Analysis on the Piping Length Effects of the Intermediate System in a Nuclear Hydrogen Production System

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1. Introduction

The intermediate system of a linked hydrogen production is a system connecting a reactor to a hydrogen production system and is required to be located at least 70~100m away so that an accident in a system can be isolated and propagation of the accident effects can be blocked. From this, the intermediate system needs to be designed so that the undesirable effects from the long range heat transport such as heat loss, temperature decrease and circulation power can be minimized. In this study, a model was developed for the analysis of the system performance and the relationship among the design parameters of the system Using the developed model, the system performance was evaluated for various design parameter values.

2. Performance analysis model for the intermediate system

For accurate performance evaluation, it is required to develop an analysis model that considers the effects of all the parameters. However, such analysis model generally comes to be very complex in its structure and resultantly becomes inefficient in investigating the related physics. Because of these, a MARS-GCR model was developed by using the governing equation of a differential equation form.

2.1 Analysis model for the MAR-GCR circulator

The circulator of the intermediate system was modeled so that the calculation efficiency can be increased by utilizing the performance curve of the South Africa PBMM. In this study, the performance curve is calculated by utilizing the circulator efficiency that is determined from the pressure ratio of the inlet and outlet pressures. The head Δh developed in the circulator is expressed by the following [2].

$$\Delta h = \frac{P_1(PR-1)}{\rho_m g} \quad , \quad PR = \frac{P_2}{P_1} \qquad (1)$$

where P_1, P_2: inlet, outlet pressure, PR :pressure ratio.

The circulator torque is calculated by Eq.(2) with the efficiency which is determined by an interpolation.

$$\tau = \frac{\dot{m}P_1(PR-1)}{\omega\eta\rho_m} \qquad (2)$$

where, τ torque, $\dot{m}$:flow rate, ω rotation speed, η :efficiency, $_m$:average of inlet and outlet.

2.2 Model for a detailed analysis

A system analysis model that can analyze the operation performance of the intermediate system in detail was prepared by setting up an analysis model under the MARS structure based on differential equations for the transport phenomenon. In this modeling process, a model that calculates only the intermediate system region while taking the parameters interfacing the reactor and hydrogen systems as the boundary conditions was first setup, and then the model was expanded in its calculation region to the reactor and hydrogen system. The developed model of detail analysis is shown in Fig. 1.

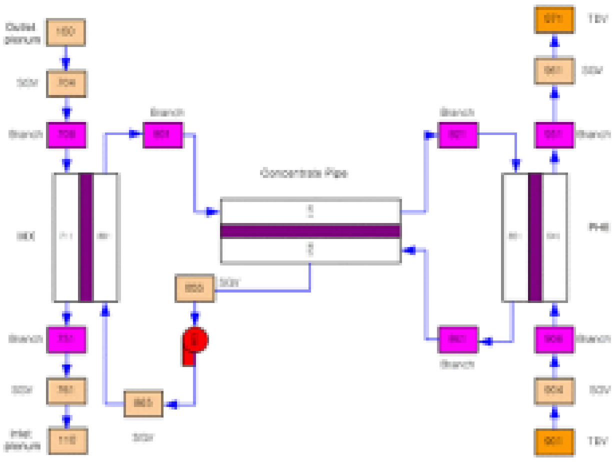

Fig.1 The developed system model for detailed analysis

In the system modeling, the intermediate system piping was modeled as a co-axial piping where hot fluid flows the inner and cold fluid flows the outer as shown in Fig.2. The circulator was modeled basically by using the MARS-GCR circulator model.

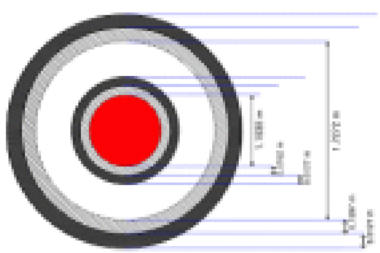

Fig.2. The modeled intermediate system piping

3. Evaluation on the performance of the intermediate system

By using the developed model, the system performance characteristics were evaluated with the conditions shown in Table1.

Table 1. The parameters and values selected for the evaluation.

Parameter	Value	Unit
coolant	He, N2	
separation distance	100, 200, 400	m
system pressure	7, 5, 3	MPa

4. Analysis Results

The summary of the analysis results is shown in the next two figures. In this analysis, the coolant was helium and the system operation pressure was 7Mpa.

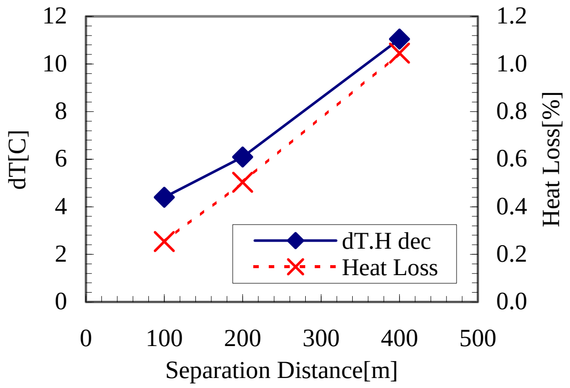

Fig. 3 Changes in the heat loss and fluid temp

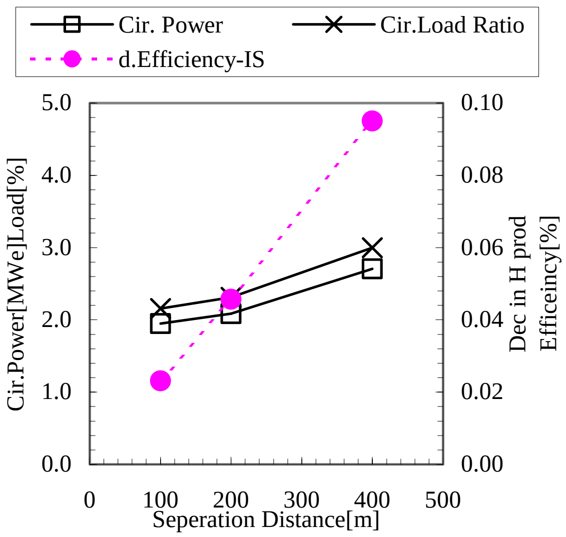

Fig. 4 The change in the circulation power and efficiency

As the separation distance increases, both of the heat loss and the decreases in the efficiency of the hydrogen production system change nearly linearly. However, the efficiency decrease is merely in the magnitude of 0.1% while the heat loss is in the magnitude of 1%. From this, it can be said that the heat loss needs to be viewed mainly from the heat loss itself but not from the efficiency decrease in the hydrogen production.

The required power for the circulation pump is manly proportional to the head loss in the intermediate fluid and the head loss consists of two components. One is proportional to the distance and the other is constant.

Regarding the first head loss component, i.e., the one proportional to the distance, its magnitude also changes as the fluid properties change with the distance change and this feature makes its changing profile non-linear and becomes the head loss increases more rapidly as the distance increases.

Theses effects make the required circulator power increase rapidly at a distance increase with a step at the beginning. Quantitatively speaking, as the distance increases by four times, i.e., from 100m to 400m, the required power increases only ~35%, i.e., from 2.2% to 3%, in the term of the load ratio.

It means that the heat loss is directly proportional but the circulation power is somewhat insensitive to the distance increase.

4. Conclusion

An efficient analysis model for the intermediate system was developed under the frame structure of the MARS-GCR and the analysis on the system by the model revealed the following.

The effects of the separation distance increase are mainly on the heat loss and minimal on the hydrogen production efficiency, which is merely in the order of 0.1%. The required circulation power is somewhat insensitive to the distance increase, which is only 35% at a 400% increase in the distance.

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