

Adhesive Bonding of Composite Materials for Armor Applications

Abstract

The joining of the two-constituent armor material is as crucial as their ballistic property itself since neither of the two ballistic materials can defeat hardened core projectiles individually at an optimum weight and thickness of an armor panel. A perfectly bonded metal or ceramic to the composite laminate can defeat one or two hits of hardened steel core (HSC) projectiles, but the same configuration might not be a right solution in the multi-hit scenario. This research work has been focused on the development of armor panels resisting multiple shots of HSC projectiles in order to counter threat level V of BIS Standard IS17051:2018 or equivalent NIJ standard 0101.07 (2023), and also to investigate the relationship between the interfacial shear properties of the bonding adhesive and the ballistic performance of the bonded armor materials. All possible adhesives were characterised to better understand the applicability for bonding armor materials particularly with ultra-high molecular weight polyethylene (UHMWPE) composite laminate. A fixture was fabricated and modified to evaluate the interfacial shear strength (IFSS) of the adhesive bonded dissimilar substrates, as per standard ASTM D4501. The modified fixture was validated by comparing shear strength values obtained experimentally with the shear values obtained in a single lap joint geometry (ASTM D 1002) on similar substrates of aluminium and steel. Interfacial shear tests were performed using fixture to optimize the thickness of resin adhesive bonding boron carbide (B4C) to steel substrates. The IFSS values were evaluated and compared for the selected adhesives

bonding different armor material combinations such as B4C/steel, B4C/UHMWPE laminae and Steel/UHMWPE laminae. UHMWPE fibers are non-polar in nature hence UHMWPE laminae was subjected to plasma treatment for incorporation of reactive sites on the surface of laminae which was to be bonded to B4C tiles to enhance adhesion of the substrates. IFSS test of the treated laminae bonded with B4C showed good improvement in shear strength. The test panels were fabricated with different adhesives using B4C/UHMWPE substrate configuration and subjected to high velocity impact tests in a single-stage gas gun. Shear strength of the adhesive bonded steel and UHMWPE-fiber laminate were also determined to understand correlation of the shear strength and its ballistic performance.