Analysis of the Natural Circulation Characteristics in the Primary Loop of the VISTA Facility for SMART by using the MARS Code

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1. Introduction

The SMART [1] uses a two-phase natural circulation in the PRHRS loop to remove the heat from the steam generators to the PRHRS heat exchangers, while a single-phase natural circulation occurs in the primary loop to transfer the decay heat from the core to the steam generator. Natural circulation operation with a power range of 20 ~ 25% was considered for SMART and nowadays the possibility of increasing the power level during the natural circulation operation is being investigated. Previously the characteristics of natural circulation in the primary loop are experimentally investigated [2] during various operational conditions by using the VISTA facility [3]. In the present paper the experimental data on the natural circulation in the primary loop of the VISTA facility will be analyzed by using a best-estimate system analysis code, MARS. Also the experimental data will be compared with the previous correlations.

2. Test Matrix and Experimental Results

The VISTA facility has the scaled full power of 682.3 kW, which is 1/96 of the reference plant. The scaled 100% flow rates of the primary system are 19.6 m^3/hr at a pressure and temperature of 147 bar and 310 ^oC, respectively, and the scaled 100% flow rates of the secondary system are 0.25 kg/s.

Tests were performed by changing the core power and the feed water flow rate simultaneously. The initial core power and feed water flow rate are 25%. During a natural circulation operation both the core power and feed water flow rate are changed from 20% to 50%. Table I shows the test matrix for the natural circulation tests. The given parameters are the core power and feed water flow rate and the resultant natural circulation flow rates are listed.

Table I: Test matrix for the natural circulation tests

Test ID	Heater power (%)	Feed Water Flow Rate (%)	Test Results (NC flow rate)
NC2	Fixed, 20	20	about 14.25%
NC3	Fixed, 25	25	about 17.0%
NC4	Fixed, 30	30	about 17.25%
NC5	Fixed, 40	40	about 18.75%
NC6	Fixed, 50	50	about 20.0%

As shown in Table I, a variety of core power levels and feed water flow rates are given as boundary conditions. After a steady state is achieved, the main coolant pump is tripped and the primary coolant is circulated by a natural circulation as the core heater simulates the decay heat as a source and the steam generator functions as a heat sink. The coolant in the primary loop circulates naturally and the decay heat is removed through the steam generator and the injected secondary coolant is evaporated and heated to keep it at a superheated state.

Figure 1 shows the flow rates across the core for the tests of NC2 through NC6. As the core power and the feed water flow rate are increased, there is an increase in the natural circulation flow rate through the core. As the natural circulation starts, there is a rapid drop of the flow rate and then it recovers to a steady natural circulation flow rate. The flow rate fluctuates a little and it increases with an increase of the core power from about 14.25% for NC2 (20% power) to about 20% for NC6 (50% power).

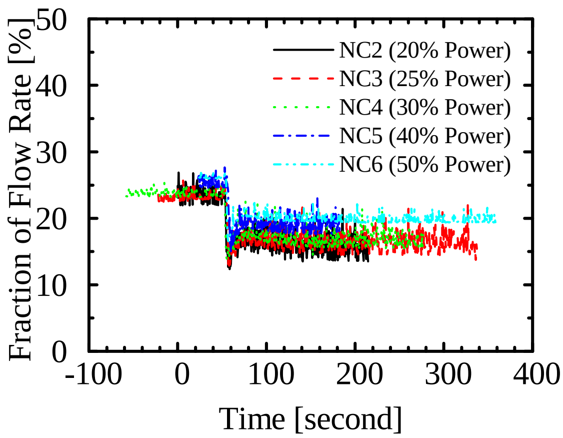

Fig. 1 Core Flow Rates for the Natural Circulation Tests

3. MARS Calculation for Natural Circulation Characteristics in the VISTA Primary Loop

3.1 MARS Nodalization

Figure 2 shows the MARS nodalization for the passive residual heat removal system of the VISTA facility. The present MARS nodalization used for this simulation contains 236 control volumes, 43 junctions, seven valves, and three heat structures. The modeling of the PRHRS includes a reactor pressure vessel, core simulator, main coolant pump, steam generator, a compensating tank, a heat exchanger, and the emergency cooldown tank, pipes and valves.

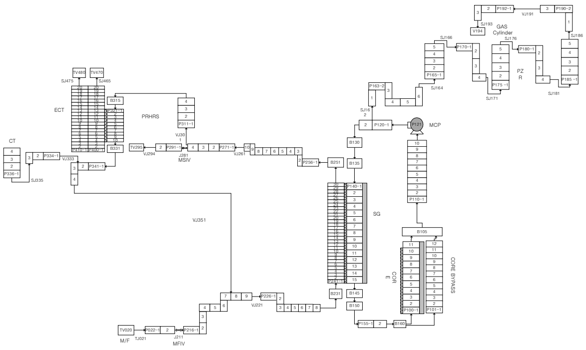

Fig. 2. MARS nodalization for the VISTA Facility by using the MARS Code

3.2 Initial and Boundary Conditions

The simulated heat transfer and feed water flow rate is 25% of the nominal values. However, the flow rate in the primary loop was set to be 100%. The pressures of the primary and secondary sides in the steam generator are 14.7 MPa and 3.45 MPa, respectively. The pressure, temperature, and flow rate are given to simulate the experimental data using the time-dependent volume and time-dependent junction. The injection of the feed water and the vent of the superheated steam are treated with boundary conditions, and the time-dependent junction.

3.3 Simulation Results and Discussion

Figure 3 shows the natural circulation flow rates simulated by using the MARS code. The natural circulation loop was formed within a few seconds but their flow rates are fluctuating throughout the simulation. The NC flow rate calculated from MARS is bounding the experimental data but the change of flow rate is very small compared with the experimental data.

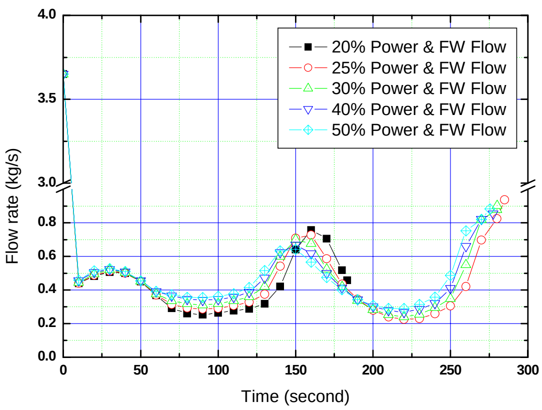

Fig. 3. The natural circulation flow rates simulated by using the MARS code

4. Comparison of the experimental data with the previous correlations

The experimental data was compared with the correlations of Vijayan [4] and Duffey et al. [5]. Both correlations under-predict the experimental data.

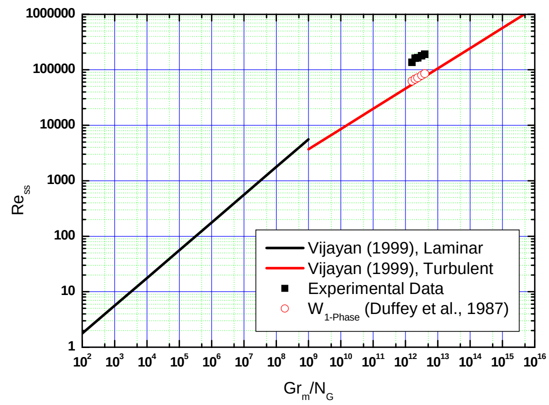

Fig. 4. Comparison of the experimental NC flow rate with predictions from existing correlations

5. Conclusion

The natural circulation experiments have been analyzed by using the MARS code to investigate the thermal-hydraulic characteristics in the primary loop of the SMART reactor by using the VISTA facility. The experimental data was compared with predictions from the existing correlations, which under-predict the natural circulation flow rate. In a near future more detailed analysis should be given to the natural circulation flow tests

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