Membrane humidifier model for PEM fuel cell systems

S. Mull[1*], L. Weiß[1], S. Buhl[2], M. Wensing[1]

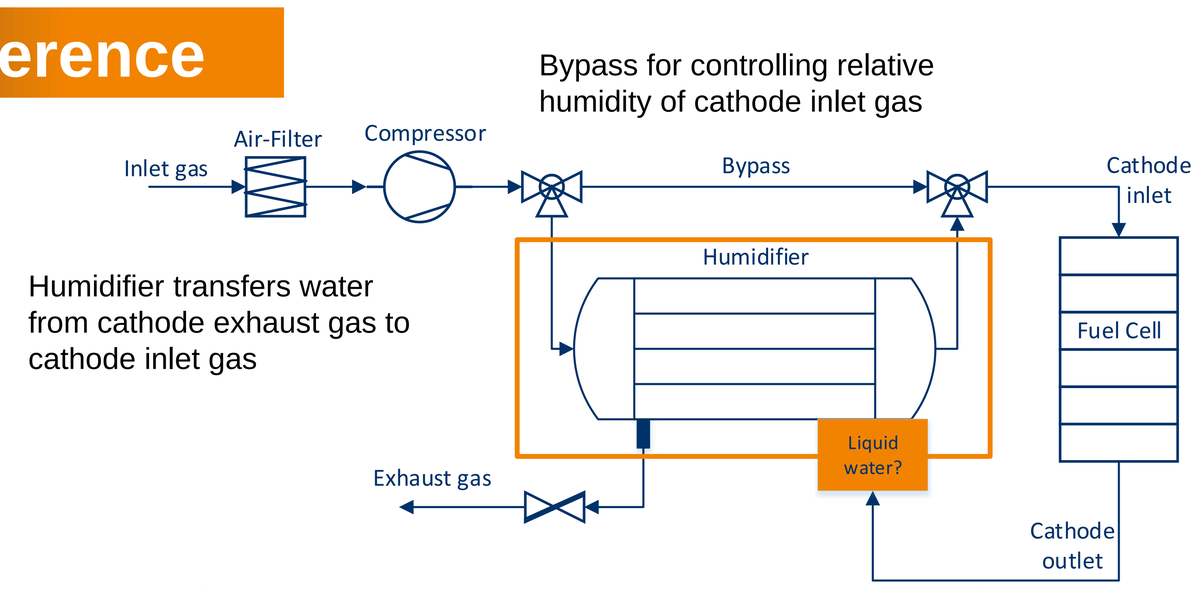
1 Friedrich-Alexander-Universität Erlangen-Nürnberg, Professorship for Fluidsystemtechnology, Cauerstraße 4, 91058 Erlangen

2 MAN Truck & Bus SE, Vogelweiherstr. 33, 90441 Nürnberg

Liquid water makes the difference

Simulation and experimental analysis of membrane humidifier

- Current models and experiments [1] neglect the presence of liquid water at the humidifier inlet even if it is possible for multiple operating points
- In this work a new model and experimental setup for membrane humidifier is proposed that accounts for the differences in the water transport depending on the physical state of the water



Presence of liquid water in the cathode exhaust gas depends on multiple factors (e.g. operating point, stack, system, thermodynamic boundary conditions)

Experimental Setup/ Simulation

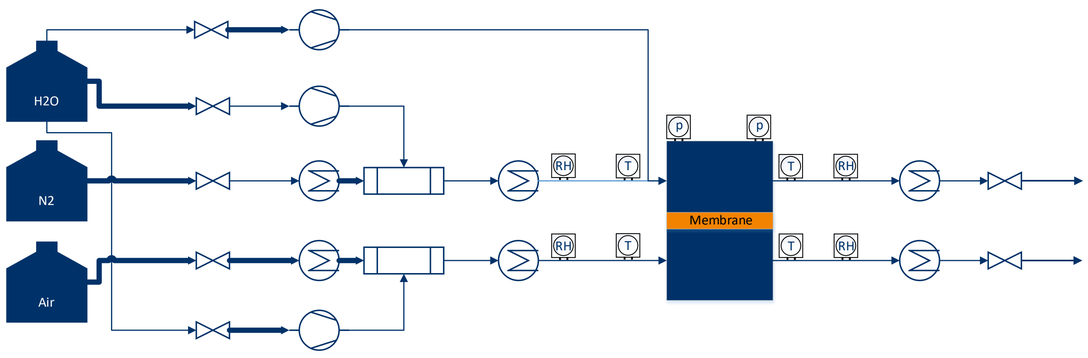


Figure 1: Schema of test stand for analysing the membrane transport properties in dependence of the aggregation state of the inlet water

- Possible measurements: water transfer of water in only vapor phase, only liquid phase or liquid and vapor phase in dependence of different temperatures, pressures, flow rates, membranes, flow fields
- Direct liquid water insert on membrane surface possible by a bypass pump

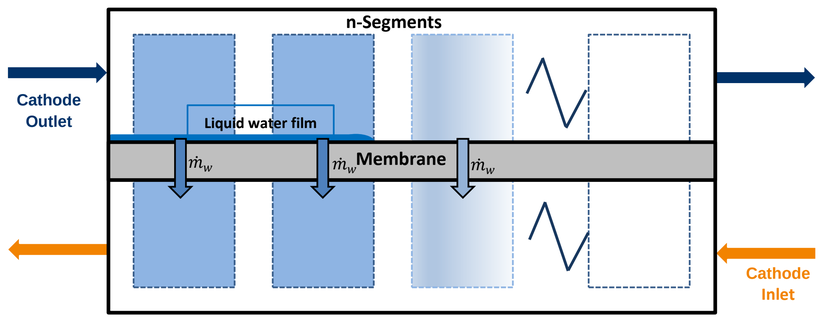


Figure 2: Schematic figure of the segmented humidifier simulation model, the blue color indicates the relative humidity of the gas stream

- Simulation tool: Matlab Simulink
- Aim of simulation: calculation of the water transport through the membrane in dependency of: RH, T, p, flow rate, flow field, membrane type, membrane surface area and presence of liquid water
- The humidifier system was implemented as a counter flow system
- Discretization in ten segments along the main flow direction of the inlet and exhaust air path (along the channel)

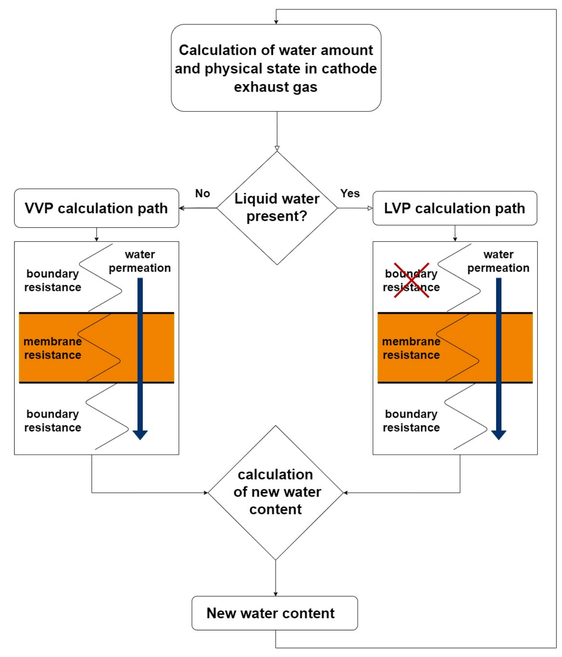


Figure 3: Flow chart of the simulation switching part for deciding if vapor vapor permeation (VVP) [2] or liquid vapor permeation (LVP) calculation path is used for the segment

Results

- Mapping humidity evolution, presence and ending of a liquid film at the humidifier membrane along the channel
- As evidenced by experiments consideration of liquid water results in higher water transport and thus higher relative humidities of the cathode inlet gas (humidifier outlet dry side) than in commonly used models for membrane humidifiers in respect to set membrane area

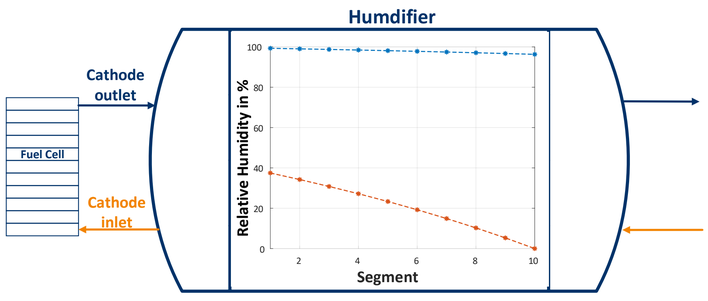


Figure 4: Current models: No liquid water at the inlet considered, lower cathode inlet humidity reached

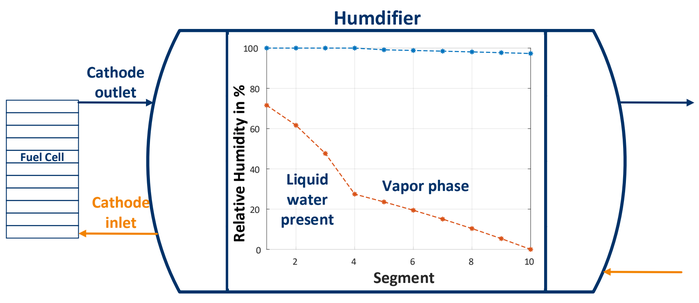


Figure 5: New model: Liquid water film ends in segment four, higher water transport ratio while liquid film is present

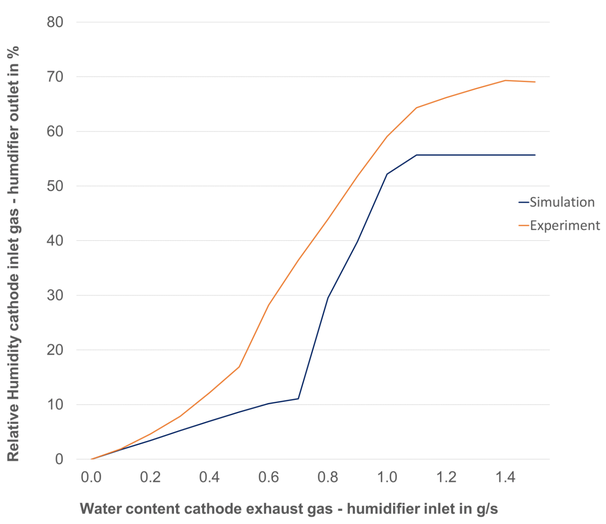


Figure 6: Comparison between simulation and experiment, water content at cathode exhaust gas – humidifier inlet was increased, resulting in increasing relative humidity at cathode inlet gas - humdifier outlet

Conclusions & Outlook

- Liquid water may be present at the membrane humidifier inlet; Current membrane humidifier models neglect the presence of liquid water, the aim of the here presented model is to close this gap
- As a simulation and experimental result consideration of liquid water enhance greatly the water transport properties of the humidifier and therefore the performance of the humidifier
- Next step: Fitting of simulation by own experimental data

Literature

[1] Cahalan, The Analysis of Membranes for External Humidification of PEM Fuel Cells, 2018

[2] Springer et al, Polymer Electrolyte Fuel Cell Model, 1991

Acknowledgements

This work was carried out as part of the FCS-HD project, which is funded by the German Federal Ministry of Digital and Transport as part of the National Hydrogen and Fuel Cell Technology Innovation Programme. The funding directive is coordinated by NOW GmbH and implemented by Project Management Jülich (PtJ).

Friedrich-Alexander-Universität
Technische Fakultät

Professur für Fluidsystemtechnik
Prof. Dr.-Ing. Michael Wensing
www.fst.tf.fau.de

Contact:
sophie.mull@fau.de
ModVal 2023