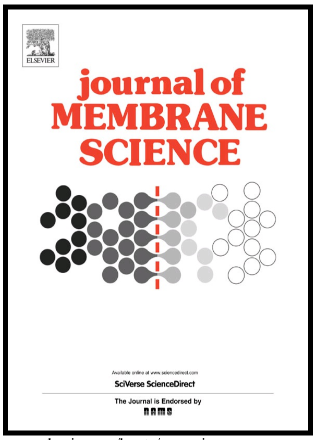
Author's Accepted Manuscript



www.elsevier.com/locate/memsci

Hydrogen Production from solid Feedstock by using a Nickel Membrane Reformer

Jonas M. Leimert, Marius Dillig, Jürgen Karl

PII: S0376-7388(17)32066-5
DOI: https://doi.org/10.1016/j.memsci.2017.10.059
Reference: MEMSCI15686

To appear in: *Journal of Membrane Science*

Received date: 19 July 2017
Revised date: 22 October 2017
Accepted date: 29 October 2017

Cite this article as: Jonas M. Leimert, Marius Dillig and Jürgen Karl, Hydrogen Production from solid Feedstock by using a Nickel Membrane Reformer, *Journal of Membrane Science,* https://doi.org/10.1016/j.memsci.2017.10.059

Hydrogen Production from solid Feedstock by using a Nickel Membrane Reformer

Jonas M. Leimert*, Marius Dillig, Jürgen Karl

Friedrich-Alexander-University of Erlangen-Nuremberg; Institute of Energy Process Engineering; Fürther Str. 244f; 90429 Nürnberg

Abstract

The Heatpipe Reformer technology allows the generation of hydrogen-rich, pressurized synthesis gas from solid feedstock like lignite or biomass. The resulting high hydrogen partial pressure and thus driving force makes it suitable for membrane separation. This work promotes the application of hydrogen permeable membranes as hydrogen separators directly in the reformer. This should allow a high hydrogen yield due the shift of the gasification reactions to the product side when hydrogen is removed continuously. The material of choice for this task is nickel as it combines good hydrogen permeability with good mechanical properties at the operation temperature of biomass gasification of 800°C.

The experimental section presents measurements with a bundle of nickel membranes used for the demonstration of the shift of different gas mixtures to the product side by hydrogen removal. Hydrogen removal enhanced CO and CH_4 conversion at an operation temperature of 800°C. A high purity of at least 99.9 % was achieved by the highly selective solution-diffusion process of the separation. The experimental data was also used for an energy balance of the membrane process to allow a proper membrane layout in terms of membrane area per hydrogen production.

As a last step, the membrane bundle was applied directly in the Heatpipe Reformer, an allothermal pressurized gasifier. It produced 200 ml min^{-1} of hydrogen and showed no signs of degradation or fouling. This proof of concept showed the suitability of nickel membranes for hydrogen separation under gasification conditions.

Keywords: membranes, hydrogen, gasification, Heatpipe Reformer, membrane reactor, steam reforming

1. Introduction

The Heatpipe Reformer, designed by TU Munich during EU project "BioHPR" (Ref. ENK5-CT-2000-00311), poses a gasification system ideally suited for the generation of hydrogen: The allothermal gasification provides a synthesis gas with high hydrogen contents and, unlike other gasifiers for solid feedstock, process pressures of up to 10 bar [1, 2]. For a coupled heat and hydrogen generation plant, the hydrogen from the synthesis can be separated. A conventional process chain could achieve this goal by applying a downstream CO shift reactor and hydrogen separation. As proposed by Karellas et al. and Schäfer, membranes in the reformer chamber could used for hydrogen purification [3, 4]. This system promotes hydrogen yield due to the shift of water-gas reaction to the product side when hydrogen is removed:

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \qquad (1)$$

The Heatpipe Reformer at FAU-EVT in the 100 kW scale is operational as reported in the previous publication on the combustor [5] and gasifier performance [6]. Table 1 shows the synthesis gas properties relevant for this publication.

Dense hydrogen permeable membranes, where the separation mechanisms is based on hydrogen solution and diffusion resulting in high-purity hydrogen, are a challenging choice for this task: State-of-the-art palladium membranes suffer from their limitation regarding the process temperature: The gasifier works at 800°C well above normal operation temperatures of Pd-composite membranes [7, 8]. The choice of the membrane system for this application was extensively discussed in a previous publication [9] with the result of nickel as membrane material. The results of this study were a good resistance of nickel against corrosion in synthesis gas atmosphere and even with high amounts

*Corresponding author
Email address: jonas.leimert@fau.de (Jonas M. Leimert)