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Influence of Moisture and Reduced-temperature Thermal Cycles on the Izod Notch Toughness of a Pultruded Glass-Fiber Composite

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ABSTRACT

An investigation was conducted into the effects of moisture, low temperatures and low-temperature thermal cycling on the notched Izod impact resistance of a pultruded, glass fiber-reinforced polymer composite. Impact tests were performed on composite specimens with a 90-degree V-notch resulting in a fracture surface parallel to the fiber direction. The test matrix consisted of 2 major groups, dry (as received) and wet (moisture conditioned), with each group independently tested to determine the influence of low temperatures and thermal cycling. The temperature effect was addressed by impacting several specimens at 25°, −5°, −25° and −50°C. The effect of thermal cycling was subsequently studied by impacting specimens after completion of 50, 150 and 300 cycles between 25°and −50°C. The findings reveal that moisture, temperature and low-temperature thermal cycling all influence the Izod impact toughness of the material system tested, although the effects were not always as anticipated. A summative review and discussion of previous work on the impact toughness of fiber-reinforced polymers is provided, and the results of the current test program are discussed within the context of the previous research.

INTRODUCTION

Composite materials are becoming very prominent and popular in the commercial sector. Manufacturers of fiber-reinforced plastics (FRPs) are producing various bars, plates and even structural shapes that are intended to compete with more traditional structural materials such as wood and steel. These new composites have several advantages over the traditional materials: Composites are very light, have high strength-to-weight ratios, and are extremely stiff. However, as more FRPs are placed into service in nontraditional applications, they may be required to perform in extremely adverse environmental conditions.

Cold regions are a critical service environment for composite material usage. The northern latitudes of the United States can see temperatures as low as −45°C. In addition to low temperatures, the material system may be exposed to snow, ice or moisture. Any material system to be used in such an environment must be capable of handling various combinations of loading (static, cyclic or impact), thermal cycling, moisture, ice and snow. Unfortunately, only a small amount of data are available on the performance and characterization of polymeric composites subjected to these environments.

In March 1998 an NSF-funded workshop was conducted at the U.S. Army Cold Regions Research and Engineering Laboratory, to "identify the research needs and establish priorities over the complete spectrum of topics pertinent to the applications of composite materials in cold regions." The Cold Regions Composites Workshop (CRCW) concentrated on 4 areas of concern: thermomechanical problems, durability of composites in cold environments, composite structural elements, and hybrid/smart materials for cold regions (NSF Draft Report, 1999). The CRCW's overall conclusion was that additional research was needed in these areas to ensure that FRP composite behavior is well understood and any usage of this material in these adverse environments is thoroughly engineered.

This paper addresses 2 topics concerning the use of FRP composites in severe environments. First, the paper provides a summative discussion on impact-related behavior at reduced temperatures and details the current state of knowledge in this area. Second, the paper adds to that knowledge base through the results of an independent study conducted by the authors. The study addresses the effects of moisture, low temperatures and low-temperature thermal cycling on the parallel-to-the-fiber Izod notch toughness of a commercially available glass fiber-reinforced plastic.

PREVIOUS RESEARCH

The effect of the environment on the durability and performance of polymeric composites has long been an area of concern. Polymers are sensitive to moisture and temperature; this sensitivity may lead to significant variations in the structural integrity of polymer composites with relatively small changes in environmental conditions. With the increased use of composite materials

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