Evaluation of Power Uprate Effects on NPP Components − Development of Evaluation Method for Acoustic Resonance in Main Steam Piping −

Background

The power uprating of nuclear power plants is being conducted in the United States, EU countries and so on, and is also planned in Japan. However, that may expose degradation phenomena or increase in magnitude, such as flow-induced vibration and wall thinning, under the power uprate condition.

In the Quad Cities 2 NPP, under 17% extended power uprate (EPU) condition, an acoustic-induced vibration caused by the acoustic resonance at the branch piping of safety relief valves (SRVs) in main steam (MS) lines occurred at a dryer (Fig.1). As the dryer was damaged by a high cycle fatigue, we need to develop evaluation methods for this phenomenon and the conditions of the dryer in BWR-5, which is the main type of BWR in Japan.

Objectives

For development of the evaluation method of the resonance in MS line and stress on dryer (Fig.1), this study aims to confirm numerical evaluation method of resonance conditions and power at SRVs that constitute the sound source.

Principal Results

(1) Verification of Numerical Simulation

To clarify the basic characteristics of resonance, air flow simulations in piping with branch pipe were conducted. As a result, the periodic pressure fluctuations (resonance) can be seen in specific velocity region (Fig.2), and the region and amplitude of the resonance agree well with the experiments (Fig.3).

(2) Evaluation of SRV Shape Effects

Flow calculations of piping with branch pipe which has the same radius as actual plant at the connection were conducted to evaluate the shape of the branch. As a result, Strouhal number *1 (St) of resonance becomes smaller than that without branch connection radius (Fig.4). This means that higher velocity is needed for the resonance starting in the condition with radius branch, and we found that the modeling of the piping shape was important to evaluate the actual plant case.

(3) Evaluation of Wet Steam Effects

Different from air flow, phase change occurs and different type of pressure fluctuations may be observed in wet steam flow that is used in actual plants. Therefore, to clarify the differences between them, high pressure/temperature wet steam calculations were conducted and compared with the air flow results. As a result, we found that applicable normalization gives almost good agreement between air and steam about the resonance region and amplitude (Fig.3). We suppose that the resonance at the branch piping is not affected by kind of fluid, and found that evaluation results with air flow may be useful for a prediction of the pressure resonance in actual power plants

From the above results, we found that resonance evaluation results at branch piping by numerical simulation may be applicable as an input condition of acoustic analysis of MS line/steam dome.

Future Developments

To simulate the sound source power, its propagation and the stress on dryer in actual plant condition.

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Reference: R. Morita et al., “Numerical Simulations of Pressure Fluctuations at Blanch Piping in BWR Main Steam Line”, ICAPP '09, No.9372

Remarks: This research was conducted as the collaboration research with Hitachi-GE Nuclear Energy, Ltd.

*1 : Strouhal Number, St: Normalized parameter expressed as (frequency) × (length)/(velocity), usually used to normalize the frequency and velocity

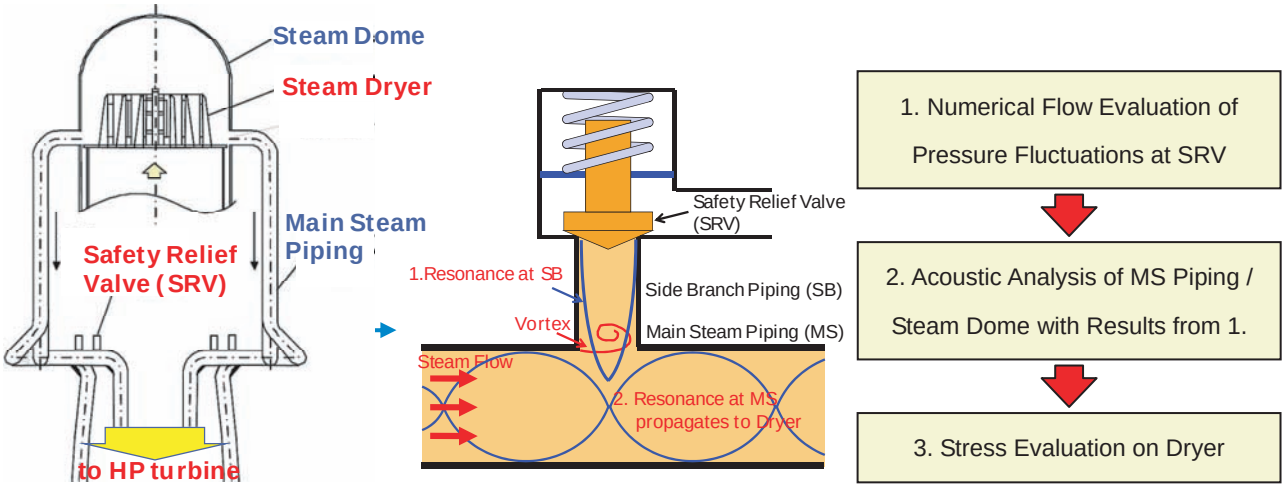

Fig.1 BWR Main Steam(MS) Line(left) / Schematics of Resonance at Safety Relief Valve(SRV) (center) / Evaluation Flowchart of Pressure Fluctuations in MS line and Stress on Dryer (right)

Pressure resonance caused by vortex shedding may occur at SRV in specific flow conditions.

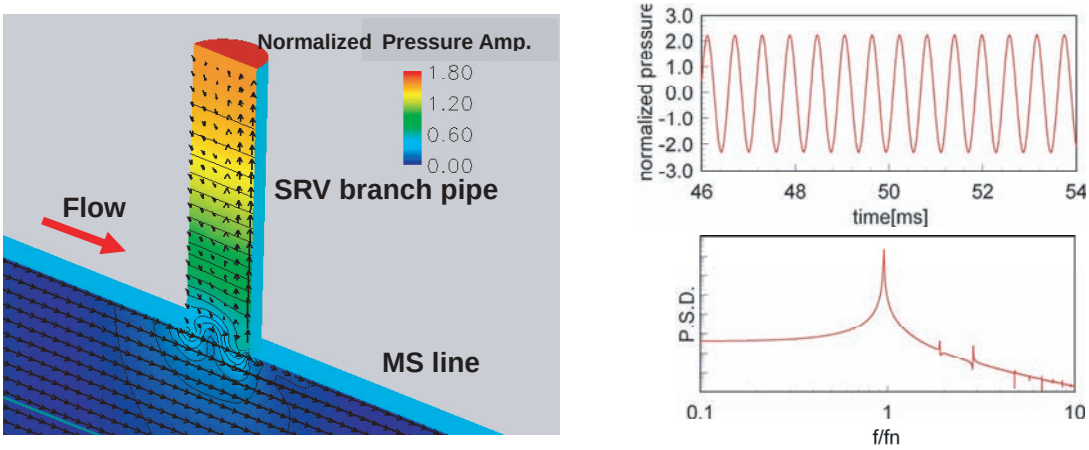

Fig.2 Resonance at SRV (left) / Pressure History and Frequency Analysis at the top of SRV (right)

Periodic pressure fluctuations (resonance) can be observed in numerical simulation

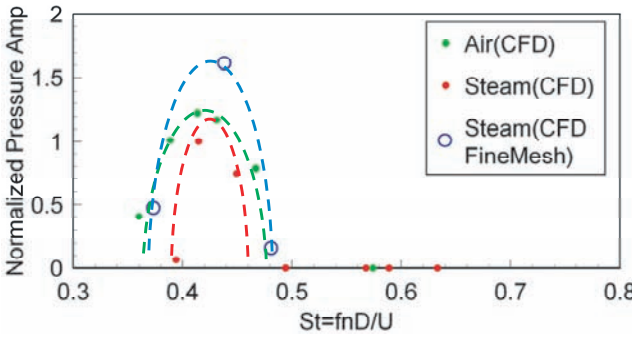

Fig.3 Comparison of Pressure Amplitude with experiment,and comparison between air and steam calculations (Air exp. and calc. : ordinary pressure/temp., Steam calc. : Plant condition (High pressure/temp.))

Air flow calculations show good agreement with experiment. As calculation results of air and steam flow agree well about resonance region, the difference of fluids does not affect the piping flow with branch.

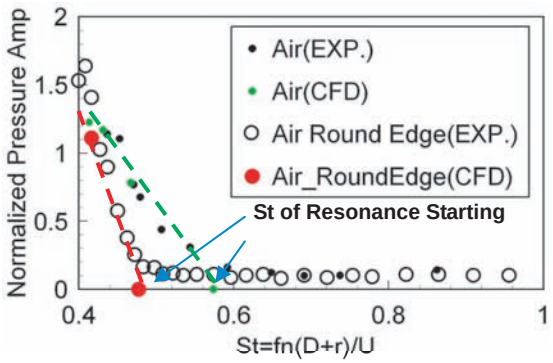

Fig.4 Effects of branch connection radius (fluid: ordinary pressure/temp. air)

As a result of the calculations with branch pipe which has radius same as actual plant at the connection, we found that Strouhal number of resonance became smaller than that without branch connection radius.