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CHARACTERIZATION OF A KEVLAR-FILLED
EPOXY MOLDING COMPOUND

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An epoxy molding compound filled with Kevlar fibers was tested at temperatures of 24, 79, and 135°C. Both 6- and 13-mm fiber lengths were evaluated. At 135°C, the material retained approximately 50 percent of its room temperature strength. Mechanical strength was approximately the same for both fiber length materials. Both compounds expanded initially with heat, but shrank when temperatures exceeded 130°C.

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SUMMARY

A Kevlar-filled epoxy molding compound was tested in fiber lengths of 6 and 13 mm. Kevlar is an aromatic polyamide fiber. Both materials were tested for tensile, flexural, and compressive strengths at 24°C. The 6 mm fiber length material was also tested at temperatures of 79 and 135°C. Thermal behavior was determined for both materials over a temperature range of 24 to 220°C.

At 135°C the 6-mm fiber length material retained 59.1 percent of its tensile strength, 51.7 percent of its flexural strength, and 46.2 percent of its compressive strength, based on the values obtained at 24°C. The respective values at 205°C were 15.9, 19.1, and 16.7 percent.

The two materials had similar thermal expansion curves, expanding initially and then beginning to shrink with further heating. The 6-mm fiber length material shrank above 104°C, and the 13-mm material shrank above 130°C. When the two specimens were cycled a second time, neither retraced its original curve. It appeared that heating above 100°C caused a change in the material.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to test a Kevlar-filled epoxy molding compound with a fiber length of 6 mm at temperatures of 24, 79, and 135°C. Also tested was 13-mm fiber length material, and the results were compared to those for the 6-mm material. The thermal behavior of both fiber length materials also was determined.

PRIOR WORK

An investigation of the same 6-mm fiber length material was reported earlier.¹ The material was tested at 24 and 205°C. In a limited molding study, transfer-molding techniques were compared to compression-molding techniques. That investigation included a chemical analysis of the epoxy resin.

ACTIVITY

Six-Millimeter Fiber Length Material

Mechanical tests were performed on the 6-mm fiber length material at temperatures of 24, 79, and 135°C. Tests included tensile strength, flexural strength, and compressive strength. Tensile strength at 24°C was determined by both the ASTM D-651 and ASTM D-638 methods. These two methods of running tensile strength use different specimen shapes; the objective was to determine if the Kevlar fibers would orient themselves differently in the different shapes and if this would affect the tensile strength.

All material used for the test specimens was B-staged for 60 minutes at 93°C. The specimens were molded at a press temperature of 155°C and a pressure of 10.3 MPa for 50 minutes.

Results of tensile, flexural, and compressive testing are shown in Table 1. On all tests above room temperature, the specimens were conditioned for 30 minutes at the test temperature before testing.

Thermal behavior of the 6-mm fiber length material was determined over the temperature range of 14 to 180°C. The specimen, machined from a 13-by 13-by 127-mm bar, was 50.8 mm long and 9.5 mm in diameter. It was molded according to the previously described method for the mechanical test specimens.

Table 1. Mechanical Properties of 6-mm Fiber Length Material

Temperature (°C)	Specimen Number						Average
	1	2	3	4	5	6	
Tensile Strength (MPa)							
24*	75.2	59.3	72.4	78.6	97.9		76.7
24**	51.7	63.4	54.5	42.8	74.5		57.4
79**	42.8	46.2	42.1	39.3	67.6		47.6
135**	37.9	33.1	32.4	33.8	32.4		33.9
Flexural Strength*** (MPa)							
24	228.2	248.2	206.8	224.8	231.7		227.9
79	181.3	146.2	208.2	195.8	131.0		172.5
135	128.1	106.2	117.2	142.0	95.2		117.8
Compressive Strength† (MPa)							
24	170.3	167.5	154.4	157.2	146.2	162.7	159.7
79	115.1	117.2	109.6	115.8	116.5	128.2	117.1
135	69.6	78.6	74.5	77.2	69.6	73.1	73.8
Tested in accordance with:							
*ASTM D-638							
**ASTM D-651							
***ASTM D-790							
†ASTM D-695							

Complete thermal expansion curves for each cycle are shown in Figures 1 and 2 respectively. The specimens shrank above 104°C in the first cycle and above 98°C in the second cycle.

Cycles 1 and 2, which are shown on graphs of identical units, are widely separated. This phenomenon, and the shrinkage of the specimens above 98°C, indicates that some irreversible change is taking place. It is believed that this change is influenced by the presence of the Kevlar, which is an aromatic polyamide fiber.

Thirteen-Millimeter Fiber Length Material

The 13-mm material was tested for mechanical properties at 24°C only. It was not tested at higher temperatures because the high temperature properties are determined by resin and fillers and are not normally affected by the fiber length. To compare the 13-mm compound to the 6-mm compound, testing at higher temperatures was not necessary. Tests included tensile strength, flexural strength, flexural modulus, compressive strength, and impact strength. Test results are shown in Table 2.

No B-staging was necessary for this material. The specimens were molded at a press temperature of 155°C and a pressure of 10.3 MPa for 50 minutes.

Thermal behavior was determined over a temperature range of 26 to 222°C. The specimen was a cylindrical rod, 50.8 mm long and 9.5 mm in diameter. It was machined from a 13-by 13-by 127-mm bar that was molded at 155°C and 10.3 MPa for 50 minutes.

Complete thermal expansion curves for the two cycles are shown in Figures 3 and 4 respectively. The specimen shrank above 130°C for the first cycle and above 133°C for the second cycle. Again, cycles 1 and 2 are shown on graphs of identical units, and, again, the graphs for the two cycles are widely separated. Although the curves are not identical to those for the 6-mm material, they have (respectively) the same general shape.

At 135°C the 6-mm material retained 59.1 percent of its tensile strength, 51.7 percent of its flexural strength, and 46.2 percent of its compressive strength, based on the values at 24°C. As reported previously,¹ the material retained 15.9 percent, 19.1 percent, and 16.7 percent respectively of its tensile, flexural, and compressive strengths at 205°C.

The 13-mm fiber length compound was expected to be somewhat stronger than the 6-mm material; however, the material strength appeared to be approximately the same, as any differences were in the range of experimental error. No reason was found as to why the 13-mm material was not stronger.

Figure 1. Thermal Behavior of 6-mm Fiber Length Material:
Cycle 1

Figure 2. Thermal Behavior of 6-mm Fiber Length Material:
Cycle 2

Table 2. Mechanical Properties of 13-mm Fiber Length Material
at 24°C

Specimen Number	Tensile Strength* (MPa)	Flexural Strength** (MPa)	Flexural Modulus** (GPa)	Compressive Strength† (MPa)	Impact Strength†† (J/cm)
1	45.3	192.4	16.5	148.9	2.4
2	37.2	211.7	16.8	154.4	8.7
3	41.1	178.6	16.1	154.4	1.2
4	45.8	202.7	15.3	150.3	10.4
5	52.6	202.7	17.0	157.9	11.2
6				161.3	
Average	44.4	197.6	16.3	154.6	6.8

Tested in accordance with:

*ASTM D-651

**ASTM D-790

†ASTM D-695

††ASTM D-256

Figure 3. Thermal Behavior of 13-mm Fiber Length Material: Cycle 1

Figure 4. Thermal Behavior of 13-mm Fiber Length Material:
Cycle 2

For both the 6- and 13-mm molding compounds, the thermal expansion specimen expanded with an increase in temperature to approximately 100 to 130°C. Above 130°C, an increase in temperature caused the specimen to shrink; when the temperature was reduced to room temperature, the specimen did not return to its original size. Apparently, some change, which appears to be influenced by the Kevlar, is taking place in the material.

ACCOMPLISHMENTS

A molding compound (an epoxy material filled with 6-mm Kevlar fibers) was tested for tensile, flexural and compressive strengths at temperatures of 24, 79, and 135°C. At 135°C, the loss in mechanical properties was in the range of 40 to 50 percent, as compared to room temperature data.

The same epoxy material filled with 13-mm Kevlar fibers was tested at 24°C and compared to the 6-mm fiber length material. Contrary to expectations, the 13-mm fiber length material was not stronger than the 6-mm fiber length material.

Thermal behavior was determined for both the 6- and 13-mm fiber length materials. The two compounds had similar thermal expansion curves, and these did not resemble the curves for other epoxy molding compounds. Two temperature cycles were run on each material, and in each case the thermal expansion curve for the second cycle was different from that for the first cycle. It appears that a change takes place during the temperature cycle.

REFERENCE

¹J. W. McFarland, Chemical and Physical Characterization Of A Kevlar-Filled Epoxy Molding Compound (Topical Report). Bendix Kansas City: BDX-613-1816, April, 1978 (Available from NTIS).

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