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Preliminary Thermo-Hydraulic Analysis of Sulfuric Acid Loop for NHDD System

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1. Introduction

Very High Temperature gas cooled nuclear Reactor (VHTR), which was coupled with Sulfur-Iodine (SI) thermo-chemical cycle, has been selected for the Nuclear Hydrogen Development and Demonstration (NHDD) project in Korea Atomic Energy Research Institute [1].

Among the various hydrogen production methods, Sulfur-Iodine (SI) thermo-chemical cycle is a good method as a massive hydrogen production without CO_2 emission. In SI cycle, the sulfuric acid decomposition is one issue for the material corrosion on high temperature and pressure condition.

For the simulation of the sulfuric acid decomposition, we designed a sulfuric acid loop with a small-scale gas loop which is simulated for the integrity and feasibility tests on a H_2SO_4 decomposition process [2].

The primary objective of the loop is to validate the corrosion and the mechanical performances of a key component of the NHDD, Process Heat Exchanger (PHE) [3].

In this paper, we discussed the preliminary thermo-hydraulic analysis of small scale sulfuric acid loop under atmosphere pressure condition.

2. Methods and Results

2.1 Small Scale Sulfuric Acid Loop

A small scale sulfuric acid (H_2SO_4 96 %wt) loop is an open loop and consists of a H_2SO_4 storage tank, a H_2SO_4 feed pump, a sulfuric acid evaporator (H_2SO_4 pre-heater) and decomposer (H_2SO_4 super-heater), a process heat exchanger (PHE), a high temperature cooler, a separator, a SO_2 trap, a low temperature cooler, and a H_2SO_4 collector as shown in Figure 1 [3]. Liquid H_2SO_4 96 %wt of room temperature is supplied from a H_2SO_4 storage tank to the evaporator through the H_2SO_4 feed pump. Liquid H_2SO_4 in the evaporator is raised from room temperature to 300°C. The outlet temperature of superheater is reached up to 500°C. In the superheater, the evaporated sulfuric acid is dehydrolyzed into water vapor and sulfur trioxide (SO_3). In the PHE, the sulfur trioxide is decomposed into sulfur dioxide (SO_2) and O_2. The mixed gas, such as SO_3, SO_2, H_2O, and O_2, passes through the cooler and the separator. Sulfur dioxide (SO_2) is trapped in the scrubber, and the oxygen is released to the atmosphere via filter system.

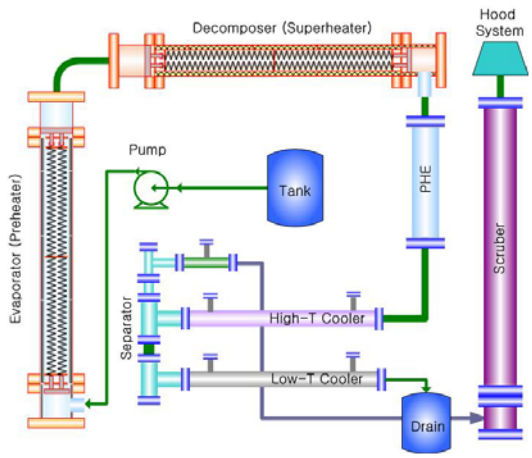


Fig. 1. Schematic Diagram of a Sulfuric Acid Loop

2.2 Thermo-Hydraulic Analysis

Sulfuric acid vapor is dehydrolyzed into H_2O vapor and sulfur trioxide (SO_3) at above 500°C. As the temperature of sulfuric acid vapor is reached up to 500°C, sulfa trioxide is decomposed into sulfa dioxide and oxygen [4].

$$H_2SO_4 \rightarrow H_2O + SO_3 \quad (1)$$

$$SO_3 \rightarrow SO_2 + 0.5O_2 \quad (2)$$

At the sulfuric acid vapor, the decomposition fraction of H_2SO_4 is the main factor for the mixture density. A homogeneous flow of the H_2SO_4 mixture is assumed. So the mixture density is as following equation:

$$\rho_{mix} = \frac{\sum_i \dot{N}_i \rho_i}{\sum_i \dot{N}_i} = \frac{(1-x)\rho_{H_2SO_4} + x\rho_{H_2O} + x\rho_{SO_3}}{1+x} \quad (3)$$

Where, x=decomposition fraction of H_2SO_4

All properties of H_2SO_4, SO_3 and H_2O were calculated from Aspen plus [5]. The vaporization latent heat of the sulfuric acid was listed by the following Rohsenow correlation [6].

$$\frac{C_{pl}\Delta T_{sat}}{h_{lg}} = C_{sf}\left[\frac{q}{\mu_l h_{lg}}\left(\frac{\sigma}{g\left(\rho_l-\rho_g\right)}\right)^{1/2}\right]^n\left(\frac{\mu_l C_{pl}}{k_l}\right)^{1+m} \qquad (2)$$

Figure 2 shows the latent heat of H_2SO_4 decomposer.

As the temperature of H_2SO_4 decomposer is increased, the latent heat is increased. Also, as the temperature of H_2SO_4 decomposer is increased, the decomposition rate of H_2SO_4 is increased as shown in Figure 3.

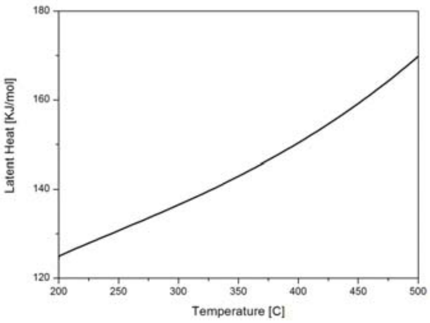
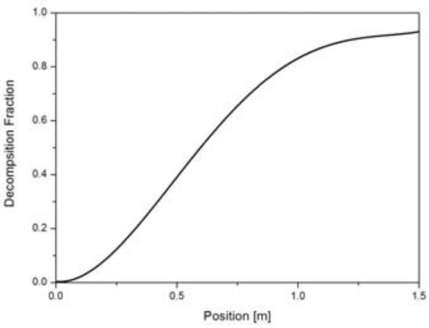
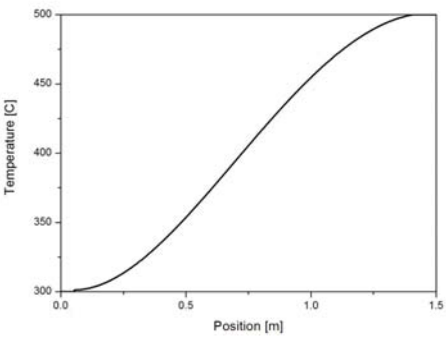


Fig. 2. Latent Heat of H_2SO_4 Decomposer



(a) Temperature



(b) Decomposition rate

Fig. 3. Temperature and Decomposition rate Profiles of Decomposer

3. Conclusions

A small scale sulfuric acid loop was simulated for preliminary thermo-hydraulic analysis of the components of the sulfuric acid decomposition process. We obtained the following results for the modeling of the small scale sulfuric acid loop.

1. As the latent heat of H_2SO_4 decomposer was increased, the temperature of H_2SO_4 decomposer was increased.
2. As the decomposition rate of H_2SO_4 decomposer was increased, the temperature of H_2SO_4 decomposer was increased.

ACKNOWLEDGMENTS

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