

HYDROGEN DIFFUSION THROUGH THIN-PLY COMPOSITES

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ABSTRACT

There is a growing need to reduce the CO₂ emissions related to transportation (24% of energy related emissions) to achieve the commitments of the Paris agreement. Hydrogen technology has therefore emerged as a sustainable alternative with applications in aviation, maritime and road transportation.

The storage of hydrogen, however, remains a key challenge in adopting the new technology as hydrogen liquefies at -253°C and even in its liquid form has low specific density [1]. Therefore, larger tanks are required with the ability to prevent hydrogen diffusion through the tank, resist moderate to high pressures and withstand thermal fatigue cycles. However, larger metallic tanks increase the weight of the structure and thus composite materials (with low specific density) are explored as a sustainable alternative to hydrogen storage.

Thin-ply composites can provide higher strength and strain to failure by delaying matrix micro-cracking and free-edge delamination and are therefore considered in this study [2]. The architecture of thin-ply composites suppresses the generation of micro-cracks during mechanical deformation and therefore makes these materials more durable and less susceptible to hydrogen diffusion. Measuring the hydrogen diffusion through the thickness of these thin-ply composites is a challenging problem. In addition, quantifying the effect of mechanical loading on the hydrogen diffusion could allow an insight on micro-crack generation which could not be identified otherwise. Showing that the hydrogen diffusion is not accelerated despite mechanical loading could provide additional confidence in the use of thin-ply composites for hydrogen storage tanks.

Thin cross-ply Carbon Fibre Reinforced Polymer (CFRP) plates were manufactured, and two different types of specimens were cut from these plates. The first type were tensile specimens with dimensions 300 x 30 mm which were used for the initial mechanical pre-loading. End tabs were bonded on the tensile specimens and the pre-loading was conducted at 1 mm/min up to a maximum tensile strain of 1%.

The second type of specimens were cylindrical discs (25 mm diameter) which were used for measuring the hydrogen diffusion coefficient at different temperatures. A closed-volume, variable pressure permeometer was used to measure the molar flux across the membrane from the pressure increase in a calibrated downstream volume, and the diffusion coefficient was determined by the time-lag method. The permeation measurements were conducted on the specimens with and without mechanical pre-loading.

Figure 1 shows an initial comparison of the hydrogen diffusion coefficient for the two types of specimens examined. In addition, a characteristic literature value [3] for a stainless-steel alloy is also plotted. The figure clearly displays that there is no significant change in the hydrogen diffusivity through the CFRP thickness despite the effect of the mechanical pre-loading. In addition, the diffusivity value is in the same order of magnitude as the stainless-steel alloy highlighting the potential of using CFRP materials without metal liners for hydrogen storage applications.

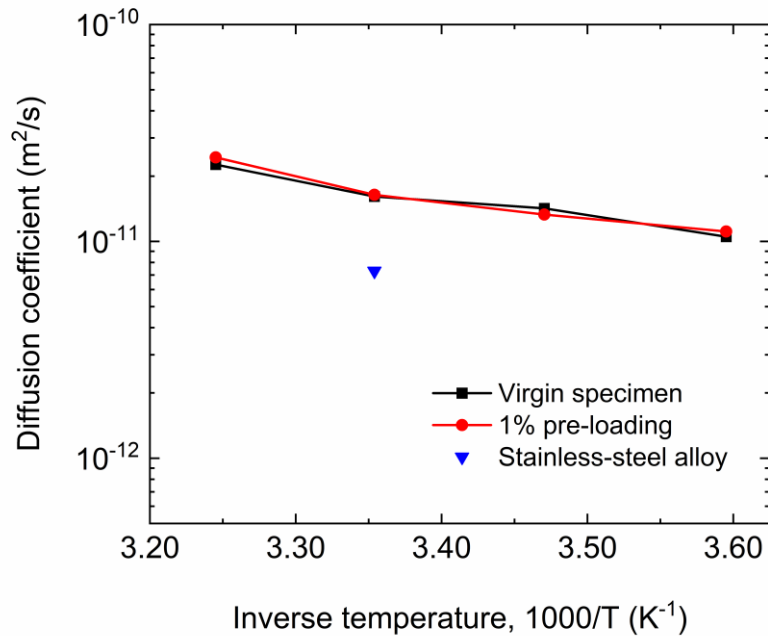


Figure 1: Diffusion coefficient as a function of temperature for virgin and pre-loaded thin-ply CFRP specimens

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