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Effect of Load Rate on Notch Toughness of Glass FRP Subjected to Moisture and Low Temperature

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An investigation was conducted into the effects of moisture, low temperatures and load rate on the parallel-to-the-fiber notched impact toughness of a pultruded glass-fiber reinforced polymer composite. Tests were performed at 2 load rate levels using Izod (low load rate) and Split Hopkinson Pressure Bar (high load rate) impact devices. For each load rate, specimens were tested at 2 moisture levels and 4 temperature levels (25, −5, −25 and −50°C). The results reveal that load rate has the greatest influence on fracture sensitivity for a notched specimen; increasing the rate of loading results in increased mean notch toughness values regardless of moisture content or temperature. It was also determined that, as temperatures are reduced below −25°C, the mean notch toughness increases for all test groups. At room temperature the effect of moisture is dependent upon the rate of loading. At low load rates, absorbed moisture is beneficial to fracture sensitivity, but at high load rates the absorbed moisture tends to reduce the notch toughness of the composite. A discussion is also provided on the effects of high load rate on the composite strength and stiffness.

INTRODUCTION

The mechanical behavior of a material system can be influenced by many external factors. Three predominant factors that can affect mechanical behavior are temperature, moisture and rate of loading. A material that exhibits ductile behavior at room temperature may become brittle at low temperatures or may soften and creep at elevated temperatures. With these temperature fluctuations, changes in strength and/or stiffness are often observed as well. Moisture can be detrimental by way of corrosion or absorption. Heavily corroded materials typically have reduced load-carrying capacity due to the reduced sectional properties, and some materials can absorb water resulting in changes in their physical and mechanical properties. The rate at which load is applied also affects material behavior. Many mechanical tests performed in the laboratory are conducted under static or quasi-static conditions. The properties obtained from these tests are valid as long as the material is loaded in a similar fashion. However, if the material is subjected to a dynamic loading, then the properties obtained from a static test are questionable. Mechanical tests performed at different load rates or strain rates would need to be conducted to determine the response of the material system to this type of loading.

One material system that is becoming very popular in the civil, military, aerospace and recreational arenas is the fiber reinforced polymer (FRP) composite. These FRP systems' light weight, corrosion resistance, and high specific strength and stiffness make them a very attractive alternative to the more traditional material systems. With their increased usage, many of these FRP systems are placed in applications where adverse environmental conditions, such as moisture and elevated or reduced temperatures, are typical. In addition, some of these applications are in structures that will be subjected to dynamic loads. Examples of dynamic loads are automobile collisions, civil structures subjected to low- and high-velocity impacts, bird strikes on aircraft, debris striking rotor blades, and explosions.

Very few studies reporting on the combined effects on FRP of moisture, reduced temperature and dynamic loading are found in the literature. Without this information the task of analyzing or designing structures made from fiber reinforced plastics becomes daunting. Resulting designs may be overdesigned to compensate for the lack of knowledge, or they may be inadequately designed with possible catastrophic results. To fully utilize this material it is necessary to determine the response of the material to adverse environmental conditions and varying rates of loading. Only then can efficient and safe designs be achieved with FRP.

The primary objective of this study is to determine the effects of moisture, low temperatures and load rate on the parallel-to-the-fiber notch toughness of a glass-fiber reinforced composite. A second objective is to compare the effects of moisture and low temperatures on the high load-rate, force-deformation behavior of the chosen glass FRP. The results provide an assessment of

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