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Short communication

# Development of a stack having an optimized flow field structure with low cross transport effects

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**Abstract**

PEM fuel cells when operated on hydrogen from renewable sources are viewed as one of the most environmentally friendly energy conversion systems due to their high electrical efficiency. However, this advantage is depending on the overall system design, which is largely determined by the allowable operating conditions of the fuel cell stack itself. Besides the active materials, design and shape of the gas distribution zone have a significant influence on stack operation. In order to optimize overall system performance, a fuel cell stack with improved flow field design and performance was developed. An investigation on channel geometries led to a serpentine flow field with a moderate degree of parallelization and ribs with variable width to reduce cross transport effects. The resulting flow field subsequently has been modified slightly to allow a high volume production process. Summarizing, power as well as the degrees of $H_2$ and air utilization could be enhanced leading to a power density enhancement. Furthermore, weight reduction of end plates nearly by half using an improved end plate design led to an overall improved stack design.


*Keywords:* Fuel cell; PEMFC; Flow field design; Rib and channel geometry; Cross transport effects

## 1. Introduction

ZSW is developing PEM fuel cell stacks for use in portable power generation and stationary applications since 1995. Stacks with 50 cells having an active area of $100\,\text{cm}^2$ per cell resulting in a total power output up to 1.4 kW have been built and operated successfully. A power density of up to $0.3\,\text{W}\,\text{cm}^{-2}$ at an averaged single cell voltage of 0.6 V has been obtained, however, at comparatively low gas utilization. From a system point of view, it is evident, that hydrogen and air utilization is of great influence to the overall system efficiency. In this work, the influence of flow direction, flow field geometry and channel geometries on the stack performance have been studied, and experimental results on the effects of relative flow direction and flow field geometry will be reported. Additional studies on the influence of channel geometries are in progress and will be reported elsewhere [1].

## 2. Experimental procedures

Starting from ZSWs standard configuration (internal manifold, cross flow), an experimental investigation on the influence of media flow directions and channel geometry has been carried out. A total of 10 different five-cell short stacks with varying width and depth of the flow channels and width of the ribs separating the channels were built and tested. Commercially available membrane electrode assemblies (MEA) and gas diffusion layers (GDL) were used. Stacks made from the previous standard design (cross flow) were tested as a reference. The experimental work was accompanied by CFD modeling using FLUENT™ software.

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**Nomenclature**

dp dew point
$X_{an}$ anode gas utilization, given as ratio between converted and supplied amount of hydrogen
$X_{ca}$ cathode gas utilization, given as ratio between converted and supplied amount of oxygen (in air)

### 2.1. Basic stack design

The flow fields to be investigated were machined in blank graphite composite plates. Anode and cathode side gas distribution fields were machined in separate plates. Each cell contained a cooling water distribution field, which was machined into the cathode plate. Separate metal ring gaskets having a screen printed silicon layer were used allowing to seal the anode and cathode part of the bipolar plate as well as an easy interchange of MEAs. The active area has been 100 $cm^2$ in all cases. Both, serpentine (anode and cathode) and pattern type (anode) flow fields were investigated for gas distribution. GORE PRIMEA 5620 MEAs having a platinum loading of 0.3 $mg\,cm^{-2}$ at the anode and 0.4 $mg\,cm^{-2}$ at the cathode side were used as MEA. SGL 10 BB material was used as GDL.

Although in the initial phase reported here, the bipolar plates used were still machined, the final design can easily be adapted to a compression molding process.

### 2.2. Test bench

The cell performance was determined using a test bench developed at ZSW in cooperation with hydrogen-systems. The test bench layout is described in [2].

The test bench allows measurement and recording of all relevant experimental parameters (stack and single cell voltages, current, temperatures and pressures). Moreover, high frequency resistance (HFR) data at a frequency of 1 kHz can be recorded online in order to determine effects related to water management and cell construction. Gas humidification is achieved by passing the premixed reactant gases through a heated and isolated bubbler.

### 2.3. Test procedures

The stacks were tested using pure hydrogen as a fuel and air as an oxidant. Furthermore, tests using synthetic reformate have also been carried out. However, since no Pt/Ru catalysts were used, CO was not added to the simulated reformate. Normal operating conditions were as follows: $T_{Stack}$ = 55–60 °C, ambient outlet pressure, dry anode gas, cathode inlet dew point 45 °C. Hydrogen utilization 70%, air utilization 25%.

The tests were carried out under variation of the operating temperature, gas composition and gas utilization at anode and cathode side.

## 3. Results and discussion

For the development process reported here, the channel and rib geometries were fixed between 0.7 and 1.0 mm, respectively. These values have been selected based on a survey of the literature [3–5] as well as on model studies performed at ZSW. The results of these studies on the influence of rib and channel dimensions were experimentally tested and will be reported in [1].

### 3.1. Comparison of flow directions

Concerning the relative media flow direction, co-, cross- and counter flow designs were evaluated. The configuration scheme of flow directions is shown in Fig. 1. The scheme should illustrate the flow pathways and is not drawn to scale.

All performance data are given as mean single cell voltage dependent on current density or gas utilization. The performance dependency on flow directions for partially humidified gas streams was found to be increasing from co- to cross- and counter flow. Fig. 2 shows the dependence of cell performance on flow directions for co- and counter flow.

Cross flow conditions were examined as well. They showed an intermediate performance compared to co- and counter flow. If dry anode gas and humidified cathode gas have been used, counter flow turned out to be the best configuration as well for current versus voltage as well as for voltage utilization characteristics. The corresponding cathode utilization voltage characteristic shows a cell voltage of 0.580 V at an air utilization of 30% for co-flow, whereas for counter

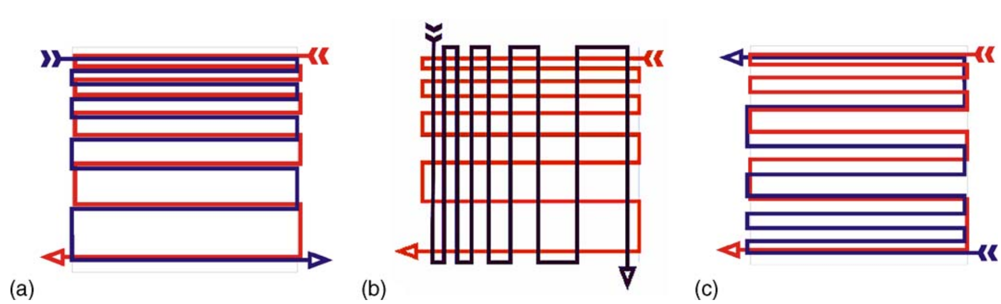


Fig. 1. Flow direction schemes for: (a) co-flow, (b) cross flow and (c) counter flow.