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

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Summary for publication of the Second and final Periodic Report

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Summary

Text used as Summary for publication of the Second Periodic Report (final) on the SyGMa portal

Revisions

Version	Date	Author(s)	Commments *(inputs added, revision, approval…)*
Final	31.03.2022	S. Escribano	

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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).

The first technical goal was to identify degradation mechanisms occurring during real ageing and to quantify their impact, for proper identification of stressors (operating conditions, usage profiles).

A parallel objective was to develop and apply performance degradation models integrating several degradation mechanisms, as needed for the simulation of accelerated ageing tests.

Final ambition was to validate the ID-FAST methodology with the application of AST protocols on different components in single cells and in stacks and the comparison of performance losses with ageing in real conditions.

Outcomes of the project, particularly generic results applicable to non-confidential cell hardware, were also aiming at giving recommendations to standardization bodies.

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 *(For the final period please include an overview of the results and their exploitation and dissemination).*

2.1 Overview of work performed and main results

As a starting point, fuel cell stack components aged in real automotive conditions have been identified from previous projects for post-mortem analyses. Reference ageing tests in real conditions were performed on test stations to get exploitable reference data with state of art MEA components and stacks. A new realistic protocol based on actual fleet data, has been defined as ID-FAST driving cycles, with specific conditions and various stop-events mimicking real life operation for an automotive application.

Real ageing testing plan in single cells and stacks provided information on stressors. Valuable results with ranking of MEAs for several designs could be obtained thanks to different core materials, with at least two types of CCMs and GDLs selected according to the stack designs. Results in stacks showed how the robustness of MEAs and homogeneity between cells are crucial criteria for correct durability assessment. Analyses by ex-situ methods showed following degradation issues: cathode platinum particle dissolution, carbon corrosion when hydrogen/air front occurred, hydrophobicity loss of GDLs, gas leakages due to membrane failure in hot-dry operation.

Main mechanisms have been modelled for the core materials. Modelling work for the development of ASTs started with the analysis of stressors like for the carbon corrosion mechanism related to the start-up / shutdown steps. Catalyst AST simulations confirmed the pertinence of the approach by showing better representativeness. Progress was done on the coupling of physical models describing platinum catalyst and membrane degradation. Simulation results were obtained by a new approach coupling membrane chemical degradation and metallic cations coming from the possible corrosion of bipolar plates' material.

An extensive modelling study on the GDLs allowed improving their description with the effect of composition, and structure of support and microporous layer. A parametric study showed the excess of temperature as the best basis for a new AST on GDLs.

However, all first results confirmed that the degradation of cathode catalyst layers was leading the performance losses at least for ageing cases and timeframe considered.

Definition of operando single components AST and AST with multiple stressors based on drive cycles could be really started after mid-term. First new results were on parameters affecting main mechanisms such as local cathode conditions on platinum dissolution or potential cycling on performance decay. The development of combined ASTs could be completed by following the selected approach consisting in modifying the ID-FAST driving cycles. The idea was to preserve but aggravate the stressors and mechanisms involved, meanwhile keeping the original design of cycles with low power and high power periods, aiming at reaching the same final performance in a shorter duration.

Stronger accelerating effect was observed with the Low Power / high Power AST cycles deeply investigated at single cell level. These ASTs were first tested separately then combined in alternating blocks of 200 cycles of each, leading to acceleration factors of 7 to 10 in terms of voltage decay rates, and to a transfer function, simpler than expected, being a ratio of 1 to 1 for the number of cycles. For the exacerbated load cycles, with lower minimum load and higher current peaks compared to the reference, tests accelerated active area losses and voltage decay but acceleration factors were smaller. Reducing slightly dwell times and enhancing some stressors, could help improving acceleration with robust MEAs. All combined AST protocols could be transferred to stack scale. If overall behaviour and ranking of MEAs are similar with different designs, acceleration factors were different from those assessed in single cells, probably due to large size effect not fully resolved.

Thanks to more experimental ageing data, successful simulation of cycles for both real ageing and ASTs could be conducted. With modelling of the differential cell performance, simulation of low power AST could be done confirming the additional impact of air stops. For the automotive stack design, simulation of the whole cell highlighted the temperature stressor effect during the high power part of cycles. Simulation of ID-FAST cycles, up to 1000 for the reference, involving the platinum Ostwald ripening mechanism, showed the accelerating effect of increasing temperature and strong impact of reducing minimum load and increasing voltage amplitude.

As a general conclusion, despite issues encountered for the availability of appropriate components and test objects and additional time lost due to covid-19 situation, ID-FAST could successfully achieve expected outcomes. Combined AST protocols were indeed developed and validated with regard to their relevance and their capability to actually reduce testing time compared to real ageing.

2.2 Exploitation and dissemination of results

Key exploitable results identified by the consortium: ID FAST driving cycle (based on BMW customer data) verified and adapted to commonly used test stations; validated ASTs; methodology and protocols for AST dedicated to PEMFC, Polimi’s Zero-P and multi-zero-P (four single cell tests in parallel) hardware.

Results have been disseminated in scientific conferences, during the successful ID-FAST final workshop and with 11 open-access publications.

Recommendations are available as support to standardization activities on AST for Fuel Cells at the IEC TC105.

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

New approaches have been proposed, applied and validated with different core components and test hardware single cells and stacks.

Operando ASTs developed show better representativeness compared to state of the art ASTs available at the beginning of the project. The approach based on new reference drive cycles, and their adaptation towards ASTs by changing the load profiles in different ways, is generic and applicable for other kinds of usage profiles. The work on the impact of stressors with experimental tests as well as assessment by simulation, actually allowed validating a fully original methodology.

The methodology developed is valuable for automotive and other field of transport or stationary applications using PEMFCs. Outcomes should be of interest for components and stack manufacturers, as well as system developers and end-users.

ID-FAST investigation activities and results did clearly achieve to contribute to all expected impacts as defined by the original topic.

4. Address (URL) of the project's public website

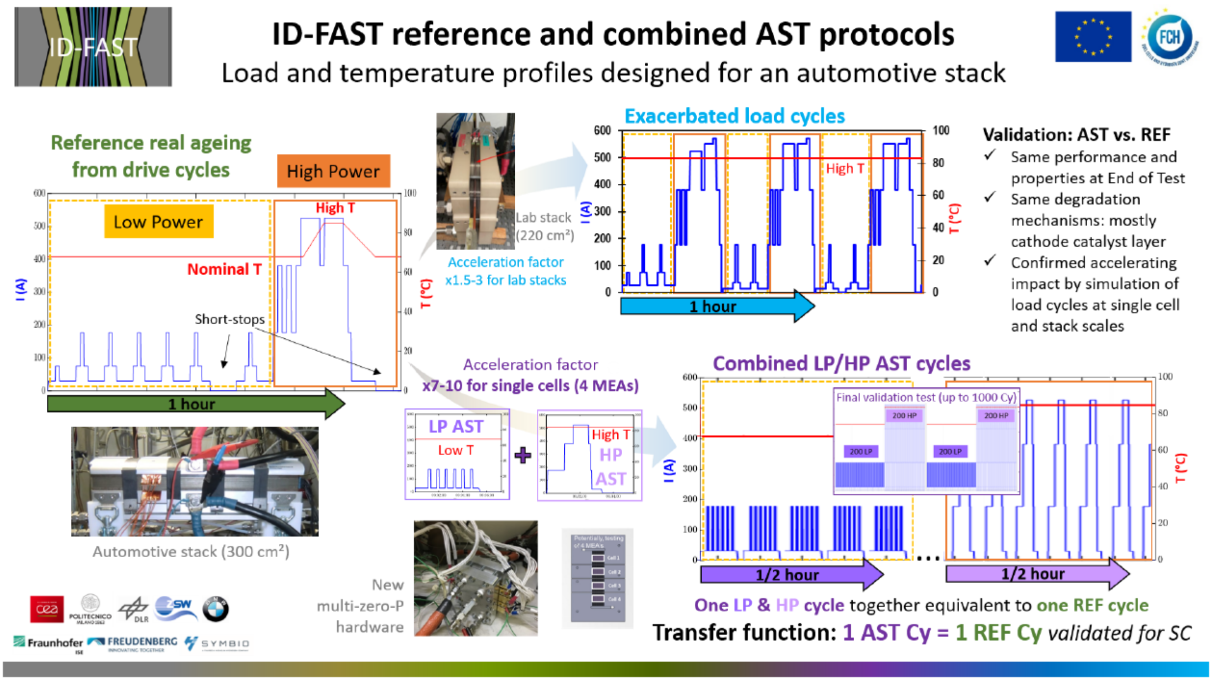
http://id-fast.eu/

5. Acknowledgement

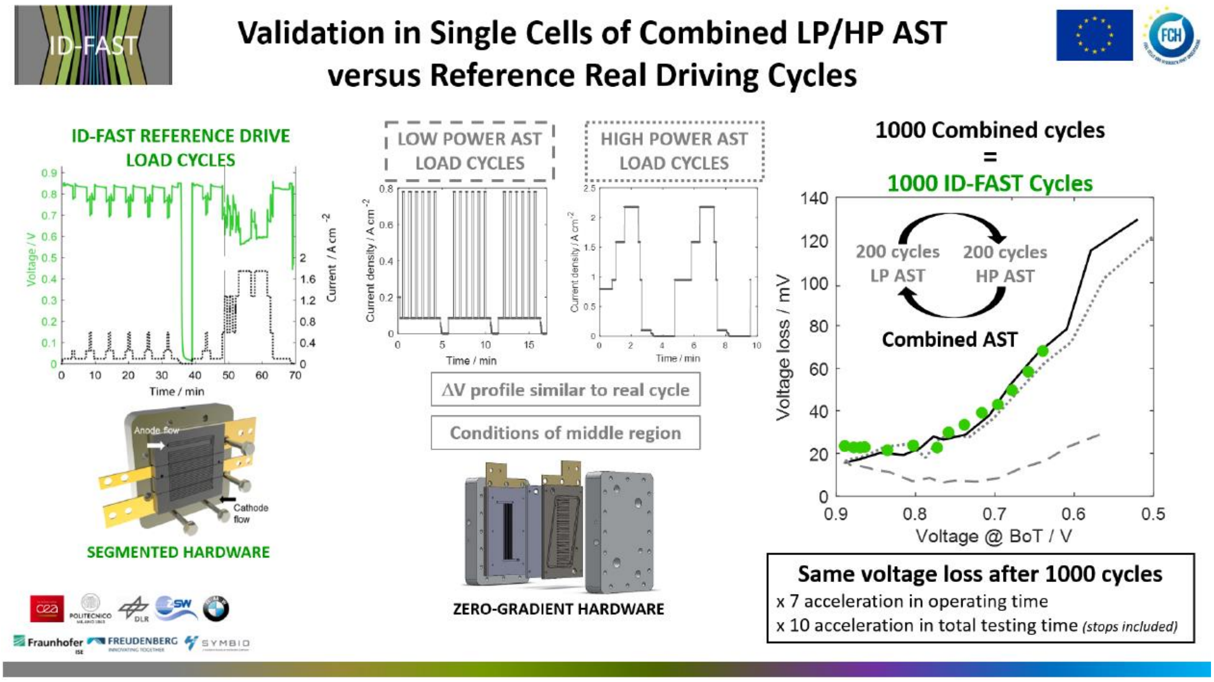
This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No (779565) (project ID-FAST). This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation program, Hydrogen Europe and Hydrogen Europe research.

6. Images

6.1 ID-FAST ref and combined AST protocols - Load and Tstack profiles designed for an automotive stack



6.2 Validation in Single Cells of Combined Low & High Power AST versus ID-FAST Reference - Driving Cycles



6.3 Characterization of cathode catalyst degradation by advanced electron microscopy techniques