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ABSTRACT

Establishing and Monitoring Fatigue Damage Criteria on Polyamide Liners for an Automotive Hydrogen Application

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Type IV hydrogen storage tanks, designed for automotive applications, consist of a semi-crystalline polyamide (PA11 or PA6) liner ensuring hydrogen impermeability, inside a carbon fiber-reinforced polymer (CFRP) composite shell providing mechanical strength. During operation, the liner undergoes severe pressure cycles (until 700 bar) at varying temperatures (from -40 to 85°C), leading to thermomechanical fatigue and potential microstructural degradation. Understanding the long-term deformation mechanisms of the liner is crucial to ensuring liner durability and safety.

Thermomechanical characterization was conducted to investigate the behavior of these polyamide liners. VidéoTractionTM tests at different temperatures allowed the identification of key parameters governing their strain rate sensitivity and temperature-dependent mechanical response. Long-term performance was assessed through creep and oligocyclic fatigue tests, revealing progressive damage accumulation and the formation of microstructural defects.

To correlate microstructural evolution with mechanical behavior, Raman spectroscopy1 was used to track crystallinity changes in real time, particularly the evolution of C=O stretching modes, which serve as indicators of molecular orientation and phase transformations2,3. In situ Wide-Angle X-ray Scattering (WAXS) experiments under thermal4 and mechanical loading5 confirm crystallinity variations and the development of anisotropic textures.

A phenomenological constitutive law based on the G'Sell & Jonas6,7 law was developed to simulate the long-term mechanical response of the liner. The model parameters, extracted from tensile data, enable accurate predictions of the material's fatigue behavior under cyclic loading. These results help to improve predictive lifetime assessments of hydrogen storage liners and to optimize their structural design. Implementation in CAE software provides a predictive approach to compute the local strain field of the liner at the tank scale, facilitating structural optimization for hydrogen storage applications.

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