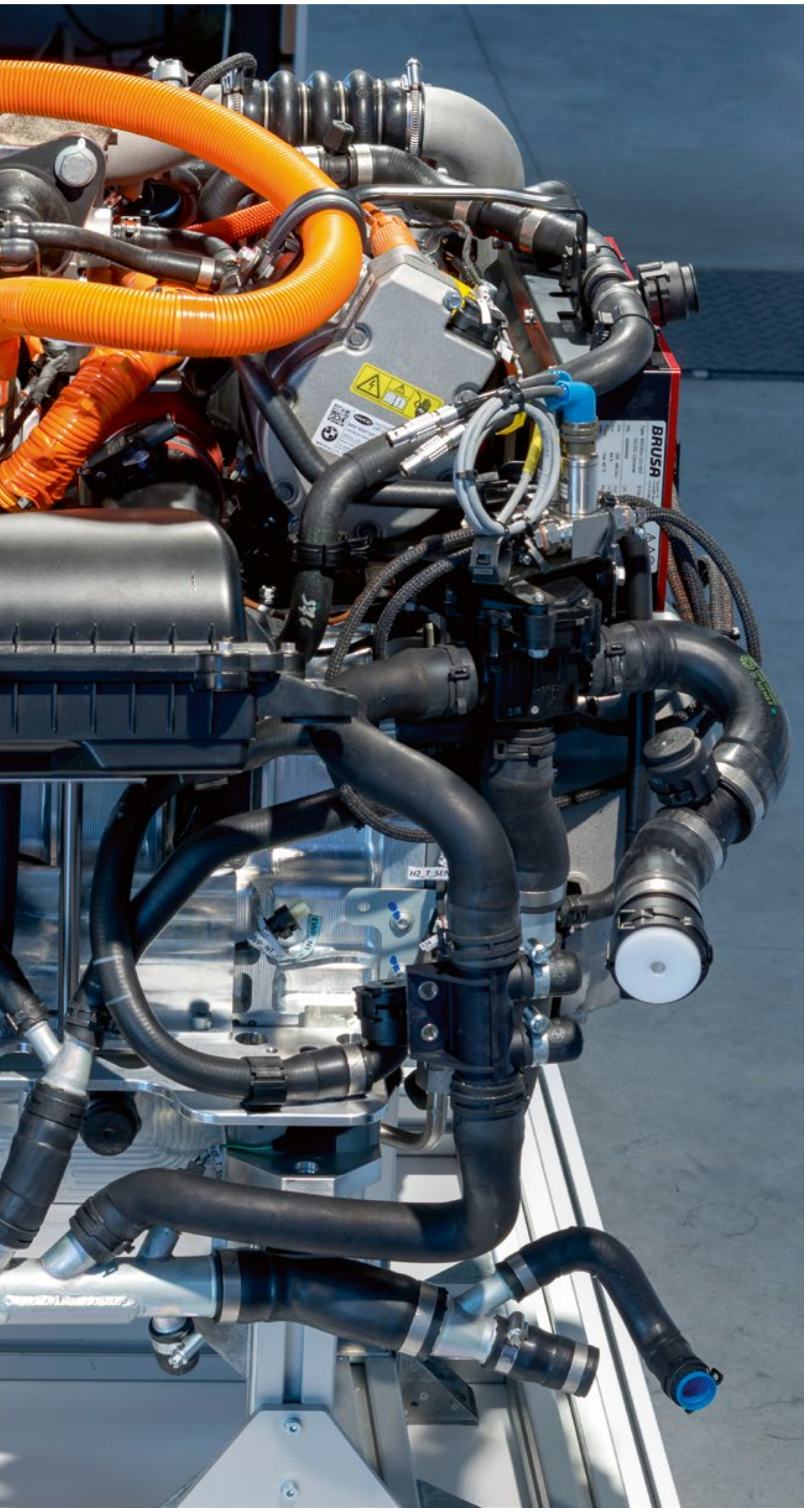
Industrial Collective Research on Fuel Cells

Late last year, the Research Association for Combustion Engines (FVV) launched its new Fuel Cell Planning Group with the primary objective of making carbon-neutral long haul and cargo mobility affordable through industrial collective research. The research projects initiated so far have revealed considerable potential for cost reductions in the field of fuel cells.

1 MOTIVATION

As a consequence of the Paris Convention, the German Federal Government has developed a climate action plan calling for "mobility to be largely greenhouse gas neutral" by 2050 [1]. To the current state of knowledge, this objective can hardly be reached through battery-electric drives alone. The energy density of batteries – even of future generations – will not be high enough to enable long haul and cargo mobility. In order to nonetheless become independent from fossile fuel energy sources and resulting CO_2 emissions, chemical energy sources produced by electricity from regenerative sources, such as solar or wind energy, present as possible options. Since the conversion paths under current discussion focus mainly on hydrogen generation by electrolysis as a first process step, research should be directed towards energy converters which will allow hydrogen to be transformed into forms of energy that can directly be used in vehicles, i.e. in hydrogen-operated combustion engines and fuel cells.

Generating on-board electricity with fuel cells has various advantages over battery-electric drives, including fast



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VOICES OF THE FVV

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Dr. Michael Bauer is in charge of fuel cell system and component development at BMW, Munich, and has been the designated Chairman of FVV's fuel cell planning group.
"Development tools for fuel cells are only partially available, also because interdependencies have not yet been sufficiently researched, which is why the new fuel cell planning group will also focus its efforts on simulation."

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Dr. Merten Jung has been heading the new fuel cell planning group in the FVV since it was first founded. Until 30th June 2017, he was responsible for fuel cell development at BMW in Munich.
"It is our aim to use application-based research to significantly lower the cost of fuel cells without compromising their everyday suitability which by now is considerable."

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Martin Nitsche is the Deputy Managing Director of the Research Association for Combustion Engines (FVV), Frankfurt/Main.
"We have little knowledge about the impact of materials used in the hydrogen path and to what extent such materials contribute to contaminating catalytically effective surfaces. Understanding the interactions of hydrogen and air supply systems is therefore a key endeavour in our research projects."

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Dietmar Goericke is the Managing Director of the Research Association for Combustion Engines (FVV), Frankfurt/Main.
"Our new focus of research will allow small and medium-sized enterprises to enter the value added chain of fuel cell production. In this new age of mobility, the results of our research will substantially improve the competitive edge of our FVV members in similar ways as has been the case in the field of engines and turbines for more than sixty years now."

FVV **http://www.fvv-net.de/en**

FIGURE 1 Hydrogen as an energy source provides emission-free and practicable long haul mobility (© Tom Kirkpatrick | BMW)

recharge, high energy density and operation independent from outside temperatures, **FIGURE 1**. However, the cost of low-temperature fuel cells suitable for vehicle applications is still too high for economically viable, large-scale standard production, one of the reasons being the use of the precious metal platinum at reactive cell membranes. This is why FVV have initiated application-oriented joint research into fuel cells with the objective to significantly lower the cost of future fuel cell generations through innovative solutions, focussing on the following technical approaches:

- Lower platinum content without sacrificing performance and service life. Peripheral systems for hydrogen and air supply play an important role in this.
- Optimised control of overall system behaviour and of subsystems, e.g. thermal management.
- The development of suitable simulation models for the quick evaluation of new ideas.

The research group, which was initiated in early 2017, is widely supported by industry. More than 45 international market and technology leaders and SMEs (small and medium-sized companies) from Germany, Austria, Switzerland, Luxemburg, Sweden and Japan have decided to join their forces in pre-competitive joint research. The group has already launched its first research projects, financed through FVV's own funds. Expected results will be serving as knowledge-based building blocks and will be contributing to the overriding aim of emission-free long haul and cargo mobility.

2 FIRST PROJECTS

2.1 CORROSION AND CONTAMINATION IN THE HYDROGEN PATH

The purity of hydrogen gas is decisive for the service life of mobile fuel cell systems. It is a known fact that minor changes in gas composition may lead to membrane damage and to the corrosion of gas-carrying components. It has not yet been explored to what extent such contamination occurs also during operation, for example through by-products released during reaction or as residual contamination in manufacturing processes. Neither the exact products nor the damage mechanisms they may trigger are known. In a first step, the products generated during operation will, therefore, be systematically recorded in a basic research project initiated by Audi, BMW and Bosch. They will be classified according to the various pressure ranges in the anode path and the sources of contamination, with a focus on the following sources:

- residual contaminants from the manufacturing process, such as lubricants and particulates
- emissions products, such as outgassing from polymer components
- interactions with other media, such as with deionised water.

The objective of this project is not only to determine the products as such but also to develop a method that will reliably investigate the impact on membrane functionality and the effect of corrosion. Random samples will reveal the damage potential of the products involved. The project will, therefore, be making an important contribution to understanding which mechanisms may reduce the lifecycle of fuel cells.

2.2 CATHODE AIR QUALITY

Similar to the gas composition on the anode side, air quality on the cathode side also has a strong impact on the service life of low-temperature fuel cell systems. For this reason, the ambient air is cleaned upstream of the cathode. So far, the design of such filters has been based on individual tests. Concentrations and compositions of air pollutants, however, vary in the different geographic regions of the world, as in Japan, where sulphurous gases from seismic activities can be measured. Moreover, the damaging effects that individual pollutants have on active membranes as well as on air-carrying components are not entirely known.

Air filter system design for fuel cells should be based on knowledge which is best obtained through standardised procedures; an FVV project initiated by Mann+Hummel will be delivering the basics. A first step will be to define critical pollutants and to then determine their maximum concentrations so that the negative impact on the service life of fuel cells is limited. One reasonable approach may be a classification system according to operational regions – as it exists for combustion engines. Such a classification system will complement a worldwide standard with special solutions for regions with poor air quality. The next step will be the definition of suitable materials for air-carrying components and, based on that, the performance required for separating the various pollutants.

"This project is about providing a general design tool for cathode air filters" explains Dr. Michael Harenbrock, Senior Expert for electric mobility and fuel cell systems at Mann+Hummel. "Other already completed projects mostlyfocussed on understanding damage mechanisms and on creating model proof-of-concept solutions for dedicated filter designs." The new project will thus establish the grounds for standard air processing solutions and contribute to making fuel cells competitive.

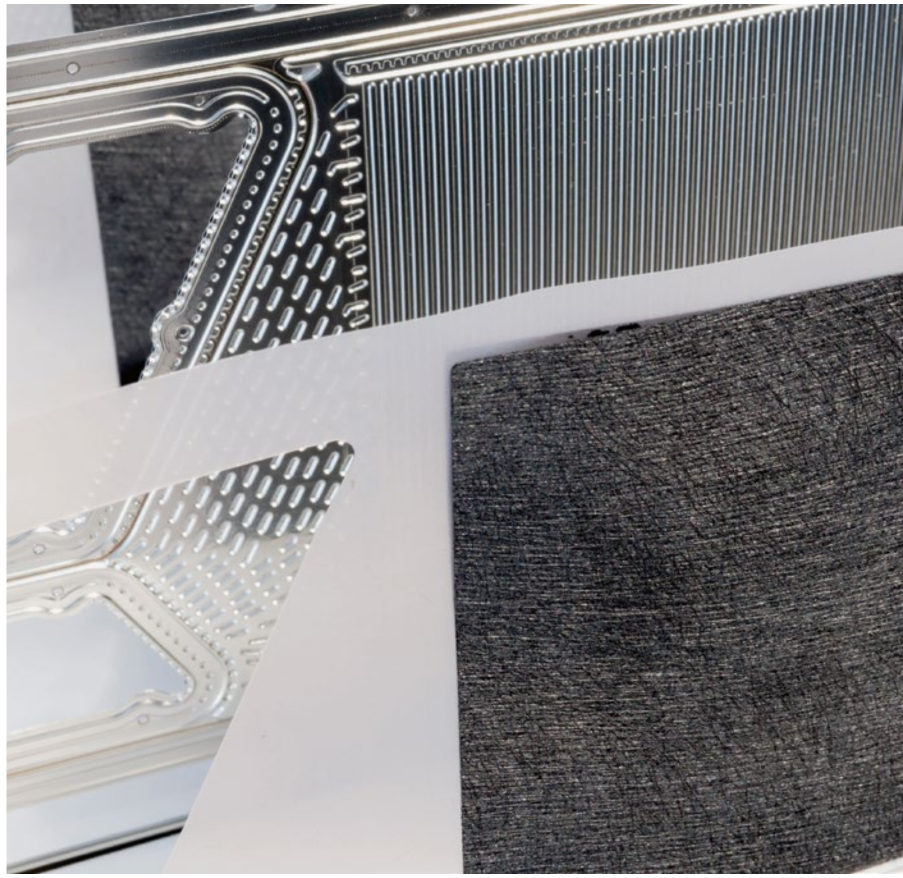

FIGURE 2: The thermal management challenge: stack-integrated cooling (© Tom Kirkpatrick | BMW)

2.3 OPTIMISED THERMAL MANAGEMENT

Since low-temperature fuel cells operate at temperatures between 60°C to 110°C and in spite of the high efficiency, the heat output generated during high load is considerable and corresponds to the provided electrical power output. Due to the low exhaust gas temperature, such heat output occurs mostly in the cooling system and needs to be continuously dissipated. Several requirements which differ greatly from those known in cooling systems of combustion engines have to be met:

- Bipolar channels used for cooling are in direct contact with the bipolar plates in the stack, **FIGURE 2**, so that the coolants' electrical conductivity needs to be limited to a maximum of 5µS/cm.
- Heat in the stack needs to be transmitted at very low temperature differences (inlet to outlet) of less than 10 K, requiring very high coolant flow rates – and leading to high shear forces in the coolant.

Standardised development tools for cooling down fuel cells which also take account of the coolant's ageing behaviour and its effect on cooling system components are currently unavailable. An FVV project initiated by TheSys, a medium-sized engineering service provider based in Kirchentellinsfurt, Germany, therefore, aims at developing a test method which is capable of assessing the suitability of coolants and materials in standard production. Its most important element is the generation of an emulator which thermal behaviour can realistically be simulated in an early stage of development. This project is thus making an important contribution to developing standardised methods and, as a consequence, to reducing the cost for developing fuel cell systems.

3 OUTLOOK ON FUTURE RESEARCH PROJECTS

The results of application-oriented research, as initiated by FVV, were suc-

FIGURE 3: The system integration challenge: numerical methods must be further developed (© Tom Kirkpatrick | BMW)

cessfully and quickly put into industry practice for classic combustion engines. Freely available simulation methods developed in research projects have played a major role in this context [2|. Especially small and medium-sized enterprises (SMEs) benefit from the fact that ideas from pre-competitive joint research can swiftly be tested for feasibility.

Such development tools are only partly available for fuel cells, for their level of maturity is not as advanced and not all cause-effect relationships have been sufficiently explored. The new planning group on fuel cells wants to, therefore, make simulation one of its focus areas. Especially promising is any approach which

- numerically maps critical subsystems such as managing membrane moistening. Humidification is key because the catalytically effective surfaces get damaged when local moisture is insufficient while, in contrast, an excess of local water can impede the reactions at the membrane.
- enables a simple and quick simulation of system behaviour. Especially the basic development of components which aims at reducing cost could benefit from numerically mapping highly complex "low-temperature fuel cell" systems and their numerous interactions.
- maps the behaviour of a fuel cell system in an electrified powertrain. Due to the transient fuel cell behaviour, vehicles will always have additional electrical storage on board. The fine-tuning of all drive components may therefore have a major impact on how competitive fuel cells will be.

The results of any research will raise new questions. The group's activities can, therefore, not cover all areas of research that may be of future relevance. The results of application-oriented pre-competitive joint research will, however, promote Germany's competitive edge for fuel cells as it has for combustion engines and turbines for now more than sixty years.

REFERENCES

[1] Federal Ministery for Environment, Nature Conservation, Building and Nuclear Safety (publisher): Climate Action Plan 2050. Berlin, 2016

[2] FVV (publisher): Prime Movers : Current areas of research into engines and turbines. Frankfurt/Main, 2016

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