Thin-ply composites for hydrogen storage applications

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INTRODUCTION: There is a growing need to reduce the CO\textsubscript{2} emissions related to transportation (24\% of energy related emissions) to achieve the commitments of the Paris agreement \cite{1}. Therefore, hydrogen technology has 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. Therefore, larger tanks are required with the ability to prevent hydrogen diffusion through the tank, resist high pressures and withstand thermal fatigue cycles. However, larger tanks increase the weight of the structure and thus composite materials (with low specific density) are explored as a sustainable alternative to hydrogen storage tanks. 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 \cite{2}.

METHODS: Thin cross-ply Carbon Fibre Reinforced Polymer (CFRP) plates were manufactured, and cylindrical specimens (25 mm diameter) were cut from these plates and were used for measuring the hydrogen diffusion coefficient at different temperatures. A closed volume permeometer was used which allows to measure the molar flux across the membrane from the pressure increase in a calibrated downstream volume.

RESULTS: Table 1 shows the diffusion coefficient measurements conducted on the thin-ply composite materials examined for this study at 25°C and compares them with characteristic values for a typical stainless steel alloy. The diffusion coefficient of the two materials is in the same order of magnitude demonstrating that thin-ply composites do not allow for faster through the thickness diffusion compared to metals which are typically used for hydrogen storage.

DISCUSSION & CONCLUSIONS: It is worth noting that the diffusion coefficient measurements were conducted on virgin materials without any prior thermal conditioning or loading. However, the materials used for hydrogen storage tanks are expected to experience high stresses and thermal fatigue cycles. Therefore, it is important that the measurements are repeated after thermal conditioning and/or mechanical preloading to ensure that micro-cracking does not accelerate the permeability/diffusion phenomena. Such observations would increase the confidence in using thin-ply composites for hydrogen storage tanks.

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<th>Stainless steel SS 304 \cite{3}</th>
<th>Thin-ply CFRP</th>
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<tr>
<td>Diffusion coefficient (m\textsuperscript{2}/s)</td>
<td>$7.3 \times 10^{-12}$</td>
<td>$5.2 \times 10^{-12}$</td>
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