Calculations of an Effective Plant Area for An Aircraft Crash into a Structure

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1. Introduction

The potential risk to nuclear power plant (NPP) induced by aircraft accident is negligible because every airspace over NPP is designated as prohibited and restricted area since 1979 [1]. However, aircraft hazard assessment to assure that the risks from aircraft hazards to NPP are sufficiently low has been conducted according to the safety review guidance (SRG) of the Korea Institute of Nuclear Safety (KINS).

Effective plant area should include a shadow area and skid area to meet the requirement of SRG 3.5.1.6(aircraft hazards). However a detailed method to calculate a shadow area and skid area is not provided in SRG 3.5.1.6(aircraft hazards). Therefore this paper introduces allowable calculation method of an effective plant area and compares the results to show the differences between those methods.

2. State of the Art

2.1 Simple method

In 1978, U.S. Nuclear Regulatory Commission (NRC) assume aircraft will approach orthogonally to a structure [2]. As depicted Fig. 1., skid area (As=w·s), plant area (Ap=w·l), and shadow area (Aw=w·hcotφ) are easily obtained by simple calculation.

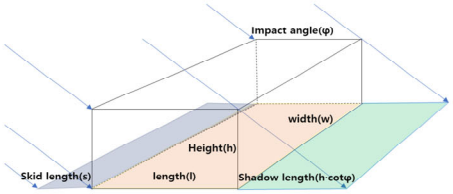

Fig. 1. Schematic View of Effective Impact Area

2.2 Los Alamos Lab. Aircraft hazard assessment

When evaluating aircraft crash hazard at Los Alamos National Laboratory facilities which is a U.S Department of Energy national laboratory initially organized during World War II for the design of nuclear weapons as part of the Manhattan Project, aircraft wingspan (ws) is considered [3]. Therefore, the total effective facility area (Ae) to be used in the aircraft crash calculation is:

$$Ae=As+Ap+Aw \quad (1)$$
$$As=w\cdot s \quad (2)$$
$$Ap=w\cdot l \quad (3)$$
$$Aw=w\cdot h\cdot \cot\varphi \quad (4)$$

2.3 DOE-STD-3014

To accommodate the direction of aircraft crash, DOE-STD-3014 [4] introduce new effective target area depicted Fig. 2. DOE-STD-3014 assumes the direction of crash will be perpendicular to the diagonal direction of bounding rectangle.

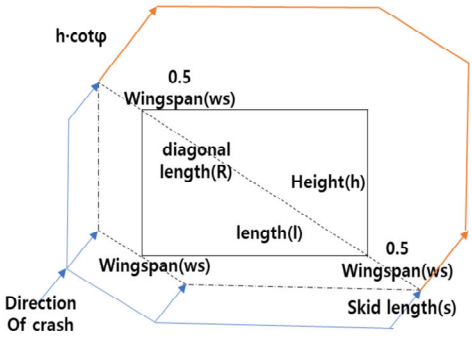

Fig. 2. Rectangular effective target area elements

$$As=(ws+R)\cdot s \quad (5)$$
$$Ap=w\cdot l+2\cdot l\cdot w\cdot ws/R \quad (6)$$
$$Aw=(ws+R)\cdot h\cdot \cot\varphi \quad (7)$$

2.4 Radially dependent effective impact area

Instead of assuming crash direction to perpendicular to the diagonal direction of the bounding rectangle, real crash direction can be used to calculate the effective area. A detailed derivation can be found in reference [5].

$$As=(ws+w\cdot \sin\varphi+l\cdot \cos\varphi)\cdot s \quad (8)$$
$$Ap=w\cdot l+ ws(w\cdot \cos\varphi+l\cdot \sin\varphi) \quad (9)$$
$$Aw=(ws+ w\cdot \sin\varphi+l\cdot \cos\varphi)\cdot h\cdot \cot\varphi \quad (10)$$

3. Typical Example of Effective Plant Area

The following examples show the effective area of APR 1400 typical structures for a typical military aircraft based on general aviation data from Table B-16, Table B-17, and Table B-18 of DOE-STD-3014. The input data is summarized in Table 1.

Table I: Aircraft Data

	WingSpan (ft)	Skid length(ft)	Impact angle (cotφ)
Small	78	447	10.4
Large	223	368	9.7

3.1 The ratio of effective area to area of structures

The ratio of effective area of APR 1400 reactor building to its base area by calculated each method are summarized in Table 2. Effective area of reactor building is not depending on the impact angle because of its cylindrical shape.

Table 2: The ratio of effective area of APR 1400 reactor building to its base area

	Ch.2.1	Ch.2.2	Ch.2.3	Ch.2.4
Small	20.31	29.84	36.64	37.84
Large	19.67	44.61	51.36	52.34

The ratio effective areas of APR 1400 auxiliary building to its base area by calculated each method are summarized in Table 3. Effective area of auxiliary building will be maximized when the aircraft crash direction will be 51.3°.

Table 3: The ratio of effective areas of APR 1400 auxiliary building to its base area

	Ch.2.1	Ch.2.2	Ch.2.3	Ch.2.4
Small	5.85	7.12	9.57	10.39
Large	5.93	9.23	11.61	12.29

The ratio effective areas of APR 1400 Component Cooling Water Heat Exchange building to its base area by calculated each method are summarized in Table 3. Effective area of auxiliary building will be maximized when the aircraft crash direction will be 46.1°.

Table 4: The ratio of effective area of APR 1400 component cooling water heat exchange building to its base area

	Ch.2.1	Ch.2.2	Ch.2.3	Ch.2.4
Small	8.64	15.83	18.12	21.62
Large	9.80	27.60	29.89	32.91

3.2 Comparison of methods

The method outlined in Ch. 2.4 produced the maximum effective impact area when large military aircraft crash into structure. Every method shows that effective impact area will be at least 5 times greater than its original area.

Even though the wingspan of large military aircraft is almost 3times greater than the wingspan of small military aircraft, the difference of effective area is relatively small. However, in case of component cooling water heat exchange building, the ratio of effective area between large and small military aircraft is larger value 1.75. It means the effective area of small size and low-height building tend to be determined by the characteristics of aircraft such as wingspan and impact angle.

The method outlined in Ch. 2.3(DOE-STD-3014) has been applied to calculate for the effective area of domestic NPP. This method does not consider the direction of aircraft crash which produce the maximum effective area but the difference is relatively small. For example, DOE-STD-3014 method assumes the direction of aircraft crash as a 57.63° while the maximum effective area is produced when the direction of aircraft crash is 46.15°. The ratio of the method of Ch. 2.4 to DOE-STD-3014 is under 1.1.

3. Conclusions

This paper introduces 4 method to consider the skid area and shadow area to calculate an effective impact area required by SRG 3.5.1.6. Depend on the assumptions, the difference of effective area is relatively large. But the conservatism of DOE-STD-3014 which has been applied to calculate of the effective impact area of NPP are demonstrated.

REFERENCES

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