Transactions of Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

Structural Integrity Assessment of Reactor Containment Subjected to Aircraft Crash

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1. Introduction

Structural integrity assessment of NPP(Nuclear power plant) has been performed from a variety of perspectives and applied to design. When an accident occurs at the NPP, containment building which acts as the last barrier should be assessed and analyzed structural integrity by internal loading or external loading.[1] On many occasions that can occur in the containment internal such as LOCA(Loss Of Coolant Accident) are already reflected to design. Likewise, there are several kinds of accidents that may occur from the outside of containment such as earthquakes, hurricanes and strong wind. However, aircraft crash that at outside of containment is not reflected yet in domestic because NPP sites have been selected based on the probabilistic method. After intentional aircraft crash such as World Trade Center and Pentagon accident in US, social awareness for safety of infrastructure like NPP was raised worldwidely and it is time for assessment of aircraft crash in domestic. The object of this paper is assessment of reactor containment subjected to aircraft crash by FEM(Finite Element Method).

2. Numerical Analysis

2.1 Finite element model

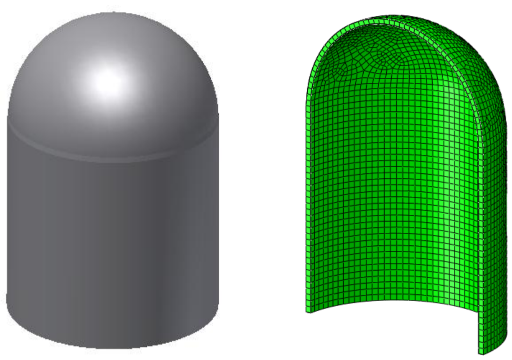


Fig. 1 3D CAD & FE models

Full-3D solid model which does not considered rebar was generated for analysis of stress subjected to crash loading[2] and FE analysis were carried out by using ABAQUS. Fig.1 shows representative FE model consist of 11,668 nodes and 5,780 elements. For expediency of analysis, model simplification was considered as follows.

1) Eliminate penetration region of containment.
2) Ignore the liner plate.

Although liner plate affects structural integrity of containment, when it is considered, can be obtained more conservative results. Therefore, the above assumptions are reasonable.

2.2 Loading and boundary conditions

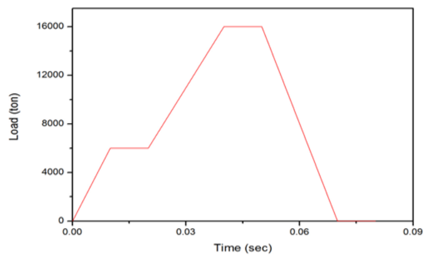


Fig. 2 Loading conditions

Geometry of the containment can be classified into dome and shell part. Due to the difference in thickness of the shell and dome, thickness variation occur at the joint part. Therefore, three case of the crash at the dome, shell and joint was analyzed. The load induced by the aircraft crash corresponding to 215m/s is shown in Fig. 2. In this paper, it was considered the two cases of the crash that horizontal and 45 degrees slanted to the z-axis. In these analyses, the bottom of the containment was fixed as actual conditions.

2.3 Mechanical properties

Table 1 Mechanical properties

	Concrete	Rebar	Steel reinforced concrete
Elasticity(GPa)	29.1	200	45
Yields strength (MPa)	37	431	250
Poisson's ratio	0.17	0.3	0.174

Table 1 shows the mechanical properties of the concrete and rebar[3]. Actually containment building consists of rebars and concrete, steel-concrete interaction should be considered. However, equivalent mechanical properties of steel reinforced concrete were used for solid model[4]. It is, approximately, 10 vol.%

of reinforcement steel in concrete.

3. Analysis Results

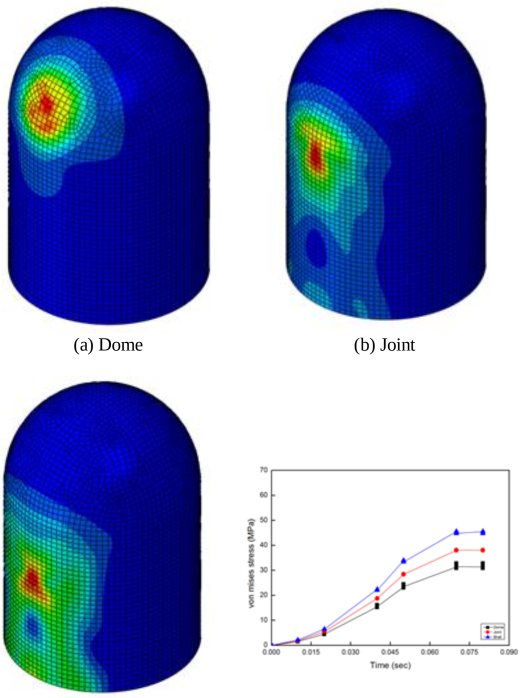
3.1 Horizontal loading

Table 2 Maximum stress and displacement

	Max. stress (MPa)	Max. displacement (mm)	Loading conditions
Dome	29.18	39.36	Horizontal
Joint	45.57	136.9	
Shell	61.21	432.6	
Dome	32.75	39.5	Slanted 45 degrees
Joint	38.06	118.6	
Shell	45.60	307.4	

Analysis results show that maximum stress of 29.18MPa in the case of shell crash, which is very smaller than yield strength of 250MPa of containment building. That means enough to maintain the integrity of containment and can prevent the leakage of radioactivity although it was the most high-impact crash occasion.

3.2 Slanted loading



(a) Dome (b) Joint

(c) Shell (d) Maximum stresses

Fig. 3 Stress distributions for slanted loading

To Implement more realistic aircraft crash, the same loading but different angle of 45 degrees to the z-axis was applied. When compared with the horizontal loading conditions, maximum stress was 45.63MPa which is smaller than that of horizontal loading condition. However, in the case of dome crash, stress value was bigger than that of horizontal loading condition. This mean that stress is affected by the slope of the target face as well as the crash loading. Similar to the horizontal loading condition, penetration of the containment did not occur. If the liner plate that eliminated from simplification of model is considered, it will be able to get more conservative results.

3.3 Discussion

For the future work, nonlinear crack evaluation considering the actual model of the rebars which embedded in the concrete will proceed to get more realistic results[5] using available data. Likewise, effect of liner plate, tendon and penetration region on containment should be considered. Also, there are several things to be evaluated in the aspect of crashing body. Intentional aircraft accident more likely to be used by large commercial aircraft that induce very large impact. Therefore, evaluation of the load induced by large aircraft and structural integrity assessment of containment building for these are performed.

4. Conclusions

In this paper, assessment of structural integrity of containment building subjected to certain aircraft crash was carried out.

(1) Verification of structure integrity of containment by intentional severe accident.
(2) Maximum stress 61.21MPa of horizontal shell crash does not penetrate containment.
(3) Research for more realistic results needed by steel reinforced concrete model.

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