Applications of Thermoelectric Devices in a HT-PEM Fuel Cell System: Two Case Studies

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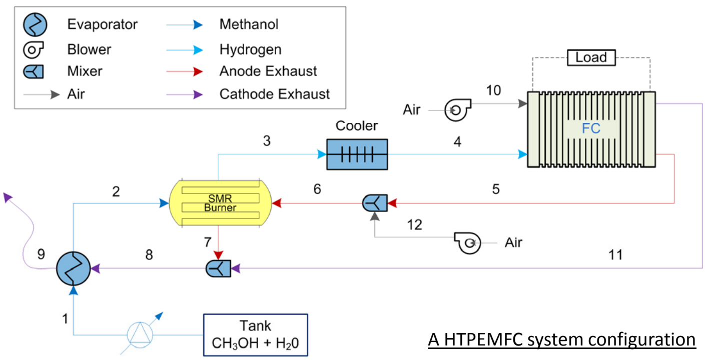
Introduction

Fuel cell

This work examines the following improvements of a 1kW High Temperature Polymer Membrane Fuel Cell (HTPEMFC) power system with an on-board methanol steam reformer:

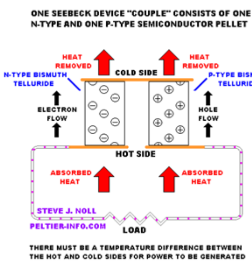


A HTPEMFC system configuration

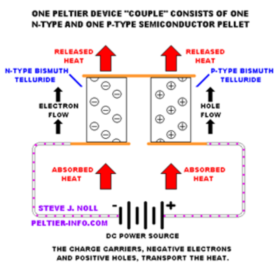
1. System efficiency improvements by recovering **the exhaust heat**, currently wasted. The potential heat available is 1.01 kW, at about 160°C.
2. System cold start and load-following performances can be enhanced. A redesign of the methanol **evaporator** is needed.

Thermoelectric Devices

1. Thermoelectric generators (TEGs) are solid-state power generators working on Seebeck effect. They are superior in low quality waste heat recovery.



TEG, Seebeck effect

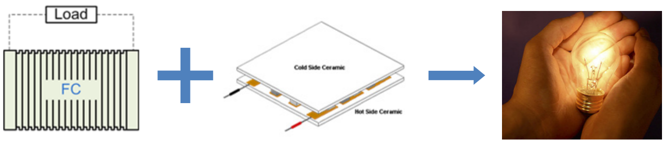


TEC, Peltier effect

2. Thermoelectric coolers (TECs) are compact heat pumps working on Peltier effect. They have excellent transient performance, in milliseconds.

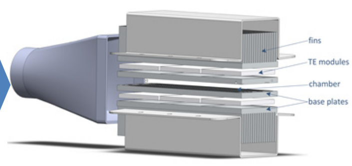
Objectives

1. Exhaust gas heat recovery for electricity: a TEG subsystem needs to be designed , modeled and optimized;



2. Novel design of the evaporator: a TE-integrated evaporator. Using the heat pumping effect to control the heat flux and use their excellent transient performance to improve the system load-following capability.

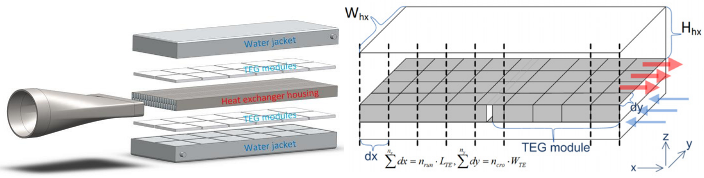
The initial evaporator



The TE-integrated

Study tools

Finite-element model of the TEG subsystem

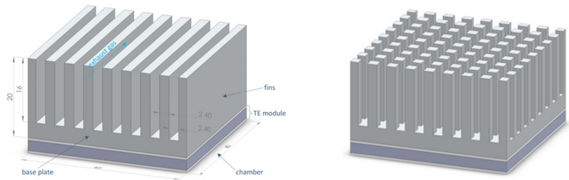


TEG subsystem architecture | Dicretization scheme

Compact heat exchanger database, more than 90 types.

Kays and London: "It should first be noted that compactness itself leads to high performance."

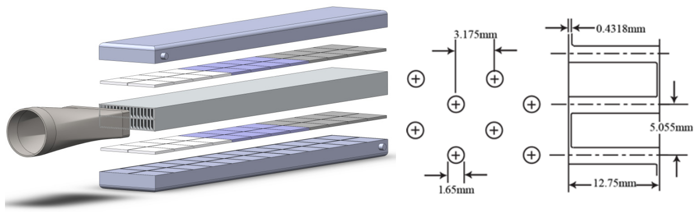
Model of the TE-integrated evaporator, in ANSYS FLUENT®



Sensitivity analysis on models: input fluctuations to study the system characteristics and identify the control variables.

Main conclusions

- An optimized TEG subsystem can produce 34W extra power from the exhaust gas, under ZT=0.5; Which will be 90W, if ZT=2.0.
- The optimized subsystem configuration: 4x12 TEG modules (type: Melcor HT8), heat exchanger type 'Pin-fin plate-fin, surface PF-4(F)'.



- The TEG subsystem is most sensitive to the exhaust temperature (44.51%) and TEG module performance (19.67% to the Seebeck coefficient).
- The TE-integrated evaporator can adjust its heat output actively from 2.5W to 152.2W. Comparing to 50.1W constant output in the initial design.

The general conclusion: TE integration into the HTPEMFC power system has unique contributions and is worthy of further study.

Publications

- X. Gao, M. Chen, S.J. Andreasen, and S.K. Kær, J. Electron. Mater. 41, 1838 (2012).
- X. Gao, S.J. Andreasen, M. Chen, and S.K. Kær, Int. J. Hydrogen Energy 37, 8490 (2012).
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- X. Gao, S.J. Andreasen, S.K. Kær, and L.A. Rosendahl, Int. J. Hydrogen Energy, to be submitted.

Acknowledgements

This project is funded by Aalborg University and China Scholarship Council.

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