Morphological Changes in HMPE Fibers Induced from Transverse Pressures and its Application to the Study and Mapping of Ballistic Impacts on Unidirectional Laminates.

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The transmission and dispersion of forces from ballistic impacts on cross-plied unidirectional (UD) laminates of high modulus polyethylene (HMPE) fibers were investigated by measuring changes in crystal morphology in HMPE fibers by wide-angle x-ray diffraction (XRD) using a parafocus geometry. The changes in crystal morphology in HMPE fiber laminates were studied by applying increasing pressure in the direction normal to the fiber axis at room temperature. With increasing pressure there was an increase in the monoclinic phase due to a partial transformation of the orthorhombic phase to the monoclinic phase. This transition has been attributed to the slipping of polymer chains in the orthorhombic structure perpendicular to the chain axis [1]. This partial transformation decreased the crystalline order in orthorhombic crystals as evident by increasing the width of its diffraction peaks. The transverse pressure also reoriented polyethylene crystals in the fibers from a random radial orientation to that with a preferred orientation in the direction of the applied pressure. The relationship between HMPE fiber morphology and transverse pressure were studied for pressures up to 414 MPa (60,000 psi).

When high velocity ballistic projectiles are stopped in a composite of layered flexible ballistic materials the force of the impact is transmitted through the remaining unpenetrated layers. The force of the impact is partially dissipated as it traverses through remaining layers of fibers, both along the extended impact axis of the projectile, and radially from the axis before being transmitted to a backing material. The transmission of the forces changes the morphology of the HMPE fibers accordingly. This results in a 3-dimensional gradient of HMPE fiber morphology which can be used to map the impact force in the underlying layers of unidirectional HMPE fiber laminates [2].

This paper will outline the XRD procedure, which was significantly expanded and improved from our initial study [2], along with examples of contoured maps of PE morphology from selected ballistic configurations.

(1) T. Seto, T. Hara, and K. Tanaka, 1968, Jpn. J. Appli. Phys., 7:31-42.
(2) S. T. Correale, L. Wagner, B. L. Grunden, and D. Hurst, 24th Proceedings of the American Society of Composites, Newark, Delaware (2009)