Study on the Drone Sabotage to NPP Structures

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INTRODUCTION

- **Background**
  - 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.
- **Purpose**
  - Selection of Drone Model
  - Threat Facility Selection
  - Analysis of TNT Explosion in Nuclear Power Plant Facilities
  - Analysis of Drone Collisions and TNT Explosion in Nuclear Power Plant Facilities

MODEL SELECTINE

- **Drone Model**
  - The study selected the Qasef-1 [1] 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.

- **Treat 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

INTERNAL EXPLOSION ANALYSIS

- **UFC Example Model**
  - UFC (Unified Facilities Criteria) 3-340-02 [2] 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.

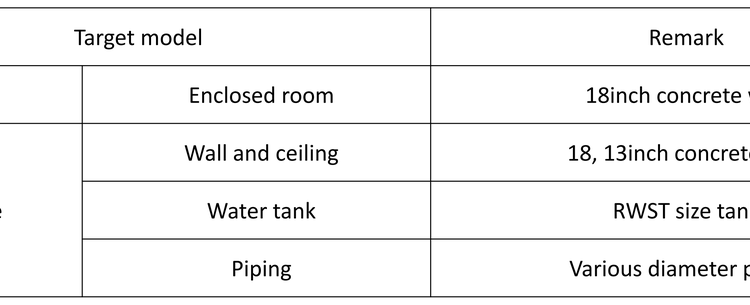

Fig. 1. UFC Example Model

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 Ⅱ: UFC Model Setting Parameter and Value

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

Table Ⅲ: UFC Example Calculation Result

- **Finite Element Analysis and Comparing Result**
  - The program used in finite element analysis is ABAQUS, and the CONWEP [3] 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.

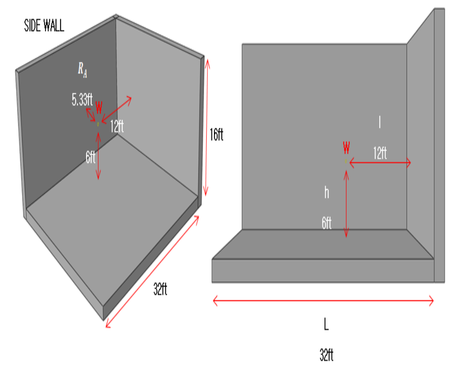

Fig. 2. FE Model

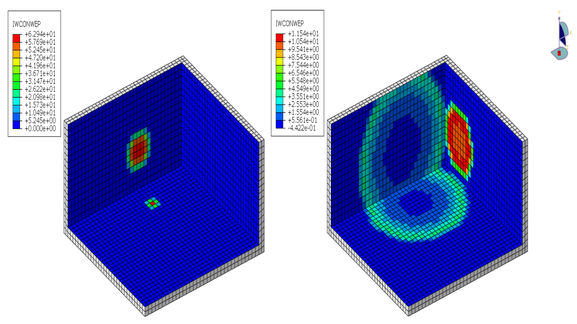

Fig. 3. CONWEP Analysis

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

Table Ⅳ: Comparison of FEA and UFC Results

- 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.

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.

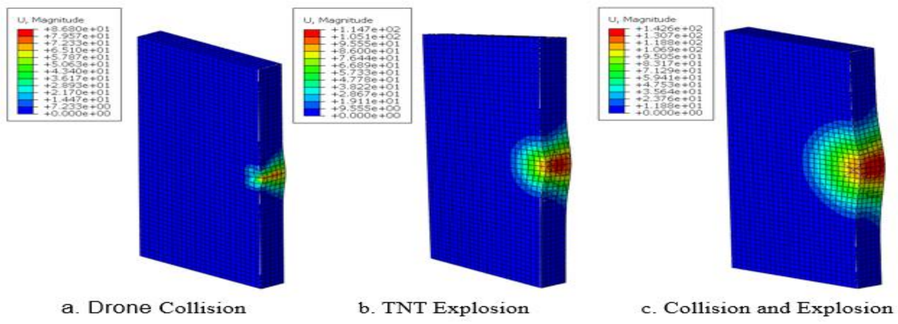

Fig.4. Collision and Explosion FE Analysis

- 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.

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.
- 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. http://www.newstof.com/news/articleView.html?idxno=2003
2. 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.
3. D. W. Hyde, User's Guide for Microcomputer Program CONWEP, Applications of TM 5-855-1, Fundamentals of Protective Design for Conventional Weapons, 1988