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Numerical Analysis of Steam Jet Impingement in Containment during Pipe Rupture

Dae Kyung Choi [a], Se-Hong Oh [a], Won Tae Kim [b], Yoon-Suk Chang [c], Choengryul Choi [a*], Sung-Man Son [a]
[a]*ELSOLTEC, 303 U-Tower, 120 Heungdeokjungang-ro, Giheung-gu, Yongin-si, Gyeonggi-do 16950, Korea*
[b] *RETECH, Samsung 1-ro 1-gil, Hwaseong-si, Gyeonggi-do 18449, Korea*
[c]*Department of Nuclear Engineering, Kyung Hee University, 1732 Deogyeong-daero, Giheung-gu, Yongin-si, Gyeonggi-do 17104, Korea*
[*]*Corresponding author: crchoi@elsoltec.com*

1. Introduction

In an event of a pipe rupture on a high energy line, the resultant high pressure steam jet emanates from the broken region[1]. Because the steam jet is energetic able to cause damage to surrounding components, nuclear power plant should be designed to endure the effects of pipe ruptures. Therefore, it is necessary to estimate the potential effect of the steam jet impingement to the adjacent and surrounding components. In this study, numerical analysis of steam jet impingement in a containment during pipe rupture has been carried out.

2. Numerical Analysis Method

For the numerical analysis, simplified geometries of steam generator, main steam piping and containment inner wall in the containment are used(Fig.1). Break failure on the main steam piping is assumed at a part close to wall. In this study, the shape of the ruptured surface on the main steam piping is considered a circular type with diameter 0.7m. Steam jetted into the containment through the broken part is toward the steam generator or the inner wall of the containment. The flow conditions were determined based on an LP code calculation. The temperature of the working fluid is 526.6K. Velocity profile is adopted at the break part. The velocity is linearly increased from zero to 409.5m/s for 0.136s and then keeps at 409.5m/s. An initial temperature of the containment is 25℃. Steam jet leads to a subsonic flow (Mach number of 0.73).

3D transient CFD(Computational Fluid Dynamics) analysis has been conducted by CFX(Ver.5) based on the finite volume method with compressible fluid flow. And K-ε turbulence model is adopted to consider a variation of boundary layer by turbulent effects. The Eulerian multi-phase model was used to consider behavior and mixing of multi-phase fluids such as steam, air and vapor. Also, phenomena of the condensation and evaporation were considered to describe the phase change between steam and vapor. Furthermore, dense grid systems were applied at the expected region of jet impingement with about 3,000,000 grids in the entire calculation domain. The numerical analysis has been performed during 2.0s with a time step of 0.01s. Preliminary simulation was carried out for free jet using an established methodology. Then jet impingement was analyzed according to the established methodology.

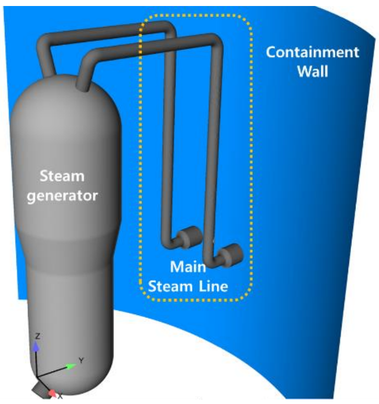

Fig.1 Configuration of the containments

3. Analysis Results

Fig.2 showed the normalized force variations acting on the steam generator and containment wall, when the steam jet impacted each components. The fast Fourier transform(FFT) results of the force acting on the steam generator and containment wall showed in Fig.3 and Fig.4.

The pressure distribution on the steam generator and steam behavior in the containment during pipe break showed in Fig.5. The steam jet concentrated pressure on the impingement region of steam generator.

4. Conclusions

In this study, numerical analysis has been performed to analysis of the steam jet impingement during a pipe rupture. Simplified containment components were used

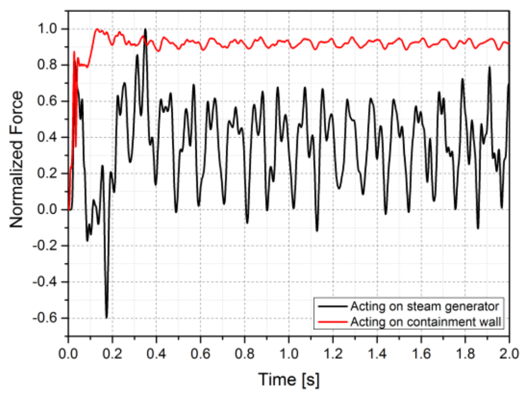

Fig.2 Normalized force acting on the components

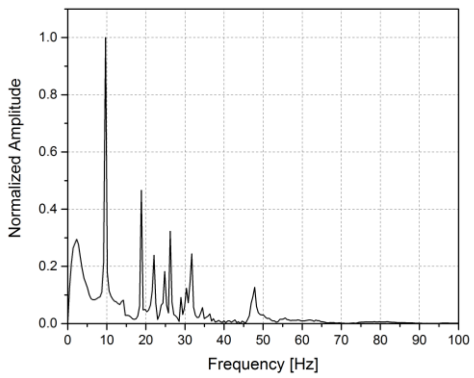

Fig.3 FFT result of force acting on the steam generator

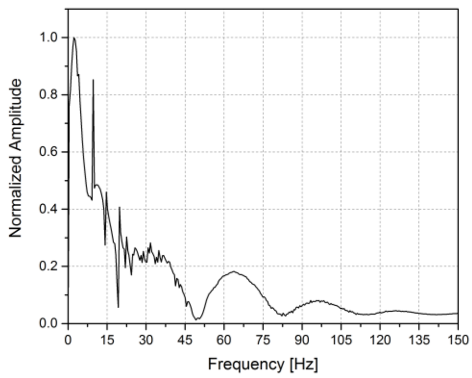

Fig.4 FFT result of force acting on the containment wall

for the CFD simulation. And steam jet impingement has been analyzed by forces acting on the containment components with FFT.

The results of this study shows that the steam jet causes the high force and pressure at the impingement region during pipe rupture. Therefore, simulating and evaluating the potential effects of the steam jet impingement to the adjacent and surrounding components is very important in design process of the nuclear power plant. The results of this study may useful to evaluating structural integrity and jet impingement during pipe rupture accidents in the containment.

ACKNOWLEDGMENT

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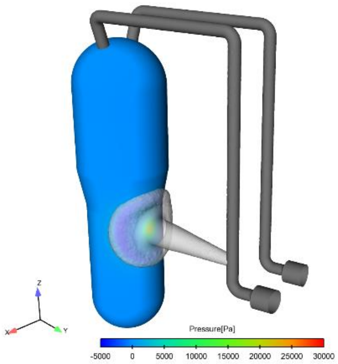
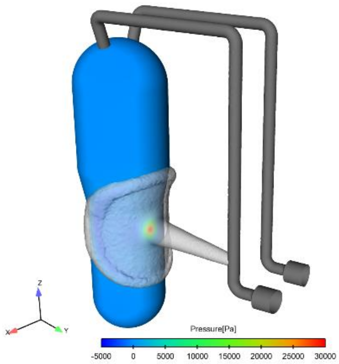
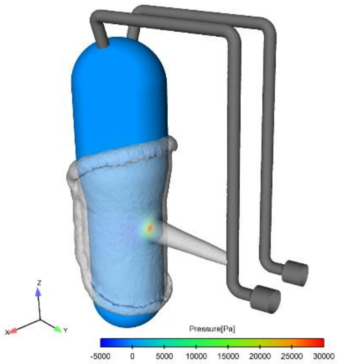


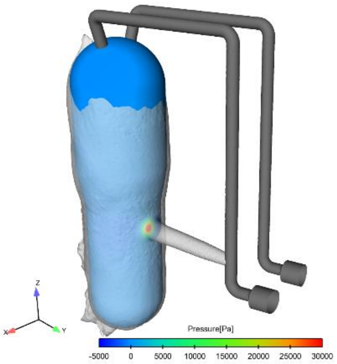
(a) 0.1s



(b) 0.15s



(c) 0.25s



(d) 2.0s

Fig.5 Pressure distribution and steam behavior during pipe break on the steam generator