Comparison of Response between RC and SC Containment Structures Subjected to Aircraft Impact

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1. Introduction

Since the aircraft terror to the World Trade Center (WTC) on September 11, 2001, an aircraft impact problem has been increasingly interested. The possibilities of aircraft impacts against nuclear power plants are one of important category. To date, the impact load of the analysis on aircraft impacts has been applied to target structures in local areas by using the impact force-time history function of Riera [1]. However, Riera forcing function is not recommended at the expectation of unreasonable damage or perforation to target structures [2]. The numerical analysis of rc and sc containment structures subjected to aircraft impact is performed by using the AUTODYN-3D [3]. It is carried out the four different types for RC and SC structures. Thus, in this study, the different behaviors of containment structures and the safety of SC structure are expected.

2. Aircraft Model and Containment Structure Model

2.1 Aircraft Model

The aircraft chosen for this analysis is the Boeing 767. The maximum takeoff weight for this aircraft is approximately 200t in the Fig. 1. The overall length of the aircraft is 61.4m and the wing span is 51.9m. In the present study shell elements are used for the aircraft model and hexahedral solid elements are used for modeling the concrete rigid target. The impact velocity of the aircraft is assumed to be 150.0 m/s (540.0 km/h), based on reported EPRI2002 [4].

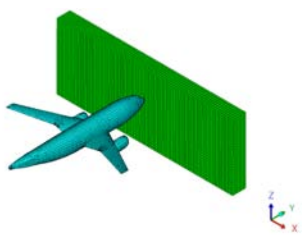


Fig. 1. Rigid Target against an Aircraft Impact

To express the intense impact loading, the material of the aircraft is adapted the AL2024T351 [5]. It takes into consideration the strain hardening and the strain rate effects.

2.2 Aircraft Impact Force Time History

The aircraft model according to the Riera assumptions is similar to a real model and is verified by Fig. 2 [6].

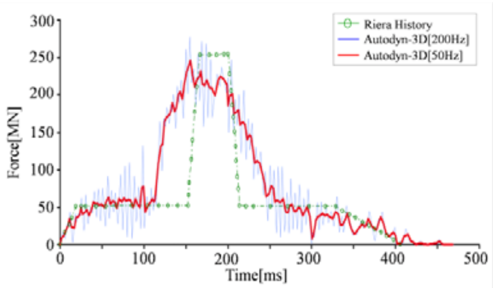


Fig. 2. Riera's Force-Time History and the reaction history at rigid target

Typically, force-time history by using the aircraft-structure interaction method is derived from this loading application contains a considerable amount of high-frequency and potential noise. Thus, to preserve the structural response upon impact, the filtered 50Hz is used in this analysis.

2.3 Containment Structure Model

Four cases of numerical analysis were carried out for different types of fictitious containment structures as shown in Table Ⅰ.

Table Ⅰ: Performed numerical analysis cases

Case	Type \ Thick	Wall Thick(m)	Plate Thick(mm)
1	RC	1.2	None
2	RC	2.0	None
3	RC+CLP	1.2	6.35
4	SC (Steel-Plate Concrete)	1.2	19.04

All the containment structures have a dome shape with the same 67m height, 44m inner diameter and a 22m dome radius as shown in Fig. 3.

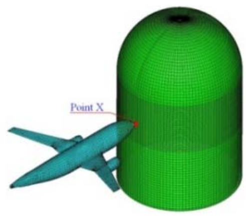


Fig. 3. Containment Structure Model

The containment structure is modeled by 16920 hexahedral solid elements. The 40.3mm diameter of beams is placed inside the concrete. The number of longitudinal beams is 188 and that of the lateral ones is 122. The containment liner plate (CLP) is embedded inside the building. In addition, the nodes at the base were constrained from movement in all directions.

The containment structure has the material properties as shown in Table Ⅱ. In order to represent the material nonlinearity of the concrete, the RHT model is adopted. However, dynamic increase factor (DIF) of concrete is not adopted in this study.

Table Ⅱ: Material Properties of INPP

Concrete	Strength	RHT Concrete
	fc	35MPa
Beam	Strength	Johnson Cook
	Shear Modulus	81.8GPa
	Yield Stress	0.512GPa
Plate	Strength	Johnson Cook
	Shear Modulus	81.8GPa
	Yield Stress	0.2846GPa

3. Numerical Results

The displacements of the rc and sc containment structure at the aircraft nose are shown in Fig. 4.

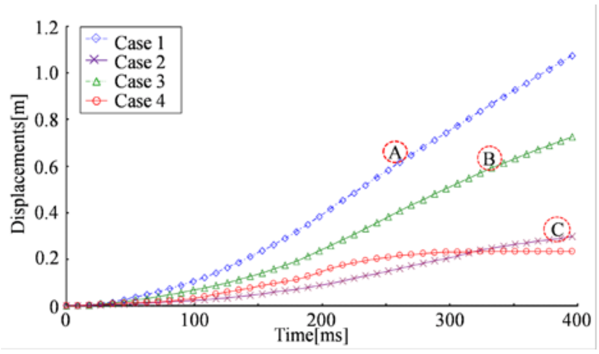
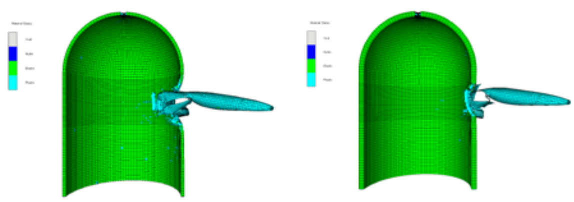


Fig. 4. Displacement-Time History

All the numerical analyses were carried out up to approximately 400ms. In the cases 1 and 3, the failure of containment structure is occurred at the point X as shown in Fig. 3. Also, it is subjected to serious deformation. However, the deformation of case 2 and 4 are less than the other cases. The perforation in the case 1 is started at the point A in the Fig. 4. A tearing phenomenon of the beam and liner plate is occurred at the point B. The local failure of the beam is started at the point C.


(a) Case 1 (b) Case 2

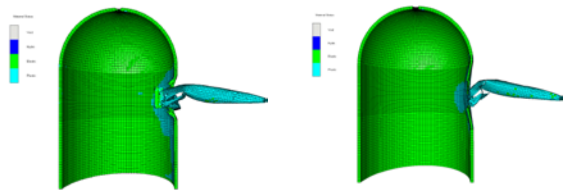

(c) Case 3 (d) Case 4

Fig. 5. Overview of the Deformations on the Aircraft and Building at 400ms

The deformations on the aircraft and building at 400ms are shown in Fig. 5. The case 1 and 3 are shown that the containment structure is perforated completely. However, the case 2 and 4 are shown that it is not perforated. In addition, the case 4 applied SC structure will prevent the scabbing, penetration and perforation phenomenon on account of outer and inner plate. Also, the displacement of case 4 is too small versus other case as shown in Fig. 4. Thus, SC structure has highly safety for aircraft impact.

4. Conclusions

In this study, aircraft impact analysis is performed for the rc and sc containment structure. The numerical models adopted in this study are effective in order to predict the response of the rc and sc containment structure impacted by aircraft. The present numerical results have successfully demonstrated that the safety of impact is more effective for SC than with a RC structure at the same concrete thickness. Also, the SC structure is highly effective in preventing the secondary damage by concrete fragment. We may conclude that the fictitious SC containment structure is not severely damaged when it is impacted by aircraft.

Acknowledgement

This research was supported by the Mid- and Long-Term Nuclear Research & Development Program of the Ministry of Education, Science and Technology, Korea.

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