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MECHANICAL PROPERTIES OF 2D AND 3D BRAIDED TEXTILE COMPOSITES

by

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Textile composite materials are receiving recognition as potential candidate materials for increased damage tolerant designs on future aircraft. Design for damage has become especially important as the fleet of aircraft age beyond their design fatigue life. Textile composites can be designed to any layup providing strength tailoring capabilities. Fibers and resins can be changed to optimized materials performance. Thus, there are a large number of material combinations, layup configurations and fiber architectures to chose from which provide a large array of potential material candidates. Common examples of textile composite materials are: stitching, knitting, 2D and 3D weaving and braiding. Textile composites offer through-the-thickness reinforcement which is the key feature for preventing propagation of damage. A number of publications are available in the literature which describe general topics in textiles such as manufacturing, nomenclature and fiber architecture (Chou and Ko, 1989; Ko, 1989; Ko et al., 1986, Ko and Pastore, 1990; Mohamed, 1990; and, Zawislak and Maiden, 1988).

Although through-the-thickness reinforcement increases damage tolerance, the performance of textile composites, e.g. strength, stiffness, toughness, is not clearly understood. In the manufacturing process, bundles of fibers called yarns are distorted to provide the through the thickness geometry. This distortion may have detrimental effects on other mechanical properties, i.e. decrease stiffness and strength.

The purpose of the summer research was to determine the mechanical properties of 2D and 3D braided textile composite materials. Specifically, 2D and 3D braided textile materials designed for tension or shear loading were tested under static loading to failure to investigate the effects of braided. The overall goal of this work was to provide the structural designer with an idea of how textile composites perform under typical loading conditions.

A test program was developed around 2D and 3D textile composite materials of two fiber architectures, one designed for end load (tension) and one designed for shear, using two resin systems, PEEK and and an epoxy applied through RTM. Specimens were tested in the following configurations: unnotched tension, open hole tension, unnotched compression and compression after impact. After testing, ultimate stress, ultimate strain, elastic modulus, and Poisson's ratio were determined from stress-strain curves. A typical stress-strain curve is shown in Figure 1. Table 1 shows the results of tests conducted.

From test results for unnotched tension, it was determined that the 2D is stronger, stiffer and has higher elongation to failure than the 3D. It was also found that the PEEK resin system was stronger, stiffer and had higher elongation at failure than the RTM epoxy. Open hole tension tests were important to determine the effect of notches in braided composites. Results showed that PEEK resin is more notch sensitive than RTM epoxy. Of greater significance, it was found that the 3D is less notch sensitive than the 2D. The literature suggests that the shear design specimen is less notch sensitive than the tension design specimen, however no data was available here to make this comparison. Strain gages mounted on the specimen showed strain magnitudes as expected: stress concentration at the hole, remote stresses at the edge gage. Unnotched compression tests indicated, as did the tension tests, that the 2D is stronger, stiffer and has higher elongation at failure than the 3D. It was also found as before that the PEEK was stronger, stiffer and has higher elongation at failure than the RTM epoxy. Results also indicated that the tension specimen was stronger and stiffer than the shear specimen, however the shear specimen had higher elongation at failure as expected. Poisson's ratio found from the longitudinal and transverse gages was determined to be large, variable and nonlinear, much different than conventional composite materials. The most encouraging results were from the compression after impact. The 3D braided composite showed a compression after impact failure stress equal to 92% of the un-impacted specimen. The 2D braided composite failed at about 67% of the un-impacted specimen. Compression after impact is a primary motivation for using textile performance, i.e. higher damage tolerance is observed in textiles over conventional composite materials. This is observed in the above results, especially in the 3-D braided materials.

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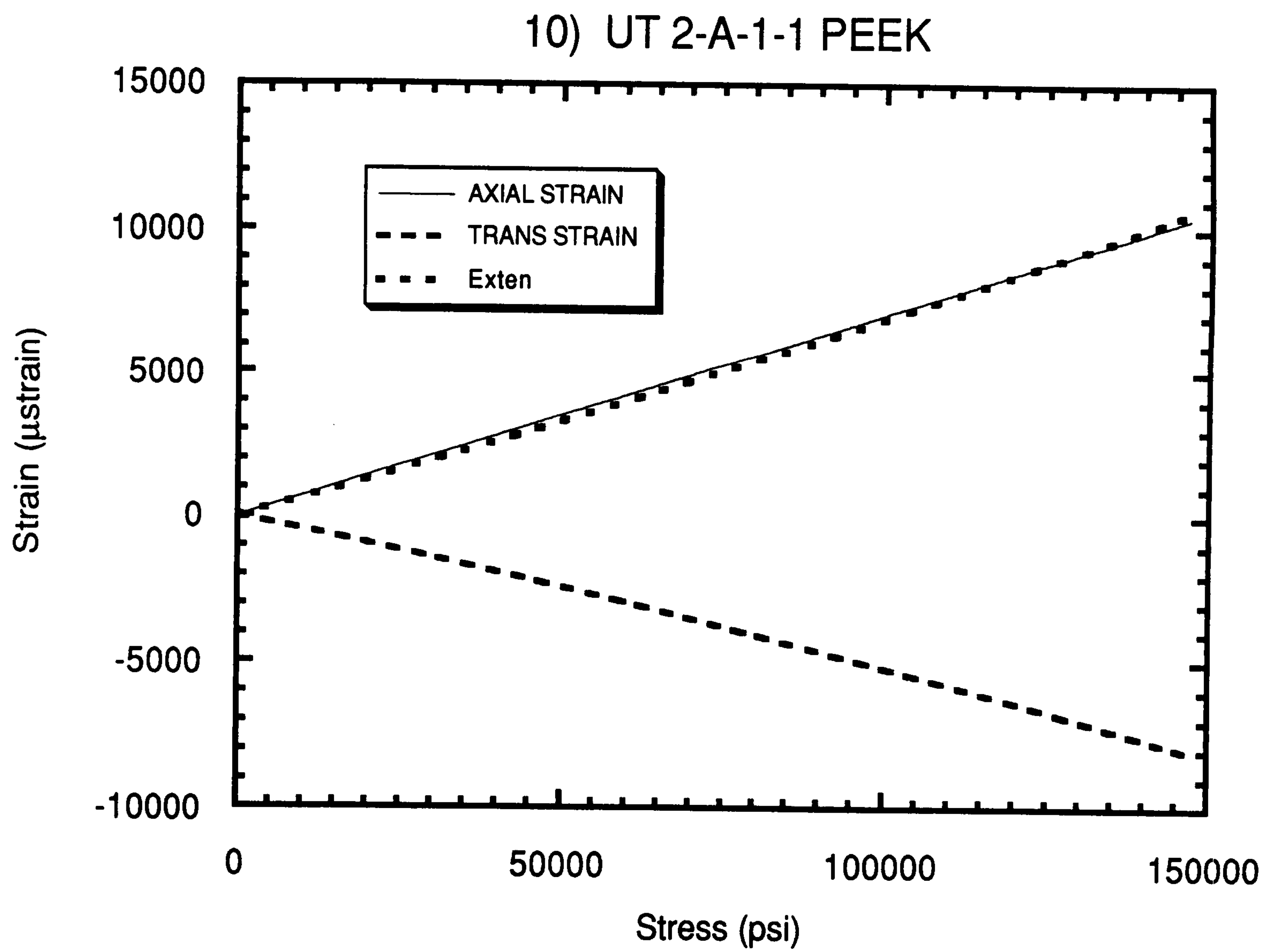

Figure 1. Stress-Strain curves for 2D tension specimen with PEEK resin.

Table 1: 2-D and 3-D Braided Average Mechanical Properties

Fiber Architecture	Loading	Failure Stress (ksi)	Failure Strain (μstrain)	Modulus (Msi)	Poisson's Ratio
2-D Graphite/PEEK	Unnotched Tension	137.9	10,262	13.39	.4 - .82
Architecture A	Open Hole Tension	81.7	5631	13.82	---
	Unnotched Comp.	71.1	5256	14.59	.56 - .65
	CAI	47.7	---	---	---
Architecture B	Unnotched Comp.	31.4	5672	6.72	.5 - .9
2-D Graphite/RTM	Unnotched Tension	106.2	8624	11.94	.78 - 1.3
Architecture A	Open Hole Tension	73.3	5313	13.43	---
3-D Graphite/PEEK	Unnotched Tension	92.0	9665	10.44	.45 - .60
Architecture A	Open Hole Tension	67.8	5263	12.98	---
	Unnotched Comp.	62.3	5551	12.05	.57 - .71
	CAI	57.4	---	---	---
Architecture B	Unnotched Comp.	39.5	5557	8.99	.43 - 1.6
3-D Graphite/RTM	Unnotched Tension	77.8	11,076	7.40	.57 - 1.3
Architecture B	Open Hole Tension	57.0	10,881	6.50	---
	Unnotched Comp.	20.9	3941	6.52	.7-.82

A - Braided geometry optimized for end load [60% Braided at 20 Degrees, 40% 0 Degrees]
B - Braided geometry optimized for shear [100% Braided at 35 Degrees]