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A Study on a Steam Distribution Technology for use in Hydrogen Production and Power Generation

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Abstract

The high-temperature steam is used in the fields of industrial, residential, and commercial. Especially, in case of high-temperature steam, it can be used to produce hydrogen and likewise it can be used to generate electricity in the field of power generation. However, the steam condition for producing hydrogen and the steam condition for producing electricity are different, it is considerably important to distribute the high-temperature steam in condition satisfying each demand. Moreover, the required pressure and the pressure loss of a steam distributor at the load side should be considered. Therefore, in this study, the numerical simulation using ANSYS fluent was performed by dividing into pipe A (4,000kPa at use of power generation system) and pipe B (300kPa at use of hydrogen production). In addition, it was simulated according to the variation of diameter of pipe B (20mm - 30mm) for analysis of a steam distribution technology. The pressure outlet that can be used in hydrogen production was about 300kPa approximately when the diameter of pipe B was 20mm. As a result, the distribution technology that is used hydrogen production and in the power generation system was obtained through numerical simulation in proposed condition.
Key words: CFD (Computational Fluid Dynamics), Distribution Technology, Hydrogen Production, Steam distributor, Power Generation

1. Introduction

According to the report of world energy resources 2016, hydrogen is the future energy source that can be reused without emitting pollutant. However, most of the produced hydrogen to date is extracted from fossil fuels such as coal and natural gas, and carbon dioxide is emitted in this process. This is exacerbating the environmental problem. Therefore, there is a need for research and development to reduce carbon dioxide emission. There are various ways to produce hydrogen, SOEC is one of them and it expressed Fig. 1 [1, 2]. Water electrolysis technology is used in this process [3]. SOEC requires the steam that is high-temperature and low-pressure. The high-temperature steam is a useful heat source in this regard. Especially, in the case of the high-temperature steam above 700℃, utilization is high enough to be used for producing hydrogen. In addition, the high-temperature steam can be used to generate electricity in field of the power generation. However, requirement for power generation system is different. The required pressure for the power generation system is about 4,000~5,000kPa. Therefore, it is important to distribute the high-temperature steam under the conditions that satisfy the requirements of each supplier. Mayurkumar S. Gandhi et al. designed a manifold-type parallel pipe to investigate the steam flow in the pipe, and observed the change in steam flow rate and pressure through numerical simulation. The experimental result showed that prediction of numerical simulation is in coincide with experimental data. The parameters of the inlet and outlet of the pipe can affect the distributed steam

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condition [4]. The purpose of this study is to analyze the steam distributor to utilize high-temperature steam for electricity generation in power generation system, and utilize the certain amount of steam for hydrogen production. Before the system is configured, the distribution technology according to the parameter was simulated by CFD program.

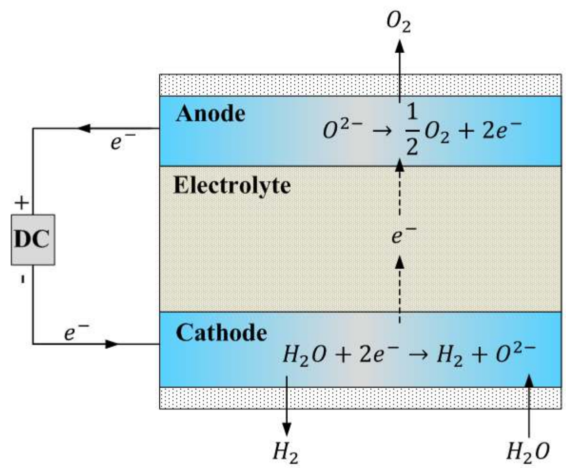

Figure 1. The principle of SOEC for hydrogen production

2. Method

2.1. Design of the steam distributor

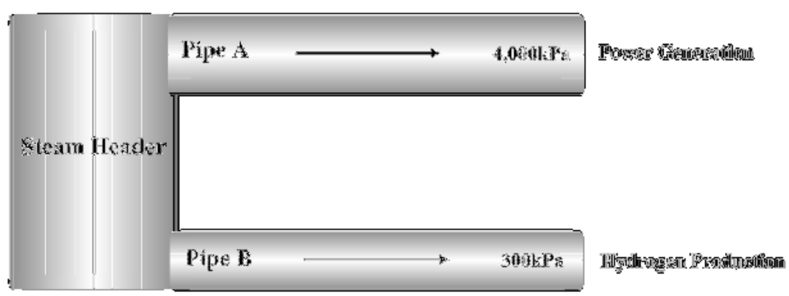

Figure 2. The diagram of the steam distributor

The steam distributor is a form distributed in both directions from the steam heater. It is necessary to consider the change in pressure due to the sudden contraction in direction of the stream and the change in pressure of the steam depending on the friction factor of the pipe wall when designing the steam header. Therefore, it is not possible to maintain a constant steam pressure in the pipe, and an optimal flow rate for division should be found. The shape for the steam distributor was designed by considering the shape created by Mayurkumar S. Gandhi et al. as shown in Fig. 2 [5]. The steam in pipe A is supplied for generating electricity in the power generation system and the condition of steam is 4,000kPa. Based on the model of industrial steam turbine provided by SIEMENS, the steam condition was selected with reference to it. Thus, the steam pressure supplied by the steam header should be at least 4,000kPa. The steam in pipe B is low pressure for hydrogen production and the steam condition is 300kPa. Pipe was designed as a separated pipe as shown in Fig. 3. The size of the steam tor is shown in Table 1. Here, the width of the steam header is 0.05 m. D_S and L_S are the diameter and the length of the steam heater, D_A and L_A are the diameter and the length of the pipe A, and D_B and L_B are the diameter and the length of the pipe B.

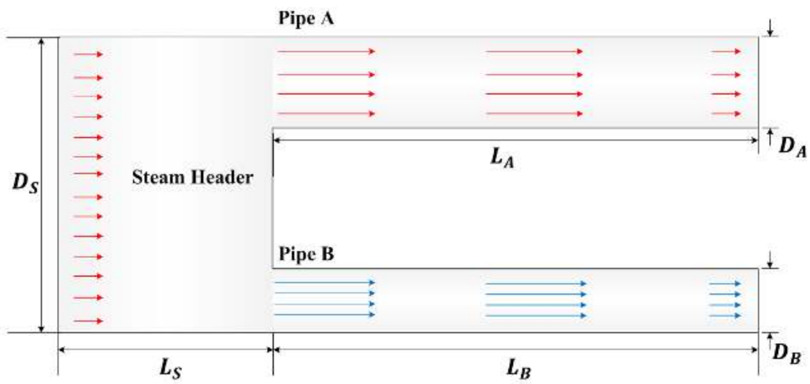

Figure 3. The flow pattern of the steam distributor

Table 1 The size of steam distributor on base model

D_S	D_A	D_B	L_S	L_A	L_B
470	100	20	200	800	800

2.2. Simulation model

The supply of steam flow rate is distributed to both sides and varies according to the diameter of the distribution pipe for each condition. Since the required condition for each application is different, the simulation was conducted to derive distribution technology before the system is configured. Here, the numerical simulation was performed using ANSYS Fluent 18.1. The fluid flow in the horizontal pipe was assumed that is steady state, incompressible, and turbulent flow. The turbulence model was used the k-ω model [6].

3. Results

In case of this kind of the steam distributor, the design of distributed pipe is important. Because the steam that flow from the steam heater to pipe B drop from 4,000kPa to 300kPa rapidly. The pressure drop can affect to outlet pressure of pipe. Therefore, the outlet pressure of pipe A was designed at 4,000kPa and the outlet pressure of pipe B was designed at 300kPa. The result of numerical simulation expressed Fig. 4. In addition, in order to derive the distribution condition it was simulated by changing the diameter of the pipe B. The size of the steam header and the pipe A is constant. The diameter of pipe B is 20 mm (base model), 25 mm, and 30 mm. Here, the length of the pipe for distribution is constant. The outlet pressure according to the diameter change of pipe B is shown in Fig. 5. If the diameter of the pipe B is more than 20 mm, the outlet pressure of pipe B gradually reduce. Because the steam condition flowing from the steam header to pipe B is occurred to a pressure drop due to sudden contraction. Also, as the diameter of pipe B increases, the diameter variation affects the steam flow rate. Therefore, the steam flow rate and the steam pressure are also reduced. It means that a suitable size of pipe exists for this condition, and it can be seen that the outlet pressure changes according to the change of diameter. The diameter of pipe B used for hydrogen production was considered 20 mm in this study.

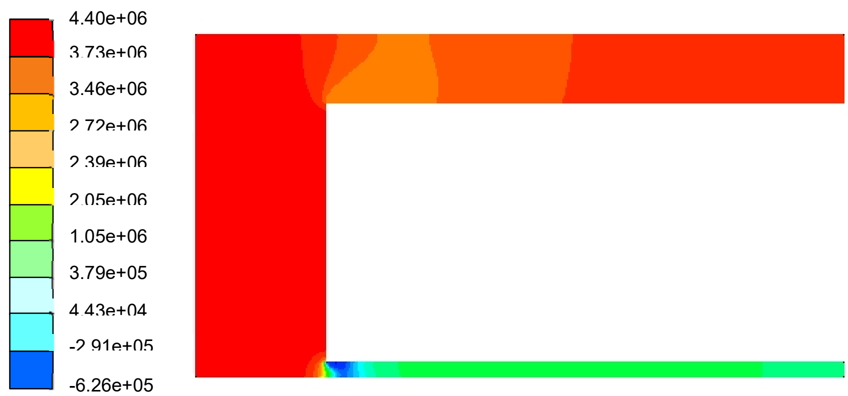

Figure 4. Contour of inlet and outlet pressure on the steam distributor (base model)

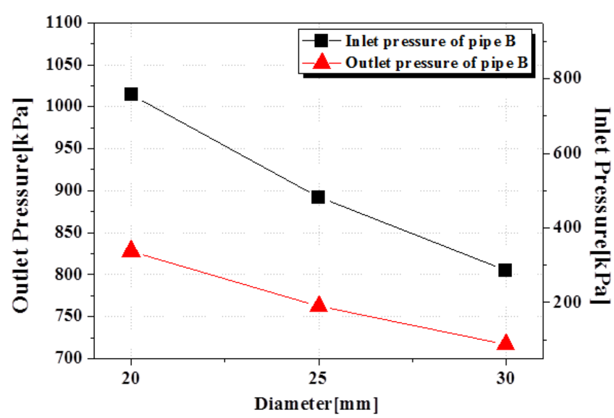

Figure 5. The variation of inlet and outlet pressure of pipe B

4. Conclusions

This study examined a steam distribution technology to utilize the high-temperature steam for power generation system and hydrogen production system, respectively. Optimum conditions were derived by varying the diameter of the steam distributor to meet the conditions suitable for each condition (4,000kPa for using a power generation system and 300kPa for hydrogen production). As a result, the outlet pressure for operating was satisfied when there pipe diameter is about 20 mm, and the distribution technology can be derived under the proposed condition in this study. However, since variation of a pipe length and temperature of the steam distributor are not considered, further studies are needed for it. And then, a high-temperature steam system which can be used power generation and hydrogen production will be configured based on the division technology derived from the result of the numerical simulation.

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