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Processing and Characterization of Needled Carbon Composites

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14. ABSTRACT
Needled carbon fiber composite materials are being investigated by the U.S. Army Research Laboratory (ARL) with the intent of reducing the sacrifices of in-plane properties typically associated with through-thickness reinforcement techniques such as Z-pinning, stitching, and tufting. This knockdown in strength is usually the result of different factors such as waviness in the fibers induced by the z-reinforcement, lowered fiber volume fractions due to swelling of the material, and physical damage to the carbon fibers themselves. Reductions in tensile strength of up to 25% for stitched carbon/epoxy composites have been reported, as have drops in elastic modulus of up to 15%. To investigate needled composite materials and overcome these issues, ARL has developed a unique in-house needle-processing capability which uses commercially-available felting needles to insert z-fibers into composite laminates at different angles (±45/90°) relative to the laminate plane. Previous work with needled glass/epoxy composites has shown a 270% improvement in Mode I interlaminar fracture toughness when needled at 90° to the laminate plane and significant increases in shear strength when needled at ±45°. In the current work, we characterize needled carbon/epoxy laminates via mechanical testing and x-ray micro-computed tomography (MicroCT) analysis. Needle wear issues associated with the carbon materials are addressed. Tensile strength of the needled carbon laminates was found to decrease minimally at low perforation densities but was reduced up to 11.5% at a high perforation density (75 perforations/cm2). Both compression strength and low velocity impact-induced delamination were found to be relatively unaffected by the needling process – even over the broad range of perforation densities investigated. Compression after impact (CAI) strength, however, increased significantly (18%) for a TTR reinforcement perforation density of 85 perforations/cm2 oriented at 90° and ±45° relative to the laminate plane.

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