15 Times More Membrane Area

How Scaling-up Affects Biogas Steam Reforming in a Fluidized-bed Membrane Reactor

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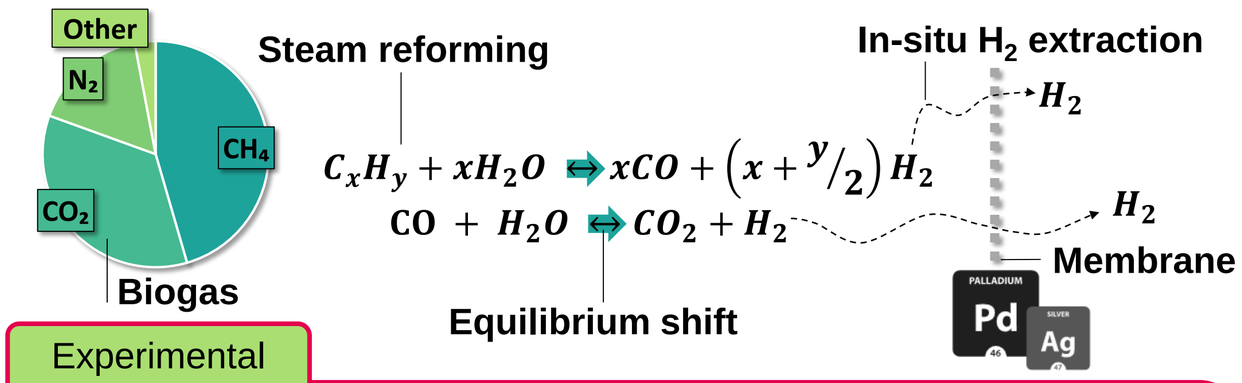
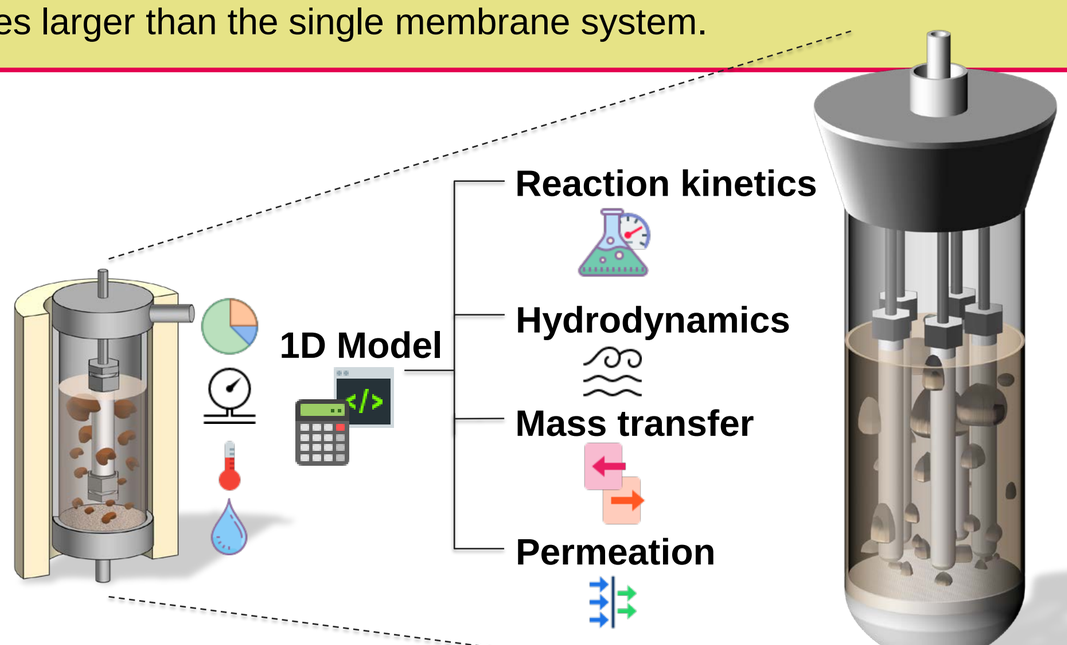
Introduction

Membranes can improve the performance of a reforming system significantly, but the transport of the hydrogen towards the membrane often limits the performance. This work aims to understanding the significance of this effect when scaling-up a fluidized bed membrane reactor.

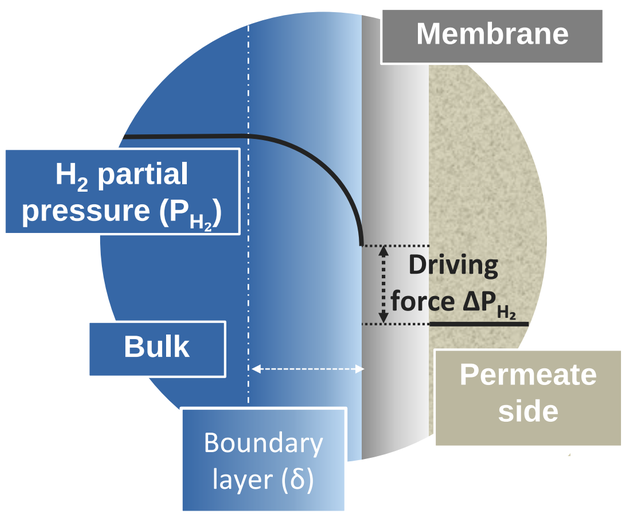


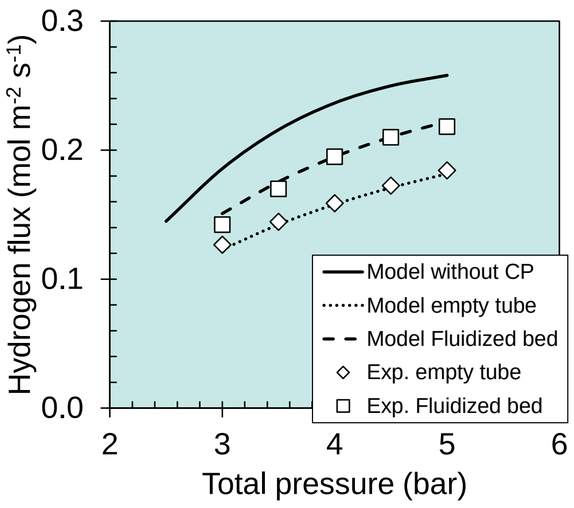
Experimental

Experimental results from a single membrane system were used to validate a one dimensional phenomenological model. This model is used to investigate a system in which the membrane area was 15 times larger than the single membrane system.



Mass transfer limitations on the transport towards the membrane are known as concentration polarization. The partial pressure of hydrogen, which is the driving force of the H_2 extraction, is reduced due to the slow transport of hydrogen towards the membrane surface.





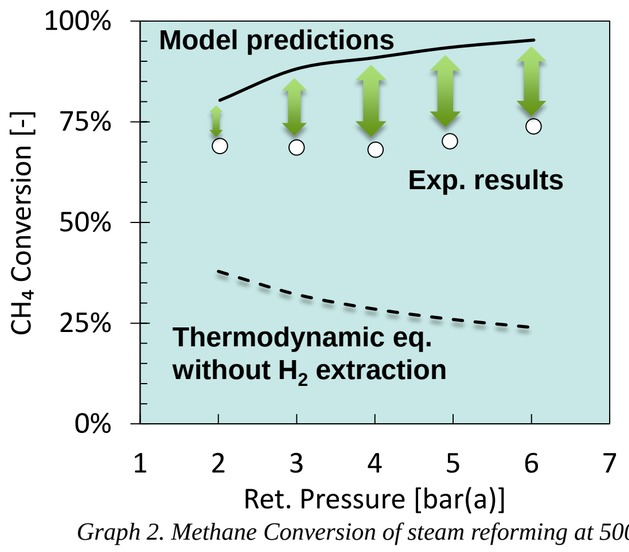
Graph 1. reduction of concentration polarization in a fluidized bed on gas extraction of a 3:1 H_2/N_2 mixture

By using a fluidized bed instead of a fixed bed the bed to wall mass transfer can be increased due to the gas mixing induced by the solid circulation.

Feed condition	Temp. (°C)	Pres. (bar_a)	CH_4 Conv. (-)	H_2 sep. (-)
Methane Steam Reforming	530	6	85%	91%
Biogas Steam Reforming	533	6	74%	82%
Autothermal Reforming of Biogas	531	6	72%	84%

Results

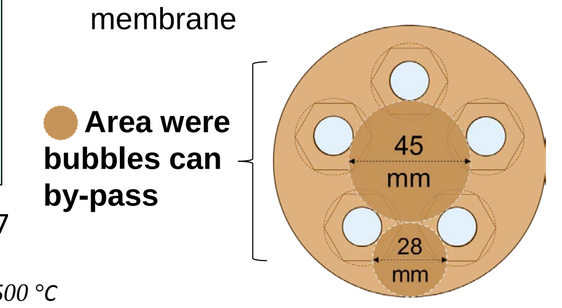
Reforming experiments show that with the increased membrane area high performance of the reactor can be obtained in terms of hydrogen yield trough the membrane (Hydrogen recovery).



Graph 2. Methane Conversion of steam reforming at 500 °C

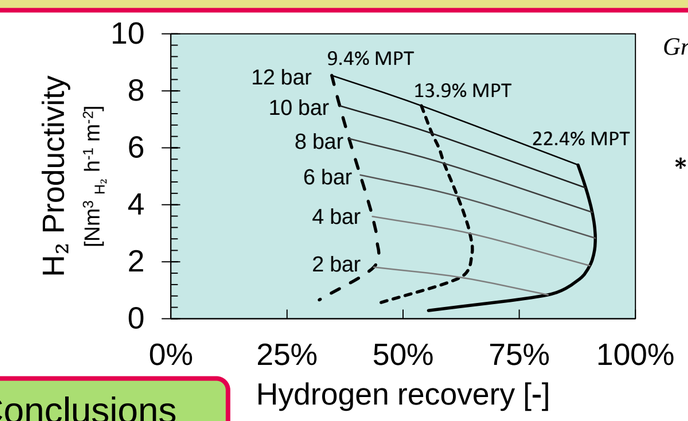
Mass transfer limitations due to:

- Low fluidization as result of relatively low residence time required.
- Gas by-pass via bubbles that do not have contact with the membrane



Although the system shows good performance, discrepancy with the single membrane validated model is found. Analysis of the results show that the extend of mass transfer limitation is larger compared to the single membrane system.

Notable improvements are expected when the membrane configuration is more compact (higher MTP). The bubbles will be in better contact with the membranes and the capacity will be more in respect to the desired fluidization regime.



Graph 3. Effect of Increased Membrane Packing Density (MPT) on system performance and capacity at a fixed fluidization regime

* *Increasing the membrane length would increase both capacity and recovery however, the high membrane tube packing would still optimize the membrane area used.*

Conclusions

Eventually could be concluded that:

- Biogas steam reforming in a fluidized bed membrane reactor can become a valued path for hydrogen production.
- Mass transfer limitations in membrane reactors can not be ignored and are critical when scaling up such a system.
- Dimensions of the membranes play a significant role in the reactor design.

Interested in more information about biogas to hydrogen? Have a look at www.bionicoproject.com or scan the QR code for a video about BIONICO.

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