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AutoStack-CORE: Development of PEM-Fuel Cell Stack Platform for Automotive Applications

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Executive Summary

Car manufacturers worldwide are moving towards market introduction of fuel cell vehicles with Asian companies in the lead. Europe has a strong base in research and industrial development of fuel cell components, yet competence of industrial stack integration needs to be strengthened. In the AutoStack-CORE project, key stakeholders from automotive OEMs, the component supply industry, stack and system integrators joint forces with research organizations to develop best-of-its-class automotive stack technology. The development deliberately was based on components which can be manufactured at industrial scale. Stringent cost engineering and analysis ensure compatibility with the cost constraints of commercial market introduction. The stack peak power density of $\sim 4 \text{ kW}\cdot\text{l}^{-1}$ at specific cost of 36.81 €kW^{-1} favorably compares with state-of-the-art stack technology and can be considered best of its class.

1 Introduction

PEM-fuel cell stack technology with high power density and commercially acceptable cost is a key element for the application in car propulsion systems. Recent progress in enhancing power and encouraging results from independent high volume cost studies in the project are now taking fuel cell technology closer to market introduction. Sharing the transportation stack platform with different non-transport applications further enhances economies of scale in the early phase of market introduction.

AutoStack-CORE is a collaborative European project joining forces of automotive OEMs, the supply industry and European research organizations to develop automotive PEM fuel cell stack technology with superior power density and performance using components designed and manufactured at industrial scale to meet commercial target cost.

2 Technical Approach

The technical stack concept is based on the results of the previous AutoStack project assessing automotive requirements and packaging constraints backed by major automotive OEMs. The resulting stack platform concept aims at benefitting economies of scale and reducing critical investment cost by sharing the same

stack hardware/technology among different car platforms, other transport and non-transport applications. The viability of the platform concept has been proven by a detailed analysis of the packaging constraints of different vehicles from three different car manufacturers.

A key feature in this project is the use of mature industrial components which are manufactured at industrial scale using industrial production equipment. The technical development work is accompanied by detailed, design specific cost engineering and cost analysis at component and stack level including relevant manufacturing processes by an independent service provider.

The technical work is undertaken in three development evolutions. Stack evolutions 1 and 2 are designed, built and tested in hardware while evolution 3 will point out further optimization potential in a design study.

3 Results

After 18 months of development time, the first stack design evolution was completed and tested in short and full sized stacks. Extensive testing allowed to identify further potential to improve several design properties, power density and cost. A comparison of specifications and achievements in evolutions 1 and 2 is shown in Table 1.

Table 1 Objectives and achievements in evolution 1

Objective	Specification	Achieved in Evolution 1	Achieved in Evolution 2
Power	95kW (continuous), 118kW (peak for 30 sec)	94 kW (continuous), 99 kW (peak for 30sec)	96 kW (continuous) 114 kW (peak)
Stack-power density	2,8 kW/l (continuous), 3,4 kW/l (peak)	2.7 kW·l ⁻¹ (continuous), 2.9 kW·l ⁻¹ (peak)	3,8kW·l ⁻¹ (continuous) > 4 kW·l ⁻¹ (peak)
Fuel	Neat hydrogen	Neat hydrogen	30% nitrogen in hydrogen
Nominal power density	1 W·cm ⁻² @ 1.5 A·cm ⁻²	0.947 W·cm ⁻² @ 1.5 A·cm ⁻²	0.978 W·cm ⁻² @ 1.5A·cm ⁻² 1.0 W·cm ² in neat hydrogen
Maximum operating temperature	95 °C	95°C	95 °C
Cathode humidity	< 50 % RH	50 % RH	50% RH
Operating pressure	2.2 ... 2.4 bar (continuous) 2.7 bar (peak)	2.2 bar (continuous) 3 bar (peak)	2.2 bar (continuous) 2.2 bar (peak)
Degradation rate	< 12 μV·h ⁻¹	47 μV·h ⁻¹	~ 20 μV·h ⁻¹
Freeze-start	From -25°C	Demonstrated from -20 °C	12.8 sec from -20 °C
Specific stack cost corresponding to DoE-study ¹	< 40,00 €kW ⁻¹	47.83 €kW ⁻¹	36.81 €kW ⁻¹

Figure 1 shows a comparison of I/V-curves indicating progress from the 2012 state of the art achieved in graphite composite bipolar plates. In a first step, the performance was successfully transferred into metallic bipolar plate design. In this step the cell pitch was reduced from 2.5 mm in the graphitic design to 1.2 mm in stack evolution 1. Further improvement in cell design allowed a reduction in cell pitch to 1 mm and a significant increase power density by optimizing the flow conditions and the water removal capabilities of the design. In combination with a further increase in the active to passive ratio, the overall stack volume became 27.2 l at a weight of 33.1 kg.

The stack evolutions 1 and 2 were subject to a thorough test program addressing stack performance and endurance. In order to account for nitrogen cross over from the cathode, evolution 2 testing was done with a nitrogen content of 30 vol% at the anode inlet.

Endurance testing was done using a dynamic load cycle. An irreversible degradation rate of approximately $20 \mu\text{V}\cdot\text{h}^{-1}$ at a current density of $1.5 \text{ A}\cdot\text{cm}^{-2}$ was found when using a pure platinum cathode catalyst.

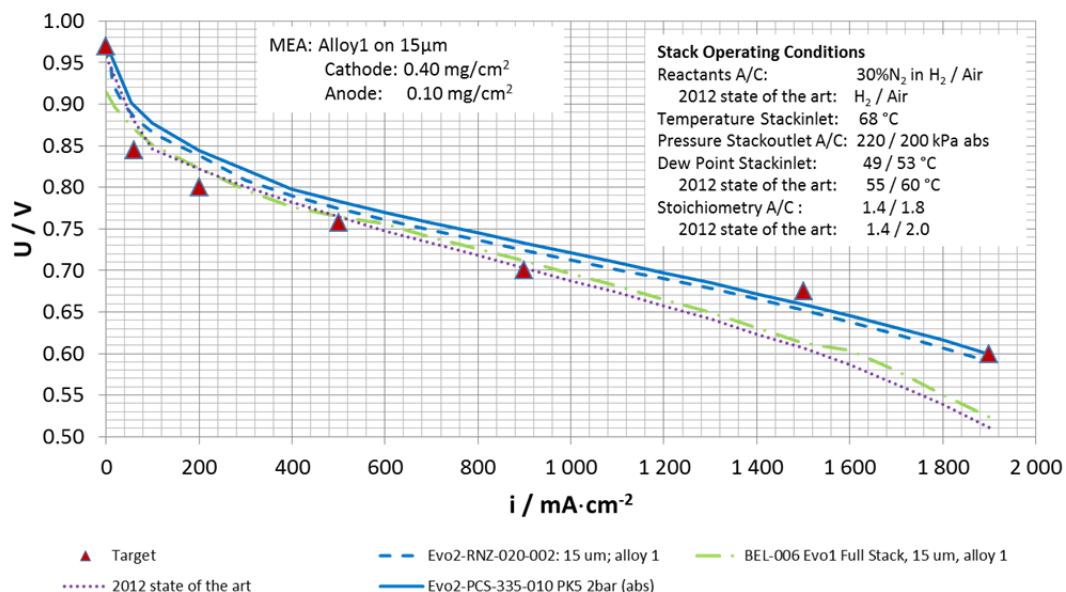


Figure 1: I/V-curves showing progress during the project

Freeze starting of the evolution 2 stack could be demonstrated starting from $-25 \text{ }^\circ\text{C}$. At a temperature of $-20 \text{ }^\circ\text{C}$, the stack reached 50% of its power density after only 12.8 sec while still using a not fully optimized freeze-start procedure.

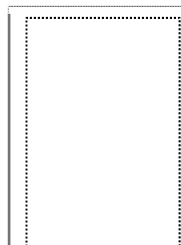
Being near to completion, the project has achieved or exceeded all its major technical and cost targets. More than 30 short and full size stacks were built and tested to validate and prove the achievements. The results are confirming robust operation of the stacks under the specified requirements. After 4 years of development, **AutoStack Core** now can provide top of class, viable and affordable automotive stack technology to support the upcoming FCEV commercialization activities.

Initial field testing of the stack is carried out in a range extender system powering an 18 ton delivery truck.

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Ludwig Jörissen is currently leading the fuel cell fundamentals team at ZSW. His main research interests are in electrochemical power sources using aqueous electrolytes as well as polymer electrolyte membrane fuel cells. He joined ZSW in 1990 after obtaining a doctorate in Physical Chemistry from University of Ulm.

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André Martin has collected long experience and background with industrial fuel cell and system development in executive positions with Ballard Power Systems and NuCellSys. He has coordinated the establishment of the Fuel Cell and Hydrogen Joint Undertaking from 2007 to 2009. Since then, he is working as consultant and has supported numerous studies and projects in the field of hydrogen and fuel cell technology. André is Member of the Board of the German Fuel Cell and Hydrogen Association, of the Board of Directors of Powercell Sweden SA and Senior Advisor to Roland Berger Strategy Consultants.