FOAM CORE SANDWICH PANELS MADE FROM HIGH THERMAL CONDUCTIVITY MESOPHASE PITCH-BASED CARBON FOAM

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Introduction

Recently, a technique for producing high thermal conductivity carbon foam from a mesophase pitch precursor was developed at the Oak Ridge National Laboratory (ORNL). However, the foam is not suitable for some applications because of its brittleness and fragility. Foam core sandwich structures were investigated to improve the mechanical properties without sacrificing the thermal properties. Preliminary tests were conducted to determine the core shear, compression and thermal properties of sandwich structures with facesheets consisting of copper and aluminum. Potential applications for the lightweight, high thermal conductivity sandwich structures include heat exchangers, radiators, and heat pipes.

Experimental

Several 38.1 mm thick foam blocks were made from AR Mesophase pitch with the standard ORNL process. Sandwich panels were constructed from a 12.7 mm thick, 152.4 mm diameter foam core sections machined from the thick blocks. Both aluminum 3003-H14 and copper 110, 0.635 mm thick, were used as facesheets. A thermally conductive film adhesive, T-gon 1/KA-08-128 (0.203 mm, 8 W/m· K), was used to bond the facesheets to the foam core with a cure at 0.241 MPa, 150°C for 30 minutes. Although a slightly higher pressure was recommended for curing the film adhesive, 0.241 MPa was found to be sufficient for bonding to the foam.

Flexural tests were conducted on 107 mm by 27.9 mm samples according to ASTM C393-94 for 4 point bending with two-point loading and one-quarter span. This specimen geometry was chosen to produce core shear or bond failure. Compression testing was conducted at 5.08 mm/min for 19 mm square samples.

The thermal conductivity of the samples was determined by flash diffusivity with a Xenon probe, room temperature device. The thermal conductivity is calculated from the specific heat, density and measured diffusivity.

Results and Discussion

Four sandwich panels were fabricated for testing: two with aluminum facesheets and two with copper facesheets. The results are given as an average of specimens from each panel because the foam machined from the lower parts of the foam block had a higher density than those from the top portion. A density gradient in the foam blocks resulted from gravity effects during processing.

A typical load displacement curve and deformed geometry for the flexural tests are given in Figure 1. The flexure specimens exhibited classic shear failure with only a slight delamination of the foam from the facesheet. The results for facing bending stress, core shear stress and core shear modulus are given in Table 1. The core shear stress ranges from 1.49 to 2.35 MPa, while the shear modulus ranges from 47.9 to 111 MPa. The values for panel B with copper facesheets had a significantly higher core shear stress and core shear modulus which has not been explained.

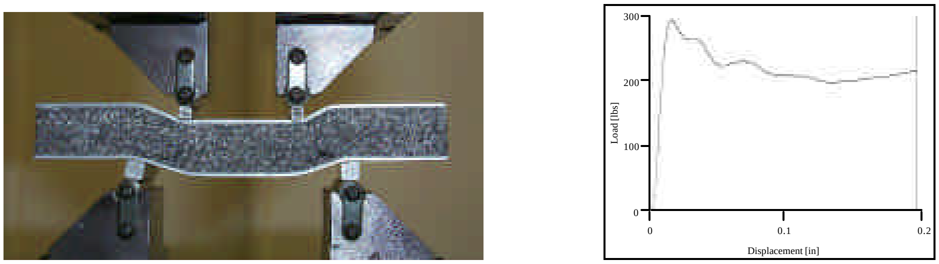
A typical load-displacement curve for the compression tests (Figure 2) shows that the foam core crushes with a fairly uniform load over a large displacement. The compression strength and modulus (Table 2) range from 1.2 to 2.5 MPa and 44 to 176 MPa respectively.

The results of the thermal conductivity testing (Table 3) indicated that the sandwich specimens had a through the thickness thermal conductivity of between 50 and 65 W/m· K with little difference between the aluminum and the copper sandwich panels. Although the thermal conductivity was decreased due to the relatively low conductivity interface, the specific conductivity of the sandwich panels is comparable to aluminum.

The average interface thickness in the sandwich panels was between 0.127 and 0.203 mm. With a thermal conductivity of only 8 W/m· K the interface was the limiting factor for the through thickness conductivity. Methods to improve the through thickness thermal conductivity include using a higher conductivity adhesive and decreasing the adhesive thickness. Several additional sandwich panels have been successfully bonded with thinner bondlines of filled epoxies (approximately 0.0254 mm). Also, a brazing technique has been developed for bonding aluminum facesheets (thermal conductivity of the brazing material is approximately 45 W/m· K).

Conclusions

Standard laminating techniques were shown to be viable for producing foam core sandwich panels. However, thin bondlines are necessary to preserve the high thermal conductivity. Through further development, graphite foam can replace honeycomb in applications that require high thermal conductivity and low weight.

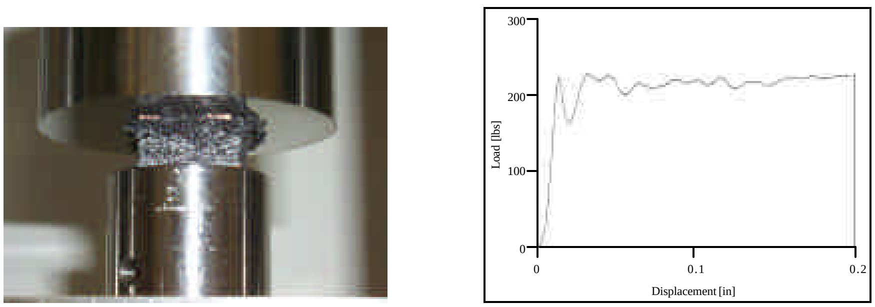


(a) (b)

Figure 1. Flexural testing (a) deformed geometry (b) typical load-displacement curve.

Table 1. Flexural test results for foam core sandwich panels.

Material	Core Density	Facing Bending Stress	Core Shear Stress	Core Shear Modulus
	g/cc (lb/ft^3)	MPa (psi)	MPa (psi)	MPa (ksi)
Al-A	*0.5 (30.8)*	*32.8 (4748)*	*1.49 (215)*	*47.9 (6.94)*
Al-B	*0.55 (33.8)*	*33.5 (4850)*	*1.52 (220)*	*58.5 (8.47)*
Cu-A	*0.43 (26.4)*	*35.7 (5163)*	*1.62 (235)*	*53.4 (7.73)*
Cu-B	*0.5 (30.8)*	*51.6 (7470)*	*2.35 (340)*	*111 (16.1)*



(a) (b)

Figure 2. Compression testing (a) deformed geometry (b) typical load-displacement curve.

Table 2. Compression test results for foam core sandwich panels.

Material	Core Density	Strength at Initial Peak	Strength at 10% deflection	Modulus
	g/cc (lb/ft^3)	MPa (psi)	MPa (psi)	MPa (ksi)
Al-A	*0.5 (30.8)*	*0.87 (126)*	*1.2 (175)*	*43.5 (6.3)*
Al-B	*0.55 (33.8)*	*2.1 (298)*	*2.2 (325)*	*134 (19.5)*
Cu-A	*0.43 (26.4)*	*2.3 (335)*	*2.2 (322)*	*199 (28.9)*
Cu-B	*0.5 (30.8)*	*2.6 (384)*	*2.5 (362)*	*176 (25.5)*

Table 3. Thermal conductivity of foam core sandwich panels.

Material	Specific Gravity	Thermal Conductivity		Specific Conductivity	
		//	⊥	//	⊥
Al-A	0.75	~150	51	200	68
Al-B	0.75	~150	64	200	86
Cu-A	1.17	~150	60	128	51
Cu-B	1.21	~150	55	124	45
Aluminum	2.77	150-200	150-200	54-72	54-72

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