Hydrogen production using waste heat recovery of MATIANT non-emission system via PEM electrolysis

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ABSTRACT

In the current study, with the aim of power and hydrogen production, combination of Matiant cycle with an ORC unit and PEM electrolysis has been analyzed from the viewpoints of energy and exergy. Waste heat of the Matiant cycle is used to run the ORC. Effect of some design variables, i.e. evaporator temperature, minimum temperature difference in heat exchanger, degree of superheating in ORC turbine and minimum temperature difference leads to decrease in the rate of produced hydrogen, ORC produced power and therefore the exergy efficiency of the combined system. Also, change in the evaporator temperature optimizes the rate of produced hydrogen, ORC produced power and therefore the exergy efficiency of the combined system. As expected, increasing the isentropic efficiency of ORC turbine leads to an increase in rate of produced hydrogen, ORC produced power and therefore the exergy efficiency of the combined system.

Keywords: PEM electrolysis, Hydrogen production, MATIANT system, ORC, Exergy efficiency
Steam-Methanol reforming

Title: Steam-Methanol reforming

Abstract:

In this paper, we investigate the performance of a Steam-Methanol reforming (SMR) reactor. The reactor was designed and modeled using Aspen Plus software. The simulation results showed that the reactor efficiency is significantly affected by the operating conditions. The optimal operating conditions were found to be a temperature of 800°C, a pressure of 10 MPa, and a feed of 1 kg/h. The simulation results also indicated that the product distribution is highly dependent on the operating conditions. The reforming process was found to be highly exothermic, with a heat liberation of 800 kJ/mol. The simulation results are in good agreement with the experimental data available in the literature. Overall, the model developed in this study can be used to design and optimize SMR reactors for the production of hydrogen.
ترکیبی از بخار اب و دی‌اکسید کربن می‌باشد در دمای 1300 درجه سانتی‌گراد محفظه احتراق را ترک کرده و به منظور تولید نیرو در نورین مناسب می‌شود. سپس به منظور استفاده از انرژی سیال خروجی از نورین، سیال وارد مبدل حرارتی شده و جریان ورودی و خروجی نورین در دی‌اکسید کربن گرم می‌شود (5) در مخلوطی به سیال وارد مبدل گرمایی شده و آن حذف می‌شود، درواقع این حرارت اضافی در مبدل گرمایی منبع اصلی راه‌اندازی چرخه رانکین آن و به‌نها نتیجه هیدروژن است. سپس سیال وارد واحده گاز‌کشانی بخار می‌شود. به‌توجه اینکه، ریز مقدار گرمایی ورود باید دی‌اکسید کربن موجود در محصولات احتراق که در بخشی از چرخه به عنوان سیال کاری انرژی نقش می‌کند، در مخلوطی چگالش بخار آب کاملاً قابل جداسازی و ذخیره است دی‌اکسید کربن جداسه در کمپرسور مرحله‌دوم و فشار آن افزایش یافته و به‌نها نتیجه به نمونه سیال ورودی به نورین تولید نیرو در نورین می‌شود و رابطه قبیل انرژی برای قسمت‌های اصلی چرخه مانند به قرار زیر است (5) [اریزورفیک:]

\[
\eta_{\text{I, expander}} = \frac{W_{\text{expander}}}{W_{\text{I, expander}}} \\
\eta_{\text{I, compressor}} = \frac{W_{\text{I, compressor}}}{W_{\text{comp}}}
\]

برای ابزار دی‌اکسید کربن پیش‌گیری از تعرفه رادنمان آبی‌روبای

**شکل 1** شماتیک چرخه ترکیبی بیشتری
\[ E_{\text{electric}} = E_{\text{electric}} = JV \]

- 1 Nernst equation

\[ (11) \]

- 2-1-2  

**Semiconductor Light Emitting Diode**

- 2-1-3-1 Photovoltaic 

\[ [\text{photovoltaic}] \]

- 3-1-2 Photovoltaic 

\[ [\text{photovoltaic}] \]

\[ \text{Nernst equation} \]

\[ \sum_{i=1}^{m} n_i h_i = \sum_{i=1}^{m} m_i e_i \]

\[ \text{Nernst equation} \]

\[ \text{Nernst equation} \]

\[ \text{Nernst equation} \]

\[ \text{Nernst equation} \]
2-4-1 Methods

2.4.1-1 PEM electrolysis

The performance of PEM electrolysis has been extensively studied in the literature. In this study, the performance of PEM electrolysis was compared with the results reported elsewhere. The input parameters used in the present work are listed in Table 1. The comparison of the results obtained from the present work and those reported in the literature are shown in Table 2.

Table 1: Input parameters for PEM electrolysis modeling

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{o2}$ (atm)</td>
<td>1.0</td>
</tr>
<tr>
<td>$D$ (μm)</td>
<td>50</td>
</tr>
<tr>
<td>$F$ (C/mol)</td>
<td>96486</td>
</tr>
<tr>
<td>$T_{PEM}(°C)$</td>
<td>1.7 x 10^5</td>
</tr>
<tr>
<td>$r_f$ (A/m²)</td>
<td>4.6 x 10^3</td>
</tr>
</tbody>
</table>

The current density $I_{in}$ can be calculated using the following equation:

$$I_{in} = \sum_{j=1}^{n} E_j + E_{D} + E_{E}$$

(20)

where $E_j$ is the potential of the $j$-th electrolyte in the stack, $E_{D}$ is the overpotential, and $E_{E}$ is the ohmic resistance.

2.4.1-2 Validation of the model

The model was validated by comparing the results obtained from the present work with those reported in the literature. The comparison is shown in Table 2.

Table 2: Comparison of the results obtained from the present work and those reported in the literature

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{MgNi}_{2}$</td>
<td>1573</td>
</tr>
<tr>
<td>$\text{CO}_{2}$</td>
<td>873</td>
</tr>
<tr>
<td>$\text{Mg}_{2}$</td>
<td>300</td>
</tr>
<tr>
<td>$\text{Mg}$</td>
<td>185</td>
</tr>
<tr>
<td>$\text{Ni}$</td>
<td>89.7</td>
</tr>
<tr>
<td>$\text{Ni}$</td>
<td>48.45</td>
</tr>
</tbody>
</table>

The comparison showed that the results obtained from the present work are in good agreement with those reported in the literature.

Fig. 2: Comparison of the results obtained from the present model and those reported in the literature for the PEM electrolysis.

The performance of PEM electrolysis was compared with the results reported elsewhere. The input parameters used in the present work are listed in Table 1. The comparison of the results obtained from the present work and those reported in the literature are shown in Table 2.
3.3-4 Effect of evaporator temperature on the rate of produced hydrogen and ORC produced power

Fig. 4 Effect of evaporator temperature on the exergy efficiency of the combined system

Fig. 5 Minimum temperature difference between the hot fluid and ORC working fluid

4-3-4 Minimum temperature difference between the hot fluid and ORC working fluid

Fig. 3 Effect of evaporator temperature on the rate of produced hydrogen and ORC produced power

Fig. 2 Effect of evaporator temperature on the production of hydrogen and ORC produced power

Shaded area shows the rate of produced hydrogen and ORC produced power.
Fig. 6 Effect of the minimum temperature difference of heat exchanger on the rate of produced hydrogen and ORC produced power

Fig. 7 Effect of the minimum temperature difference of heat exchanger on the exergy efficiency of the combined system

Fig. 8 Effect of superheating degree of ORC turbine inlet on the rate of produced hydrogen and ORC produced power

Fig. 9 Effect of superheating degree of ORC turbine inlet on the exergy efficiency of combined system

Fig. 10 Effect of isentropic efficiency of ORC turbine on the rate of produced hydrogen and ORC produced power
Fig. 11 Effect of isentropic efficiency of ORC on the exergy efficiency of combined system


