Preliminary Study on the Drone Sabotage to NPP Structures

Yong-Tae Kim*, Jong-Sung Kim, Woo-Sik Jung
Quantum and Nuclear Engineering, Sejong University, 209 Neungdong-ro, Gwanggin-gu, Seoul, Republic of Korea
**Corresponding author: kytae713@naver.com*

1. Introduction

Recently, the emergence of drones in important national facilities is increasing. Unauthorized drone flight at French nuclear power plants (2014), direct drone attacks on oil facilities in Saudi Arabia (2019), and articles related to unauthorized drone flight can be easily found around domestic nuclear power plants.

Drones, which are emerging as a new threat in recent years, are also called UAV (Unmanned Aerial Vehicle), and refer to devices capable of remote automatic flight without humans.

Drones are much smaller than conventional aircraft, are difficult to detect, can carry chemicals or explosives, and can fly over long distances.

Drones with these functions can attack important national facilities and are emerging as a new threat.

However, in domestic drone research, there are many studies on technology improvement such as imaging, detection, delivery, and anti-drone, but it is difficult to find research on the impact or protection of drone collisions and explosions.

KINAC designs and evaluates a physical protection system (PPS) to protect nuclear power plants from DBT (Design Basis Threat) [1].

DBT refers to the attributes and characteristics of potential insiders and outside intruders who might attempt unauthorized removal or sabotage of nuclear materials.

According to the Korean Radiation Disaster Prevention Act [2], threat assessment and DBT settings are conducted every three years, and drones can become one of the DBTs.

Therefore, for the first time in this study, a drone model that poses a threat to a nuclear power plant facility was selected, a threat target facility was selected, and collision and explosion analysis on the inner and outer walls among the selected facilities was conducted.

2. Drone and Threat Target Structures

2.1 Drone Model

The study selected the Qasef-1 [3] drone, which was allegedly used in terrorist attacks on the oil facilities in Saudi Arabia. The Qasef-1 has a total weight of 80-100kg, a total length of 288cm, and a payload of 40kg, and can fly up to 700km at 360km/h, and is capable of direct strike and air explosion.

2.2 Threat Target Selection

Nuclear power plants (NPP) have thick-walled structures such as containment building that can withstand aircraft collisions, but not all structures have thick walls. So, the structures that can pose a threat to drone collisions and explosions are summarized in Table I.

Table I: Threat Target Structures

Target model		Remark
Inside	Enclosed room	18inch concrete wall
Outside	Wall and ceiling	18, 13inch concrete wall
	Water tank	RWST size tank
	Piping	Various diameter piping

3. Internal Explosion Analysis

3.1 UFC Example Model

UFC (Unified Facilities Criteria) 3-340-02 [4] is a representative document of explosion and facility standards for the prevention of terrorism. Parameter values such as explosion pressure and impulse on the document graph have been created through numerous experiments.

In the example model of an internal explosion in the UFC document, the conditions of the structure and the location of the explosive set up as shown in Fig. 1 and Table II. The results of the average peak reflected pressure of the side wall, unit positive normal reflected impulse, and duration are summarized in Table III.

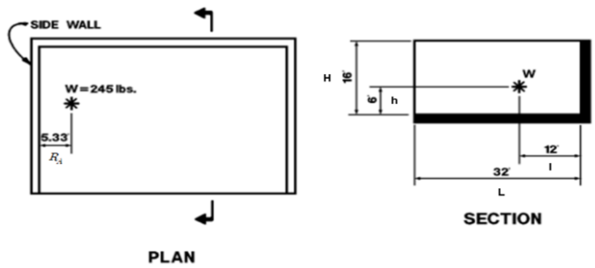

Fig. 1. UFC Example Model

Table II: UFC Model Setting Parameter and Value

Parameter	Value
N (Reflecting surfaces)	2EA
H (Vertical length)	16ft
L (Horizontal length)	32ft
R_A (Standoff distance)	5.33ft
l (Horizontal charge location length)	12ft
h (Vertical charge location length)	5ft
W (TNT charge weight)	245lbs

Table III: UFC Example Calculation Result

Parameter	Value
P_r	1714psi
$i_r/W^{1/3}$	111psi-ms/$lb^{1/3}$
t_0	0.81ms

3.2 Finite Element Analysis and Comparing Result

The program used in finite element analysis is ABAQUS, and the CONWEP [5] function that can perform explosion analysis through the amount of TNT was used. Figure 2 is a figure modeled with the size shown in Table II.

In the UFC example, wall thickness and material information is not provided. Therefore, the wall thickness to withstand missile collisions and tornadoes was set at 18 inch, which is the wall thickness set in NUREG-0800 [6] written by the U.S NRC, and used the concrete properties in ABAQUS manual[7].

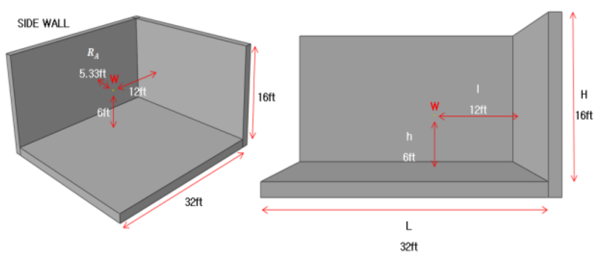

Fig.2. FE Model

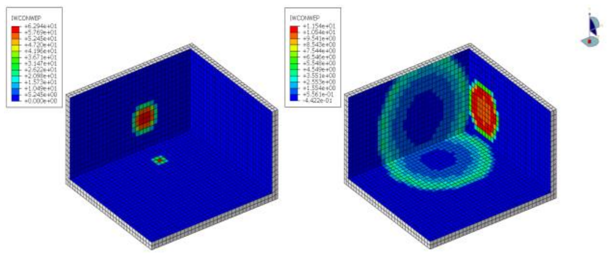

Fig.3. CONWEP Analysis

In CONWEP analysis, an explosion occurs and the pressure change occurring on the wall is shown in Fig. 3. As a result of Abaqus analysis, P_r was 1637psi and $i_r/W^{1/3}$ was 128psi-ms/$lb^{1/3}$. Table IV summarizes the comparison results of UFC examples and FE analysis.

As a result of comparison, there is a slight difference in both the pressure and the amount of impact, but it can be judged as an acceptable error since the mesh size, boundary condition, and material properties are not considered.

Table IV: Comparison of FEA and UFC Results

	UFC	FEA
P_r	1714psi	1637psi
$i_r/W^{1/3}$	111psi-ms/$lb^{1/3}$	128psi-ms/$lb^{1/3}$

4. External Collision and Explosion Analysis

Explosion and collision analysis on the outer wall was performed by 1) drone collision 2) TNT explosion 3) explosion after collision, and compared the displacements changed during the same time.

Concrete used the same properties as 3.2, and the properties of the drone were used the same as the iron properties in the ABAQUS manual [7], the same as the drone weight and speed of 2.1, and 40 kg for TNT.

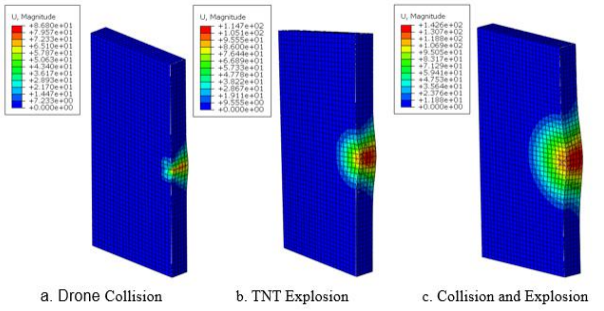

Fig.4. Collision and Explosion FE Analysis

According to the analysis, the smallest displacement movement occurred when the drone crashed for 2.5ms, and the biggest displacement movement occurred when the drone exploded after the collision, and it was confirmed that the impact was wide on the wall when the drone exploded.

5. Conclusions

In this study, we selected drones and threat target structures that could pose a threat to nuclear power plant.

Examples of internal explosions in UFC manual documents and FE analyses result in similar analytical results, thus achieving reliability in the analysis results.

Drone collision and explosion analysis on the outer wall shows a great effect when a drone crashes and explodes at the same time.

Therefore, it was confirmed that a drone attack could be a threat enough, and drones can become one of the DBTs

In a future study, a method to evaluate the degree of damage through the degree of displacement and movement of the wall caused by a drone collision and explosion will be presented, additionally selected facilities will be analyzed, and related references will be presented.

REFERENCES

[1] IAEA, Nuclear Security Series No. 13 - Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, INFICRC 225/Rev. 5, 2011.

[2]원자력시설 등의 방호 및 방사능 방재 대책법 시행령 [시행 2020. 2. 15.] [대통령령 제 30352 호, 2020. 1. 14., 타법개정]

[3] http://www.newstof.com/news/articleView.html?idxno=2003

[4] Unified Facilities Criteria, UFC 3-340-2 Structures to Resist the Effects of Accidental Explosions, U.S. Army Corps

of Engineers, Naval Facilities Engineering Command, Air Force Civil Engineer Support Agency, 2008.
[5] D. W. Hyde, User's Guide for Microcomputer Program CONWEP, Applications of TM 5-855-1, Fundamentals of Protective Design for Conventional Weapons, 1988.
[6] U.S. NUCLEAR REGULATORY COMMISSION STANDARD REVIEW PLAN, NUREG-0800 Chapter 3, Section 3.5.3, Revision 3, Barrier Design Procedures, 2007
[7] ABAQUS Example Problems Manual 6.11