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Thermal and electrical performance of an alkaline fuel cell

Ivan Verhaert [a,b,c,*], Sebastian Verhelst [a], Henk Huisseune [a], Isabelle Poels [b], Griet Janssen [b], Grietus Mulder [c], Michel De Paepe [a]

[a] Department of Flow, Heat and Combustion Mechanics, Ghent University – UGent, Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium
[b] KHKempen, University College, Kleinhoefstraat 4, 2440 Geel, Belgium
[c] VITO, Flemish Institute for Technological Research, Boeretang 200, 2400 Mol, Belgium

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ABSTRACT

Fuel cells have interesting prospects to integrate in alternative energy systems. Alkaline fuel cells have the potential to be manufactured at low cost, as they don't require noble materials for catalysts. To analyse the thermal-physical behaviour of an alkaline fuel cell (AFC), allowing a well designed integration in a new energy system, a heat and performance study is performed on the AFC stack. An outlook is presented of the different electrical and thermal power outputs and how they can be influenced by the main operating parameters. This will enable the integration of all these power outputs in an optimized energy system. To optimize stack performance, taking both electrical and thermal performance into account, an evaluation method, based on primary energy savings, is presented. Finally, a parameter study is performed, which will enable an improved system design or control strategy for an AFC-based CHP-unit. Most of these improvements are found in a reduction of transmission losses and by increasing input air temperature and humidity, resulting in both higher electric and thermal performance.

1. Introduction

Both for mobile as for stationary applications, fuel cells are considered as a promising alternative to traditional systems in energy generation [1–4]. One of the major challenges still remaining for fuel cells is reducing capital cost of the stack, since most fuel cells use noble materials like platinum as a catalyst. This led to a resurgence of interest in the alkaline fuel cell technology [5–7], since AFCs have the possibility to be manufactured at less cost, using non-noble materials for catalysts [8,9]. With the emergence of the proton exchange fuel cell (PEMFC), the interest in AFC technology was reduced to a minimum. However, despite this diminished interest in AFCs, compared to PEMFC, the electrical efficiencies presented in [10,11] are still competitive to PEM fuel cells used for stationary applications, like micro-CHP [12]. At this moment, the research and development activities in AFC technology are rising again, leading to new market opportunities, further efficiency improvement and cost reduction.

Within the stationary power applications, the AFC can be integrated in a power generator or micro-CHP [13,14]. In Ref. [15] different methods for electrode preparation are discussed, indicating possible efficiency improvements. Recently, a first prototype of a stationary AFC-system is commissioned [16], with the potential to use non-noble materials.

With this evolution in perspective, it is significant to understand and research the behaviour of the alkaline fuel cell from an engineering point of view. For PEMFC a numerous amount of these studies have already been performed, examining performance, heat integration and water management [2,12,17–20]. Although both PEMFC and AFC are low temperature fuel cells, these results can't be copied or extrapolated, because the thermal and water management of an AFC stack shows some fundamental differences with the PEMFC.

To understand the behaviour of AFC, a number of models have been developed in the last years, based on the research in the 1980s. A first set of models focused on electrical performance [21,22]. The model described in Ref. [23] predicts next to electrical performance also thermal behaviour of the fuel cell developed in [13]. This model is later improved by including water management [24], which has a large impact on the ability of heat recovery.

These models can be used to analyse and optimize the AFC behaviour. The impact of different operating parameters on water management was simulated and examined in Ref. [24]. In Ref. [25] a typical electric AFC model is used to define an optimal electric performance, as a balance between maximum electrical power and maximum electrical efficiency. In the present paper, the model of

* Corresponding author. Department of Flow, Heat and Combustion Mechanics, Ghent University – UGent, Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium. Tel.: +32 (0)14 56 21 34.
E-mail address: ivan.verhaert@khk.be (I. Verhaert).

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