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INHOUSE DEVELOPMENT OF ADDITIVE MANUFACTURED (AM) DIAPHRAGM TANK FOR GREEN MONO-PROPELLANT (GMP) BASED PROPULSION SYSTEM

Abstract

This study focuses on the development of diaphragm tank of 150 ml capacity with a short cycle development time, emphasizing design for additive manufacturing (DFAM) of propellant tanks for short duration space missions. The objectives are to show that additive manufactured propellant tanks can meet the requirements similar to conventionally manufactured tanks for such applications. The study utilizes the Selective Laser Melting Technique (SLM) for AM propellant tank production and explores positive expulsion mechanism using internally mounted diaphragm, adhering to aerospace qualification standards. Based on compatibility studies for the BHM 01A (HAN based Green Monopropellant) propellant, SS316L was chosen as the material for construction. Material properties assessment including tensile and fracture properties for material in as built condition and heat-treated condition is conducted and comparison with the conventional SS316L material properties is done. Design is done based on finite element stress analysis, with properties derived from material characterization. Tensile testing results for AM test coupons demonstrated high yield and ultimate strength compared to conventional materials, with non-destructive fracture critical studies showing higher side compliance with conventional material's fracture strength.

Detailed fracture mechanics analysis, pressurization fatigue, and structural vibration analysis were employed to identify failure points using isotropic material assumption. Conservative design considerations were applied as technology development exercise. Two all-welded configuration tanks were manufactured one for destructive testing and another for non-destructive testing. Hydro static burst pressure destructive testing aimed to assess the design factor of safety. Tank was passed through severe environmental conditions such as more than 50 proof pressure cycles, more than 5 minutes pressure holding, sinusoidal vibration, random vibration, and shock as per PSLV qualification requirements. Vibration test results showed compliance with computed natural frequencies and structural response during testing within acceptable range.

The developed propellant tank's qualified model received flight heritage in the RUDRA 0.3 HPGP mission by Bellatrix Aerospace in January 2024, demonstrating the gas free delivery of GMP expulsion to thruster. The developed methodology is being leveraged for the design and production of optimized AM propellant tanks for spacecraft applications.