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Missile Target Interaction Analysis of B747 Aircraft Using Hydrocode LSDYNA

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1. Introduction

After the 11 September 2011, we newly recognized the importance of intentional aircraft impact on national critical infrastructure such as tall buildings, military facilities, and nuclear power plants. A lot of research has been performed to measure the capability of current nuclear power plants to withstand unusual impact loadings. As a result, Nuclear Regulatory Commission (NRC) concluded that the impact of a large, commercial aircraft is a beyond-design-basis event (BDBE) [1].

Fig. 1. September 11, 2011 attacks on WTC and the importance of safety evaluation against the aircraft impact

In this paper, we demonstrate the assessment of the impact load of large, commercial B747 aircraft by using the so called missile target interaction analysis method. The results of impact force is compared with the reported impact force time histories [2,3] of B747. To perform the missile target interaction analysis, an FE mesh model of B747 is developed. Rigid wall impact tests are performed numerically using commercial Hydrocode LS-DYNA with FE model of B747 to demonstrate the accuracy and applicability of the rigorous missile target interaction analysis.

2. Review the Riera model for impact force time history

The construction of a loading function for use in time history analyses is generally referred to as the Riera methodology [2,3]. The key formula in the computation of the force applied to the rigid target, F(t) or the impact force time-history is given by

$$F_{missile}(t) = P_c(x) + \alpha\mu(x(t))v^2 \qquad (1)$$

where $P_c(x)$ is the static force required to crush a lamina of the airframe axially at location x, α is a coefficient determined experimentally, and $\mu(x(t))$ is the mass per unit length at location x. Usually, the crushing load $P_c(x)$ does not greatly affect the magnitude of the impact force. Preferably, a mass distribution and the important coefficient α should be evaluated precisely for the estimation of the impact force.

In principle, an impact force of target $F_{target}(t)$ generated in a time interval of dt corresponds to the change rate of a momentum $[M(t)V(t)]$ during dt is as follows.

$$F_{target}(t) = \frac{d}{dt}[M(t)V(t)] \qquad (2)$$

In the rigid wall impact test, the target is assumed to be perfectly rigid. Since, the momentum of Eq.(2) for impact force cannot be determined because of the zero velocity of rigid wall. On the other hand, the impact force of rigid wall might be calculated using the normal reaction force of rigid wall.

Consequently, the two functions should match closely if the principle of momentum conservation is applicable and there are no other energy losses.

The unknown coefficient α in Eq.(1) can be determined by comparing the impact force of a missile (Eq.(1)) and a target (Eq.(2), normal reaction force of rigid wall). Previously, the Riera methodology was validated against full scale test data involving an F-4 Phantom military aircraft impacting a rigid reinforced concrete reaction block [5], and the coefficient, α was determined to be 0.9. However it is highly dependent to the characteristics of mass distribution of each aircraft and difficult to determine experimentally.

3. Missile target interaction analysis

To perform the missile target interaction analysis [1,7], the FE mesh model of B747 is developed based on the CAD model. As shown in Fig.2, the mass distribution of B747 was determined according to the impact force time history which was reported by OECE/NEA reports [2].

Fig. 3 and Fig.4 show the results of the missile target interaction analysis and impluses using the Hydrocode LS-DYNA. According to the result of Fig.4, we can estimate the coefficient α as 0.95, which is a similar to the value of experiment [5]. However, it is reasonable to consider that the coefficient value 0.95 of this study might deviate case by case. The exact value of α for B747 can be determined by experimental study. Sugano et al. [5] suggested the value of α is 0.90. However, it is just the case of F-4 Phantom military aircraft. There is no evidence that it can be effective value to any other aircraft. Nonetheless, the analysis of this study can be applicable to the problem of aircraft impact simulation with pre-determined value of α.

4. Conclusions

In this study, we performed so called missile target interactive study using Hydrocode B747 with FE mesh model of B747. The resulting impact force of B747 aircraft shows good agreement with reported time history of B747 which is based on the Riera model. There is no information for the value of coefficient α of B747. Therefore it can be understood that the reported impact force of time history of B747 [2] is upper bound value with $\alpha=1$. It is not difficult problem to match the analysis to the specified value of mass distribution coefficient α.

By using the method of this study which is rigorous FE analysis of initial value problem (initial velocity impact simulation), we can assess the effect and safety of aircraft impact on the national critical infrastructure such as nuclear power plant containment building.

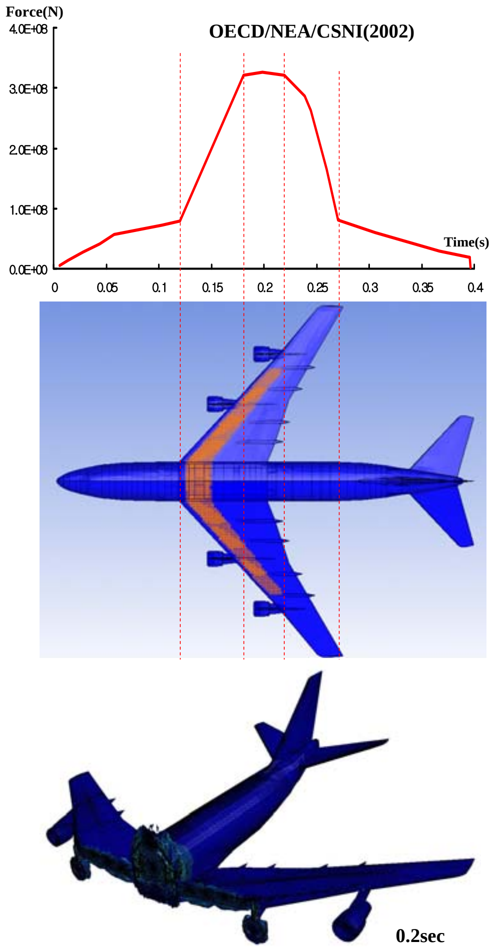

Fig. 2. Mass distribution of B747 according to the impact force of OECE/NEA(2002)

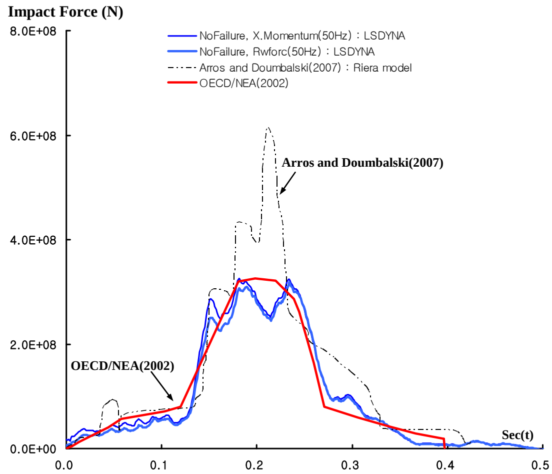

Fig. 3. Impact forces of B747 by using the missile target interaction analysis(filtered, 50Hz)

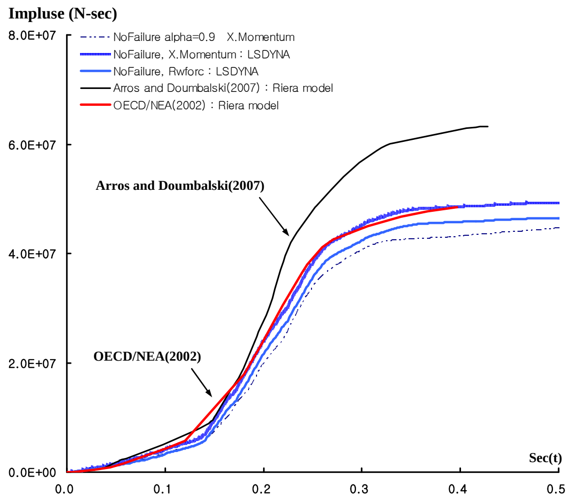

Fig. 4. Impluses of Impact forces of Fig.3

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