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Full floating structure underwater explosion with pulsation and cavitation effect FEM simulation case

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STRESZCZENIE: As far as literature researches has been made author predict this is the first full floating structure with pulsation an underwater explosion (UNDEX) FEM official presentation problem. The results of a study on the impact of an initial shock wave on a floating structure, followed by a subsequent bubble shock wave caused by UNDEX, are presented. The findings illustrate the immediate effects of an underwater explosion near a floating structure, including the resulting shock wave and structural deformation. The formation of the bubble shock wave from the explosion-generated gas and the consequent deformation of the floating structure is detailed. Additionally, the phenomena that occur following the re-expansion of explosion-generated gas after the bubble shock wave are examined. The analysis reveals that the time scale required to study the effects of the bubble shock wave is significantly longer—over 100 times—than that needed for the initial shock wave propagation. This disparity in time scales introduces a major computational challenge. This study, conducted using LS-DYNA, showcases the software's comprehensive capability to tackle these issues.

KEY WORDS: UNDEX, Underwater Explosion, Floating Ship, LS-Dyna

1. Introduction

In the past, several UNDEX experiments, particularly those conducted in the far field, both with and without the presence of a floating structure, were documented and the studies are publicly available [1][2]. These experiments successfully confirmed the pulsation phenomenon and the behaviour of gas bubbles generated by the explosions, as well as their impact on submerged objects. Currently, a comprehensive and detailed review of the classification of the effects of underwater explosions on a ship can be found in [3], where the acoustic method was widely studied in relation to UNDEX. Apart from the classical UNDEX theory [4], the works in [5][6] should be also distinguishing as the most complex. The mentioned works, along with many others, address the topic of UNDEX both from the experimental side and through FEM simulations, but they share a common denominator: they mainly concern far-field underwater explosions and generally do not take into account the added mass effect or the physical impact of gas bubble pulsations on the loading of the floating structure.

Given the increasing and current wartime threats, where the use of combat drones and autonomous underwater vehicles designed to damage and disable floating structures, including critical infrastructure [7] is intensifying at close ranges, the development of research and numerical simulations on close-in and contact underwater explosions appears essential. This is a topic that remains insufficiently explored.

It should be noted that scientists from China have quickly recognized this aspect and are intensifying research in the aforementioned direction. In the last three years, after a long hiatus, there has been a significant surge in research specifically in the field of close-range UNDEX simulations, where Chinese scientists are currently leading, particularly in full-scale underwater explosion tests [8][9]. The presented results demonstrate that the level of simulation research is being maintained on par with the global forefront.

2. Conditions of the simulation

The simulation was carried out as an MMALE case. Materials were defined to accurately reflect the physical conditions, including air within the 'ship', hydrostatic pressure and the strain rate effect for the steel structure. Figure 1 shows a schematic diagram of the floating structure and the close-in underwater explosion analysis model.

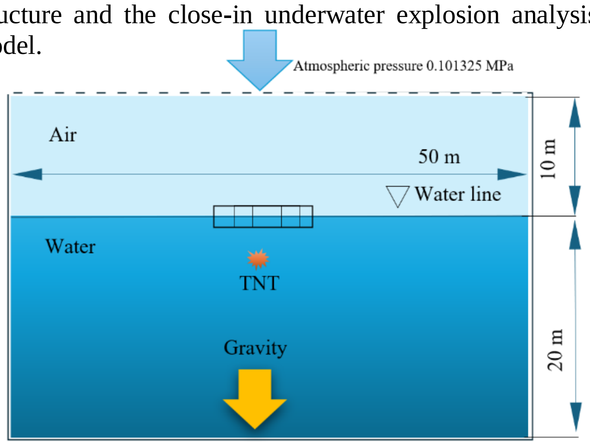

Figure 1. Diagram of the close-in UNDEX simulation

Depending on whether a coarse mesh (445,492 elements) or a fine mesh (5,065,736 elements) is used, the computation takes about 5 to 20 hours, depending on the speed of the processors, available memory, and number of cores. The simulation is classified as resource-demanding.

3. FEM simulation results

In experiments involving close-in underwater explosions near a floating structure, it has been challenging to clearly understand the detailed behaviour of the explosion-generated gas bubbles due to the difficulties associated with visualizing these events for that reason FEM simulation (Fig. 2) is a good solution to deeply study a phenomena of the issue.

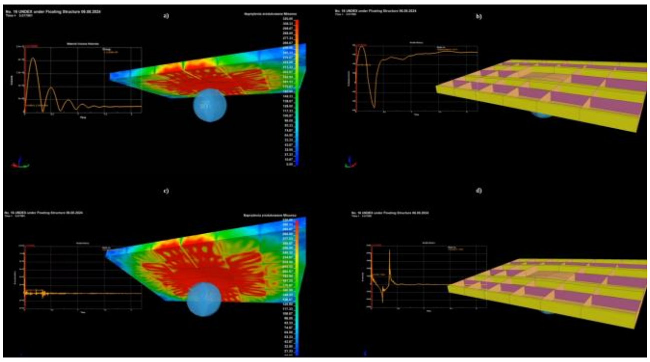

Figure 2. Tracking UNDEX results: a) pulsation, b) displacement, c) acceleration, d) velocity—at the central point of the structure

Moreover, the limited amount of explosives that can be used in laboratory settings has made it difficult to carry out experiments that would cause significant damage to floating structures. As a result, there is a growing demand for numerical analysis to investigate the relationships between various scenarios (Fig 3) and factors—such as the type and

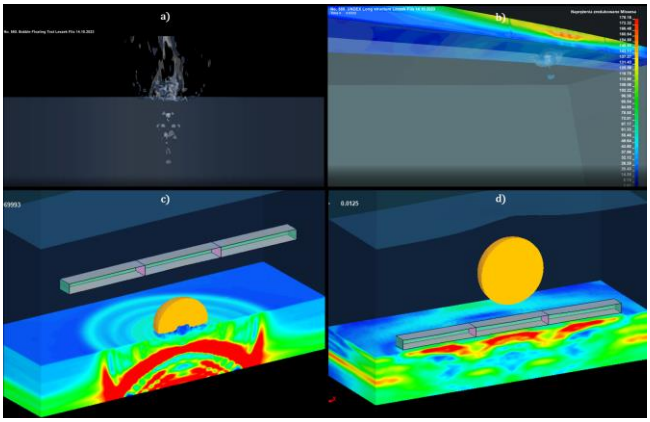

Figure 3. Possible UNDEX simulation scenarios: a) pure underwater explosion, b) long structure UNDEX, c) UNDEX on the bottom of a submerged structure, d) explosion near infrastructure lying on the seabed.

amount of explosive, the depth of water, and the standoff distance (the distance from the structure)—and the pulsation behaviour of explosion-generated gas bubbles, as well as the deformation and damage to floating structures in the case of close-in underwater explosions.

Although the power of the bubble shock wave —the second shock wave—is smaller than that of the initial shock wave generated immediately after the explosion, it still contributes a non-negligible amount of damage (Fig. 4).

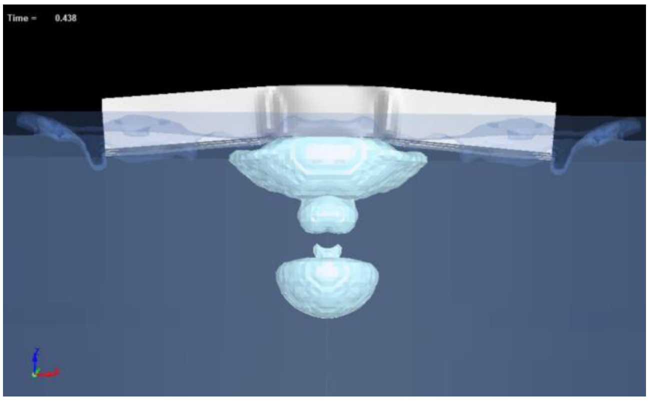

Figure 4. Buckling of a structure as a result of UNDEX pulsation.

This is because the floating structure has already sustained significant damage from the initial shock wave of the close-in explosion. Consequently, it is necessary to track the physical phenomena over an extended period to accurately evaluate the deformation and damage of the floating structure in a close-in underwater explosion, which complicates the analysis.

4. Summary

The conducted simulations allowed the observation that the initial shock wave impacts the floating structure within a few milliseconds, while the bubble shock wave occurs approximately 10 times later, or even more after the explosion. Figure 2 shows the underwater shock wave and the deformation of the floating structure immediately after the underwater explosion occurred near the floating structure. It is possible to observe the generation of the bubble shock wave from the explosion-generated gas, its pulsation, the cavitation region, and the stress or deformation of the floating structure. Far field with the presented method UNDEX can be done as well.

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