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# ABSTRACT:

## Decompression failure in polymers exposed to high-pressure hydrogen: challenges for experimental characterization and modeling

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Any decompression following the exposure of polymers to high-pressure diffusive gases may damage the material, as soon as the pressure is released faster than the gas desorption ability. This so-called decompression failure can refer to cavitation and cracking depending on the polymer properties, the microstructure scales, and the exposure conditions. Such a phenomenon has been evidenced in different gas polymer systems in the past, mostly through qualitative approaches and not that much in hydrogen. Interest in this gas has been raised recently when considering it as an alternative energy carrier, involving the use of polymeric components in Fuel Cell Vehicles, storage vessels, and refueling stations. The relatively high pressures in use, combined with the safety standards for hydrogen manipulation lead to challenges in terms of material and design. After a general overview of the phenomenon in thermoplastics and rubbers, the main part of the talk will be focused on rubbers.

The two key challenges for both experimental characterization and modeling of decompression failure are (i) to accurately capture the full couplings between diffusion and mechanics and (ii) to overcome the poor knowledge obtained from residual damage with time-resolved and 3D tracking of damage all along the process.

Some recent experiments based on in-situ X-ray tomography in synchrotron source to finely capture the cavity growth kinetics and morphology during decompression will be presented. Regarding the applications, the effect of repeated pressure cycles is of prime importance; it will be considered all along the presentation.

The two above-listed challenges are variably declined depending on the scale at which decompression failure is addressed. At the macroscopic scale of the component or coupon, the challenge briefly illustrated here, is to capture the statistics of cavity fields (known to depend on decompression conditions and material properties) and the impact of gradients, in order to model the residual mechanical and permeation properties.

At the cavity scale, the diffuso-mechanical coupling directly affects the driving force responsible for cavity or crack growth. Indeed, the difference of pressure between the internal pressure inside a pre-existing cavity (Pi) and the external hydrostatic pressure (Pe) cannot be known all along the cavity inflation and deflation only from the cavity volume. Pi also depends on the amount of gas molecules inside the cavity. The few models recently reported in the literature neglect this contribution. In the case of so small molecules as di-hydrogen and low-density molecular networks, it is a very strong assumption, especially when the inflation – deflation process lasts several minutes.

Some results from a full-coupled cavity growth model will be presented as an alternate, trying to include as much as possible the cross-dependence of constitutive laws and parameters.

The type of mechanisms responsible for cavitation is another issue, for soft matters in general, regardless of the specific decompression failure context. The gain in spatial and time-resolution reached from synchrotron-source X-ray tomography made it possible to access early stages of growth, to properly quantify anisotropy and to better detect residual damage. These different elements showed the existence of a first rapid spherical growth regime which then evolved into an anisotropic regime which reflected an underlying mechanism of cracking that should be introduced in the modelling in the future.