Numerical analyses of an aircraft crash on containment building

Jae-Min Sim[a], Seung Hyun Kim [a], Yoon-Suk Chang [a,*]
[a] *Dept. of Nuclear Engineering, Kyung Hee University, 1732 Deokyoungdae-ro, Yongin, Kyunggi, 446-701, Korea*
[*]*Corresponding author: yschang@khu.ac.kr*

1. Introduction

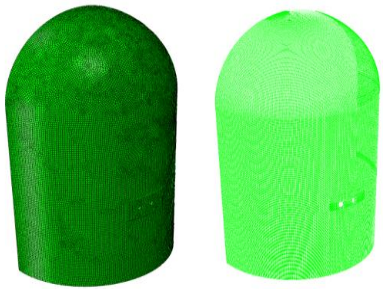
Since containment building of NPP (Nuclear Power Plant) is the last barrier under accident conditions, high level of safety design and structural integrity assessments are required. The containment building is responsible to isolate and protect internal devices against external conditions like earthquake, hurricane and impact loading. It has also to protect leakage of radioactivity, like LOCA (Loss Of Coolant Accident), when severe accidents occurred. Meanwhile, social awareness such as terrorism has been increased globally after international aircraft crashes at World Trade Center and Pentagon [1]. In this paper, FE (Finite Element) analyses according to variation of crash locations and speeds were carried out to examine the aircraft crash impact on a domestic containment building.

2. Effects of crash locations

There are several plausible locations of aircraft collision with the containment building. Particularly, dome and connectors were selected as the typical locations based on previous researches on anticipated crash scenario and structural damage. Additionally, wall part was selected due to its possibility. As for the crash angle and speed were chosen as 15° and 156m/s reported considering fairway maintenance etc [2].

2.1 Analysis conditions and FE models

Systematic analyses of the containment building were performed by using FE models as illustrated in Fig. 1. Its height, radius and thickness of which were approximately 71.49m, 23.16m and 1.22m. With regard to individual component, the containment wall was modeled by employing 8-node 3D concrete elements consist of 10,977 nodes and 7,130 elements. The steel liner plate was modeled by employing shell elements and merged with the concrete. The vertical and horizontal rebars embedded in the concrete was modeled by using beam elements with 39,365 nodes and 38,331 elements. Contact condition was defined inside of the containment building. Table I represents material properties of the containment building [3]. A representative damage model was employed to predict failure for which UTSs (Ultimate Tensile Strengths) and compressive strengths were taken into account. For the steel materials, the well-known kinematic hardening plasticity model with a rate dependent was adopted to represent bi-linear elastic-plastic behaviors [4].



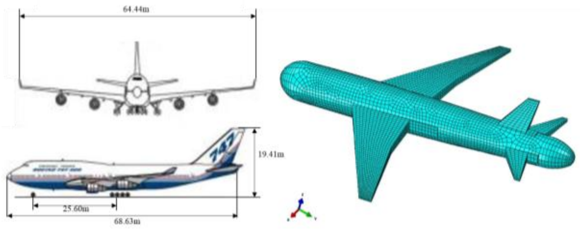
(a) Concrete (b) Rebars
Fig. 1 FE models of containment building

Table I: Material properties of containment building [3]

Material	Elastic modulus (GPa)	Poisson's ratio	Yield strength (MPa)	Tensile strength (MPa)
Concrete	31.12	0.2	49.83*	2.81
Liner plate	199.95	0.3	344.73	475.78
Rebar	199.95	0.3	510.21	751.53

[Note] *: compressive strength

Fig. 2 shows main dimension and FE model of the aircraft used in these analyses and its material properties were summarized in Table II [5, 6].



(a) Dimension (b) FE model
Fig. 2 Schematic illustraion and FE model of aircraft

Particle conversion method was employed for the aircraft so as to simulate its breaking when the maximum stress exceeds corresponding strength.

Table II: Material properties of aircraft [5, 6]

Material	Elastic modulus (GPa)	Poisson's ratio	Density (kg/m^3)
Aluminum plate	69.0	0.35	2,700

2.2 Analysis results and discussion

Fig. 3 depicts damage distribution of concrete structure and Fig. 4 compares stress distributions of the liner plates at each location. The maximum stress value of 363MPa occurred at the connector. Since this value did not exceed UTS of the liner plate, it seemed that the containment building would not be penetrated.

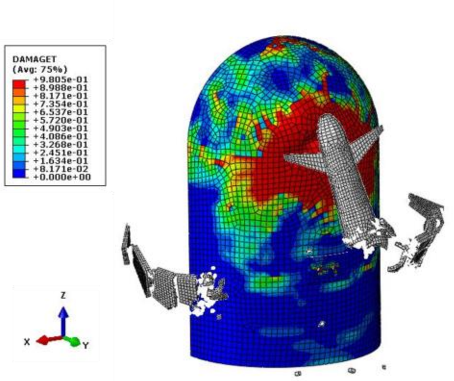


Fig. 3 Damage distribution of concrete

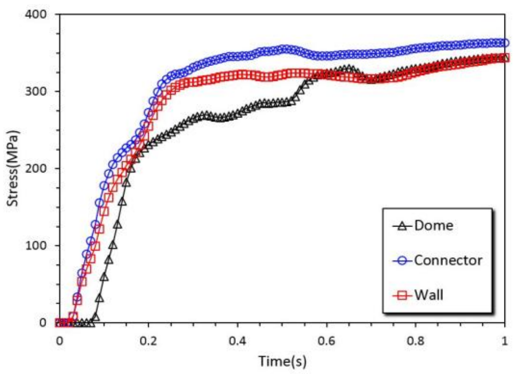


Fig. 4 Stress distributions of liner plate at each location

3. Effects of aircraft speeds

3.1 Analysis conditions

The connector was evaluated as the most critical location in section 2, in which the crash speed of civilian aircraft was set to about 156m/s. However, in general, the collision speed is greater than that of civilian aircraft [2]. So, an increased speed of military aircraft of 210m/s was applied to the connector for further investigation.

3.2 Analysis results and discussion

Fig. 5 shows stress distributions of liner plate at the connector and the maximum stress value was about 400MPa. Comparing to that in section 2, the maximum stress value increased as the increase of the crash speed. Despite of the increment, it was also estimated that containment building would not be destroyed.

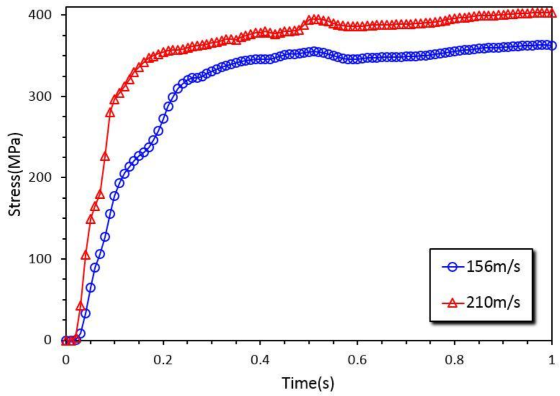


Fig. 5 Stress distributions of liner plate at connector

4. Conclusions

In this paper, numerical analyses of aircraft crash on NPP's containment building were performed taking into account different locations and aircraft speeds.

(1) Amounts of concrete failure were dependent on the crash locations and the connector was the most delicate location comparing to the dome and wall part.

(2) Maximum stress values generated at the liner plate and rebars did not exceed their UTS values.

(3) 34% increase of the aircraft speed from 156m/s to 210m/s led to 10% higher maximum stress value of the corresponding liner plate. Therefore, it seemed that effect of the aircraft speed on steel components would not significant.

REFERENCES

[1] J. Y. Kim, Y. S. Chang, Structural Integrity Assessment of Reactor Containment Subjected to Aircraft Crash, Transactions of Korean Nuclear Society Spring Meeting, Vol. 1, pp. 443-444, 2013

[2] Korea Institute of Nuclear Safety, Development of NPP Structures Safety Regulatory Technology, Vol. 2, pp. 12-71, 2005

[3] S. H. Kim, Y. S. Chang, Y. J. Cho and M. J. Chung, Modeling of Reinforced Concrete for Reactor Cavity under Energetic Steam Explosion Condition, Nuclear Engineering and Technology, Vol. 48, pp. 218-227, 2016

[4] ABAQUS User's Manual, Ver. 6014, Dassault Systems, 2014

[5] D. K. Thai, S. E. Kim, Safety Assessment of a Nuclear Power Plant Building Subjected to an Aircraft Crash, Nuclear Engineering and Design, Vol. 293, pp. 38-52, 2015

[6] T. Zhang, H. Wu, Q. Fang, Z. M. Gong, Influences of Nuclear Containment Radius on the Aircraft Impact Force Based on the Riera Function, Nuclear Engineering and Design, Vol. 293, pp. 196-204, 2015