Damage detection in type IV hydrogen tank liner after rapid gas decompression

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Type IV hydrogen tank, which uses a polymeric liner, is considered one of the most suitable options for hydrogen storage or transportation, in particular for fuel cell vehicles. Compared to earlier designs with metallic shell, the polymeric version provides a higher gravimetric efficiency and eliminates the risk of hydrogen embrittlement associated with steel [1]. The liners currently in use, often extruded and welded or rotomolded, are designed to serve both as a mechanical support for the composite reinforcement and as a gas-tight barrier. A drawback, however, is that hydrogen can slightly diffuse through the polymer, particularly under high pressure, to reach an equilibrium saturated state. In case of emergency, a rapid tank emptying procedure may be required. During this Rapid Gas Decompression (RGD), the hydrogen trapped inside the material might generate internal stresses, leading to potential structural damage. Although such defects have been observed and documented in elastomers [**2**], their occurrence detection and characterization remain a challenge for thermoplastic materials today.

This study discusses the RGD consequences on three semi-crystalline polymers (Polyamide 6, Polyamide 11 and High-density polyethylene), under particularly extreme conditions. RGD tests were performed thanks to IFPEN facilities. For each of the three studied materials, plates of different dimensions plates are placed in a chamber at 90 MPa of H_2 and 80 °C until saturation is reached, then rapidly decompressed at a rate of 420 MPa/min down to 0.5 MPa. The samples are kept at this low pressure for 5 hours before starting the second cycle. In total, four pressurization–decompression cycles are performed.

Internal damage, expected in the form of cavities is investigated using ultra-small-angle X-ray scattering (USAXS). The USAXS/SAXS measurements are carried out at the ESRF facility in Grenoble, France. For each material, three exposed samples and one unexposed reference sample are analyzed. Scattering patterns are recorded across the available q-range, from 0.0016 to 7 nm^{-1}. A qualitative comparison of the I(q) scattering curves reveals noticeable differences between exposed and unexposed samples, indicating the presence of new, approximately spherical scatterers.

The possible induced degradation of the mechanical properties is also assessed by tensile testing. Exposed and reference samples are tested at room temperature with a crosshead speed of 5 mm/min. Surprisingly, the results show no significant differences between the two states, despite what was observed on elastomers damaged by RGD [3]. This tends to indicate that rapid decompression does not affect the macroscopic mechanical performance of the considered polymers. Further investigations through permeability tests and viscoelastic dynamic analysis are required to assess whether the detected damage affects the functional performance of the decompressed liners.

References :

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