# Dynamic behaviors of main steam piping under high energy line break conditions

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## 1. Introduction

If HELB (High Energy Line Break) accident occurs in NPPs (Nuclear Power Plants), not only environmental effect such as release of radioactive material but also secondary structural defects should be considered. Sudden pipe rupture causes ejection of fluid with high temperature and pressure, which acts as a thrust force on the ruptured pipe. Pipe whip phenomenon caused by the thrust force may lead to generation of defects around the components such as safe-related injection pipes and other structures. The aim of this study is to examine effects of the pipe whip on components and structures according to pipe break position through FE (Finite Element) analyses.

## 2. Analysis Methods

### *2.1 Analysis conditions*

A MSL (Main Steam Line) of NPP was selected for structural integrity assessment due to the pipe whip[1]. It was modeled by employing SG (Steam Generator), pipes, penetration anchors(head fittings and sleeves) and containment building. Structural analyses of the MSL were carried out by using a commercial FE analysis software[2]. A typical steady state operating condition was assumed and a total of 6 break locations were selected to investigate the effects on components.

Each rupture location was selected by diverse reasons; Case 1(SG outlet nozzle) for an axial force induced by ejected fluid on the SG. Case 2(Rear end of first elbow from SG outlet nozzle) for maximum moment to the SG nozzle. Case 3~5(Rear end of second elbow from SG outlet nozzle) for different nozzle reactions according to the pipe break lengths. Case 6(Connection with pipe and penetration anchor) for maximum moment to the pipe.

Table I summarizes the material properties used in the structural integrity assessment.

Table I: Material properties used in structural integrity assessment

| Material | Elastic modulus (GPa) | Poisson's ratio | Yield strength (MPa) | Tensile strength (MPa) |
|---|---|---|---|---|
| Concrete | 31.12 | 0.2 | 38.68* | 2.18 |
| Head fitting & sleeve | 183.92 | 0.3 | 296.47 | 503.32 |
| MSL piping & SG | 183.08 | 0.3 | 303.36 | 503.32 |

[Note] *: compressive strength

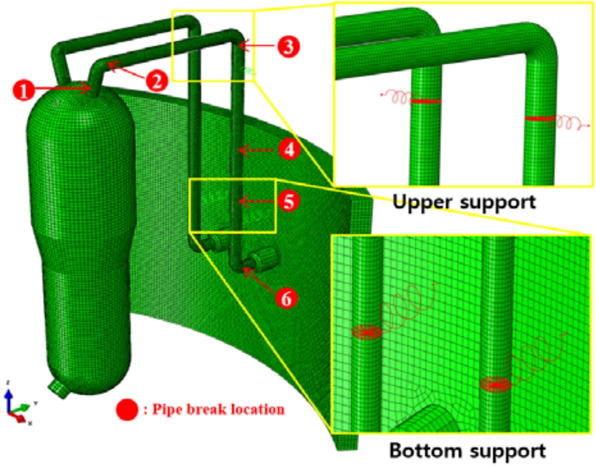

Fig. 1. Combined FE model of MSL and pipe break location

### *2.2 FE models*

Fig. 1 shows the FE model of the MSL and pipe break location. The relevant information is summarized in Table II. Element types of each comp ㅍ onent were taken as three-dimensional 8-node brick element with reduced integration[2].

Table II: FE models information of MSL

| Component | Element type | No. of element | No. of node | Material modeling |
|---|---|---|---|---|
| Containment building | C3D8R | 79,536 | 93,854 | Damage concrete |
| Head fittings & sleeves | | 900 | 1,728 | Bi-linear plastic |
| MSL pipes | | 20,700 | 27,692 | |
| SG | | 55,020 | 64,663 | |

### *2.3 Boundary and loading conditions*

Radial boundary condition was defined on each side of the containment wall by using local coordinate system. Also each MSL piping was supported by two supports, for which x- and y-directional spring stiffness values were assigned[1]. Spring supports modeled by FE analysis software are shown in Fig. 1.

Loading condition was determined from thermal hydraulic analyses(RELAP5)[3,4]. The SG and MSL piping were modeled to calculate the thrust force until 1 second. Sudden rupture accident at penetration anchor was assumed. The result calculated from the RELAP5 code was shown in Fig. 2[4]. The loading condition was equally applied to all analysis cases.

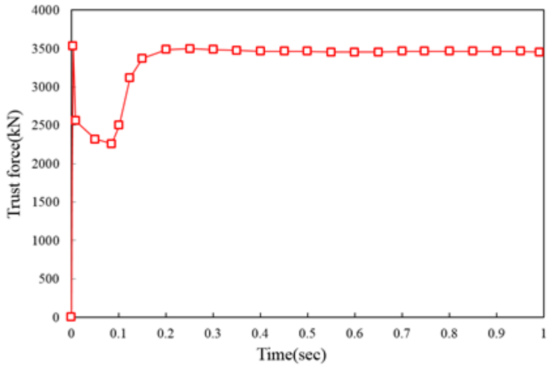

Fig. 2. Variation of thrust forces at pipe break point[4]

## 3. Analysis Results and Discussion

Maximum von Mises stresses and displacements of the SG or MSL piping are summarized in Table III followed by each case. Von Mises stress distribution of MSL in Case 2 is shown in Fig. 3, representatively. The resulting stress of Case 2 was high at the SG nozzle due to direction of the thrust force which causes maximum moment on the SG nozzle; the von Mises stress value was 397.40MPa. While it did not exceed its tensile strength but overtake the yield strength. Results of the other cases(Case 1,3,4,5 and 6) did not exceed the yield strength.

The largest displacement occurred in Case 3, and its value was 376.51mm(372.25mm along z-axis). Resulting displacement contour is depicted in Fig. 4. As shown in the figure, the whipped pipe did not strike adjacent components and structure.

Table III: Maximum von Mises stresses and maximum displacements

| Case | Max. von Mises stress(MPa) | Max. displacement(mm) |
|---|---|---|
| 1 | 103.71 | 6.32 |
| 2 | 397.40 | 282.71 |
| 3 | 282.07 | 376.51 |
| 4 | 276.15 | 74.00 |
| 5 | 234.56 | 54.61 |
| 6 | 289.40 | 296.65 |

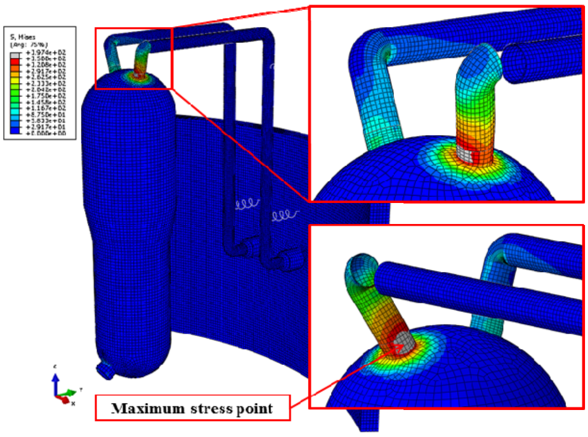

Fig. 3. von Mises stress contours in Case 2

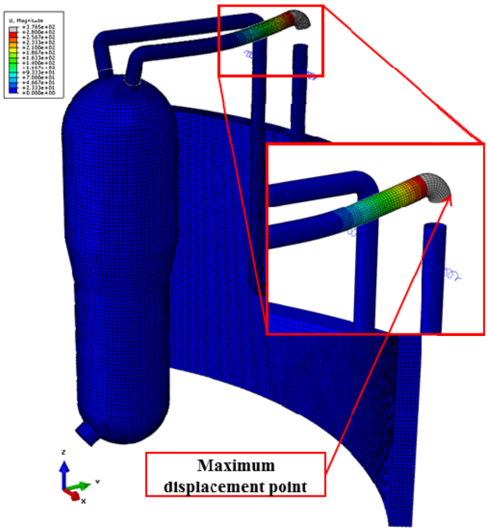

Fig. 4. Displacement contours in Case 3

## 4. Conclusions

In this paper, FE analyses to examine the effect of the pipe whip on components and structures were carried out under HELB scenarios. Particularly, total of 6 break locations were selected for structural integrity assessment. The thrust force obtained from the RELAP5 was applied to FE analyses as loading condition. Thereby, the following conclusions have been derived.

(1) In Case 2, the largest stress was found out at the SG nozzle. The resulting value was greater than the yield strength. Except Case 2(rear end of first elbow from SG outlet nozzle), the resulting stresses did not exceed the yield strength.
(2) Maximum displacement occurred in Case 3(rear end of second elbow from SG outlet nozzle). The value was 376.51mm. The whipping motion of the pipe did not affect other pipes or structures.

## REFERENCES

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