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Heat transfer problems for the production of hydrogen from geothermal energy

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Abstract

Electrolysis at low temperature is currently used to produce Hydrogen. From a thermodynamic point of view, it is possible to improve the performance of electrolysis while functioning at high temperature (high temperature electrolysis: HTE). That makes it possible to reduce energy consumption but requires a part of the energy necessary for the dissociation of water to be in the form of thermal energy.

A collaboration between France and Iceland aims at studying and then validating the possibilities of producing hydrogen with HTE coupled with a geothermal source. The influence of the exit temperature on the cost of energy consumption of the drilling well is detailed.

To vaporize the water to the electrolyser, it should be possible to use the same technology currently used in the Icelandic geothermal context for producing electricity by using a steam turbine cycle. For heating the steam up to the temperature needed at the entrance of the electrolyser three kinds of heat exchangers could be used, according to specific temperature intervals.
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Keywords: Hydrogen; Geothermal energy; High temperature electrolysis; Heat transfer; Iceland

1. Introduction

The use of hydrogen as a substitute to hydrocarbons, is currently the object of many research and development tasks in the world. To be sustainable, a hydrogen production process must be carried out without consumption of raw materials other than water and driven by energy produced without greenhouse gas emissions. Electrolysis at low temperature carried out using sustainably produced electricity satisfies these constraints and is currently used to produce hydrogen. However, today it is more expensive than the process of producing hydrogen by steam reforming of natural gas, which presents a double disadvantage since it consumes natural gas and rejects carbon dioxide. From a thermodynamic point of view, it is possible to improve the performance of

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Nomenclature

A	heat exchange surface area (m^2)
B	width of the plate exchanger (m)
d_h	hydraulic diameter (m)
$\dot{m}$	mass flow rate (kg/s)
μ	dynamic viscosity (kg/m s)
k	thermal conductivity (W/m °C)
h	heat transfer coefficient (W/m^2 °C)
U	overall heat transfer coefficient (W/m^2 °C)
e	height of the channel (m)
$\dot{Q}$	power, heat flow rate (kW)
ε	effectiveness of the heat exchanger
Re	Reynolds number
Pr	Prandtl number
M	molar mass
r	recycling ratio

Subscripts

1	steam no 1
2	steam no 2
3	steam no 3
4	steam no 4
HT	high temperature
MT	medium temperature
LT	low temperature
H_2	properties of hydrogen
O_2	properties of oxygen
H_2O	properties of water

electrolysis while functioning at high temperature (HTE). That makes it possible to reduce energy consumption but requires a part of the energy necessary for the dissociation of water to be in the form of thermal energy.

Recent HTE research programs have profited from new financings, mainly within the Generation IV International Forum framework for developing long term nuclear reactors [1]. The forum considers the possibilities of using nuclear energy, particularly high temperature helium cooled reactors (HTR) which include the possibility of producing hydrogen.

A collaboration between France and Iceland aims at studying and then validating the possibilities of producing hydrogen with HTE coupled with a geothermal source. Its principal objective is the production of hydrogen by HTE coupled with a geothermal source in the Icelandic context. The goal is to build a 5 kW e prototype on the site of Nesjavellir, which is 20 km from Reykjavik [2]. Iceland brings its competences and its experience in the field of geothermal drilling, the exploitation, the transport and the transformation (in particular in electric power) of steam extracted at the geothermal sources. France brings its scientific knowledge and its industrial experience on the thermal problems of heat transfers for various ranges of temperatures, as well as the results of the research and development on Solid Oxide Fuel Cells, which works in reverse of the electrolysers at high temperature.

1.1. Hydrogen from geothermal energy

The economically harnessable geothermal energy in Iceland has been estimated at approximately 200 TW h/year, of which only 1% has been harnessed up to now. Assuming the same technology used in

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