PEM FUEL CELL STUDY BY MULTIDISCIPLINARY APPROACH

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Proton exchange membrane fuel cells (**PEM FC**s) are developed worldwide for vehicle, stationary and portable applications. Optimization of the electrochemical and heat and mass transfer processes in the fuel cell stack's components such as bipolar plates and gas diffusion layers is one of the main tasks for **PEM FC**s engineering. According to the main task this multidisciplinary study aims:

- Optimization of **PEM FC**s manufacturing;
- Optimization of working regimes and parameters in the **PEM FC**s, with special attention to water condensation and heat release;
- Complex diagnostics and metrology development with respect to **PEM FC**s studies;
- Visualization and monitoring the electrochemical and heat and mass transfer processes in the **PEM FC**s;
- Numerical simulation of these processes in the **PEM FC**s;

Such approach needs multidisciplinary efforts and a number of teams joined in the frame of this study. In cooperation of LET and LACCO optimization of **PEM FC**s manufacturing is conducted and new methods of electrochemical flow measurements using carbon-based electodiffusion probes are developed. The study demonstrated that carbon-based sensors can be successfully used for electrochemical flow diagnostics. In particular, these probes allow the measurements of the mass flux and the mean wall shear stress on the surface [1].

In cooperation of LET with Kurchatov Institute, electrodiffusion flow measurements in gas distribution channels of bipolar plates with different design of these channels and conditions closed to practical one have been performed. Analysis of the results shows that the design of bipolar plate with spots-like channels is preferential, especially at high current densities, despite of possible existence of the “dead zones”. However, as demonstrate measurements of cell resistance, caused first of all by contact area between bipolar plates, channel flow and meander-like field structure generally leads in fuel cell performance in comparison with spots- structure.

In the frame of joint investigation with KAI, the pulse method for measurements of space distribution of physical fields with the using of CDS was developed and justified by means of numerical experiments. The mathematical background of this method is the solution of the inverse operator problem for parabolic differential equation. This operator problem was solved by reducing to the problem of the optimal control. The measuring and the numerical algorithm are proposed for the realization of the pulse method. The algorithm was studied under the influence of the measurement noise which corresponds to the real level of experimental errors of modern measuring devices. Two methods of regularization of the measuring algorithm were used, namely Tikhonov regularization and the iterative regularization. The results of the numerical simulations show that for low level of the experimental noise 0.1%-0.5%, which can be achieved by using modern measuring devices, the proposed algorithm is able to restore the space distribution of the measuring physical field with 0.6%-4% accuracy. For the moderate and high level of the experimental noise the error of restoration increase up to the 0.5%-1% and the algorithm remains its stability.

Development of novel optical methods of **PEM FC**s diagnostics has been jointly conducted with HMTI team. It is shown that digital laser dynamic speckle photography is an effective tool for quantitative flow diagnostics in micro-channels of advanced fuel cells. Simple theory of dynamical statistics of speckle fields has been developed and necessary mathematical relations are presented. Software developed allows reconstructing as much as 250 000 velocity vectors in 2d area of 20x30 square millimeters by using optical magnification M=1. The obtained results confirm high temporal and spatial resolution of the techniques and prove the possibility of the real-time operation. Using presented scheme, spatial resolution about 100 μm has been achieved. It is demonstrated, that noise reduction is an essential part of the speckle-images analysis. Software developed allows noise filtration both under direct evaluation of the correlation functions and in Fourier space under the use of the FFT.

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