STRESS ENGINEERING SERVICES INC.

Testing & Characterizing COMPOSITES

For Challenging Industrial Applications

From Aerospace to Pipelines

Advanced, high-performance composite materials have their roots in the aerospace industry. However, their high stiffness, strength, and ability to be laid-up onsite with relatively little manufacturing overhead have found other uses. These uses include the design and repair of large stationary equipment like pipelines, heat exchangers and pipe hangers. One of the more challenging applications is related to pipelines where composites are being used *in the field* to remediate mechanical damage and corrosion. This includes temporary and even permanent repair of leaks as a possible secondary pipeline application.

Think of Industrial Duct Tape . . .

The flexibility, both literal and figurative, of fiber-reinforced composites holds the promise that, in time, they could become the heavy industrial strength version of Duct Tape, with the same expanding list of uses offered by this ubiquitous household product.

. . . With Some Unique Challenges

The application of high-performance composites in an industrial setting, such as dents and gouges in buried piping, also generates problems of its own, not least of which is the need to lay-up laminates in circumstances which are less than ideal for producing precision fiber orientations, thicknesses, or surface quality (Figure 1). All these practical issues must be taken into account when testing composite materials intended for "rough" industrial use.

Figure 1 *Composite field repairs being completed by Armor Plate, Inc.*

Elevated Temperature Characterization of Composites

Polymer-based high-strength composites suffer from a large disparity between the strengths of the fiber and the polymer—usually a thermoset resin, resulting in a material which is very sensitive to load transference. One consequence of this characteristic is the need for great care to be taken in gripping specimens for the purpose of mechanical testing. In so-called "high tech" and early development applications, this problem can be dealt with by very carefully manufacturing specimens with machined and/or molded-in features to facilitate load transfer (Figure 2).

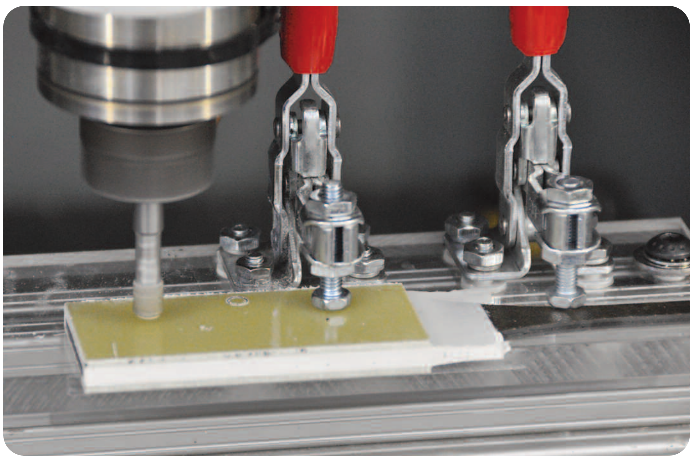

Figure 2 *4-axis mill used by SES to machine grip areas of test specimens.*

The same careful approach cannot be taken for a material whose end use may be a repair performed under difficult circumstances in the field (Figure 3).

Figure 3 *Illustration of challenging field applications of composite repairs.*
Images provided by Armor Plate, Inc.

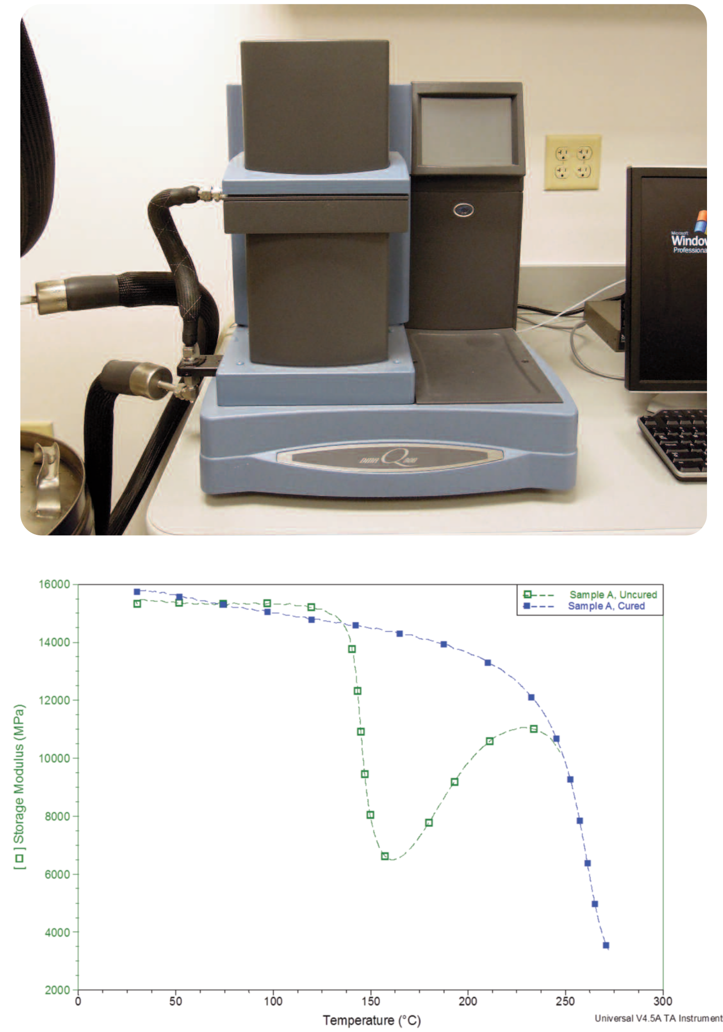

Figure 4 *DMA used to generate data for Fully Cured vs. Non-Fully Cured composite samples.*

SES Provides the Missing Link

While special test samples can, in principle, be fabricated to exactly the same standards as accepted in more sophisticated or lab applications, this may not provide a realistic measure of the product as it is used in the field. Therefore, a working knowledge of typical field conditions and application of some ingenuity to reproduce them in the lab are both needed to serve this segment of the composites industry. Stress Engineering Services (SES) provides this linkage. Using tools such as Dynamic Mechanical Analysis (DMA) technology, SES can determine whether or not the material has been fully cured—a condition that is necessary to reach the maximum strength of the composite lay-up (Figure 4).

The data shown in Figure 4 is a graph of Storage Modulus (G') from a typical Dynamic Mechanical Analysis (DMA) experiment. The samples tested above include a composite specimen that was not fully cured during the fabrication process.

Residual curing causes the sample (Sample A, Uncured) to show an initial drop in Storage Modulus followed by a rapid rise. Once the sample is fully cured (Sample A, Cured) the Storage Modulus gradually declines until the steep decline observed at the glass transition (Tg) is reached. The situation of partial curing is a real concern in field lay-ups.

Creep Testing and Elevated Temperature Tensile Testing of Composites

Composite pipeline repairs, and most all other industrial applications must be shown to be effective and safe for long periods of time. To develop the data needed to characterize and enable predictive analysis of a particular composite's performance, SES has developed a laboratory devoted to elevated temperature tensile and creep testing of plastics, composites, elastomers and metals. The lab currently includes 56 customized creep testing machines and five tensile testing machines that can be adapted to the temperature and load range required for any particular material (Figures 5 & 6).

Figure 5 *Stress Engineering Services creep testing laboratory.*

Experience Means a Culture of Ingenuity

SES's long association with piping, pipeline and pressure vessel construction in the gas, oil and power industries has developed into an in-house culture of ingenious testing procedures which suit the needs of composite material testing very well. A recent example is the development of reliable specimen gripping and heating methods for the testing of carbon fiber reinforced repair composites containing uneven surfaces and imprecise lay-ups.

Figure 6 *Stress Engineering Services Materials Characterization Laboratory.*

Meeting Challenges of Creep and Fracture

It is common for most composite repair applications to be subject to elevated temperatures. In complex geometries, where load cannot always avoid being transferred by shear in the polymeric matrix, time dependent deformations (creep) and fracture can be problems. This poses a special challenge in the laboratory. Typically, components intended for elevated temperature service will eventually fail. The only question is the length of their useful life.

Accelerated Testing is Key

In heavy, static ground-based compositiess applications, the required service life is invariably several years or even decades. It is not practical to wait 30 years for the results of tests which will be used in designing a component with a 30 year design life, so accelerated testing, either by raising the stress or the test temperature, are the most practical approaches. Both of these actions significantly increase the challenge of gripping the specimen while avoiding premature failure *in the grips* instead of the test gauge length.

For these industrial applications, the only practical method of accelerating the test is raising the temperature. With temperature as the only option, a challenge still remains because the through thickness compression strength of the specimen is largely provided by the polymer matrix, which relaxes depending on the manner of gripping, with premature failure occurring in the grips.

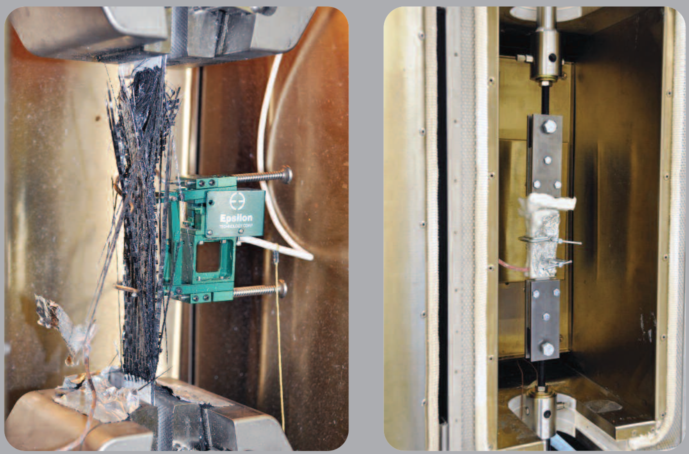

Figure 7 *Local heating of composite specimens during tensile testing.*

SES has developed a solution to this problem by using local heating only in the gauge length, while the gripped ends are maintained at a lower temperature (Figure 7). This approach, which has been used for both creep testing and elevated temperature tensile testing, eliminates the issue of premature grip failure.

Stress Engineering Services has the resources and the capabilities to perform the innovative tests needed to characterize the properties of composite materials for a wide range of industrial applications. The data that can be collected is invaluable to determining both the short and long term performance of industrial composite applications.

For All Your Composite Testing and Material Characterization Needs

Call SES Today at 513-336-6701

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