PURDUE UNIVERSITY

School of Aeronautics and Astronautics

The AAE Fall 2009 Colloquium Series

COLLOQUIUM

Damage Mechanisms in Ballistic Fibers: A Systematic Study

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Abstract

The unexpected failure of soft body armor composed of polybenzoxazole (PBO) fibers ushered in an intense investigation to identify the mechanisms associated with the apparent reduction in ballistic performance of PBO fibers that comprised the vest. For the case of PBO fibers acid catalyzed hydrolytic degradation, associated with the presence of residual phosphoric acid from the manufacturing process, has long been suspected of reducing the mechanical properties of the PBO fibers by attacking the benzoxazole ring found in the polymer chain. However, this suspicion was only supported by data very recently. It has been found for the first time that the 25 % by mass extractable phosphorus detected by previous researchers was a phosphorus processing aid used in the manufacturing process. Furthermore, using model compound studies, the remaining non-extractable phosphorus was found to be chemically bound to the PBO polymer structure as a mono-aryl phosphate ester. This type of phosphate ester was found to be resistant to caustic hydrolysis that is usually used in the manufacturing process.

Degradation associated with folding that occurs during normal wear was also found to be a factor. Using a device designed to impart localized folding damage, the strain to failure and ultimate tensile strength of PBO fibers were found to be reduced. In tests designed to simulate 6 months and 10 years of wear, the strain to failure of PBO fibers were reduced by 14 % and 40 %, respectively (Kim 2008). These results coupled with analyses of field returned vests showed that the folding damage creates localized regions in the vest that are weaker than the damage caused by hydrolytic action (Holmes 2009). Similar tests on poly-paraphenylene terephthalamide (Kevlar type) fibers indicate that folding damage is much less severe than observed in PBO fibers.

Biography:

Gale Holmes received a B.S. degree in chemistry from the University of Texas @ Austin in May 1977. He then worked for the Dow Chemical Co in Freeport, Texas as an analytical chemist for 12 years. In August 1989 he left Dow for Texas A&M University to pursue a Ph.D. in Mechanical Engineering. After graduation in August 1994, he was briefly employed at Federal Mogul in Ann Arbor, Michigan before accepting a research position in April 1995 with the National Institute of Standards and Technology. He was the vice-chair of the Gordon Research Conference (GRC) on Composites 2008 and is the chair of the GRC on Composites 2010 that will be held on January 17-22, 2010 in Ventura, California. He also received the Deparment of Commerce Gold Medal in 2007. His research interests are ballistic fibers, nano-tailored multi-functional materials, embedded interfaces, composite micromechanics, time-dependent relaxation phenomena in polymeric systems.

An informal coffee & cookie reception will be held prior to the lecture at 2:30 p.m. in the AAE/ARMS undergraduate lounge (directly in front of ARMS 3rd floor elevators)