Environmental Effects on Glass Fiber Reinforced PPS Stampable Composites

A.Y. Lou and T.P. Murtha

Abstract. The application of polymer composites in engineering structures is contingent upon their property retention and dimensional stability after extended temperature-humidity exposure in service. Mechanical properties of composites decrease with increasing temperature-humidity and the percentage of property retention generally depends on the exposure time. In this paper, the properties of a long and a short glass fiber reinforced polyphenylene sulfide were evaluated after exposure to elevated temperatures, both in air and in water, for extended time periods. Properties measured included tensile, compressive, flexural, impact, and fatigue. The polyphenylene sulfide (PPS) composites exhibited good dimensional stability, as well as property retention, after exposure to the severe temperature-humidity conditions. Effect of temperature alone was negligible; however, some property reduction was measured in the presence of water at elevated temperatures. These property reductions were observed to level off over time at respectable values. The fatigue performance of PPS composite was unaffected by exposures to the high temperature-humidity.

INTRODUCTION

The behavior of polymer matrix composites when subjected to a combination of high temperature-high humidity environments is critical in many engineering applications. ASTM has devoted several exclusive volumes [1-3] to this subject, mainly for the advanced thermoset composites. The influence of water absorption becomes even more severe for the glass fiber reinforced composites since it is known that moisture attacks the glass fiber-matrix interface, especially in the presence of high temperature [4-5]. Polyphenylene sulfide has been used extensively in the neat resin form as a coating material and as matrix materials in injection molding compounds. It has good resistance to hostile environments, which include high temperature-moisture and corrosive chemicals [5-10]. The chemical resistance has been studied and reported in a recent paper [11] for the thermoplastic, PPS stampable composite, AG20-40, together with a brief description of its resistance to humidity. In this paper, the scope of study on effects of environmental exposure have been expanded to include more subjects.

1. Two PPS stampable composites were selected for this study—a long glass fiber reinforced, AG20-40, and a short glass fiber reinforced, AG10-20.
2. Expansion of material property measurements was undertaken to include tensile, compressive, flexural, impact, and fatigue properties.
3. Additional environmental conditions were considered—high temperature and/or high humidity—for various time frames.

MATERIALS AND INSTRUMENTATION

Composite Materials

The composite materials used in this study are described in Table 1 and represent two different classes of stampable composites, long/continuous and short/chopped fiber reinforcement. These composites, designated as AG20-40 and AG10-20, respectively, are commercially available from Phillips Petroleum Company. AG20-40 is reinforced by 40% (by weight) continuous, swirl glass mat and AG10-20 has 20% 1 in. chopped glass fibers.
Table 1. Glass Fiber Reinforcement

<table>
<thead>
<tr>
<th>Glass Fiber</th>
<th>AG20-40</th>
<th>AG10-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Swirl mat</td>
<td>Chopped fiber mat</td>
</tr>
<tr>
<td>Fiber length</td>
<td>Continuous</td>
<td>1 in.</td>
</tr>
<tr>
<td>Content, wt%</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>

Specimen Preparation
10 in. × 10 in. × 1/8 in. composite panels were compression molded by using a heated positive pressure mold from layup stacks of either AG20-40 or AG10-20 production sheets following the procedures outlined in previous publications [12-14]. Tensile, compressive, and flexural specimens were cut from these panels by using a circular diamond saw. The dimensions of these specimens were specified by ASTM D 3039, D 3410 and D 790 standards, respectively. All specimens were inspected carefully for voids and imperfections and annealed at 204 ~ C (400 ~ F) for 2 h before environmental aging and testing.

Environmental Conditions
In this study, specimens were tested at elevated temperatures up to 232 ~ C (450 ~ F). Environmental aging of the composite specimens was conducted at elevated temperatures with and without exposure to water.

Temperature Chamber
An Instron model 3110 environmental chamber was used for aging in hot air as well as for testing at elevated temperatures. This environmental chamber utilizes radiant heat for uniform temperature control up to 315 ~ C. The long-term thermal stability is ±1 ~ C.

Exposure to Hot Water
As described in an early paper [11], stainless pipes 1.5 in. inside diameter and 12 in. long were instrumented for hot water aging. Composite specimens were placed in sealed tubular containers filled with distilled water. Elevated temperatures were provided by placing these tubes in a Techne oil bath filled with DC-200 silicon oil. Constant temperature within ±1 ~ C was controlled up to 200 ~ C by a Techne TU-16A.

Environmental Aging
Specimens were measured for their dimensions and weighed precisely before either temperature exposure in the Instron environmental chamber or hot water aging in tubular containers. After a predetermined aging period, specimens were weighed and dimensions measured immediately after cool down. In the case of hot water aging, specimen surfaces were dried with a cloth after removal from the pipe containers.

Testing
Tensile, compressive, and flexural tests were conducted on an Instron 1125 loading frame following the procedures outlined in ASTM Standards D 3039, D 3410, and D 790, respectively. Impact tests were carried out on a MTS High Rate Impact Tester, and fatigue tests were conducted on an Instron 1331 fatigue tester. The test equipment and procedures were described in references [15] and [16], respectively.

RESULTS AND DISCUSSIONS
Room Temperature Properties
Static tests of tensile, compressive, and flexural properties were conducted at room temperature, 24 ~ C (75 ~ F), for both stampable composites, AG20-40 and AG10-20. Results obtained from these original specimens are listed in Table 2 and used as the unaged controls. Data shown is an average of measurements from three specimens. All tests were conducted under 2.54 mm/min (0.1 in./min) crosshead speed. An ITFRI compression fixture was used for the compressive tests, with a MTI DSST strain transducer to record the strains in tensile and compressive evaluations. Impact tests were carried out on the MTS high rate impact tester at 1.27 m/sec (50 in./sec). Previous results have shown that the maximum impact resistance was observed at this impact speed for both stampable composites [15]. In Table 2, both initiation and impact energies are listed.

Properties at Elevated Temperatures
The mechanical performance of an amorphous polymer depends strongly on its glass transition temperature, Tg. Above this temperature the mechanical properties decrease rapidly. Polyphenylene sulfide has been shown to be a semicrystallized polymer with 60–65% crystallinity. Because of this material characteristic, PPS-based composites exhibit good property retention at temperatures much higher than its Tg—approximately 85 ~ C (195 ~ F) as measured from a differential thermal analysis (DTA) thermogram [17–19].

Both tensile and flexural properties were measured for the long glass fiber reinforced PPS composites, AG20-40, at elevated temperatures up to 232 ~ C (450 ~ F). In Figure 1, the tensile modulus decreases slowly with increasing temperature. The rate of modulus decline does not increase substantially around the glass transition temperature. This is a typical material characteristic for a semicrystalline polymer. As high as 60% of its modulus is retained at 232 ~ C (450 ~ F).

Tensile strength is a measure of failure in materials under tensile loads. The PPS composite retains surprisingly high strength values at elevated tempera-