# CAE Application Method for Determining Basic Structure to Improve Performance of Electrochemical Hydrogen compression stacks

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ABSTRACT: In order to expand the use of hydrogen, a convenient hydrogen compression technology is needed. As one of the means to achieve this, we are developing an Electrochemical Hydrogen Compression (hereinafter referred to as EHC) technology to compress hydrogen electrochemically. In EHC cells, water management around the electrocatalyst is important. Therefore, we are developing design that would improve performance efficiently by extracting structural elements using requirements analysis, and by utilizing CAE technology and quality engineering. To equalize the flow velocity of hydrogen in the reaction area, quality engineering was used to identify a sensitive factor of the hydrogen flow path structure, and so we could reduce the range of flow velocity to 4%. For the porous structure, which are important parts of EHC cells, we used simulation and optimization software to find the optimal specification. Through these efforts, the current density at the same voltage was increased by a factor of 4 from the initial specification.

KEY WORDS: electrochemical hydrogen compression stacks (EHC),
requirements analysis, quality engineering, CAE

## 1. Introduction

As the global trend toward achieving carbon neutrality grows, the need for efficient hydrogen utilization technologies to expand the use of renewable energies is increasing. Since the 1990s, in parallel with the development of fuel cell technology, we have been developing hydrogen compression technology using renewable energy without mechanical compressor. In recent years, various CAE methods have been applied to the development of this hydrogen utilization technology in order to improve development efficiency. This paper reports on CAE methods that have been utilized to improve the critical current density of EHC cells .

## 2.Objective

In EHC cells, hydrogen is compressed by the electrical movement of protons generated on the electrocatalyst on the Anode side through the Proton Exchange Membrane (PEM) to the Cathode side. To improve the hydrogen throughput per unit area, the critical current density must be increased. However, it is necessary to continuously remove water that is returned from the high pressure side due to the pressure difference and to supply hydrogen uniformly to the reaction area. The image of the basic reaction principle is shown in Fig. 1. The structural elements for uniform supply of hydrogen include a wide range of parameters such as the hydrogen path structure and the porous structure, so prototyping and verifying each one individually would require a huge amount of time and cost. Therefore, in this study, we developed design methods utilizing CAE, quality engineering to efficiently improve the critical current density of EHC cells.

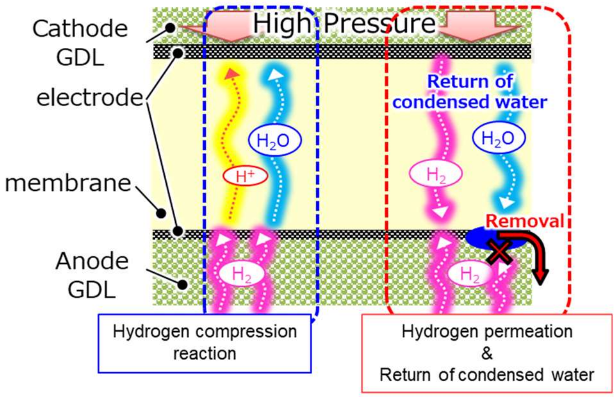


**Fig.1**

3. Methods

3-1: Factor Analysis

We connected the requirements for EHC cells with the factors constituting the cell, and extracted the factors that affect the critical current density. The outline is shown at Fig.2. As mentioned earlier, in EHC cells, water returns from the high pressure side, and if it stays on the electrocatalyst, the hydrogen reaction is inhibited. Therefore, the flow path structure that distributes hydrogen uniformly to the reaction area and the distributivity inside the porous structure are important parameters.

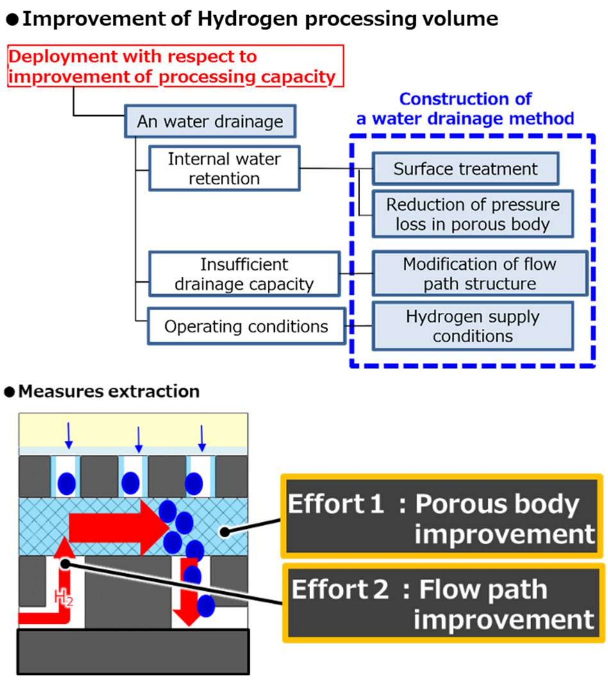


**Fig.2**

On the other hand, since a verification method using simulation of fluid distribution is essential in this study, a visualization cell was established to identify the fluid model and analysis by CFD. The results are shown in Fig. 3. This effort allowed us to confirm residual water in areas of low flow velocity.

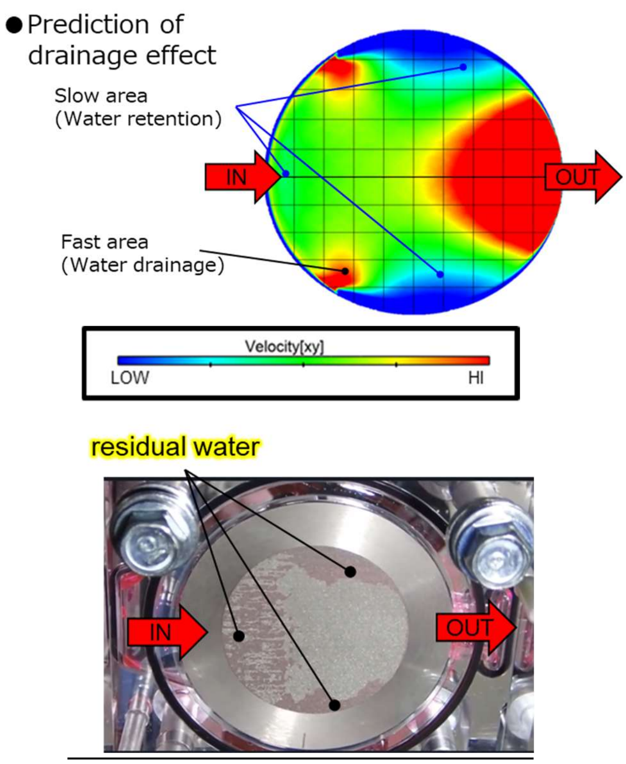


Fig.3

3-2: Flow Structure Optimization (Quality Engineering)

Fig. 4 shows the appearance of the min-size cell used in this study. Because of the wide variety of factors (design target) for fluid distribution uniformity, quality engineering was utilized to obtain sensitivity factor and signal-to-noise (SN) ratios for each factor. The obtained sensitivity factor are shown in Fig. 5. As a result, the structure with high SN ratio specification was found to reduce the in-plane range of hydrogen velocity to 4%. The simulation results are shown in Fig. 6.

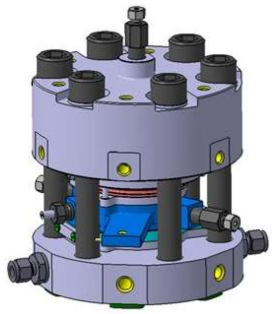

Fig.4

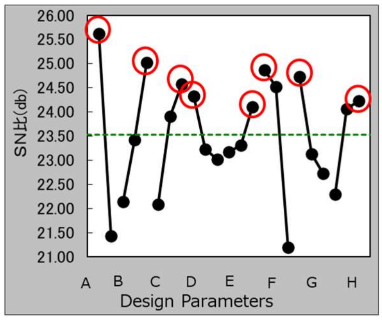


Fig.5

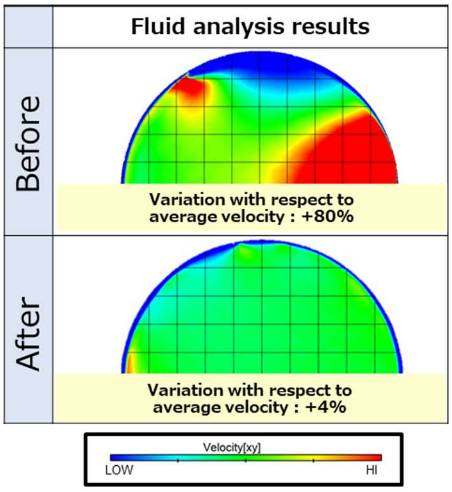


Fig.6

3-3: Porous structure optimization (quality engineering + multi-objective design)

The porous structure used on the Anode side must be high strength and dense enough to prevent damage to the PEM due to pressure differences, but must also be fluid permeable to hydrogen and water. In this study, CAE was used to model the porous structure and parameter studies were performed for diffusivity. It was found that the pressure drop and diffusivity varied in an inverse relationship depending on the combination of coarseness and denseness. To improve the diffusivity while avoiding the increase in pressure drop, we used the L18 straight line table from Quality Engineering and the multi objective optimization tool to find the optimal specification. Fig. 7 shows the results of the flow analysis inside the porous structure and the multi-objective optimization results. This approach has enabled us to confirm that the new specifications maintain diffusivity and reduce pressure drop variation.

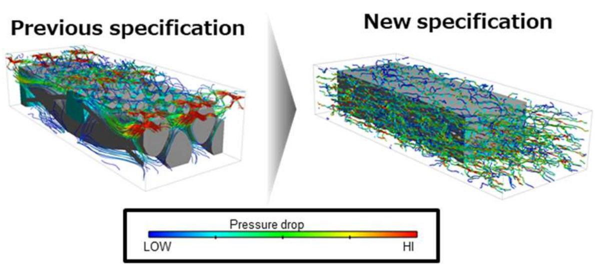


**Fig.7**

4.Result

The changes in the IV curve due to the above efforts are shown in Fig. 8. In the initial specification, the water drainage was not sufficient and the critical current density was limited, whereas in the improved specification, the performance was improved by a factor of 4 at the same voltage by improving the internal conditions and by selecting the membrane specifications.

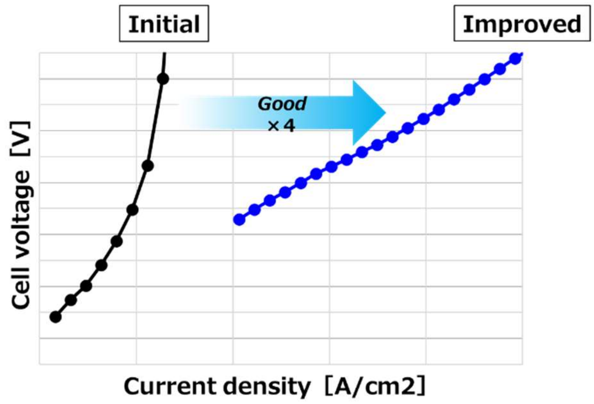


**Fig.8**

5.Conclusion

Through these efforts, we efficiently clarified and solved technical issues by combining virtual and real technology. We also developed a method to control the critical current density of EHC cells by analyzing the flow paths and porous structure to clarify the effect of the structure on the performance. In the future, we will apply this method to the development of optimal EHC cells for various applications.