Preliminary Assessment of Steam Chugging Phenomena in a Vent Pipe using MARS Code

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1. Introduction

In a high pressure steam system, one of the design concerns is the treatment of discharged steam. The discharged steam from a high pressure and high temperature system can cause significant increase of pressure and temperature in a reservoir. One method of the clean and efficient steam treatment is using a DCC (direct contact condensation) in a subcooled water. From an earlier stage of nuclear power plant development, this DCC system has been introduced, and in particular, BWRs (Boiling Water Reactors) has usually used it. Besides BWRs, recent advanced reactors or SMRs (Small Modular Reactors) also frequently uses this system.

Quencher (or sparger) is a kind of substantial device for the steam DCC. The steam DCC phenomena in the quencher vary broadly according to the steam mass flux and pool subcooling. For relatively high pool temperature and high steam mass flux, the DCC occurs in a way of ‘stable condensation’, whereas violent DCC occurs in a way of ‘chugging’ for low pool temperature and low steam mass flux. Thus, ‘condensation regime map’ was proposed, and one example is shown in Fig. 1 by Chan and Lee (1982) [1].

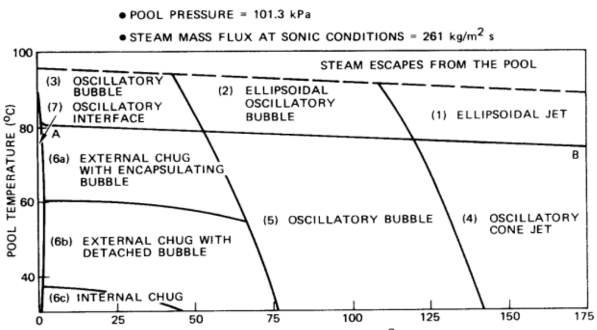

Fig.1 Condensation regime map by Chan and Lee (1982)

Among the several regimes chugging phenomenon has attracted so many concerns because of its high hydrodynamic load and the resultant impact. According to NUREG-0783, several earlier BWRs underwent damages from the violent chugging load[2]. So chugging phenomena have long been studied, and there are so many research papers. Nowadays, Gregu et al.(2017) experimentally studies the chugging phenomena and mechanism [3]. In analytical study, several authors suggested analytical model for the analysis of the chugging. In spite of such efforts on the chugging phenomena, there is few studies on analysis using computer codes. As is understood, it is very convenient and efficient to use computer codes in the analysis of general thermal hydraulic phenomena.

The objective of this study is to assess the chugging phenomena using MARS code [5]. Considering chugging mechanism, the interfacial heat transfer in MARS code may be applicable to this phenomenon. Only the magnitude of interfacial heat transfer coefficient may be a big concern. Fortunately, MARS code provides with the dialing function. For the assessment, Aya and Nariai et al (1980) was referred to[4]. This paper presents detailed modeling process and experimental comparison.

2. Brief Description of Experiment

Outline of the test facility is shown in Fig.2. A boiler, a steam header, and vent pipes compose the steam system. Pool water and pool atmosphere are a pool system. For this assessment one vent pipe case is used. The volume of the steam header is $0.4m^3$, the vent pipe diameter is 18mm, the vent pipe length is 500mm, and the submergence of the vent pipe is 250mm. The steam flow rate is about 0.001kg/s, which is corresponding to mass flux $3.9kg/m^2s$, and the pool water temperature is 20℃.

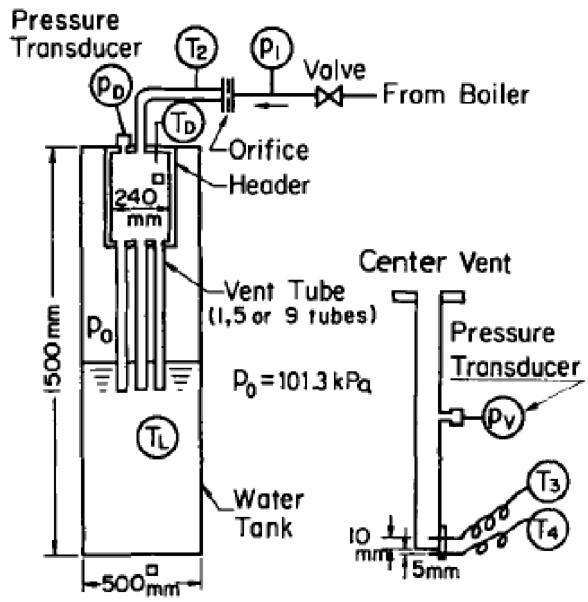

Fig.2 Conceptual schematics of test facility of Aya and Nariai (1982)

This condition is internal chugging according to the regime map of Fig. 1. For the internal chugging, the steam-water interface goes up into the vent pipe due to high condensation rate, and sooner it comes down because of the decrease of condensing power by water warmup. The experimental and analytical results of Aya and Nariai et al (1980) are shown in Fig. 3. The cycle frequency of water level in the vent pipe is around 2Hz.

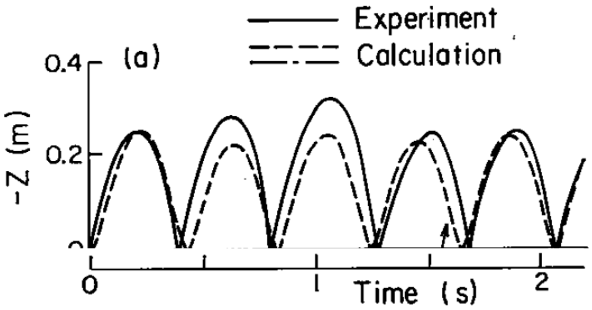

Fig.3 Water level in vent pipe of Aya and Nariai (1982)

3. MARS Assessment

MARS-KS1.5 (subversion 145) was used for the assessment.

2.1 Nodalization

The used nodalization is present in Fig. 4.

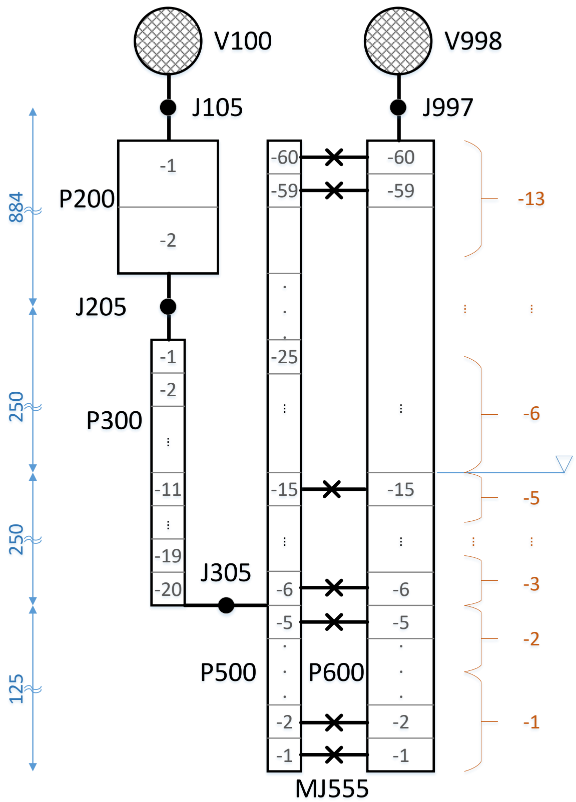

Fig. 4. Nodalization for MARS assessment

In case of fine node for the pool, the calculation failure was resulted in, and the coarse node shown in brown color was used. It might be caused by so small length-to-diameter ratio on numerical volume.

2.2 Assessment Using Original Version

The mass flow rate of steam was set using orifice and choked flow as like in the experiment of Aya and Nariai et at. (1980), which enabled a stable constant flow. 0.001kg/s (~3.9kg/m^{2}s) was obtained.

The raw calculation result is shown in Fig. 4. This result does not show anything interesting. The steam from the boiler goes through the pool without any concerns. It is because the so small interfacial heat transfer coefficient in MARS original code

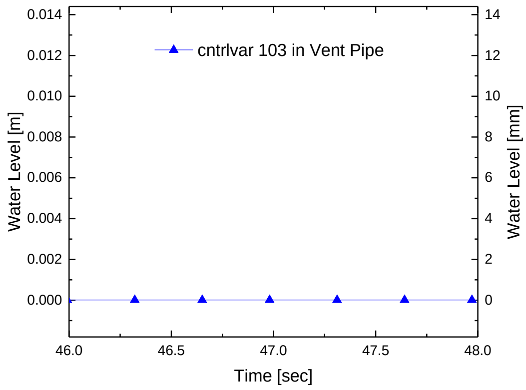

Fig. 4 Water level in vent pipe in case of no dialing

2.3 Assessment Using Dialing

The interfacial heat transfer coefficient was multiplied by 2.0million times. The result is shown in Fig. 5. The cycling frequency is around less than 1.0Hz, which is somewhat different from 2.0Hz of Aya and Nariai et al. (1980).

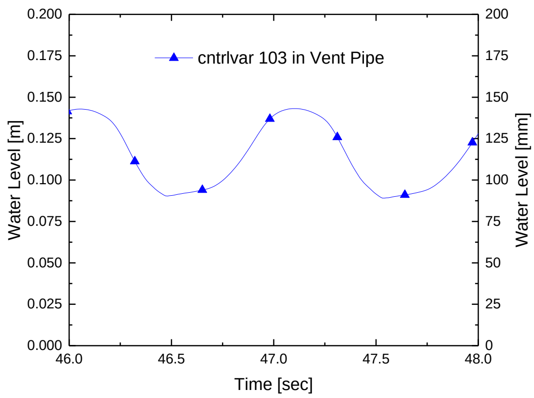

Fig.5 Water level in vent pipe in case of dialing 2.0e6 times

And the water level maintains above the vent exit, differently from the experiment.

4. Conclusions

The original code of MARS was revealed not to appropriately predict the chugging phenomena. But the dialing option gave the trial possibility. When the interfacial heat transfer coefficient is multiplied by several orders of magnitude, the DCC rate was enhanced, and the chugging phenomena was a little simulated.

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