Experimental Mechanics of Fiber Reinforced Composite Materials

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Projectile Impact Behavior of Flock Fiber Z-Reinforced Composites

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ABSTRACT

The performance of laminar composite materials under high strain rate impact loading conditions is studied. Laminated composite materials are widely used in industry. Historically, one of their main disadvantages is their poor interlaminar shear strength. Recent work has demonstrated a method of Z-direction reinforcement of these composites using electrostatic flocking techniques that improves delamination resistance and fracture toughness without degrading the composite's tensile strength or other in-plane properties. Z-direction reinforcement is accomplished by inserting short fibers perpendicular to and between the composite layers.

Since impact by foreign objects can occur in many industry/military applications, it is important to understand the performance of these reinforced composites under high strain rate impact loading conditions. In this study, Z-direction reinforced test panels were fabricated using established techniques. A gas gun was constructed and used to shoot .45-caliber lead and copper projectiles in a direction perpendicular to the plane of the laminar panels at test velocities above and below the ballistic limit of the laminar panel material. Muzzle velocity and after-impact velocity histories of the projectile were recorded and used to calculate the kinetic energy absorbed by the panels. The damage area was also quantified and compared. The results show that Z-direction fiber reinforcement favorably affects the impact resistance of laminar composite materials. It was shown that the panels constructed from glass fiber mat are 3 to 4 times better at absorbing ballistic impact energy than the glass fiber woven fabric, regardless of their Z-direction reinforcement methodology. Even though less capable of absorbing ballistic impact energy, the glass fiber woven fabric based panels exhibit a greater improvement when reinforced in the Z-direction than the glass fiber mat based panels.

Keywords: Flock Fiber Reinforcement, Projectile Impact, Laminated Composites

1. INTRODUCTION

Laminated composite materials are widely used in many industry applications. Impact by foreign objects can occur in many of these applications. Impact rates on composites can range from 1 m/s for a falling object to 10-100 m/s for runway debris hitting an airplane and 100-1000 m/s for a bullet impact on body armor [1], [2].

Historically, one of the main disadvantages of laminated composite materials is their poor interlaminar shear strength due to little reinforcement between the layers. Recent work by Hoskote et al. [3] and Feng [4] demonstrated a method of fabricating layered fabric composites using inter-ply electrostatic flocking techniques that improves delamination resistance and Mode I and Mode II fracture toughness without degrading the composite's tensile strength or other in-plane properties. The electrostatic flocking method has been used in the textile industry since the 19th century and involves using an electrical field to transport and orient short mono-filament textile fibers orthogonal to the fabric layers during manufacture.

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