Extended spring-damper equivalent stiffness model for the mechanical design of a PEM electrolysis stack

Peter Willaczek (1,2), Holger Janßen (1), Martin Müller (1), Ralf Peters (1,2)
(1) Institute of Energy Technologies (IET-4: Electrochemical Process Engineering), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany
(2) Faculty of Mechanical Engineering, Ruhr-Universität, 44721 Bochum, Germany
Tel.: +49 2461/61-9036
p.willaczek@fz-juelich.de

Abstract

A key factor in the mechanical design of a PEM electrolysis stack relates to the interaction between the clamping mechanism and the compression of the active area and sealing regions. In this context, spring-equivalent stiffness models are used in the literature, only describing the initial compression of the stack.
It is proposed to implement an extended equivalent stiffness model in order to predict the mechanical behavior for additional operating points as well. The material model of the CCM (Nafion N117 based) is extended to include relaxation and damage terms, as well as swelling and temperature-dependent behavior. The behavior of the GDL (Toray H120) is extended to account for damage mechanisms. A material model that accounts for both relaxation, creep and damage has been developed for the gasket. This model is based on experimental compression data and open-source data used to characterize seals as a function of temperature. This study not only develops a material model but also examines three representative material models for PTFE, elastomer, and fiber-reinforced gaskets. The developed model can be used to simulate an electrolysis cycle that includes not only a specified relaxation time of 4h for the components but also the initial pre-load, the flooding of the stack with water, and a heating cycle up to minimal 40°C and maximal 80°C. Through the implementation of statistical analyses, the operating parameters as well as sealing and clamping concepts are varied to determine their influence on the overall stack mechanics. In detail the initial compression of the gasket will be varied by +/-50%. Designs with coil springs and disc springs of different modules, hardstops or the operation under constant force will be discovered. The initial GDL compression will be varied from 10% to 40%. Also, the influence of the expanded metal modulus from 5000 MPa up to 10000 MPa will be examined. The built-in conditioning of the CCM will be varied from about 50% to 100% humidity.
This results in a D-optimal DoE with 92 parameters, wherein the influences of the contact pressure on the active area and the contact pressure on the sealing area are investigated.

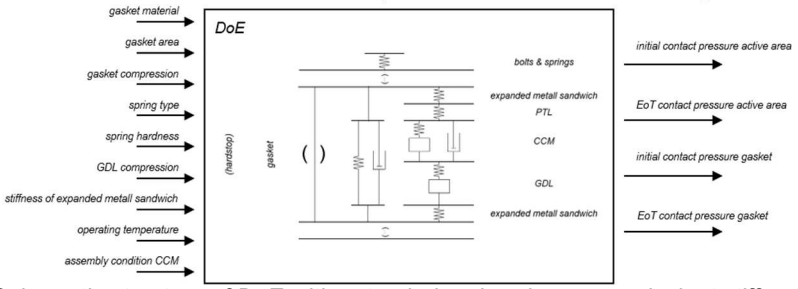


Fig. 1: Schematic structure of DoE with extended spring-damper equivalent stiffness model