HYPERVELOCITY IMPACT EXPERIMENTS ON EPOXY/ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE COMPOSITE PANELS REINFORCED WITH NANOTUBES

Suman Khatiwada[1]*, Jay W. Laughman[2], Carlos A. Armada[1], Eric L. Christiansen[2] and Enrique V. Barrera[1]
[1]Department of Mechanical Engineering and Materials Science,
Rice University, Houston, TX, USA 77005
[2]NASA Johnson Space Center, Houston, TX 77058

Advanced composites with multi-functional capabilities are of great interest to the designers of aerospace structures. Polymer matrix composites (PMCs) reinforced with high strength fibers provide a lightweight and high strength alternative to metals and metal alloys conventionally used in aerospace architectures. Novel reinforcements such as nanofillers offer potential to improve the mechanical properties and add multi-functionality such as radiation resistance and sensing capabilities to the PMCs.

This paper reports the hypervelocity impact (HVI) test results on ultra-high molecular weight polyethylene (UHMWPE) fiber composites reinforced with single-walled carbon nanotubes (SWCNT) and boron nitride nanotubes (BNNT). Woven UHMWPE fabrics, in addition to providing excellent impact properties and high strength, also offer radiation resistance due to inherent high hydrogen content. SWCNT have exceptional mechanical and electrical properties. BNNT (figure 1) have high neutron cross section and good mechanical properties that add multi-functionality to this system.

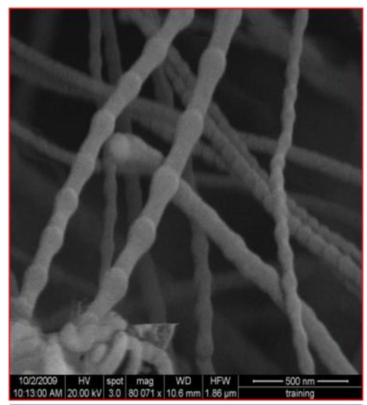

Figure 1. Scanning Electron Micrograph of boron nitride nanotubes

In this project, epoxy based UHMWPE composites containing SWCNT and BNNT are assessed for their use as bumper shields and as intermediate plates in a Whipple Shield for HVI resistance. Three composite systems are prepared to compare against one another: (I) Epoxy/UHMWPE, (II) Epoxy/UHMWPE/SWCNT and (III) Epoxy/UHMWPE/SWCNT/BNNT. Each composite is a 10.0 by 10.0 by 0.11 cm^3 panel, consisting of 4 layers of fabrics arranged in cross-ply orientation. Both SWCNT and BNNT are 0.5 weight % of the fabric preform. Hypervelocity impact tests are performed using a two-stage light gas gun at Rice University.

Two sets of hypervelocity impact experiments are carried out on the composite panels. In set A, the panels are used as bumper shields (figure 2). They are impacted directly by aluminum projectiles of varying size and mass at velocities around 7 km/s. Aluminum metal sheets are used as witness plates, placed 10.2 cm behind the panels. An ultra-high speed camera is used to capture the images of the debris cloud upon impact (figure 3). Characteristics of the entry holes and the debris cloud properties are analyzed for all three types of panels. In set B, the composite panels are used as intermediate plates in a Whipple Shield formation. Aluminum projectiles of varying size and mass are impacted onto thin aluminum bumper shields. The resulting debris clouds impact the composite panels. Aluminum witness plates are used as rear walls. Scale of damage to the composite panels and rear walls are assessed in the post-test analysis. The initial results indicate that the addition of nanotubes increases the HVI resistance of the composite panel. These results give the first insights into the HVI behaviors of composites reinforced with nanotubes.

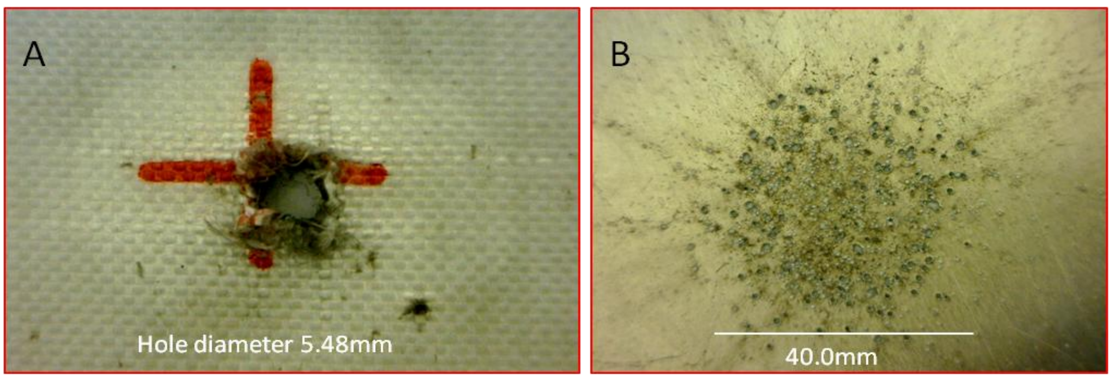

Figure 2. (A) Entry hole and surrounding delamination zone on a Epoxy/UHMWPE laminate impacted with 1.58mm Al projectile at 7.03km/s. (B) Al rear wall showing damage from the debris cloud impact. Rice shot#0443.

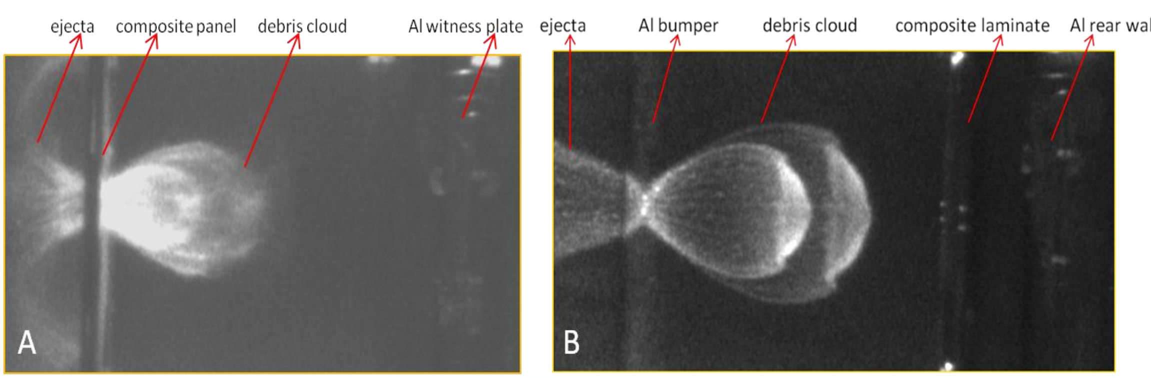

Figure 3. Debris cloud formations after hypervelocity impact of Al projectiles onto: (A) epoxy/UHMWPE composite, (B) Al sheet. (A) is the test set up for assessing composites as bumper, and (B) as intermediate plate in a Whipple Shield. Both images have two frames 3.0μs apart. (A)Rice shot #0455. (B)Rice shot #0472.

*Suman Khatiwada, Dept. of Mechanical Eng. & Materials Science, Rice University, Houston, TX, USA. Email: suman.khatiwada@rice.edu. Phone: 443-857-2654.