A Flow Change in the Conceptual Two-Phase Heat Exchanging System due to the Line Pressure Drop Variation

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1. Introduction

The current study is motivated by a hydrogen system having boiling and condensation phenomena in a circulation loop. During the manufacturing process of the loop system, the weld bead is incepted into the circulation flow pipe at a few locations, which contracts the flow area at the junction point and induces an additional hydraulic resistance. As the consequences, the equilibrium status would be changed, which can need a special control logic or some system complement to a target system performance.

In the previous study [1], a preliminary study was performed under an artificially assumed geometry and heat boundary conditions. As the results, a reduced flow rate and increased primary system pressure and void fraction degree in the riser section was calculated. The hydraulic head loss due to the line resistance increase induces 2% of flow reduction, which supports the pre-expected flow variation trend. The primary system pressure is maintained a similar level though small increase. In the current study, a more detailed geometry and boundary information closer to the interested system have been adopted to the simulation to have an insight for the thermal hydraulic condition and seek an adequate system control strategies. Since we don't have adequate simulation code for the system that hydrogen is used as the working fluid, a conventional water and steam system was adopted for the simulation of the conceptual system. Although the working fluid is different from that of the interested system, the overall trend is expected quite similar and the strategy for the transient loop condition mitigation can be setup from the insight from the current simulation.

2. Methods and Results

The conceptual system consists of the boiler, riser, heat exchanger and downcomer, of which the primary side forms a closed system and there is no inventory loss or addition. The primary system pressure is controlled only by the heat transfer rate at the heat exchanger. Fig. 1 shows a nodalization diagram for the simulation. MARS_KS version 1.5 has been utilized for the thermal hydraulic calculation.[2] The four "pipe" components were adopted for the boiler, riser, heat exchanger and downcomer, respectively. The detailed geometric information has been updated based on the previous study [1].

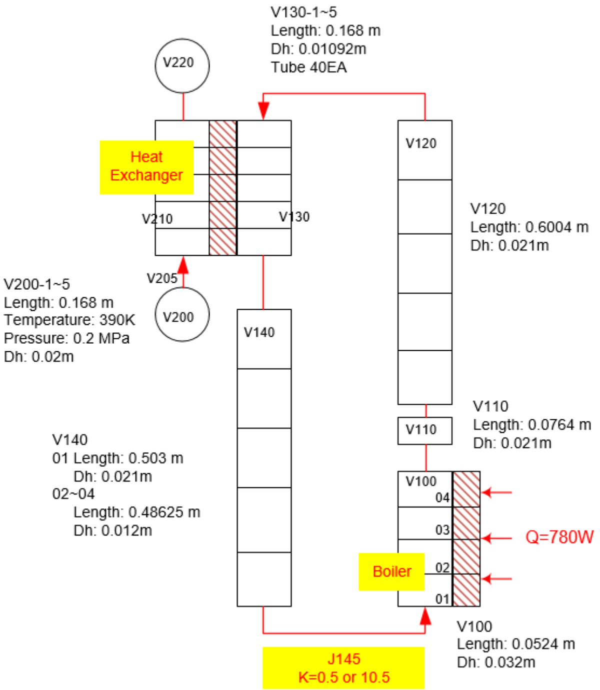

Fig. 1. MARS model for conceptual heat exchanging system

The generated two phase mixture due to boiling in the boiler flows directly into the riser and condensing in the heat exchanger. The pressure of the heat exchanger primary side is set at 0.2MPa, which is the similar condition of the target system. As summarized in Table I, the applied power is 780 W which are set as similar level of the target system. Surely, since the target system is operated with hydrogen as the working fluid, the phenomena would be different from the system working with water due to the property differences. However the pattern are very meaningful to the consequences of the target system and essentially referred to develop a system control strategy.

The additional line pressure drop in the manufacturing process due to the weld bead insertion into the flow path was modeled by pressure drop coefficient referred to the handbook of hydraulic resistance [3]. We are considering three weld points in the circulation pipe line. The flow résistance increase due to the three points of bead inception has been assumed by form loss coefficient increase of 10.0, which is very conservative value adopting a severe bead inception geometry. The line restriction was applied to the junction between volume 140 and 100 which represent the downcomer and boiler, respectively.

Table II shows the case definition. The base case, case 0, assumes the two volumes of the downcomer and boiler be connected smoothly according to the ideal design. The case 1 has been defined the line resistance due to the additional flow resistance such as due to flow area contraction. The loss coefficient, K is assumed to 10.5 with some conservatism referred to the handbook of the hydraulic resistance as described before.

Table I. Major boundary conditions

Parameter	Value
Heating Power, W	780
Pressure at HX, MPa	~0.2
HX 2danary Inlet Temp, K	392

Table II. Case Definition

	Boiler Inlet Junction K (between V140 and V100)
Case 0 (Base)	0.5
Case 1	10.5

3. Results

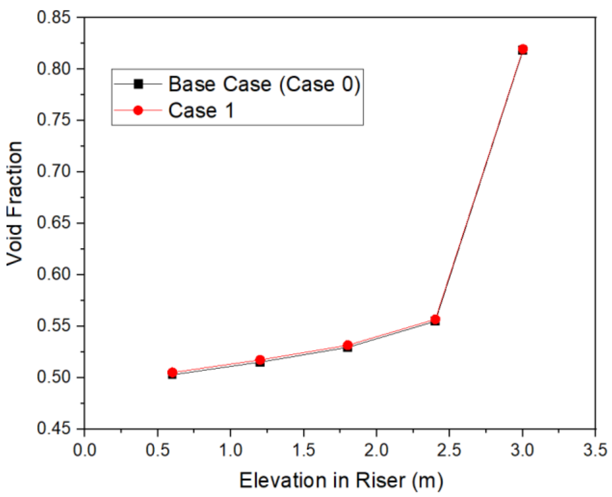

Fig. 2.Void fraction distribution in the riser

Table III shows the calculation results for the important parameters. The current simulation has the water level in the downcomer by the inventory control. Therefore, the liquid fraction in the HX is approximately zero. As expected, the line resistance due to the bead inception into the line reduces the flow velocity. However, the effect is not so much, which are less than 1%. The water level increase in the downcomer due to the hydraulic resistance increase is important cause for the velocity recovery in the case 1.

The system pressure can be increased due to the enthalpy rise induced by the flow reduction. However, there is very little effect on the pressure in the current case. The void fraction profile shown in Fig. 2 also shows the thermal hydraulic consequences, which shows a meaningless increase in the riser void fraction.

3. Conclusions

A simple conceptual heat exchange system has been simulated to have an insight for the new equilibrium thermal hydraulic condition and to seek an adequate system control strategies. The thermal fluidic boundary conditions were referred to the target system which is operated with hydrogen gas in the primary side. Since we don’t have an adequate simulation tool for the hydrogen boiling and condensing system, the simulation has been performed under the working fluid as water. As the results, a reduced flow rate has been acquired as expected preliminarily due to the flow restriction increase due to the weld bead inception. However, there is very little effect on the pressure in the current case. The void fraction profile and pressure change between the two cases were trivial.

Although the working fluid is different from that of the interested system, the overall trend is expected quite similar and the strategy for the undesired loop condition can be setup from the insight from the current simulation.

ACKNOWLEDGEMENTS

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Table III. Major Results

Parameter	Case 0	Case 1 (Bead Inception)
V130 (HX) Water Level, m	~0	~0
V140 (Downcomer) Water Level, m	1.51	1.53 (Small Increase)
J145 Velocity, m/s	0.233	0.2316 (Meaningless decrease)
HX Primary Pressure, MPa	0.1193	0.1193