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CONTINUOUS UNIDIRECTIONAL FIBER REINFORCED COMPOSITES: FABRICATION AND TESTING

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CONTINUOUS UNIDIRECTIONAL FIBER REINFORCED COMPOSITES: FABRICATION AND TESTING *

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ABSTRACT: The study of the anisotropic mechanical properties of an inexpensively fabricated composite with continuous unidirectional fibers and a clear matrix was investigated. A method has been developed to fabricate these composites with aluminum fibers and a polymer matrix. These composites clearly demonstrate the properties of unidirectional composites and cost less than five dollars each to fabricate.

KEY WORDS: anisotropy, composite, fibers, matrix, reinforcement, strain, stress.

INTRODUCTION: A process was developed to make fiber composites with continuous fibers spanning the composite and aligned in one direction (Fig. 1). H.A. West and A.F. Sprecher have been studying the mechanical properties of this type of composite with samples of rubber reinforced with nylon cord.[1] These samples, however, are not readily available and require a hot press for consolidation and curing. It would be desirable to develop a system which sufficiently demonstrates the effect of fiber orientation, yet is easily fabricated from available materials. In addition to studying the parameters of this type of composite, a clear matrix was desired in order to view the fibers.

While developing this process to demonstrate anisotropic mechanical properties, it was very important to limit costs and to develop educational opportunities for composites in the laboratory and classroom. Composites are widely used in our society today; fiberglass, plywood, and concrete are just a few examples.[2]

PREREQUISITE KNOWLEDGE: The previous or concurrent study of composites, specifically continuous unidirectional composites, and their mechanical properties would be beneficial. The effect of fiber orientation on elastic modulus, Poisson's ratio, and state of strain can be investigated.

OBJECTIVE: An inexpensive fabrication process was developed for continuous unidirectional fiber reinforced composites with clear matrices in order to study material properties such as elastic anisotropy.

EQUIPMENT AND SUPPLIES: (1) Six 3" x 5 1/8" pieces of aluminum screening; (2) Utility knife; (3) Cutting board; (4) transparent or masking tape; (5) Manicure scissors or small wire cutters; (6) Three 200 mL plastic containers; (7) Plastic container 1" x 3" x 5" ; (8) Ferris see thru; (9) Por-a-mold;

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(10) Release agent (Synair 1711); (11) Vacuum pump; (12) Oven (350 F); (13) Ferris jig (see Fig.3); (14) Two 4" x 6" x 1/8" glass plates; (15) Two clamps; (16) Isopropyl rubbing alcohol to clean containers.

PROCEDURE: Composite fabrication began with the preparation of either plain or anodized aluminum screening, the fibers, which were then set up for the matrix addition of either Por-a-mold or Ferris see thru. After the composite cured completely, its mechanical properties were tested.

Fibers

After cutting the screening with the fibers at the desired angle and affixing a 1/2" border of tape to all sides (to hold the screen together), a utility knife and a pair of manicuring scissors were used to cut out the unwanted fibers. By cutting the columns between every two desired fibers, the unwanted fibers slip away and leave the desired fibers intact (Fig. 2).

While preparing several layers, usually three or five, it was beneficial to leave three of the unwanted fibers intact near the center (support wires) and place the layer under a book while working on the others. Finally, the tape and support wires were removed; the preparation time ranged from 20-60 minutes per layer.

Matrix: Por-A-Mold

In the plastic container sprayed with the release agent, three layers of identical fibers were stacked flat. Then, the por-a-mold matrix was prepared by:

(1) stirring the curative thoroughly and measuring 75 mL in a plastic container
(2) stirring the prepolymer thoroughly and measuring 75 mL in a plastic container
(3) noting the time when adding the curative to the prepolymer (9-12 minutes working time)
(4) mixing it to a clear consistency (< 2 minutes)
(5) vacuuming it for 4 minutes
(6) pouring it evenly over the fibers
(7) spraying the release agent on the surface to remove additional air bubbles.

Finally, after allowing the matrix to cure at room temperature for 16 to 24 hours,[3] the composite was removed from the container and trimmed for testing.

Ferris See Thru

When a matrix of Ferris see thru was desired, three or five identical layers of fibers were fit into the grooves of the ferris jig before clamping a glass plate to each side (Fig. 3). Then, a small amount of the white ferris see thru liquid was dripped along the edges between the glass and jig to be heat cured at 350 degrees Fahrenheit until it turned clear (5-10 minutes). After a good seal was made, 175 mL of the ferris see thru was poured into the jig and vacuumed for five minutes. The Ferris see thru was then heat cured at 350 degrees Fahrenheit. After 50-60 minutes, the matrix became a clear solid with a slight medium yellow tint. The new composite was removed from the jig after it cooled.

Testing

Several composites were made using the two matrices, two types of fiber, and angles of 0, 15, 30, 45, 60, 75, and 90 degrees. Also, a few support wires were left in many of the first composites. Before testing, the supporting border of fibers was trimmed off to yield the continuous unidirectional fiber reinforced composite.

One purpose of combining two (or more) distinct materials to create a composite was clearly demonstrated by the first two samples tested under tension. A sample of solid por-a-mold elongated 7.5 inches with only 0.19 inches of plastic deformation and broke under merely 9.5 pounds. However, the por-a-mold and anodized Al fiber composite maintained its length up to 50 pounds and did not break under 110 pounds.

The most interesting tests depict elastic anisotropy. After a 90 degree angle is marked in the center of the sample, it is placed under tension while recording any angle change and the tension (Fig.4). The original 90 degree angle may or may not change, depending on the fiber orientation.

SAMPLE DATA: For a composite of por-a-mold and three layers of anodized Al:

30 degree fibers	@ 40 lbs.	90 degrees became 97
45 degree fibers	40 lbs.	90 degrees stayed 90

INSTRUCTOR'S NOTES: These composites can be used to demonstrate and study the Rule of Mixtures and Poisson's ratio[4] in addition to calculating percent fiber content by volume and observing deviations due to slight alterations. For example, if a 90 degree fiber composite is trimmed to leave only a few unwanted (0 degree) fibers along the length of one edge, it will torque under tension. However, once the 0 degree fibers are removed, it does not torque. At high forces, slippage and fiber pullout may occur. Also, the kinks in the fibers from being woven might want to be considered.

REFERENCES:

(1) West, H.A.; and Sprecher, A.F.: "Fiber Reinforced Composite Materials," National Educators Workshop: Update '90, NIST Special Publication 822, 1991.

(2) Askeland, Donald R.: The Science and Engineering of Materials, PWS-Kent,Boston, 1970.

(3) Product Bulletin Number CC-91-02, "Basic Techniques For Using Por-A-Mold, Clear-Cut," Synair Corporation.

(4) Agarwal, Bhagwan D.; and Broutman, Lawrence J.: Analysis and Performance of Fiber Composites, Second ed., John Wiley & Sons, Inc., New York, 1990.

SOURCES of SUPPLY: While the aluminum screening can be easily purchased at a hardware store (less than $0.15 sq. ft.), the Ferris see thru can be obtained through a jewelry dealer (approximately $55 per gallon). Unfortunately, por-a-mold is no longer on the market.

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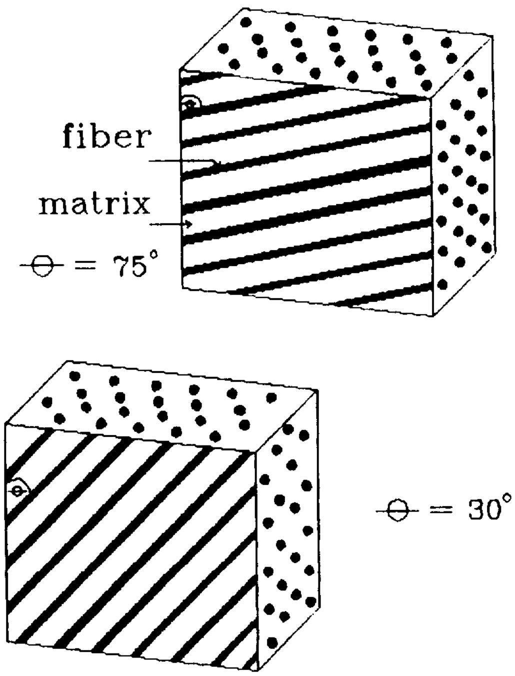

Figure 1. Continuous unidirectional fiber-reinforced composite

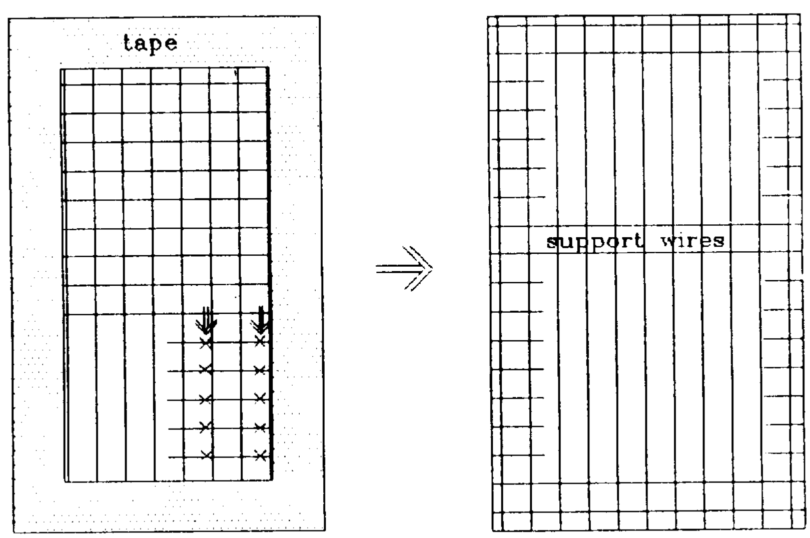

Figure 2. Fiber preparation of Al screening

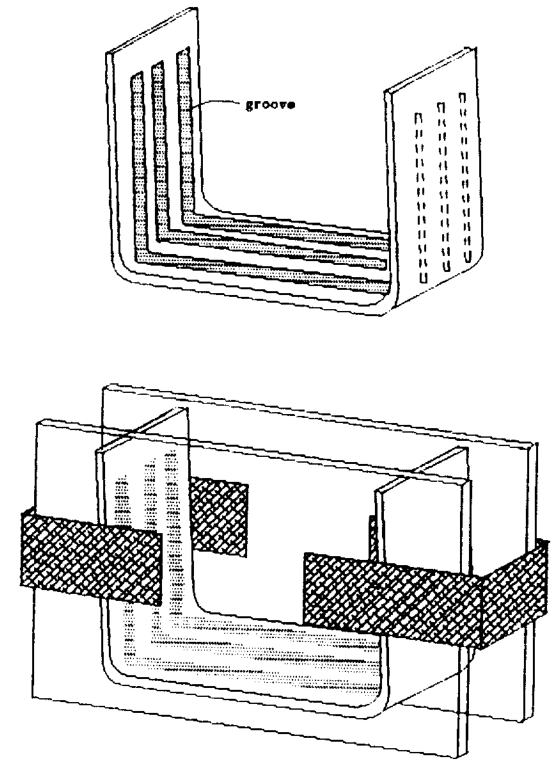

Figure 3. The Ferris Jig

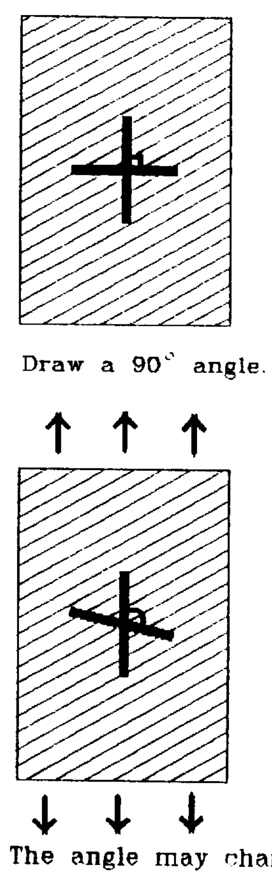

Figure 4. Composite under uniaxial tension