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Vibration and Freeze-Thaw Cycling Tests on Fuel Cells for Automotive Applications

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Abstract : Hydrogen fuel cell technologies have experienced a great boost in the last decades, significantly increasing the production of these devices for both stationary and portable (mainly automotive) applications; these are influenced by two main factors: environmental pollution and energy shortage. A fuel cell is an electrochemical device that converts chemical energy directly into electricity by using hydrogen and oxygen gases as reactive components and obtaining water and heat as byproducts of the chemical reaction. Fuel cells, specifically those of Proton Exchange Membrane (PEM) technology, are considered an alternative to internal combustion engines, mainly because of the low emissions they produce (almost zero), high efficiency and low operating temperatures (< 373 K). The introduction and use of fuel cells in the automotive market requires the development of standardized and validated procedures to test and evaluate their performance in different environmental conditions including vibrations and freeze-thaw cycles. These situations of vibration and extremely low/high temperatures can affect the physical integrity or even the excellent operation or performance of the fuel cell stack placed in a vehicle in circulation or in different climatic conditions. The main objective of this work is the development and validation of vibration and freeze-thaw cycling test procedures for fuel cell stacks that can be used in a vehicle in order to consolidate their safety, performance, and durability. In this context, different experimental tests were carried out at the facilities of the National Hydrogen Centre (CNH2). The experimental equipment used was: A vibration platform (shaker) for vibration test analysis on fuel cells in three axes directions with different vibration profiles. A walk-in climatic chamber to test the starting, operating, and stopping behavior of fuel cells under defined extreme conditions. A test station designed and developed by the CNH2 to test and characterize PEM fuel cell stacks up to 10 kWe. A 5 kWe PEM fuel cell stack in off-operation mode was used to carry out two independent experimental procedures. On the one hand, the fuel cell was subjected to a sinusoidal vibration test on the shaker in the three axes directions. It was defined by acceleration and amplitudes in the frequency range of 7 to 200 Hz for a total of three hours in each direction. On the other hand, the climatic chamber was used to simulate freeze-thaw cycles by defining a temperature range between +313 K and -243 K with an average relative humidity of 50% and a recommended ramp up and rump down of 1 K/min. The polarization curve and gas leakage rate were determined before and after the vibration and freeze-thaw tests at the fuel cell stack test station to evaluate the robustness of the stack. The results were very similar, which indicates that the tests did not affect the fuel cell stack structure and performance. The proposed procedures were verified and can be used as an initial point to perform other tests with different fuel cells.

Keywords : climatic chamber, freeze-thaw cycles, PEM fuel cell, shaker, vibration tests
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