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DEVELOPMENT OF A MODULAR RESEARCH CAR INGENIO AS A PLATFORM FOR ANALYSIS OF FUTURE DRIVE SYSTEMS

With the new goal of the German government, to have at least one million hybrid or electric cars on the street at the year 2020, the studies on such cars have become more and more important in the industry. A second reason for this project is the emission target of the European Union for the year 2020, which limits the average fleet emission of CO_2 to 95g/km. This constraint forces the car manufacturer to build cars with lower fuel consumption like hybrid cars.

Hydrogen (H_2) is praised for a long time as a future energy carrier. Yearly ca. 600 billion Nm^3 of H_2 are generated worldwide. Of these 40% are from industrial processes as a by-product. The remaining 60% are directly produced, primarily over reformation of fossil fuels [1]. Today H_2 production out of water plays a very low role on account of the high energy involved. In a quite possible future H_2 economy all renewable energy sources can be used to produce hydrogen as a multi-purpose fuel. In the course of that volatility of the electricity grid due to the already high proportion of volatile energy generators (e.g. wind power stations or photovoltaics) can be compensated.

Beside the domestic energy supply also new ways for transportation must be found to countervail the depletion of fossil fuels. The problems of today's pure electric drive concepts can be divided in three areas: high investment costs, short range and high weight. The utilization of braking energy has just a small positive impact on these problems. However, the use of braking energy is one of the great advantages of battery electric concepts. Drive systems based on fuel cells thus always require an additional battery pack to make the "free" braking energy by recuperation available. When using a convertible electrolyser the extra battery pack is not needed, as a invertible electrolyser acts both as a fuel cell and an electrolyser by using braking energy.

Research vehicle: The new modular research car INGENIO (s. figure 1) will become a Platform for the development of new technologies like hybrid and pure electric cars. Major priorities of INGENIO are drivetrain research, cell monitoring and simulating and testing different modes of operation. INGENIO is build up in several stages, where mainly the modular rear frame will be changed. The first stage is a set up with two electric motors at the front axle near to the wheels. The second stage is a hybrid set up, where the modular rear frame is equipped with an ICE range extender. At the third stage, the ICE range extender will be connected directly to the rear wheels (axle split hybrid).

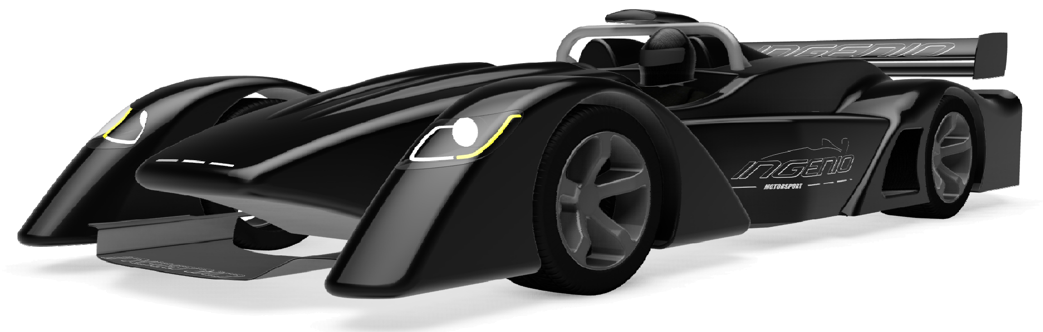

Figure 1: The new modular research car INGENIO

Parallel to the practical work in the last stages, research is going on, to build an own fuel cell stack and an invertible electrolyser to equip the modular rear frame with an fuel cell range extender at the fourth stage and with an invertible electrolyser at the fifth stage.

The front axle is build up with two GKN electric motors with 140 kW maximum power and 1400 Nm torque at each wheel. They are working at 600 V nominal, have at maximum 8000 rpm and are connected over planetary gears to each wheel with a ratio of 4:1. A theoretical top speed of over 200 km/h is possible with an 18 Inch wheel. The weight of one Motor including the gearbox is about 50 kg. The maximum current of the Motors is 300 A. The electric energy is stored in 540 Li-Ion cells which are arranged in two battery packs, placed at the sides of the frame (s. figure 2). The battery packs with a capacity of ca 10 kWh and a weight of 96 kg supply a maximum current of 300 A and a peak power of 210 kW.

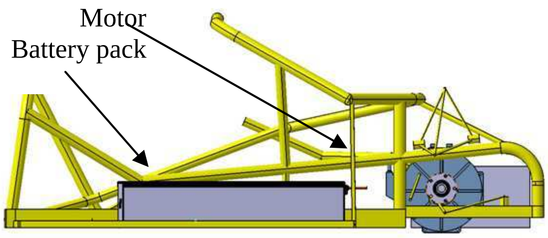

Figure 2: CAD model of the front part according to first stage.

Invertible electrolysis: On the way to an invertible electrolyser stack an electrolysis cell will be examined, then a fuel cell and as last step the invertible electrolysis. The current focus of this work is, to produce Catalyst Coated Membranes (CCMs) by using different coating methods. The final result of this work should create a basis to be able to produce favorable electrolysers. For this purpose studies for the development of a single electrolysis cell are carried out. After the necessary materials, methods and processes are known, an electrolyser with higher power can be built up, which consists of stacked cells.

To work with a not already existing technology is the great difficulty of this work. To reduce the cost of water electrolysis, a completely new electrolysis cell is examined – the Anion Exchange Membrane Electrolysis Cell (AEMEC). Research activities are currently limited to a small extent only to the Anion Exchange Membrane Fuel Cell (AEMFC) and on the corresponding catalysts and membranes. The AEMEC is a combination of a conventional Alkaline Electrolysis Cell (AEC) with a liquid electrolyte and a Proton Exchange Membrane Electrolysis Cell (PEMEC).

Approach: To be able to build up a functioning electrolysis cell, catalysts on both sides of the AEM must be placed in a way that water is in contact with the catalyst that the catalyst is in contact with an electric conductor and the AEM, the ionic conductor. To achieve this, various methods are examined. For these methods catalyst inks with different composition and viscosity must be produced. The catalyst inks are homogeneous suspensions which do not separate themselves, do not hinder the ionic conductivity but promote it and are electrically conductive. The ink may be either applied on the gas diffusion layer (GDL) or directly onto the membrane. Therefore the ink must not damage neither the GDL, nor the membrane. In the dry state on the GDL or the membrane, the catalyst material may not modify or get removed. The coating results are evaluated with the help of SEM (s. figure 3), AFM and also with AEMEC polarization curves.

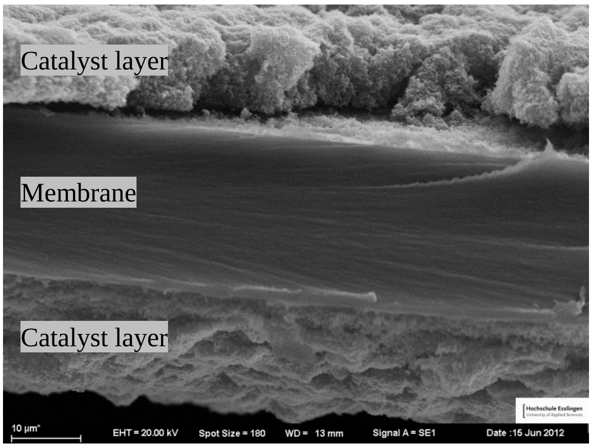

Figure 3: SEM cross-section picture of a CCM using spraying method.

Results: With a spraying method homogeneous and porous coatings with layer thicknesses of 1.5 - 15 µm could be produced. First coatings were done with inks out of an ionomer solution, demineralized water, 1-propanol, carbon powder and catalyst powder (cathode: C-10-PT, 3020 Series from Acta; anode: IrO_2). The polarization curves of some Membrane Electrode Assemblies (MEAs) are shown in figure 4. The catalyst loading was around 0.1 to 0.2 mg/cm². The ionomer content of the catalyst layer was around 0.8 to 1.1 mg/cm². In the experiments CCMs were used, which were coated with IrO_2 on the anode side and 3020 series on the cathode side. The CCM "KatMem6" also contains no Platinum. The lower overpotentials were achieved mainly by improving the coating procedure.

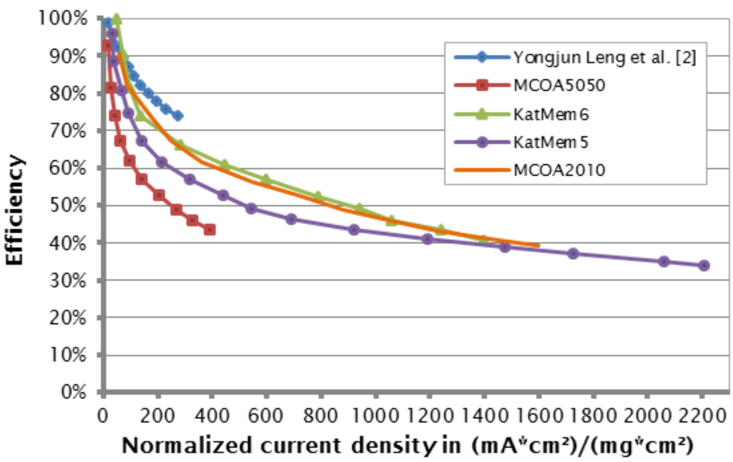

Figure 4: Efficiency curves normalized to the catalyst loading of produced MEAs in comparison to [2].

Conclusion: The first results show that the overvoltages are very high. However, this was expected. According [2] at an applied power of 50 W an efficiency of 78% is achievable. Nevertheless, in [2] platinum was used as catalyst and the catalyst loadings were higher than the here presented results by a factor between 16 and 32. Figure 4 shows the efficiency curves of two CCMs produced by using the spraying method (KatMem) and two CCMs produced with the screen printing method (MCOA) in comparison with the CCM from [2]. To be able to compare the values, the current density has been normalized to the catalyst loading. By normalizing the values, the improvement of the coating process can be seen clearly from KatMem5 to KatMem6 resp. from MCOA5050 to MCOA2010.

The focus of these first tests did not aim at achieving the highest possible efficiency. It was rather to understand the coating process to be able to make conclusions from polarization curves for the optimization of the coating process.

References:

[1] Eichlseder, H.; Klell, M.: Wasserstoff in der Fahrzeugtechnik. Vieweg + Teubner Verlag, 1 Auflage, 2008.

[2] Leng, Y.; Chen, G.; Mendoza, A. J.; Tighe, T. B.; Hickner, M. A.; Wang, C. Y.: Solid-State Water Electrolysis with an Alkaline Membrane. Journal of the American Chemical Society, May 15, 2012