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ABSTRACT

Composite materials have many desirable characteristics that contribute to the improvement of product designs that currently exist today. Use of composites brings about many changes in design, manufacturing, and production of such products, including the interface of tradition materials with composites. This study examines the interaction between carbon fiber and aluminum. The results showed that surface finish and the manufacturing of such interface did play a significant role in the strength of each sample.

INTRODUCTION

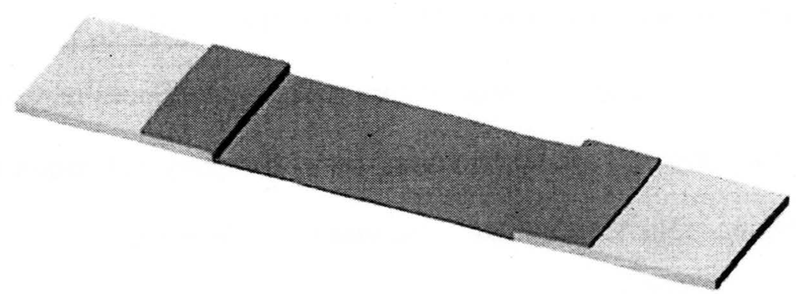
Separation, or delamination, is largely due do to a force acting along the same axis or plane of the materials interfacing surface. Tensile testing along this same plane provides adequate means for examining the strength of the interface between the carbon fiber and aluminum. In an attempt to determine the strongest bond between carbon fiber and aluminum, a simple tensile test was conducted to provide shear values for the various sample pieces. Three different surface textures and four means of attachment were tested to determine which provided the strongest bond. Each sample was tested in exactly the same manner so as to provide results acceptable for comparison.

HYPOTHESIS

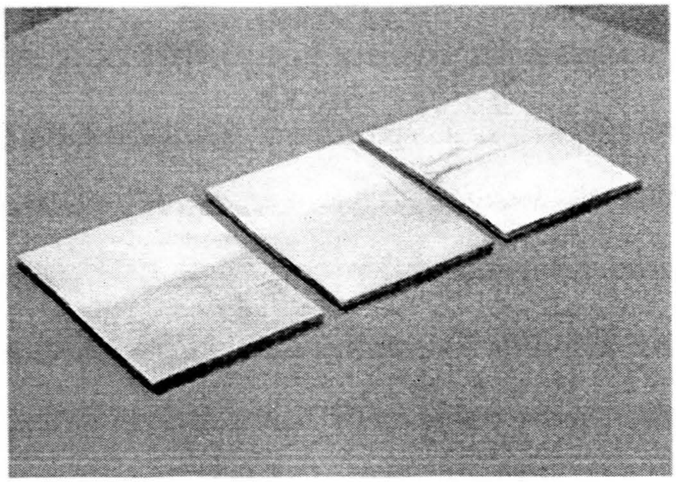
After sampling of various materials, it was proposed that a rough texture would provide a stronger bond than a smoother surface. Cotton flock is commonly used as a strengthening additive to aeropoxy and is often used for bonding carbon and aluminum interfaces. Glass beads are used as filler and were expected to be the weakest among the samples. Therefore, it was believed that the strongest sample would be the rough sample laid-up with cotton flock, and the weakest would be the glass beads laid on a smooth surface.

SETUP

Each sample consisted of two aluminum pieces that were connected using three layers of 5.7 oz. carbon fiber. The 1/8" aluminum pieces were machined using a vertical mill in order to achieve the same surface area for the bond between the two materials. Each piece was then taped off along exactly the same area to provide an adequate gripping surface. This also allowed for exactly the same bonding area to ensure proper comparison between samples. The laying-up of each sample was then conducted to connect the carbon and aluminum pieces. This is described below. The figure below shows the setup used for each sample.



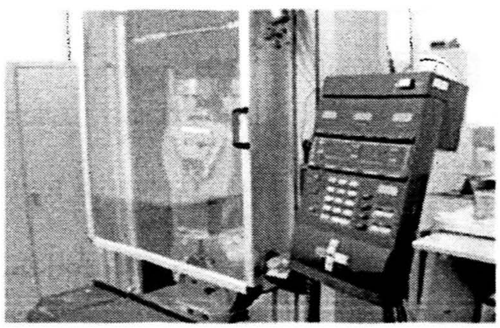
Surface texture has been found to have a rather significant role in determining the strength of a bond between items glued or epoxied together. Three surface textures were created for each lay-up process to determine the strongest surface texture associated with each lay-up process. The textures tested were as follows: a "rough" texture created by 80 grit sandpaper, a "medium" or "standard" texture created using scotch-brite pad, and a "smooth" texture created using 1500 sandpaper. The standard texture is similar to that found on a regular aluminum tube that has had the aluminum oxide layer removed from the surface. Each may be seen in the following figure. From left to right the surfaces are as follows: rough, medium, and smooth.

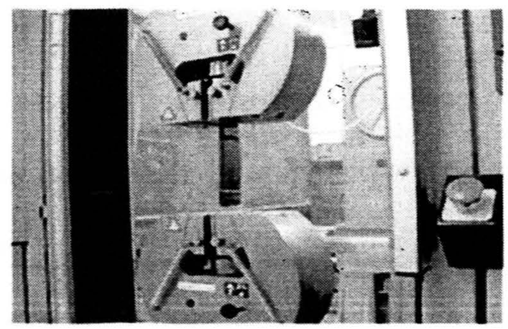


The process and medium used were proposed as the most influential factors in determining strength of the bond found between the two materials. Four different methods of bonding were used in determining the strongest bond. The first method used an aeropoxy and glass beads slurry that was squeegeed on and allowed to cure under regular room temperature. The second method used a similarly consistent slurry consisting of aeropoxy and cotton flock laid-up in the same "typical" fashion. The third method used was a simple lay up using aeropoxy, which was then put into a vacuum and allowed to cure under pressure, thus eliminating any voids between the materials. The final attachment method used consisted of a single piece of carbon that was laid-up with aeropoxy and upon curing was attached to the aluminum plate using five minute epoxy. A picture can be seen below that illustrates the setup of the vacuumed test samples.

TESTING

Each sample was placed into a tensile testing machine which applied a force to both ends to determine the shear at which each would fail. Both aluminum pieces were gripped with hydraulic clamps along the clean aluminum surface. The machine separated each end at a steady rate of 0.1 in/min. Displacement and load were recorded and graphed. The figures below show the setup used for testing.





RESULTS

The following table represents each texture and lay-up ranked according to how much strength they were found to have.

	Texture		Lay-up
1	Smooth	1	Glass Beads
2	Medium	2	Cotton Flock
3	Rough	3	Vacuum
		4	Five Minute

Shearing stress for each sample was found by using the following formula.

$$\tau = F/A$$

Where "F" is the force or load applied parallel to the area "A". The samples tested had the same area which was found by multiplying the height and width of the sample, resulting in an area of 1.6406 square inches. The force at which each sample failed varied and may be seen in the following table.

Sample	Load (lbs)	Shear Stress (psi)
11	911.70	555.70
21	1039.00	633.30
31	1221.00	744.23
12	1107.00	674.74
22	1051.00	640.61
32	879.50	536.08
13	744.20	453.61
23	590.60	359.98
33	727.00	443.12
14	17.18	10.47
24	551.90	336.40
34	671.10	409.05
Mean	792.60	483.11

The results of the test were different than what was initially hypothesized. Each Load-Displacement graph showed a distinct pattern, leading to a belief that the results found were valid. As can be seen from the chart, the strength of the sample that consisted of five minute epoxy laid-up on the smooth surface was extremely low. This is due to a mistake made while placing the sample in the tensile testing device. Partial delamination prior to loading proved to be detrimental to the shear strength of this sample. After examination of the data, it can be seen that the trend of results shows that this was in fact likely the weakest sample that was tested. The strongest sample tested turned out to be the glass beads laid-up on a rough surface.

CONCLUSION

The results found differed slightly from the hypothesis formed before the tests were performed. Texture, as well as bonding method, had significant effect on the strength of each sample. The mixture of glass beads and aeropoxy with a rough texture was found to be the strongest bond. It was more than twice as strong as the weakest sample tested. This proves the validity of the statement originally made that the bond between aluminum and carbon does in fact ultimately determine the strength of such an interface. After further examination, it appears that various adhesives may provider a stronger bond for such applications. After thorough examination of industry practices, it appears that many companies actually use a Loctite brand adhesive for such interfaces. The strength of these bonds could be again tested under the same conditions and compared to the results found in this report.

ACKNOWLEDGMENTS

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