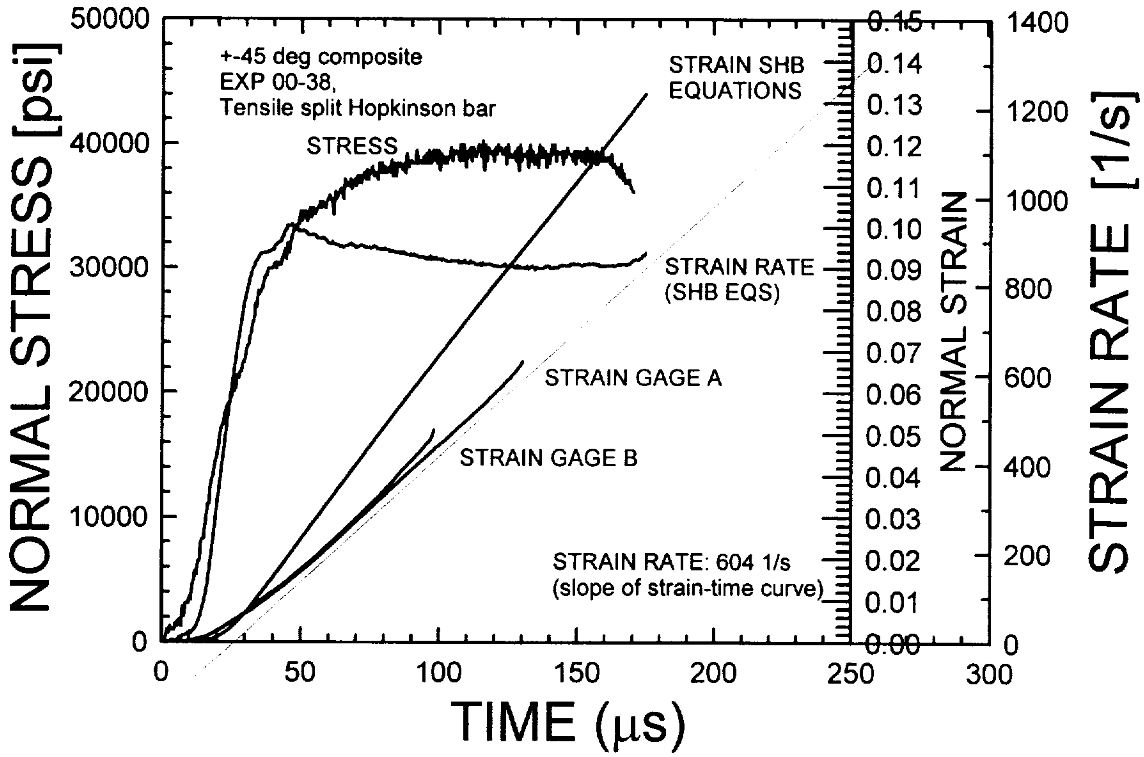
STRAIN FROM
STRAIN GAGES
STRAIN FROM
SHB EQUATIONS
+-45 deg composite
EXP00-36, Tensile split Hopkinson bar
NORMAL STRESS [psi]
NORMAL STRAIN

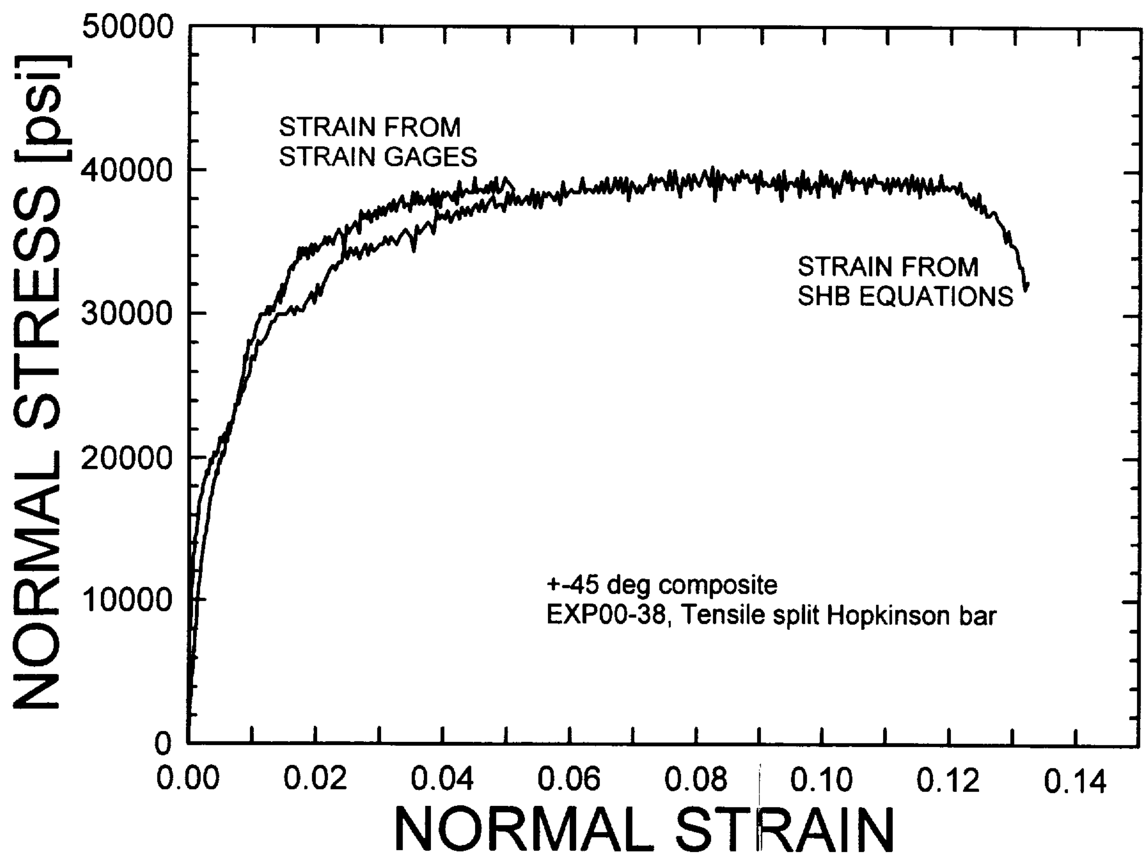


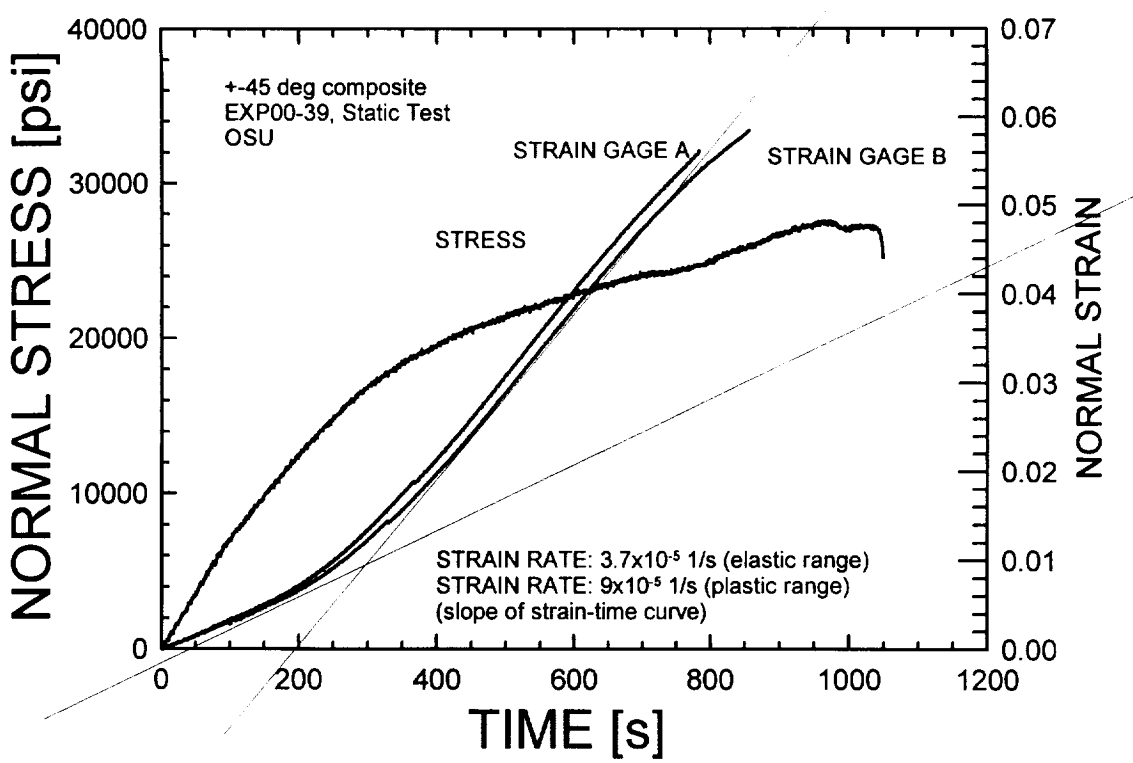
+-45 deg composite
EXP 00-37,
Tensile split Hopkinson bar
STRESS
STRAIN SHB
EQUATIONS
STRAIN RATE
(SHB EQS)
STRAIN GAGE A
STRAIN GAGE B
STRAIN RATE: 517 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)

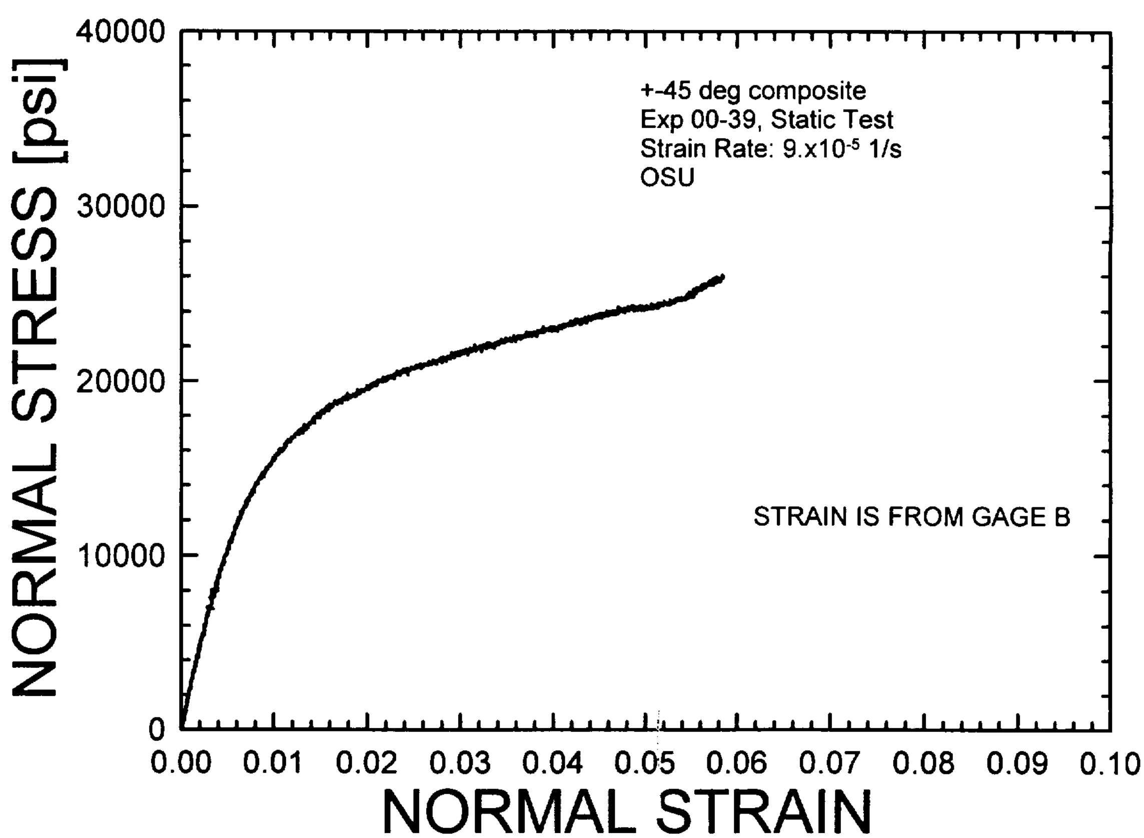


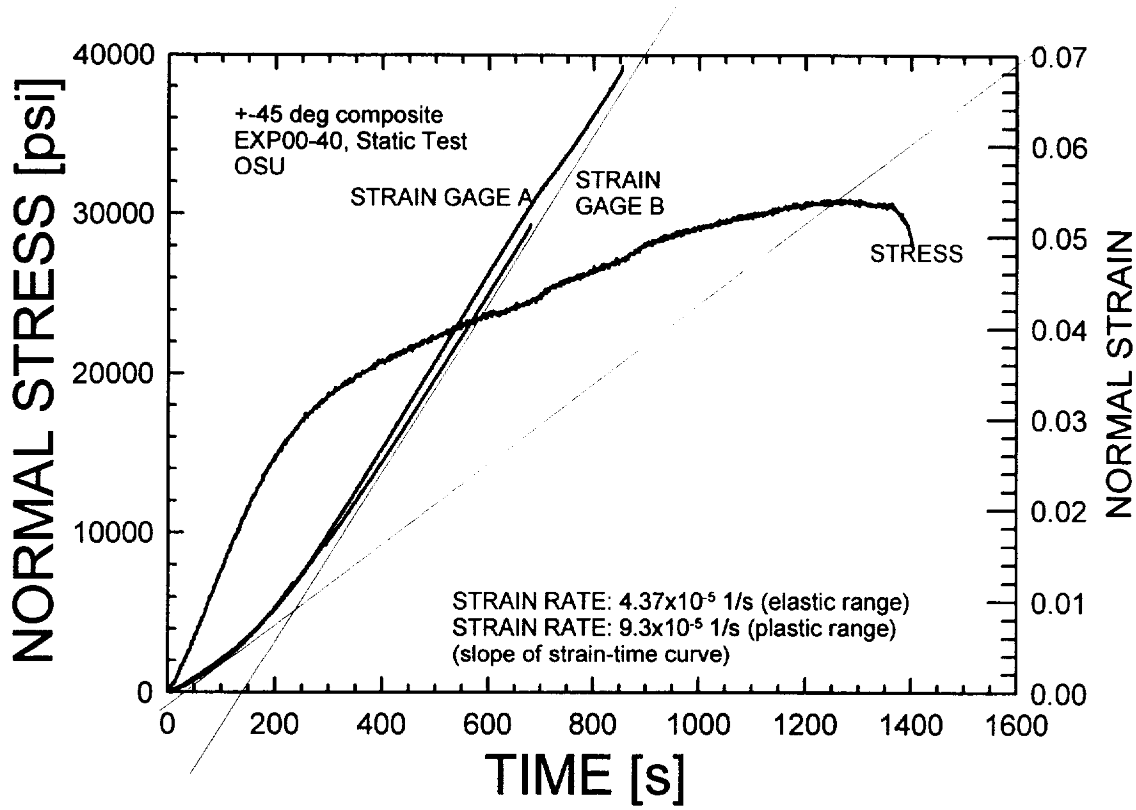
STRAIN FROM
STRAIN GAGES
STRAIN FROM
SHB EQUATIONS
+-45 deg composite
EXP00-37, Tensile split Hopkinson bar
NORMAL STRESS [psi]
NORMAL STRAIN


+-45 deg composite
EXP 00-38,
Tensile split Hopkinson bar
STRESS
STRAIN SHB
EQUATIONS
STRAIN RATE
(SHB EQS)
STRAIN GAGE A
STRAIN GAGE B
STRAIN RATE: 604 1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
STRAIN RATE [1/s]
TIME (μs)
50000
40000
30000
20000
10000
0
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300

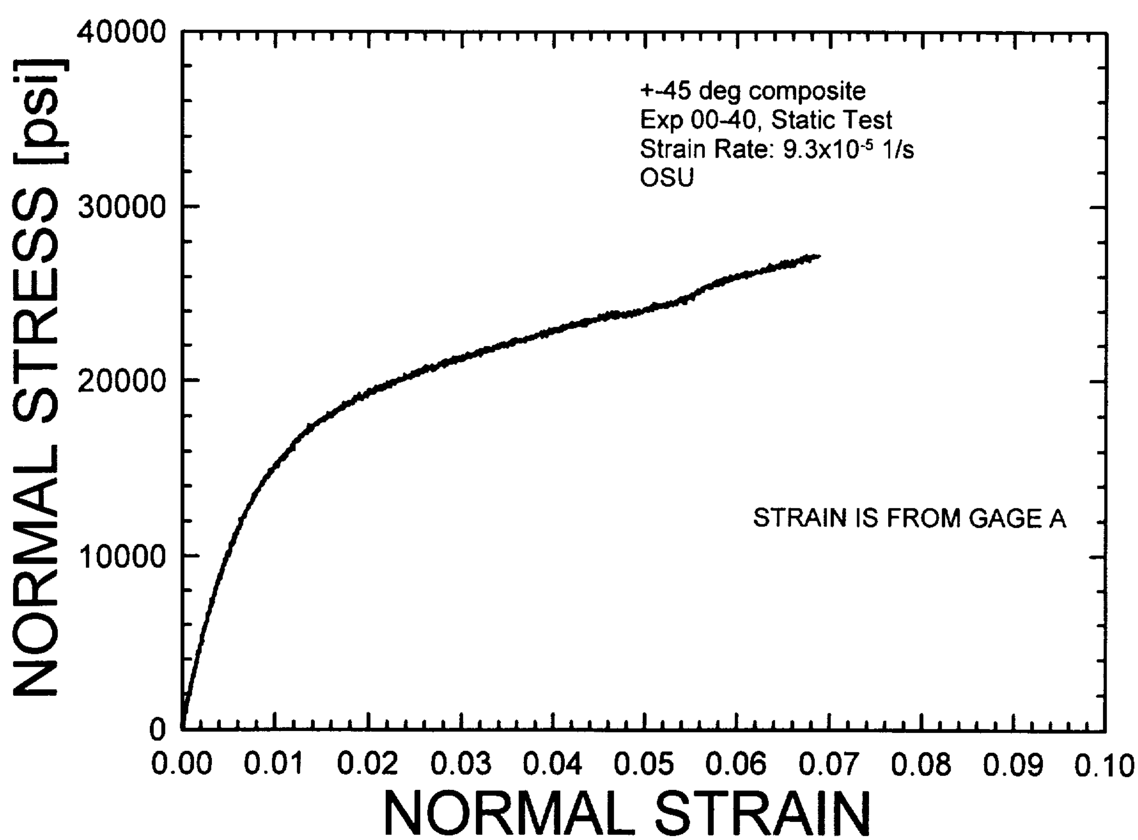

STRAIN FROM
STRAIN GAGES
STRAIN FROM
SHB EQUATIONS
+-45 deg composite
EXP00-38, Tensile split Hopkinson bar
NORMAL STRESS [psi]
NORMAL STRAIN
50000
40000
30000
20000
10000
0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14


+-45 deg composite
EXP00-39, Static Test
OSU
STRAIN GAGE A
STRAIN GAGE B
STRESS
STRAIN RATE: 3.7x10-5 1/s (elastic range)
STRAIN RATE: 9x10-5 1/s (plastic range)
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
0
10000
20000
30000
40000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
200
400
600
800
1000
1200

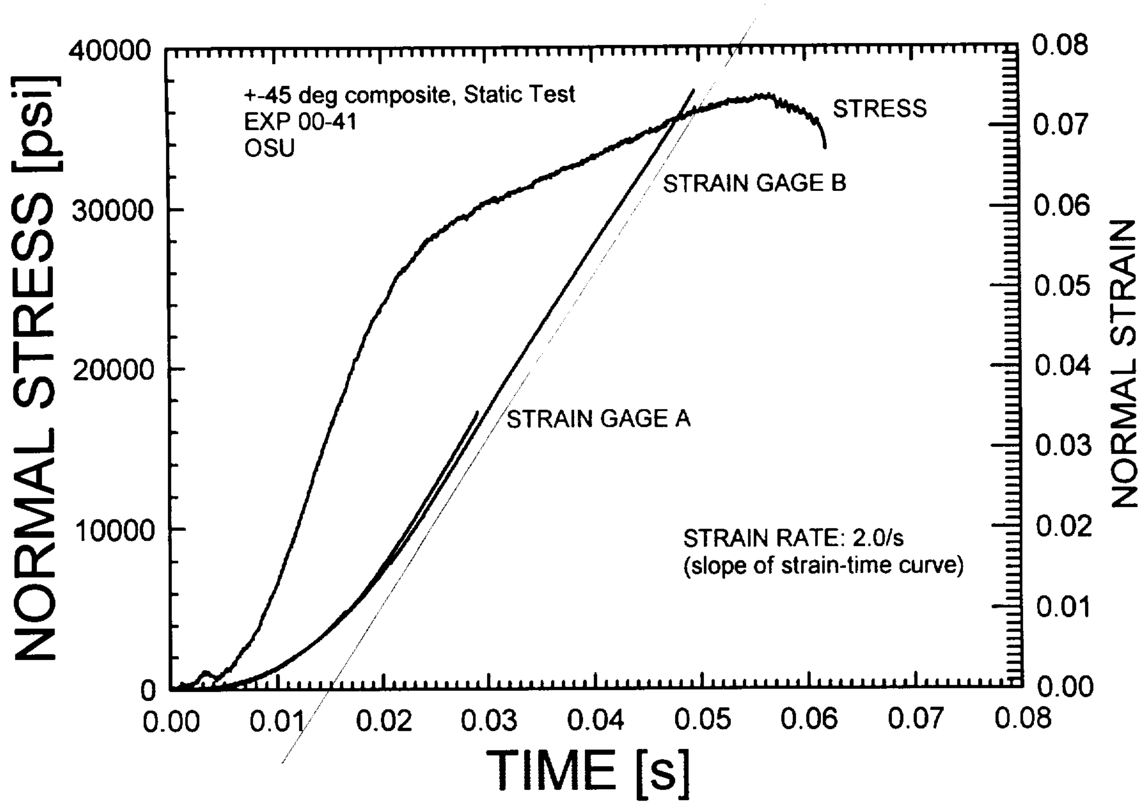

+-45 deg composite
Exp 00-39, Static Test
Strain Rate: 9.x10-5 1/s
OSU
STRAIN IS FROM GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
0
10000
20000
30000
40000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10

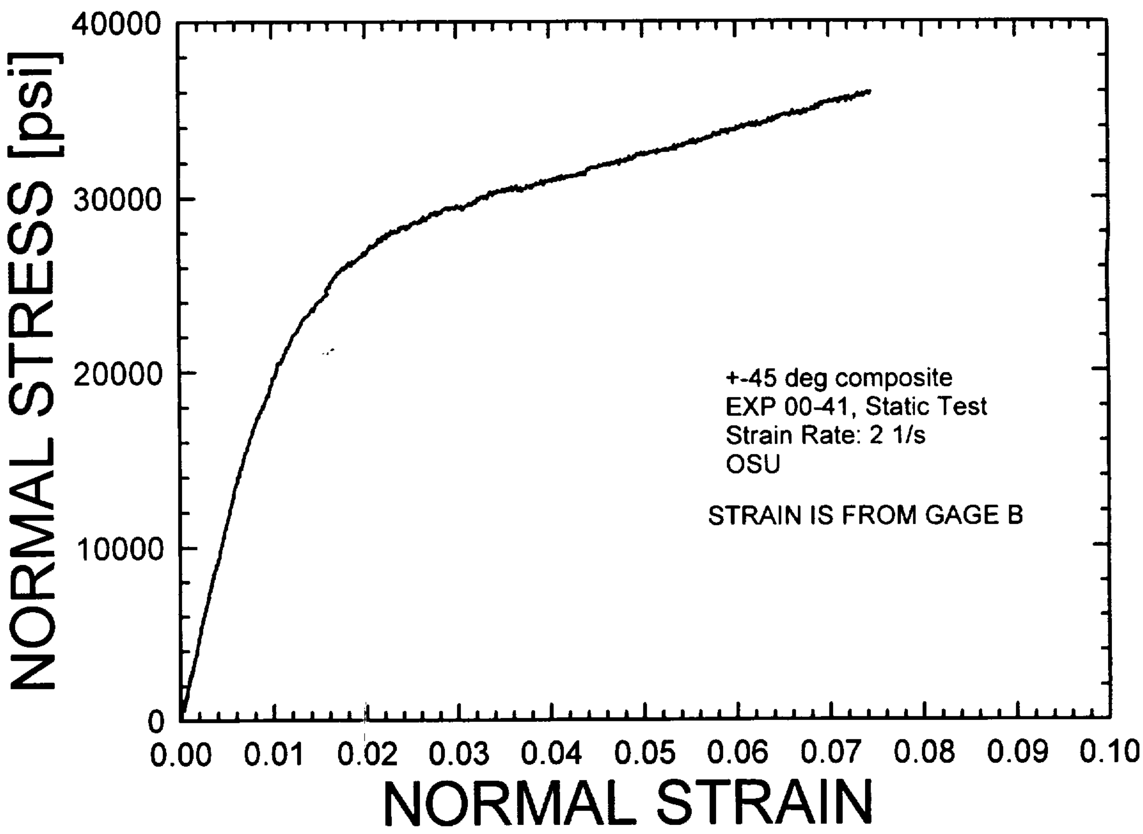


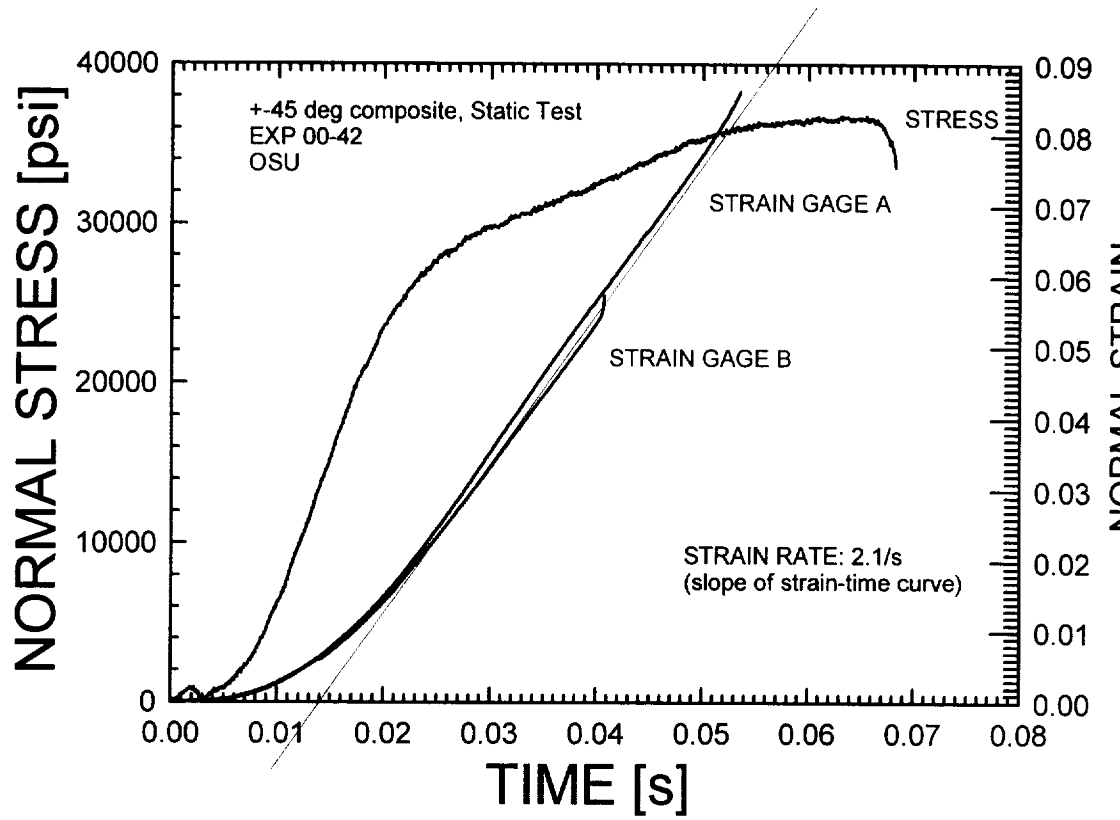
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
+-45 deg composite
EXP00-40, Static Test
OSU
STRAIN GAGE A
STRAIN GAGE B
STRESS
STRAIN RATE: 4.37x10-5 1/s (elastic range)
STRAIN RATE: 9.3x10-5 1/s (plastic range)
(slope of strain-time curve)
0
10000
20000
30000
40000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0
200
400
600
800
1000
1200
1400
1600



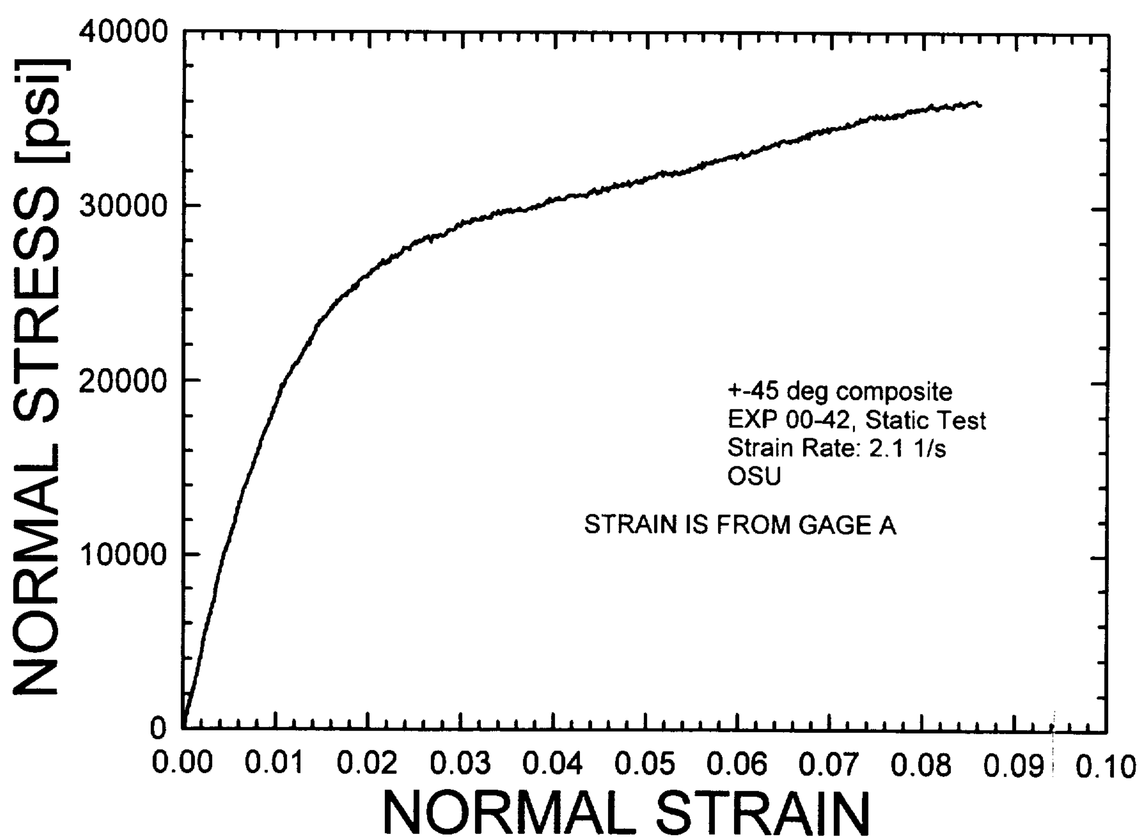
NORMAL STRESS [psi]
NORMAL STRAIN
+-45 deg composite
Exp 00-40, Static Test
Strain Rate: 9.3x10-5 1/s
OSU
STRAIN IS FROM GAGE A
0
10000
20000
30000
40000
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10


+-45 deg composite, Static Test
EXP 00-41
OSU
STRESS
STRAIN GAGE B
STRAIN GAGE A
STRAIN RATE: 2.0/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]
40000
30000
20000
10000
0
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08


+-45 deg composite
EXP 00-41, Static Test
Strain Rate: 2 1/s
OSU
STRAIN IS FROM GAGE B
NORMAL STRESS [psi]
NORMAL STRAIN
40000
30000
20000
10000
0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10



+-45 deg composite, Static Test
EXP 00-42
OSU
STRESS
STRAIN GAGE A
STRAIN GAGE B
STRAIN RATE: 2.1/s
(slope of strain-time curve)
NORMAL STRESS [psi]
NORMAL STRAIN
TIME [s]



+-45 deg composite
EXP 00-42, Static Test
Strain Rate: 2.1 1/s
OSU
STRAIN IS FROM GAGE A
NORMAL STRESS [psi]
NORMAL STRAIN