ID-FAST - Investigations on degradation mechanisms and Definition of protocols for PEM Fuel cells Accelerated Stress Testing

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Summary

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1. Summary of the context and overall objectives of the project

ID-FAST aims at supporting and promoting the deployment of Proton Exchange Membrane Fuel Cell (PEMFC) technologies for automotive applications through the development of Accelerated Stress Tests (AST) together with a methodology allowing durability prediction, thus accelerating the introduction of innovative materials in next generation designs.

The project intends to fulfil this challenging objective by the following process: starting from data of the real ageing world to achieve the prediction of lifetime in real world, thanks to the development and validation of specific ASTs and associated transfer functions enabling to relate real and accelerated performance losses.

The first technical goal is to identify degradation mechanisms occurring during real ageing in fuel cell systems used in automotive conditions and to quantify their impact, as this is mandatory for the proper identification of stressors (operating conditions, usage profiles) for the proposal of relevant ASTs.

A parallel objective in order to support the experimental investigations of the components degradation is to develop and apply performance degradation models integrating several degradation mechanisms, as needed for the simulation of accelerated ageing tests.

Final ambition is to validate the ID-FAST methodology with the application of AST protocols on different components in single cells and in stacks and the proposal of transfer functions enabling to comprehensively relate performance losses caused by accelerated degradation to losses observed during ageing in real conditions.

2. Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

As a starting point, fuel cell stack components aged in real automotive conditions have been identifed from previous projects (AutoStack-Core, IMPACT, IMPALA or COBRA for the FCH-JU funded projects and the HyWay project). After getting authorization for deep analyses of the samples, Membrane Electrode Assemblies (MEAs), gas diffusion layers (GDL) and bipolar plates have been distributed among the partners for performing post-mortem analyses.

In order to enable viable comparison between real and accelerated ageing, it is also needed to perform ageing tests in real conditions but on well known samples and following as representative as possible and well controlled ageing protocols applied on test stations. State of art MEA components and recognized stacks, such as the European Autostackcore platform and the design as range extender in the Symbio Kangoo cars have been selected for this purpose.

In parallel, a new protocol estimated more realistic than the previous FC-DLC has been defined by based on fleet data, with specific conditions and including various short or long stops mimicking real life operation for the automotive application. Based on this protocol for stacks, several sets of operating conditions have also been defined for the measurements in single cells so as to take into account the heterogeneities induced along the cells surface by the flow field design and the operation of the large size cells in real stacks and reproduce in small cells the local conditions.

Predefined in-situ ageing tests have thus been applied to get information about the impact of the stressors that will be used for the definition of the accelerated stress tests. Valuable ageing results and corresponding aged samples from ageing tests conducted in single cells or in a stack with the reference components and following newly defined real ageing protocol are now available for further analyses.

To fully investigate the impact of stressors and check the link between materials degradation and performance decay, collected aged samples from in-situ real ageing are extensively analysed by ex-situ methods. Analyses of the aged samples properties or microstructure have been conducted by numerous methods (electrochemical, transport, permeation measurements and nanocharacterization by advanced microscopy techniques).

All MEA components undergo changes during several thousand hours of operation highlighting the importance of identify operando stressors for each component in order to develop suitable in-situ AST. General observations are cathodic catalyst dissolution and subsequent platinum band formation in the membrane, carbon corrosion when hydrogen/air front occurred, hydrophobicity loss of GDLs, gas leakages due to membrane failure occur in hot-dry operation.

The main mechanisms that have been identified to play an important role in the MEA degradation have been modelled for the core materials: catalyst (platinum oxides, dissolution and growth), membrane (break of ionomer structure), gas diffusion layer (loss of hydrophobic binder PTFE) and carbon support (carbon corrosion). At mid-term, These models have been validated against data from literature or previous projects.

Modelling work directly related to the development of ASTs started with the analysis of stressors particularly for the carbon corrosion mechanism related to the start-up / shutdown steps. First AST simulations have also been performed and compared to real ageing ones. These comparisons allowed to get some recommendations concerning the AST protocol. Preliminary coupling of various degradation mechanisms have been successfully performed.

Extensive study conducted on start-up / shutdown (considering the relative impact on platinum dissolution and carbon corrosion for real case or state of art ASTs) enabled to identify possible improvements and to propose a new AST for start-up.

New results are also available on the parameters affecting some mechanisms such as local cathode conditions on platinum dissolution or potential cycling on performance decay.

In-situ ageing protocols applied on gas diffusion layers allowed to check the impact of several stressors, showing particularly the effectiveness of the excess of temperature as the best basis of a new AST.

First combined ASTs were assessed and a general approach to identify transfer function was developed.

3. Progress beyond the state of the art, expected results until the end of the project and potential impacts

New approaches have been proposed and applied as well for real ageing protocols as for the investigation of stressors and definition of accelerated tests.

The project will result in the definition of new AST protocols to be exploited by industry partners for shortening their developments and should be disseminated for public usage through stadardization activities related to PEMFC testing.

Combined AST protocols will be developed and validated with regard to their capability to actually reduce testing time and their relevance assessed by correlation to real world ageing. The methodology developed will allow prediction of stack lifetime and thus will be valuable for the whole automotive fuel cell community.