THE FIFTH CONFERENCE ON ADVANCED ENGINEERING FIBERS AND TEXTILE STRUCTURES FOR COMPOSITES

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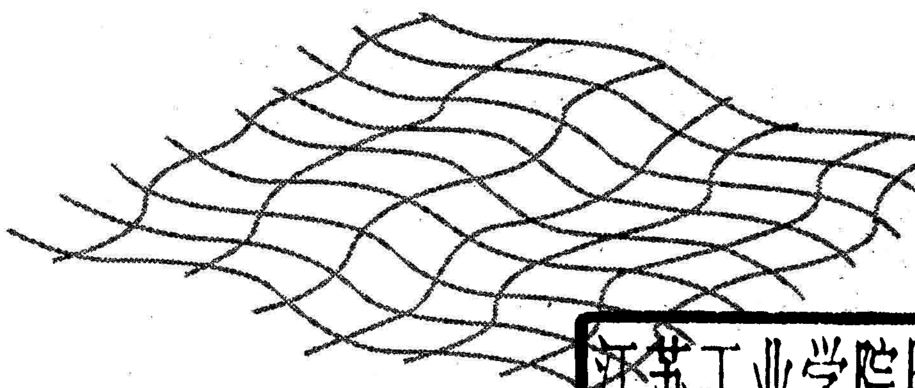
The Fifth Conference on Advanced Engineering Fibers and Textile Structures for Composites



Proceedings of a conference held in Raleigh, North Carolina October 15–17, 1991

NASA

PREFACE

The *FIBER-TEX 1991* proceedings contain the papers jointly sponsored by the National Aeronautics and Space Administration, the Center for Advanced Engineering Fibers at Clemson University, the Department of Defense, the North Carolina State University, and Drexel University. The conference was held in Raleigh, North Carolina on October 15–17, 1991 to create a forum to encourage an interrelationship of the various disciplines involved in the fabrication of materials, the types of equipment, and the processes used in the production of advanced composite structures. Topics discussed were Reinforcing Fibers, Matrix Materials, Mechanics of Woven Materials, Structural Fabric Production, Pultrusion and Composite Processes, and Structures and Applications.

Certain materials and processes are identified in this publication in order to adequately specify procedures. In no case does such identification imply recommendation or endorsement by the government, nor does it imply that the materials or processes are the only or best ones available for the purpose.

John D. Buckley
NASA Langley Research Center

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An Evaluation of Composites Fabricated from Powder Epoxy Towpreg

J. Timothy Hartness and Tim Greene

BASF Structural Materials

Abstract

BASF has developed a unique process for applying powdered resin systems to continuous reinforcement fibers in order to produce flexible towpreg material. Evaluation of three powder epoxy resins by BASF using this towpregging process is in progress under NASA contract NASI-18834. Shell RSS-1952, Dow CET-3, and 3M PR500 powder epoxy systems have been successfully towpregged with G30-500 6K carbon fiber. Both neat resin and basic unidirectional composite properties have been developed to compare performance. Cure cycles for each system have also been developed for repeatable fabrication of high-quality composite laminates. Evaluations of the powder towpreg material for use in textiles processes such as weaving and braiding are underway. Traditional 8-harness weaving has been successfully performed with one system (PR500/G30-500) to date, with some basic composite properties generated. Ongoing work will demonstrate scaleup of the towpregging process for higher throughput, as well as evaluation of the powder towpreg material in advanced preforming processes such as 3-D braiding and weaving.

POWDER EPOXY TOWPREG DEVELOPMENT

- NASA Contract/Materials Characterization
- Primary Focus Subsonic Applications (180°F Service)
- Evaluate Mechanical Performance
- Evaluate Use in Textiles Preforming
- Evaluate Manufacturing/Processing Methods

ADVANTAGES OF "DRY" MATERIAL FORMS

- Conformability
- Textile Yarn Form/Textile Technology Applications
- No Refrigeration Required

POWDER EPOXY TOW ADVANTAGES

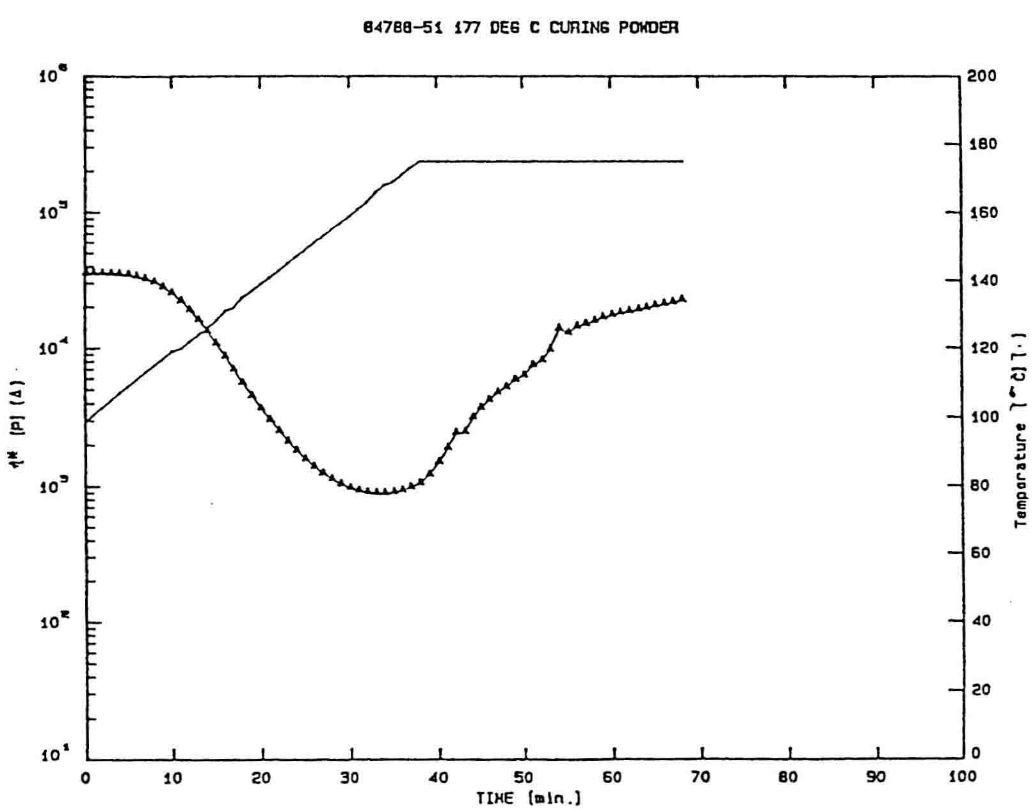
- Predetermined Fiber Volume
- "Predetermined" Chemistry
- Good Fiber/Resin Distribution
- No Solvents
- Room Temperature Storage

CANDIDATE POWDER EPOXY SYSTEMS

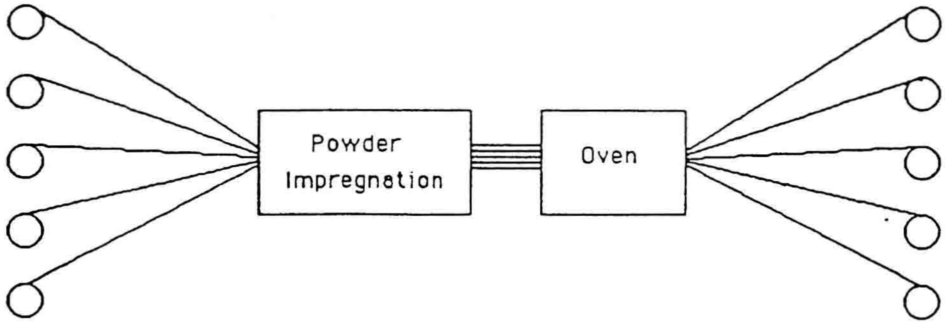
- PR-500 (3M)
- RSS-1952 (SHELL CHEMICAL)
- CET-3 (DOW CHEMICAL)

PHYSICAL PROPERTIES, NEAT RESIN

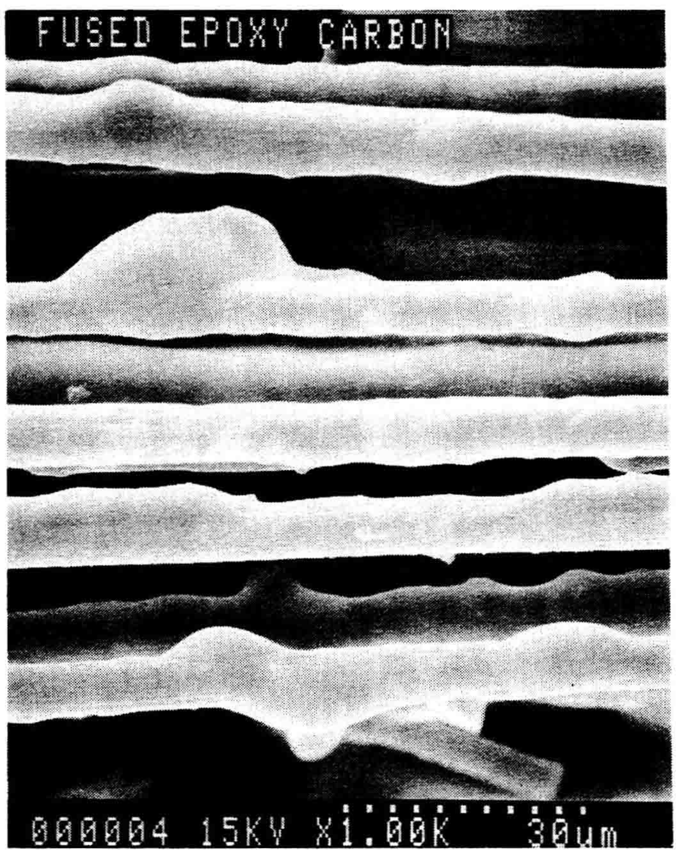
		PR-500 (3M)	RSS-1952 (SHELL)	CET-3P (DOW)
Tg (DSC, °C/°F)		205/401	219/426	164/327
TENSILE	STRENGTH (KSI)	8.3		13.0
	MODULUS (KSI)	507		410
	ELONGATION (%)	1.9		5.0
FLEXURAL	STRENGTH (KSI)	18.4	16.9	21.0
	MODULUS (KSI)	504	426	450
	STRAIN (%)	4.2	5.1	7.0
DENSITY (gm/cc)		1.25	1.15	1.27
MOISTURE ABSORPTION (% WT.)		1.56	1.1	1.35



PR-500 Powder, Viscosity Sweep



Schematic, Powder Coating Process



Powder Coated Tow, 1000X

CURE CYCLE, FUSED TOWPREG

PR-500 (3M):	350°F/2 hours
RSS-1952 (Shell):	300°F/2 hours, ramp to 400°F/4 hours
CET-3P (Dow):	300°F/4 hours; 400°F/4 hour post-cure

COMPOSITE PROPERTIES, UNIDIRECTIONAL TOW

	PR-500/G30-500	RSS-1952/G30-500
FIBER VOLUME	55%	63%
0° 3 PT. FLEXURE (RT, 32-1)		
STRENGTH (KSI)	242	320
MODULUS (MSI)	16	19
0° 4 PT. SHEAR (RT, 16-1)		
STRENGTH (KSI)	12.2	10.0
90° 3 PT. FLEXURE (RT)		
STRENGTH (KSI)	11.0	9.0
MODULUS (MSI)	1.2	1.18

PHYSICAL PROPERTIES, 8-HARNESS FABRIC

RESIN: PR-500 (3M)

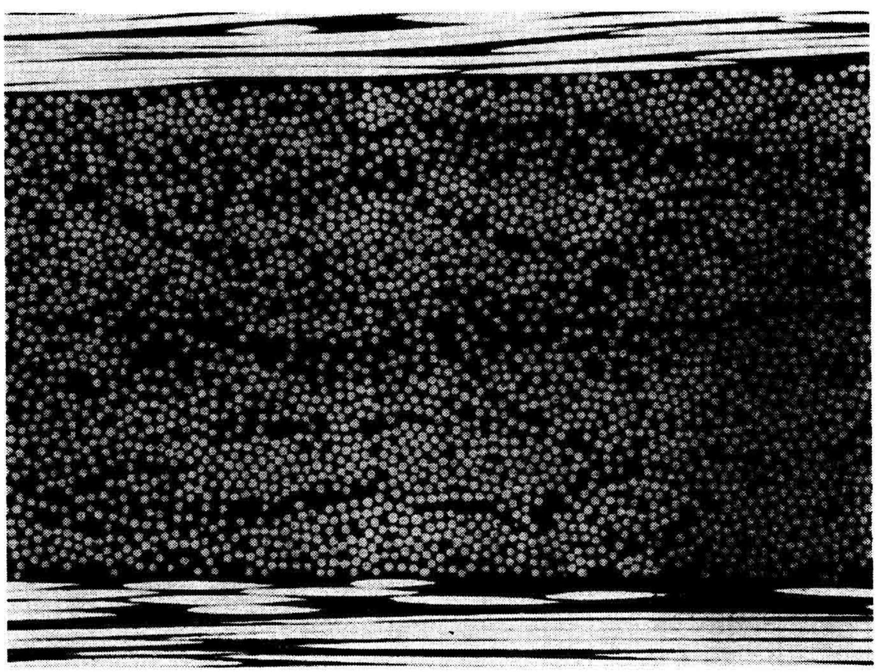
FIBER VOLUME: 56%

3 PT. FLEXURE (RT, 32-1)

STRENGTH (KSI)	102.0
MODULUS (MSI)	7.1

4 PT. SHEAR (RT, 16-1)

STRENGTH (KSI)	6.0



Photomicrograph, Cured 8 Harness Laminate

CONCLUSIONS/ACCOMPLISHMENTS

- Fused Towpreg Approach Is Viable With Powder Epoxy
- 5-Ends Successfully Demonstrated
- Fused Epoxy Tow Is Weaveable Using Standard Techniques
- Good Fiber/Resin Distribution and Wet-Out Demonstrated
- Initial Unidirectional and 8-Harness Data Generated

FUTURE PLANS

- Generate RSS-1952 and CET-3 8-Harness Fabric Data
- Complete RT and Hot/Wet Mechanical Testing
- Determine Processing Window
- Verify Preforming Feasibility (2-D and 3-D)
- Develop De-bulking and Part-Manufacturing Methods

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ADVANCED STITCHING TECHNOLOGY

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INTRODUCTION

In the design of textile composites, the selection of materials and constructional techniques must be matched with product performance, productivity, and cost requirements. Constructional techniques may vary from slow and expensive, hand laid-up batch manufacturing (one unit at a time) to very quick and cost effective continuous pull-through processing. No single textile material, resin system, textile assemblage, or constructional technique can be considered optimal for all applications.

A classification of various textile composite systems is given in Table I. In general, the chopped fiber system (Type I) is not suitable for structural composite applications because of fiber discontinuity, uncontrolled fiber orientation and a lack of fiber integration or entanglement. Linear filament yarn systems (Type II) are quite acceptable for structural components which are exposed to simple tension in their applications. To qualify for more general use as

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structural components, filament yarn systems must be multi-directionally positioned. With the most sophisticated filament winding and laying techniques, however, the Type II systems have limited potential for general load-bearing applications because of a lack of filament integration or entanglement, which means vulnerability to splitting and delamination among filament layers.

TABLE I. TEXTILE COMPOSITE SYSTEMS

Type	Reinforcement System	Textile Construction	Fiber Length	Fiber Orientation	Fiber Entanglement
I	Suspended	Chopped Fiber	Discontinuous	Uncontrolled	None
II	Linear	Filament Yarn	Continuous	Linear	None
III	Laminar	Simple Fabric	Continuous	Planar	Planar
IV	Integrated	Advanced Fabric	Continuous	3-D	3-D

The laminar systems (Type III) represented by a variety of simple fabrics (woven, knitted, braided and nonwoven) are especially suitable for load-bearing panels in flat form and for beams in a rolled up or wound form. The main features of simple fabric systems are fiber continuity, planar fiber orientation and planar fiber entanglement or integration, in general. The major vulnerability of simple fabric laminate systems is delamination between layers of the fabrics which tends to be more critical in flat panels than in rolled up tubular or rectangular configurations.

The totally integrated, advanced fabric systems (Type IV) are thought to be the most reliable for general load-bearing applications because of fiber continuity and because of controlled multiaxial fiber orientation and entanglement. Consequently, the risk of splitting and delamination is minimized and practically omitted. Type IV systems can be woven, knitted, braided or stitched through with very special equipment.

In general, multiaxial fabrics are classified as Type IV in Table I. A practical advantage of multiaxial fabrics is the elimination of much of the hand lay-up work in composite manufacturing which is so labor intensive and time consuming. Also, multiaxial fabrics are easier to handle because the various yarn orientations are held in a fixed position during manipulation. (1)

MULTIAXIAL FABRIC TECHNOLOGIES

Several alternate technologies are commercially available today for the conversion of yarn into multiaxial constructions for a variety of industrial fabric applications, but particularly for flexible and rigid composites. These multiaxial fabric technologies include adhesive bonding, triaxial weaving, triaxial braiding, weft insertion warp knitting, bias ply stitch bonding and bias warp knitting. Each multiaxial fabric technology has unique attributes and limitations, and accordingly, will find a place in the industrial fabric market on a cost/performance/availability/processability/machineability/joinability/maintainability basis.

Adhesively-bonded multiaxial systems are easily produced by combining several layers of yarn or fabric at various angles (including skewed WIWK fabrics, bias woven, etc.). While the productivity is