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Pump design for High Temperature Sulfuric acid transfer system

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1. Introduction

Steam reforming is a method of producing hydrogen from hydrocarbon. It is the most common method of producing commercial bulk hydrogen at high temperatures (700~1100℃) with various ways. It using fossil fuel dose not eliminate carbon dioxide to release into atmosphere. Among hydrogen production technology that does not need fuel energy, one with highest possibility for commercialization is nuclear hydrogen. Nuclear hydrogen is a method of producing large amount of hydrogen by water decomposition cycle at very high temperature gas cooled reactor (VHTR) with high temperature about 950 ℃. Recently, there are about 400 kinds of proposed nuclear hydrogen production cycles, and among them the sulfur- iodine (SI) thermo-chemical cycle by Funk *et al* [1] is being in spotlight because its theoretical heat transfer efficiency of hydrogen is higher than 50 %.

Intense experimental and theoretical research activity has been carried out worldwide during the last decade to investigate the potentialities of this process [2]. But, many researches were reported for whole cycle process problems. In the sulfuric acid concentration / decomposition section, consequent issues handling material corrosion and the coupling with high temperature energy source were generated, as well as the study of catalyst activity and stability [3,4,5]. And Onuki *et al.*, mentioned that material resistance issues are also important for the development of the hydriodic acid concentration/decomposition section [6]. Moreover, the transfer of high temperature H_2SO_4 is a very important factor considering safety in successive reaction process and efficiency.

As mentioned above, the pump to carry sulfuric acid is very important in SI process, but this study is insufficient. After forced cooling of high temperature H_2SO_4, reduction of safety and process efficiency which is caused by transfer, re-heating, and pressurization is one of the weaknesses in H_2SO_4 transfer system. Therefore, in this study, we proposed the newly designed H_2SO_4 transfer system for SI thermo-chemical cycle and the proposed H_2SO_4 transfer system was analyzed using computational fluid dynamics (CFD) analysis in order to investigate thermodynamic /hydrodynamic characteristics.

2. Methods

2.1. Dynamic characteristics of H_2SO_4 transfer system

Pumping part is consisted of check valve, bellows box which is connected to check valve, and driving unit which expands/contracts bellows inside the box. H_2SO_4 is transferred into the bellows box through fluid course formed by connecting bellows box and check valve, and the fluid is discharged by pumping from bellows' movement. By the cooling water flowing inside the box, bellows in high temperature becomes cooled so that it can maintain its temperature limit during continuous operation. Therefore, to satisfy this condition, Teflon which has high acid resistance is adopted as the material of the bellows.

The check valve controls the H_2SO_4 fluid to be inserted or discharged into bellows box in pumping part by opening or closing check ball which is installed inside the upper and lower chamber. The amount of H_2SO_4 fluid can be adjusted by controlling bellows reciprocating amplitude and motor RPM.

2.2. Numerical Model Design

The CFD analysis was conducted to obtain easily continuous operation reliability and thermal analysis for bellows box and bellows as H_2SO_4 transfer rate changes.

Bellows box has size of 600 ㎜ × 350 ㎜, bellows has 250 ㎜ × 115 ㎜, span is 25 ㎜, pitch (1/2) is 10 ㎜, and the material is Teflon which is installed inside the bellows box on adiabatic condition. Bellows end plate has thickness 10 ㎜(W) × length 115 ㎜(L), made out of STS(stainless steel), diameter of entrance/exit part of cooling water is 30 ㎜, and diameter of entrance/exit part of H_2SO_4 fluid 60 ㎜. H_2SO_4 fluid is consisted of 98 wt% H_2SO_4 + 2 wt% H_2O (density 1.8 g/㎤), amount of transfer is calculated by equation(1) as follows;

$$\mathbf{Q}(l/\mathbf{sec}) = \mathbf{A}(\mathbf{m}) \times \frac{1}{2}\ \boldsymbol{Frequence(Hz)} \times \pi \times d^2(m) \tag{1}$$

Where, A is amplitude of bellows (0.03 m), frequency (Hz) is 1/T (*i.e.*, T is cycle), and d is radius of bellows.

User Defined Functions (UDF) of FLUENT is used in CFD analysis in order to provide actual operation condition. UDF is a user-defined function that can be used for FLUENT analysis, which can controls boundary condition, definition of properties and source term. And, moving grid area as the dynamic mesh structure is set and movement of bellows is reproduced by using UDF.

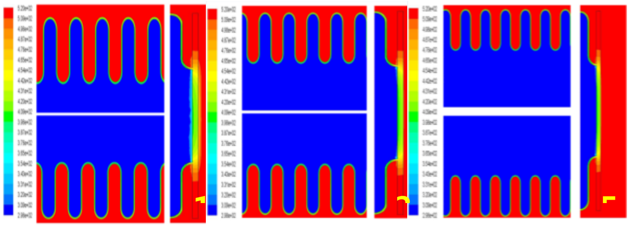
3. Results

We presented temperature and pressure distribution of bellows for various frequencies (*i.e.*, 1, 3, 5 Hz) at 71.082s. The heat transfer was observed because temperature different was generated between cooling water flowing into Bellows and sulfuric acid being Bellows outside. And the temperature of span is lower than the material limit of Teflon. So it can be considered that designed system provides reliability and durability.

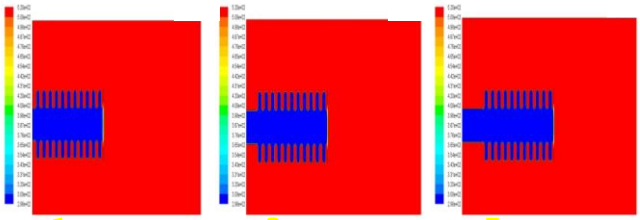
Second, the temperature contours of bellows box were presented at various frequencies. The localized high temperature parts were not observed.

Figure. Temperature distribution of Bellows and Bellows box with various frequencies:

(A) Detail view of top/bottom/end-plate side



(B) Bellows box



4. Conclusions

As the results, we identify as follows as:

1) By the thermal analysis result of bellows in developed transfer system, it is verified that continuous operation is possible within the deformation temperature limit of Teflon 430 K.
2) Physical/chemical environment of inside the bellows box and performance of bellows in continuous operation condition were evaluated. It is verified that not only the bellows, but also the end-plate made of STS can provide reliability and durability during continuous operation.
3) The CFD results on thermohydrodynamic characteristics show good performance for the proposed H_2SO_4 transfer system.

It is evaluated that it will be efficient in actual manufacturing process because it can provide quantitative transfer and prevent heat loss.

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