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A Comparison of Force-Time History Analysis Methods for Simplified Aircraft Impact Simulation

Shin, Sangshup [a b], Daegi Hahm [a*], In-Kil Choi [a]
[a] *Korea Atomic Energy Research institute, 1045 Daedeok-daero, Youseong, Daejeon, 305-353*
[b] *Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul, 133-791*

[*] *Corresponding author:dhahm@kaeri.re.kr*

1. Introduction

The reaction force-time relationship for accidental strike of Boeing 707-320 aircraft against a rigid surface was proposed by Riera [1]. After that, the aircraft impact analysis has been studied significantly in the last few decades. The only way to acquire an exact solution of the aircraft impact analysis is direct impact test. However, for the large commercial aircraft impact, this direct test has been hardly performed because the scale of aircraft and impacted wall is very huge. Up to date, the numerical simulation using Missile-Target (M-T) Interaction analysis method is known as the only way to obtain a relatively accurate solution. However, because of its massive computational efforts and modeling complexity, this method is inadequate and inefficient to the application of the fragility analysis and risk assessments which is required many times of iterative simulations. Thus, a more simplified and conservative analysis method is required. The simplified method such as Force-Time (F-T) History analysis method has been studied by Riera [1, 3], Sugano et al. [2], Mullapudi et al. [4] and etc. In this paper, by comparing the various F-T History analysis method, we are about to propose the most reliable simplified method under the same condition with M-T Interaction analysis method.

2. Finite Element Model

2.1 RC Wall

A three-dimensional (3D) finite element model of the rectangular reinforced concrete (RC) target wall is shown in Fig. 1.

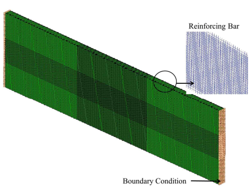

Fig. 1. Mesh of the RC target Wall and Reinforcing Bar

The geometric size of the target wall is 80m width, 30m height and 2.0m thickness. A hexahedral solid element is used to model the concrete elements in the analysis. The reinforced bar elements are modeled by truss elements. The target wall contains approximately 120,000 elements. In order to minimize the rebounded energy, fixed boundary conditions are applied by restraining translations and rotations at the wall side edges as shown in Fig. 1.

2.2 Aircraft Model and Riera Force-Time History Curve

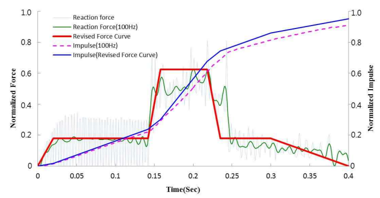

Fig. 2. Riera Force-Time Curve and Impulse Curve

As shown in Fig. 2, the reaction force in a rigid target is obtained from impact simulation with the 767 model crashed into the target at the assumed initial velocity 150m/s and fuel 30%. The computed reaction force curve (light blue line) contains a considerable amount of high-frequency and potentially spurious structural response ("noise"). In order to compare the reaction force curve with the revised force curve (thicker red line), the reaction force curve is passed through a low-pass numerical filter (100Hz). The total area under the two curves (red and green line) is equal to impulse, match within 4.5%.

3. Various Load Areas for Riera Force History versus Impact Modeling

The various loading area and M-T Interaction analysis method are shown in Fig. 3.

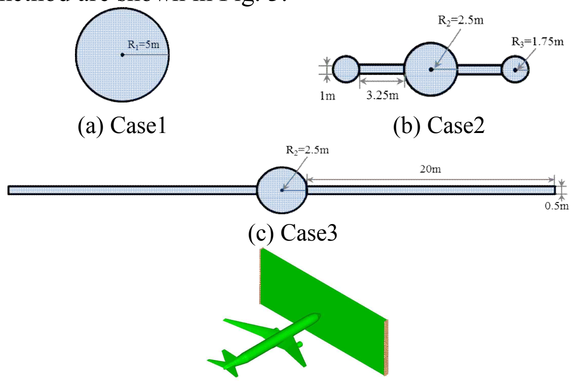

Fig. 3. Various Loading Areas for Riera force history and Missile-Target Interaction Method

The impacted area at Case 1 is twice the cross sectional area of the used aircraft fuselage on Case 4. This method was proved by F-4D experiment [2]. The loading area at Case 2 is similar to the Riera's method [3]. And, the impact region at Case 3 is similar to the Mullapudi's method [4]. The M-T Interaction analysis method with detailed aircraft model is used at Case 4. The revised F-T curve in Fig. 2 is converted to equivalent pressure-time histories using a loading area in Fig. 3. In the Case 1, the revised F-T curve is applied on the impacted area. In the Case 2 and 3, the loading up to 0.142 Sec is only applied to the fuselage. After the loading until 0.235 Sec is applied to the wing also added to the fuselage. Finally, the fuselage load is continued until reaching the end of the analysis. The load is applied as time varying uniform pressures over the area indicated in Fig. 3(b), (c).

4. Numerical Results

The numerical simulations for varying aircraft impacted areas on the RC wall were carried out using Hydrocode. As shown in Fig. 5, the global deformation for the time variation at the rear face of RC Wall has been plotted along the central longitudinal axis. The maximum deformation at 0.1 Sec is similar to all case. The maximum deformation up to 0.3 Sec was found at case 4. However, the maximum deformation at 0.4 Sec was indicated at case 3. Also, the range of deformation along the central longitudinal axis at case 3 was larger than case 4. The result of deformation at case 3 is conservative than case 4 such an M-T Interaction analysis method. On the other hand, the others case are not conservative at the center of RC wall.

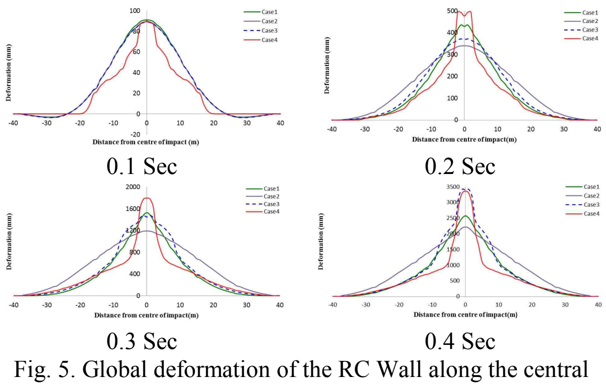

Fig. 5. Global deformation of the RC Wall along the central horizontal axis for the Time Variations

As can be seen Fig. 6, the global contours of damage at 0.4 Sec on the front and rear face of RC Wall has been presented along the central longitudinal axis. On the front face in Fig. 6, the results have some difference. The contour of damage on the front face at case 4 was presented that the severe damage on the surface of the target wall was occurred around the aircraft impact region. However, in case of F-T history analysis method, the severe damage was only occurred around the fuselage circle. Unlike the presented results on the front face in Fig. 6, the severe damage on the surface of the target wall was occurred around the area subjected to impact load.

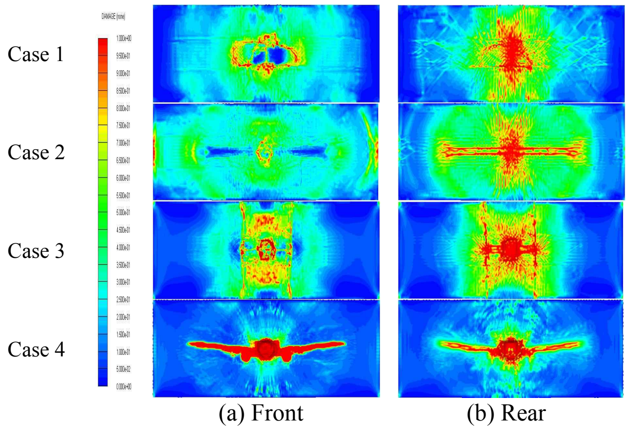

Fig. 6. Contours of Damage at 0.4Sec

5. Conclusions

To find the suitable loading area applied aircraft crash, the studies for a various loading area (Case 1, 2, 3) ware performed using F-T History analysis method, and the former results were compared to the result of Case 4 using M-T Interaction analysis method. The various results according to the proposed loading area were pointed out. Thus, the results for a simplified loading area applied impact load may be fairly sensitive to the assumption associated with loading area. Finally, we can conclude that the Case 3 shows conservative and the most similar results with realistic simulation using M-T Interaction analysis method, i.e., Case 4.

Acknowledgement

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