Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

A Scheme of 3-D Breakdown-whip Analysis Methodology for High Energy Piping

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1. Introduction

High energy piping systems are operated with either or both conditions of maximum operating temperature exceeding 200˚F(93.3℃) or maximum operating pressure exceeding 275 psig(19.3kg/cm^2) during normal operating conditions in nuclear power plants[1]. A high energy pipe failure is postulated in branches or piping that runs larger than one inch nominal diameter. The resultant consequences of these postulated pipe breaks must be analyzed for the effect on maintenance of plant safe shutdown capability, containment integrity. And the analyzed results must be applied to the system design so that a pipe failure can not damage essential systems to an extent of impairing design function nor affect necessary component operability. The considerable effects of pipe break are as follows; dynamic effects such as pipe whip, jet impingement and environmental impact by release of system contents. Two types of forces are occurred by the pipe whip. The one is pipe whip impact force that broken pipe directly hits the structures or components, and the other is breakdown whip force, which is occurred by rapidly behavior of the pipe connected to components and supports due to the reaction force of released fluid.

The assessment of dynamic effects of postulated piping break is conducted by analyzing fluid transient which is occurred by the released fluid and making structural analysis which evaluates dynamic behavior of broken pipe by using the results of fluid transient analysis as input data. Several computer programs are used to analyze breakdown-whip of high energy piping. The fluid transient loads has been calculated by thermal-hydraulic computer programs such as PRTHRUST or RELAP5/MOD3 with REFORC and the dynamic behavior is analyzed by PIPERUP which performs nonlinear response analysis of a piping subjected to static and time-dependent dynamic forcing function. But these programs are use of one dimensional simple model, so the result tends to have poor accuracy and excessive conservatism. It is thought that more accurate and effective system design is possible by making a combination of fluid transient analysis and 3-D structural analysis.

The main purpose of this study is to introduce the procedure and method for analyzing 3-dimensional breakdown-whip of high energy piping. This study also shows some results of analyzing the fluid transient loads at the main steam line of APR1400.

2. Procedure and Method of pipe-whip Analysis

2.1 Break location

If stress and fatigue analysis are not performed, the locations of postulated piping break analysis are determined at the every fitting which includes elbow, T-branch, and cross type connection as well as every terminal ends. If stress and fatigue analysis are not performed, the results determine the break locations including every terminal ends.

2.2 Break configuration

The types of postulated pipe breaks are classified as circumferential and longitudinal breaks and they do not occur simultaneously. Circumferential breaks are not postulated in piping runs of a nominal diameter equal to or less than 1 inch. Longitudinal breaks are not postulated in piping runs of a nominal diameter less than 4 inches. Longitudinal breaks are not postulated at terminal ends.

2.3 Analysis method

Postulated piping break analysis is the combination of fluid transient analysis and 3-D structural analysis with using numerical computer programs. RELAP5/MOD3 and REFORC are used to analyze fluid transient. The thermal hydraulic data obtained from RELAP5/MOD3 are used as input of REFORC program to obtain forcing functions. The forcing function is converted into ANSYS input data for calculating structural analysis. 3-dimensional displacement and stress data are calculated by ANSYS. Figure 1 shows the procedure of postulated piping break analysis with computer programs.

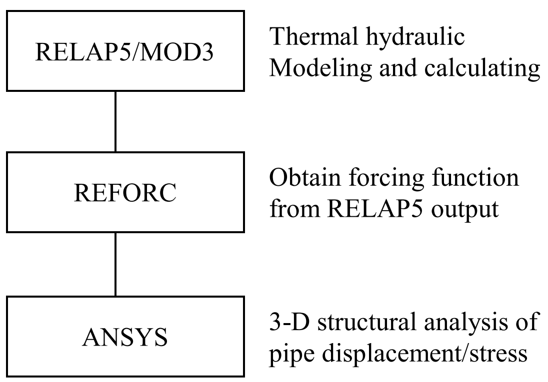

Figure 1. Computerized analysis flow of postulated piping break

3. Fluid transient analysis

Calculation was performed to evaluate the transient loads transmitted to the steam generator nozzles due to main steam (MS) line break of APR1400.

3.1 Assumptions

Several items are assumed to analyze postulated pipe failure. Insides of steam generator and main steam piping are filled with 100% steam. The operating plant condition is hot standby (1,100psia. 556.3 ˚F). Infinite volume and height of S/G is assumed to be 1,000,000 ft^3 and 159.6 ft. The postulated pipe break location is at the containment penetration anchor. Both of circumferential and longitudinal breaks are assumed. Only one of S/G nozzles is considered in this calculation. Friction factor of piping is assumed to be 0.012. It is assumed that it takes 0.001 sec from the beginning of piping break to the fully break according to the SRP 3.6.2

3.2 Calculation

RELAP5/MOD3 code is used to calculate fluid transient between steam generator nozzle and containment penetration anchor. Figure 2 shows the nodalization of main steam line of APR1400. It is made up of one hydrodynamic system. Heat structures are not applied to the modeling with the assumption that there are no heat transmission between MS line and atmosphere.

Transient force histories are calculated against the each segment by REFORC using the output data of RELAP5/MOD3. Figure 3 shows the force history of segment 4 where the pipe break is occurred. In this graph, the reaction force by released fluid and de-compressed wave force occurred inside of pipe are appears together.

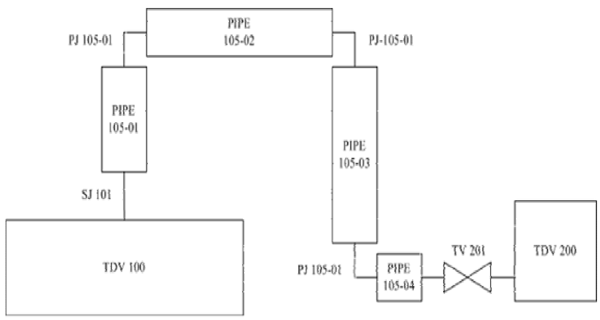

Figure 2. Nodalized main steam line of APR1400

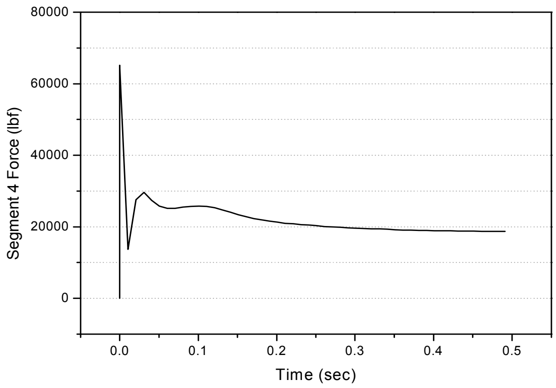

Figure 3. Transient force at the break location

4. Conclusion

In this study, the procedure and method for analyzing 3-D break-whip of high energy piping is presented. As the first step of analyzing postulated pipe break, fluid transient analysis was performed on main steam line of APR1400. By using the results of calculating transient force histories, 3-dimentional structural analysis will be continued. We expect that more accurate and effective system design will be possible by means of calculating the reasonable nozzle loads of pipe connections and reaction force of pipe supports through 3-D pipe whip analysis.

REFERENCES

[1] Standard Review Plan 3.6.2, Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping
[2] KEPIC NDC-3000
[3] ANSI/ANS-58.2 Design Basis for Protection of Light Water Nuclear Power Plants Against the Effect of Postulated Pipe Rupture
[4] RELAP5/MOD3 Code Manual Vol.2 User's Guide and Input Requirements
[5] REFORC-DEC code user's guide
[6] APR1400 Main Steam Line Isometric Drawing