PROJECT CLOSEOUT - NOTICE

Closeout Notice Date 30-SEP-1998

Project Number E-16-N21 Doch Id 38631

Center Number 10/24-6-R8832-0A0

Project Director TALREJA, RAMESH

Project Unit AERO ENGR

Sponsor CLARK ATLANTA UNIVERSITY/ATLANTA, GA

Division Id 5858

Contract Number OSP-95-12-437-001 Contract Entity GTRC

Prime Contract Number NAS 3-27881

Title LONG TERM DURABILITY OF POLYMER MATRIX COMPOSITES FOR HIGH TEMP APPLICATIO

Effective Completion Date 10-OCT-1997 (Performance) 10-OCT-1997 (Reports)

Closeout Action:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	15-JUN-1998
Final Report of Inventions and/or Subcontracts	Y	
Government Property Inventory and Related Certificate	Y	
Classified Material Certificate	N	
Release and Assignment	Y	22-JUN-1998
Other	N	

Comments

Distribution Required:	
Project Director/Principal Investigator	Y
Research Administrative Network	Y
Accounting	Y
Research Security Department	N
Reports Coordinator	Y
Research Property Team	Y
Supply Services Department/Procurement	Y
Georgia Tech Research Corporation	Y
Project File	Y

NOTE: Final Patent Questionnaire sent to PDPI (new) E-16-N21 #1

Project No. E-16-N21

Contract No. OSP-95-12-437-001

Project Title: Long Term Durability of Polymer Matrix Composites for High Temperature Applications

Sponsor: Clark Atlanta University, Atlanta, GA

FIRST PROGRESS REPORT

Period Covered: 11/10/95 - 02/29/96

The reporting period covered following activities.

SPECIMEN PREPARATION

Procedures for preparing specimens from panels of unidirectional T650-35/AMB21 composite were developed. The panels were post cured and then machined into test coupons.

Small specimens were prepared for glass transition temperature and fiber content measurements.

Procedures for tab preparation and mounting were developed. Tab material selected was polyester reinforced with glass fiber woven fabric. Use of adhesives in the form of films or paste-on two-component epoxy was discussed.

MECHANICAL TESTING

Testing procedures were developed for monotonic testing to determine the basic stress-strain behavior. The role of tabs, strain gages and extensometer were discussed to minimize premature failures and to reduce errors. Issues concerning gripping specimens were discussed to avoid slippage and failure from tabs.

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Project No. E-16-N21

Contract No. OSP-95-12-437-001

Project Title: Long Term Durability of Polymer Matrix Composites for High Temperature Applications

Sponsor: Clark Atlanta University, Atlanta, GA

MONTHLY PROGRESS REPORT

Period Covered: 03/01/96 - 03/31/96

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The roles of tabs, strain gages, extensometer and loading rate were scrutinized. The testing procedure was witnessed in person to assure it was in accordance with normal practice. In particular the placement of specimen in the MTS testing machine, gripping, programming of loading and startup of a test were reviewed.

TEST RESULTS

Test results obtained under monotonic stressing were reviewed. Repeatability of Young's modulus, tensile strength and strain to failure were examined. The reasons for differences from expected values were discussed. Possible improvements were considered.

The failure mode under monotonic testing was discussed. Possible sources of failure initiation were considered. Attention was paid to splitting caused from tab ends versus "true" failure initiating from gage area of specimens.

Fatigue testing procedures were discussed. Selection of loading level, loading ratio and cycle shape were considered. Due to limited number of specimens available optimization of results was discussed.

Failure modes in fatigue tests were examined. Surface replication was done to get information of local failure initiation. Replicated were studied and initial conclusions concerning failure modes were drawn.

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PROGRESS REPORTS
(Deliverables 4,5,6 and 7)

Period Covered: 04/30/96 - 08/31/96

Fatigue testing of unidirectional ply laminates made of T650-35/AMB21 under computer control on a closed-loop, servo-hydraulic MTS system with a 20 kips capacity has been continued. Specimen gripping was accomplished with surfalloy finish wedge grips. Strain measurements in the longitudinal direction were obtained by a 1.0 inch gage length extensometer mounted on the side of each specimen.

Fatigue Testing

Fatigue experiments at room temperature were conducted for five unidirectional samples at a level of maximum stress, $S_{max} = 0.70\ \sigma_{ult}$, with $R_\sigma = 0.1$ $(\sigma_{min}/\sigma_{max})$. The S_{max} values were based on the average ultimate tensile strength, σ_{ult}, obtained from the static tensile test ($234*10^3$ psi). A cyclic load frequency of 10 Hz with a sinusoidal command wave form was employed.

In an attempt to overcome the problem of failure at tabs (see specimens 4 to 6a of Table I), specimens (6b, 7a, 7b, 15b and 15c) of different sizes were tested (~8.0" x 1.0" and ~10" x 0.5" inches). The reduction from a width of 1.0" to 0.5" is mainly to reduce the stress concentration at the tabs. Specimens were machine choped at AT&T in Atlanta. Epoxy liquid has been used (specimens 15b and 15c) instead of epoxy paste to obtain a more uniform bond between the tabs and the specimens.

Young's Modulus was continuously monitored throughout the test by recording the strain and the associated load. However, no stiffness reduction was observed. All specimens failed in a fiber broom failure type associated with "popping" sounds caused by the fiber bundles fracturing. An increase in number of cycles to failure has been experienced (specimens 15b and 15c). This increase is mainly due to the use of liquid epoxy, however, failure initiating at the tabs is still observed.

Based on the previous results, adhesive tapes were sought as an alternative to epoxy paste/liquid. Three candidate adhesive films were selected after contacting Mr. John Packston and R. Wallace of Cytec Engineering Materials. These candidate materials are:

1. FM34B-18 (arsenic-free versions of FM34 polyimide adhesive film),
2. FM 57 (condensation polyimide adhesive with a woven fiber glass carrier), and
3. HT424 (aluminum filled, modified epoxy-phenolic resin coated on a glass carrier)

The use of adhesive films under temperature and pressure to bond the tabs was discussed in the recent visit of the Principal Investigater to NASA Lewis Research Center, in August, 29th, 1996. It was agreed to use dog bone samples instead of rectangular ones based on the recommendation of Mr. Michael Castelli. Three panels (3" x 10" each) will be cut into nine dog bone samples (1" x 10" each) at NASA Lewis Research Center and will be tested at CAU. Adhesive films may be used in the future if failure initiating at the tabs is not overcome with the introduction of dog bone samples.

EQUIPMENTS

The following MTS equipments have been received:

1. Environmental Chamber with built-in controller (-200°F/600°F),
2. Hi-Temperature Hydraulic Grips, and
3. Hi-Temperature extensometer

The MTS machine has been rotated 90 degrees to accomodate the environmental chamber. These equipments wil be used for the fatigue testing under high temperature.

TABLE I - FATIGUE AND MATERIAL PROPERTIES OF T650-35/AMB-21 UNIDIRECTIONAL LAMINATE AT ROOM TEMPERATURE

Specimen	S_{max} (psi)	N_f	Remarks
4	0.84 σ_{ult}	127	
5	0.86 σ_{ult}	151	
1	0.85 σ_{ult}	66	
6	0.77σ_{ult}	348	
3a	0.75 σ_{ult}	3251	
2a	0.70 σ_{ult}	145	Failure initiated at tabs
2b	0.70 σ_{ult}	8	Failure initiated at tabs
4a	0.70 σ_{ult}	33	Failure initiated at tabs
5a	0.70 σ_{ult}	128	Failure initiated at tabs
6a	0.70 σ_{ult}	118	Failure initiated at tabs
6b	0.70 σ_{ult}	13,490	Epoxy paste, Failure initiated at tabs
7a	0.70 σ_{ult}	5,206	Epoxy paste, Failure initiated at tabs
7b	0.70 σ_{ult}	12,975	Epoxy paste
15b	0.70 σ_{ult}	36,222	Epoxy liquid (half width), Failure initiated at tabs
15c	0.70 σ_{ult}	20,909	Epoxy liquid (half width)

Project No. E-16-N21

Contract No. OSP-95-12-437-001

Project Title: Long Term Durability of Polymer Matrix Composites for High Temperature Applications

Sponsor: Clark Atlanta University, Atlanta, GA

FINAL REPORT

Period Covered: 10/11/95 - 9/11/96

SPECIMEN PREPARATION

Procedures for preparing specimens from panels of unidirectional T650-35/AMB21 composite were developed. The panels were post cured and then machined into test coupons.

Small specimens were prepared for glass transition temperature and fiber content measurements.

Procedures for tab preparation and mounting were developed. Tab material selected was polyester reinforced with glass fiber woven fabric. Use of adhesives in the form of films or paste-on two-component epoxy was discussed.

MECHANICAL TESTING

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FATIGUE TESTING

The fatigue testing procedure and strategy were discussed. The load levels (mean stress and amplitude) for fatigue testing were selected. The validity of tests as to the correct failure mode and location of failure in the specimen were considered. Means of reducing tab failures by varying grip pressure, adhesive type and bonding procedure were investigated. Fatigue data for neat resin was discussed and consideration was given to the type and size of specimens, load levels, test control mode, etc.

TEST RESULTS

Test results obtained under monotonic stressing were reviewed. Repeatability of Young's modulus, tensile strength and strain to failure were examined. The reasons for differences from expected values were discussed. Possible improvements were considered.

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Fracture surfaces were examined for signs of damage mechanisms that operated and led to criticality.

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#3

Project No. E-16-N21

Contract No. OSP-95-12-437-001

Project Title: Long Term Durability of Polymer Matrix Composites for High Temperature Applications

Sponsor: Clark Atlanta University, Atlanta, GA

MONTHLY PROGRESS REPORT

Period Covered: 04/01/96 - 04/30/96

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E-16-N21
#8

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