Vibration and freeze – thaw cycling tests to characterize PEM fuel cells stacks to use in vehicles

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INTRODUCTION

Hydrogen fuel cell technologies have experienced a great boost for last decades, significantly increasing the production of these devices for both stationary and transport applications, influenced by two main reasons: 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 by-products 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 (< 100°C). However, the introduction and use of fuel cells in the automotive market require the development of standardized and validated procedures which must be applied to test and evaluate the fuel cell performance, safety and durability in different environmental conditions including vibrations and freeze – thaw cycles. In this work the CNH2 researches evaluated the behavior and performance of a 5 kWe PEM fuel cell stack as initial testing sample and scale-up the electric power of the fuel cell to be placed in vehicles.

EXPERIMENTAL INSTALLATIONS

TEST RING FOR PEMFC STACKS 1 – 10 kW

WALK-IN CLIMATE CHAMBER

VIBRATION PLATFORM

MAIN TECHNICAL SPECIFICATIONS

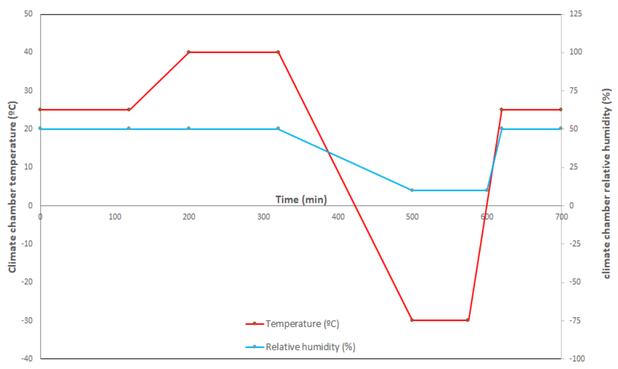
Capacity of stack testing up to 130 cells.
Operation pressure range: up to 2 bar_g.
Operation temperature range: up to 75 °C.
Electronic load: 0 – 160 V and 0 – 500
Humidification by cartridges: semipermeable membrane
Liquid and air thermal management
UNE – EN 62282 – 2 . Fuel cell modules.

Walk-in climate chamber of 16 m^3 useful volume.
Operation temperature range: -40 – 75°C.
Operation relative humidity range: 10 – 95%.
Temperature ramp up / down: 3,8 / 1,4 °C/min.
Working dimensions: 2360 x 3240 x 2800 mm.

Maximum par generated of 8 kN.
Programable frequency range: 0 – 2200 Hz.
Sine, random and shock operation modes.
127g in sine mode and 89g rms in random mode.
2,2 m/s in sine mode and 3,5 m/s in shock mode.
Sliding table of 630 x 630 mm.
Maximum weight on sliding table: 200 kg.

RESULTS AND CONCLUSIONS

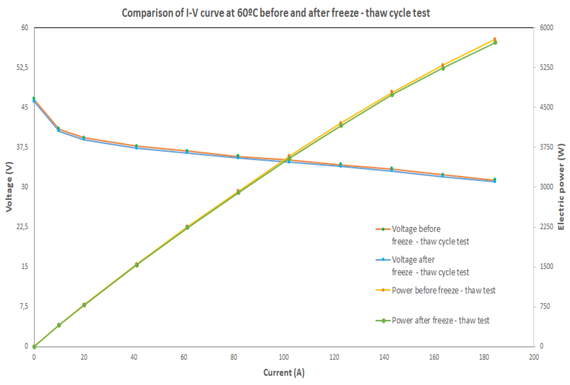
LEAK AND PERFORMANCE RESULST AFTER CLIMATE TEST

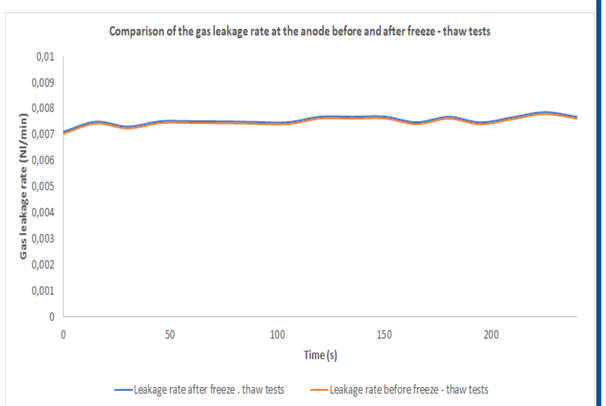


The stack was subjected to a very long term climate test, by following the temperatures and relative humidity according to the temperature and HR profile shown in the picture at the left.

These values of temperature together the relative humidity make the stack to operate under very several conditions, the same ones that one stack can suffered if it is installed in a car, train, ship or any other automotive vehicle that may be considered.

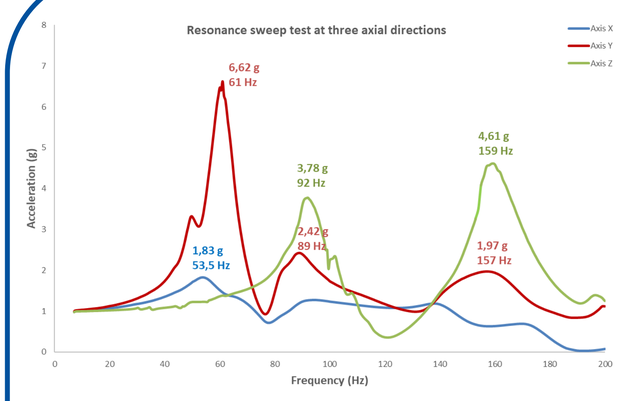
In this test, these values of temperature and relative humidity were maintained for some hours and, after that, the mechanical integrity and the performance of the stack were checked, in order to find out if the these parameters generated any external damage as well of measuring any performance reduction due to this, showing the results of this last issue in pictures just below.

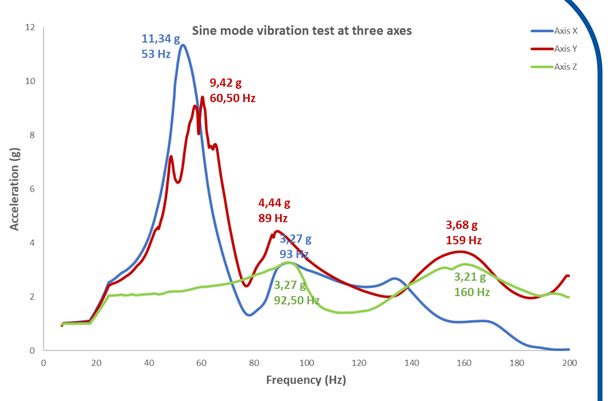




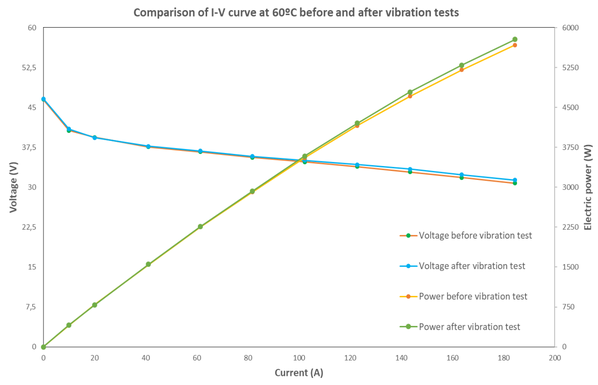
An analysis of the I-V curve at 60°C and an internal gas leakage test were conducted before and after the vibration test. The I-V curves before and after the vibration test are very similar with a variation of less than 1%, which indicates that the performance of the stack has not been altered after the vibration tests. The leakage test was carried out at the anode compartment by using helium gas. The outlet of the anode compartment was closed and pressurized up to 0,4 bar_g. The gas leakage rates obtained were: 7,47 Nml/min and 7,54 Nml/min before and after the vibration test respectively. This indicates that there is not mechanical damage to the stack, the difference could be due to improper tightening of stack connections.

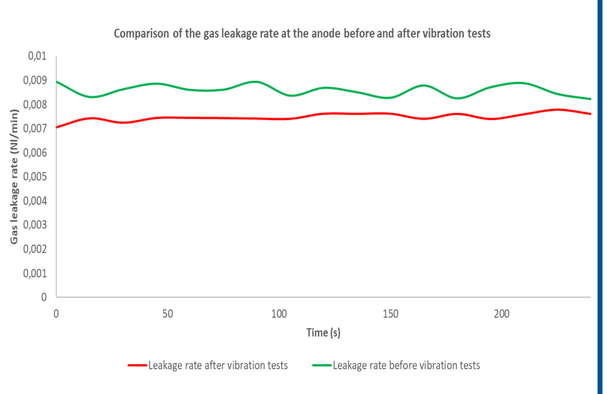
LEAK AND PERFORMANCE RESULTS AFTER VIBRATION TEST





The stack was subjected to a resonance sweep test and a sine mode test in the three axes direction. The resonance sweep test conducted in the range 7 – 200 Hz and 1g detected different resonance peaks which indicates that the mechanical of the fuel cell stack could be damaged if exposed for long periods of time to the detected resonance frequencies. The sine mode vibration test was sinusoidal with logarithmic frequency sweep between 7 – 200 Hz forth and back traversed in 15 minutes repeating the cycle 12 times in the three mutually perpendicular directions of the stack. Resonance peaks are very similar at the three axes direction.





An analysis of the I-V curve at 60 °C and an internal gas leakage test were conducted before and after the vibration test. The I-V curves before and after the vibration test are very similar with a variation of less than 2%, which indicates that the performance of the stack has not been altered after the vibration tests. The leakage test was carried out at the anode compartment by using helium gas. The outlet of the anode compartment was closed and pressurized up to 0,4 bar_g. The gas leakage rates obtained were: 8,2 Nml/min and 7,6 Nml/min before and after the vibration test respectively. This indicates that there is not mechanical damage to the stack, the difference could be due to improper tightening of stack connections.

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