

Advanced Booster Composite Case/ Polybenzimidazole Nitrile Butadiene Rubber Insulation Development

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Sponsoring Program(s)

Human Exploration and Operations Mission Directorate
Space Launch System Advanced Development

Project Description

The NASA Engineering and Safety Center (NESC) was requested to examine processing sensitivities (e.g., cure temperature control/variance, debonds, density variations) of polybenzimidazole nitrile butadiene rubber (PBI-NBR) insulation, case fiber, and resin systems and to evaluate nondestructive evaluation (NDE) and damage tolerance methods/models required to support human-rated composite motor cases. The proposed use of composite motor cases in Blocks IA and II was expected to increase performance capability through optimizing operating pressure and increasing propellant mass fraction. This assessment was to support the evaluation of risk reduction for large booster component development/fabrication, NDE of low mass-to-strength ratio material structures, and solid booster propellant formulation as requested in the Space Launch System NASA Research Announcement for Advanced Booster Engineering Demonstration and/or Risk Reduction. Composite case materials and high-energy propellants represent an enabling capability in the Agency's ability to provide affordable, high-performing advanced booster concepts.

The NESC team was requested to provide an assessment of co- and multiple-cure processing of composite case and PBI-NBR insulation materials and evaluation of high-energy propellant formulations.

Notable Accomplishments

The following accomplishments were made:

Hydroxyl terminated polybutadiene (HTPB) and hydroxyl terminated polyether (HTPE) propellant mixes were made in 1 pint, 1 gallon, and 5 gallon sizes. HTPB formulation is being worked to improve tensile properties and HTPE tensile properties were acceptable. Laboratory hazard testing and the end-of-mix viscosity testing are complete with acceptable results. The burning rates and pressure slopes are acceptable, and can be modified to meet program requirements.

Ablative liner mixes were made in 1 pint and 1 gallon sizes. The end-of-mix viscosities and tensile properties were acceptable.

Kevlar®-filled ethylene propylene diene monomer was down-selected as insulation for bondline evaluations. Accelerated aging of HTPE propellant and its bondline specimens has commenced.

Forty-five bottles were manufactured and NDEs completed for the following: Eight test bottles each and one defect standard each for (1) prepreg co-cured and (2) prepreg multiple-cured in an oven; (3) wet wound and co-cured, (4) wet wound and multiple-cured in an oven, and (5) prepreg co-cured in an autoclave.

Impact trials were conducted to determine the lower bound on detectable damage via NDE. Burst testing of bottles was performed to evaluate possible differences in the structural capability of different processing methods. Comparison in burst pressures of the pristine co-cured and pristine multiple-cured bottles do not reveal a visible difference in burst strength.

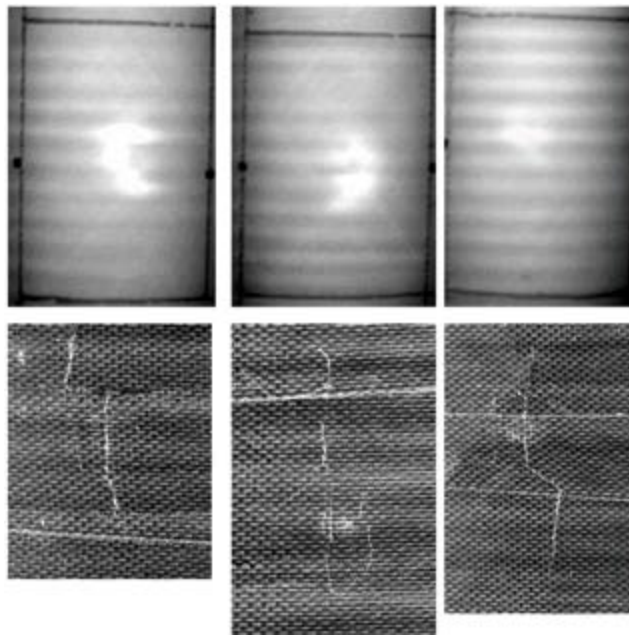


(a)

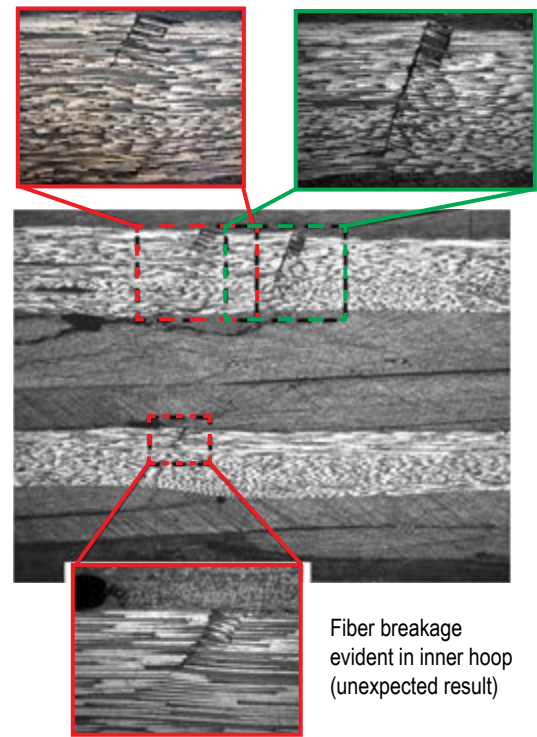


(b)

Burst testing (a) before burst and (b) after burst (failure in hoop).



(a)



(b)

Fiber breakage evident in inner hoop (unexpected result)

Damage to the bottle due to impact energy: (a) Flash thermography detected the impact damage from an impact energy of 3.2 ft-lb. Visual damage was also present on the exterior of the bottle and (b) photomicroscopy shows fiber damage is evident with an impact energy of 3.3 ft-lb.

The NDE techniques that were evaluated include the infrared flash thermography (IRT), proven to be an excellent method for finding indications; radiography, which has been successful in finding inserts in defect standards; and computed tomography, which is unable to find inserts in defect standards or indications found by IRT but has been excellent in detecting thickness and density changes.

References

Crumbly, C.M.; Bickley, F.P.; and Hueter, U.: "Space Launch System Spacecraft/Payloads Integration and Evolution Office Advanced Development FY 2014 Annual Report," NASA/TM—2015–218201, NASA Marshall Space Flight Center, Huntsville, AL, January 2015.