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MATERIALS AND STRUCTURES SYMPOSIUM (C2)
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STRUCTURAL PERFORMANCE AND HELIUM / HYDROGEN PERMEABILITY RATES OF FUSED DEPOSITION MODELING POLYMERS AT CRYOGENIC TEMPERATURES

Abstract

Engineering plastics provide a crucial alternative to metal alloys when low thermal conductivity is as important as mechanical strength. At cryogenic temperatures, polymers such as polyamide (Nylon), polyimide (Kapton), and polyethylene terephthalate (Mylar) are used to isolate temperature sensitive devices from heat via low thermal conductivity. Structural supports made from polyetherimide (ULTEM) and Nylon may be used to isolate cryogenic dewars for storage of liquid helium, liquid oxygen, and liquid hydrogen for satellite propulsion and instrument cooling. Composite pressure vessels often require low-permeability liners when used for storage of hydrogen or helium. Traditional fabrication methods are unlikely to achieve complex shapes with internal voids, and injection molding is expensive for limited production due to high initial mold cost. However, additive manufacturing offers several advantages to the production of cryogenic rated support and isolation systems. For designs that emphasize storage of liquid cryogens, curvilinear flow passages can be printed into the structure that would otherwise be impossible to manufacture. Material strength data measured at cryogenic temperatures are limited for polymers that may be suitable for cryogenic service, while helium and hydrogen permeability experiments have been limited to composite materials and epoxy resins. Three polymers in particular that have either been used in, or are candidates for cryogenic systems include ULTEM, polyphenylsulfone (PPSU - Radel), and Nylon, and are available for use in rapid prototyping machines. This paper discusses the mechanical properties of ULTEM 9085, PPSU, and Nylon 12 at 77 K and permeability properties at 20 K. Tensile and compressive test coupons were created using fused deposition modeling and were immersed in liquid nitrogen during mechanical tests. Permeability test specimens were prepared using fused deposition modeling and held at 20 K while a pressure of 310 kPa, simulating typical liquid hydrogen storage pressure, was applied using helium and hydrogen gas. Permeability was measured as a leak rate (mbar l/s) with an Adixen ASM 142D leak detector.