Durability Characterization of Advanced Polymeric Composites at Cryogenic Temperatures

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The next generation of reusable launch vehicles will require technology development in several key areas. Of these key areas, the development of polymeric composite cryogenic fuel tanks promises to present one of the most difficult technical challenges. It is envisioned that a polymer matrix composite (PMC) tank would be a large shell structure capable of containing cryogenic fuels and carrying a range of structural loads. The criteria that will be imposed on such a design include reduced weight, conformal geometry, and impermeability. It is this last criterion, impermeability, that will provide the focus of this paper.

The essence of the impermeability criterion is that the tank remains leak free throughout its design lifetime. To address this criterion, one of the first steps is to conduct a complete durability assessment of the PMC materials. At Langley Research Center, a durability assessment of promising new polyimide-based PMCs is underway. This durability program has focused on designing a set of critical laboratory experiments that will determine fundamental material properties under combined thermal-mechanical loading at cryogenic temperatures. The test program provides measurements of lamina and laminate properties, including strength, stiffness, and fracture toughness. The performance of the PMC materials is monitored as a function of exposure conditions and aging time. Residual properties after exposure are measured at cryogenic temperatures and provide quantitative values of residual strength and stiffness. Primary degradation mechanisms and the associated damage modes are measured with both destructive and nondestructive techniques. In addition to mechanical properties, a range of physical properties, such as weight, glass transition, and crack density, are measured and correlated with the test conditions. This paper will report on the progress of this research program and present critical results and illustrative examples of current findings.