Science Arena Publications
Specialty journal of Engineering and Applied Science
Available online at www.sciarena.com
2017, Vol, 3 (2): 11-18

The effects of underwater explosion on the fixed base offshore platform at 10 metres distance

Nasser HassanKhani[1]*, Seyyed Shahab Emamzadeh[1]
[1]*Department of Civil Engineering, West Tehran Branch, Islamic Azad University, Tehran, Iran.*
Coresponding Author Email: *nasser.hassankhani@yahoo.*com

Abstract: *Field and history observations show that platforms can be used in maritime disputes by military forces and navigation, then it may be possible the explosion around them. In order to achieve the goal a case sample from offshore platforms in the Persian Gulf region was studied under variety of explosive conditions. Thefore, the main object of the present study is simulation of fixed based offshore platforms bahaviour against underwater explosions and possible subsequent events. Invasion scenario was defined by putting naval mines containing TNT of mass 50 and 100 kg at a distance of 10 meters near to the platform. Waves uploading caused by underwater explosions was applied at a certain depth in accordance with the Hunter and Gyrlz's oscillating bubbles model. The effect of water inertia around the base of the platform has been considered by added mass method. Platform structure was modeled by finite element method in abaqus software. In summary it can be said that local destruction was more observed in the near field position.*

Key words: *underwater explosion, offshore platform, fixed base*

INTRODUCTION

Marine platforms are used for oil's various purposes. Many of these platforms that were designed, constructed and installed in last years on the basis of regulations of their time, must be evaluated and re-controled. Given to the importance of marine platforms, their behavior evaluation must be done under the impact of different environmental loading conditions such as wave. Due to the increasing and growing development of weapons and threats of underwater explosion, submarines' protection from enemy's attacks and damage is very important so that they can fulfill their duty. Since many of country's oil and gas fields are shared with neighboring countries, therefore; it is necessary the hazard zonation to be offered to protect marine platforms (Sprague& Geers, 2006).

Unless stated cases the other sparse researches regarding the effects of underwater explosions on nearby structures has been reported (Aman et al., 2011; Zhang et al., 2008). Regarding platform, there has only been one report about destruction of old platforms by underwater explosions method (Continental Shelf Associates Inc, 2004). In the case of specific numerical methods for propagation of blast waves and their interactions with structure some reports are also presented which are collected in reference (EmamZadeh , 2008). Despite the strategic importance of offshore platforms, there is a little understanding of how these structures respond to underwater explosion. The effects of underwater explosions at different distances from the platform and different weight of explosive material has not been studied so far. Definition and underwater explosive loading is as an accidental loading of present research's innovations. As was observed, despite conducted extensive researches in the field of underwater explosion, very little studies have been done to investigate the vulnerability of offshore platforms, therefore; the necessary to do this study despite the existing platforms in the country is felt more than ever.

The phenomenon of underwater explosion

Underwater explosion is a phenomenon in which high energy is released in small amount of time and a wave is created in the water around explosive material. The laws of conservation of mass, energy and momentum governed on the propagation of blast waves. When high explosives material (TNT, RDX, HBX_1, etc.) are exploded, explosives materials are changed to a gas with high pressure and temperature within a few nanoseconds. The shock wave started from one part of explosive material (detonator) and spread throughout the explosive material, with expansion of pressure wave, a chemical reaction begins that it creates more pressure waves. Pressure wave velocity is increased steadily and equitability within the solid explosive material to exceed the speed of sound. Shock wave spread through the solid material at a constant speed, is entered into surrounding environment (water) by high temperatures and pressure behind the initial wave. High pressure gas caused by explosion is radially spread and it induces to water an external speed. At first, the pressure of explosion products are much larger than atmospheric and hydrostatic pressure of surrounding water. Although the pressure of surrounding water resistance against release of blast waves, the resultant indicates that the surrounding water of explosive material has compressive properties at everywhere. The speed of propagation of acoustic waves in the sea water is variable with depth, salinity and temperature. While the average of sound speed in the air is 340 *m/sec* the average of sound speed in water reaches to 1500 *m/sec* which is several times bigger than speed of sound in the air. Then, this speed is reduced to speed of sound. Shock wave pressure diagram is subordinate of inverse distance from explosive material. Gases resulted from explosion create an expanding bubble. The bubble began to collapse due to the hydrostatic pressure around the expanded bubble. Then the bubble is compressed to its minimum radius. This high-pressure causes to explode gases suddenly that creates second shock wave, this wave of shock called bubble pulse. With regard to the stated issues, it can be said that the pressure caused by explosion can be achieved with existing relationships at every moment. Taylor relationship is a good relationship for calculating the load on the structure in underwater explosion. These relationships are used to calculate the value of load on the platform (Cole, 1948).

Dynamic Analysis and Specification of Platform

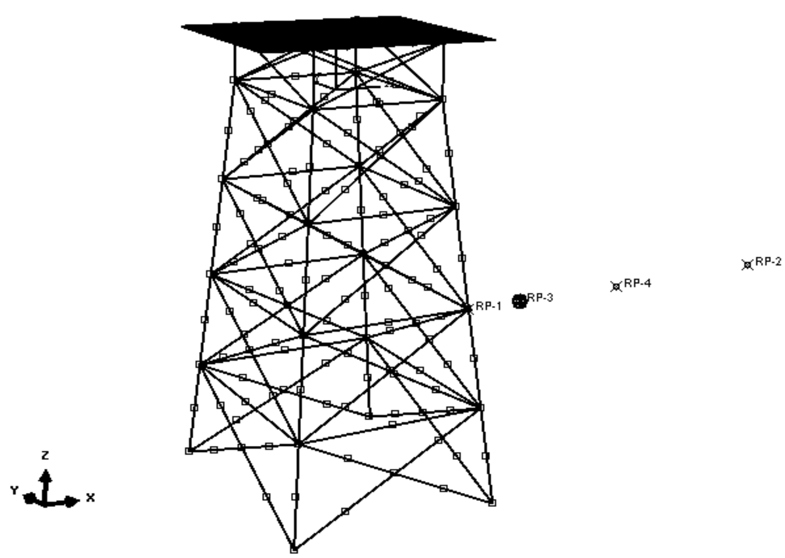
To show explosive analysis, a wellhead stool platform with six condactor and one floor deck is considered in a water at depth of 75 meter. This platform is similar to original design of South Pars region's platforms. Deck dimensions is 32 × 40 m and its approximate weight is 1,000 tons. The distance between the bases of the jacket at deck position is 22/5 × 30 meter. Jacket bases' slop is 1:10. Bases of platform depends on the loads, different diameters from one to two meters and a different thickness ranging from three to ten centimeters. Braces of platform are made of pipes 0/3 to 1/2 m diameter and of a thicknesses between two to eight centimeters. Platform's truss members are made of ST37 steel with elastoplastic behavior, flow stress of 2400 kg/square centimeters and final stress 3700 kg/square centimeters. Explosive material in mass of 100 and 50 kg in the distance of 10 meters from the platform and at a depth of 35/5 meters from surface of water is being considered and platform's behavior to explosion wave has been studied. Inertia effects of water connected to the bases is being considered by added mass method. Deck is being considered in rigid form. Death and live laoding has been applied in accordance with proposed principles of twentieth Edit API (American Petroleum Institute, 2002). Environmental loads of wave, wind and earthquakes has not been considered in time of explosion. Although the hydrostatic pressure can enhances the lateral force but due to its smallness to explosive load it was not considered in order to simple calculations. Abaqus 6.12.1 software is used to build finite element model. Deck dimensions was 32 × 40 m that was reticulated with four nodes square plate elements named R3D4 in dimensions of 2 meter. In this model the beam elements were used for the platform base. Beam elements's dimensions is 3 meter in platform base and is considered in type of B31. Two amounts are considered to investigate the weight of explosive material. The explosive material is made of TNT and has 50 and 100 kg weight in two different scenarios. Detonation time is one millisecond and underwater explosion model defined in Abaqus in name of UNDEX[1] was used for explosive loading. In this model the position of explosive material is given in one point. Explosive material placed at 37/5 meter depth from water surface. This depth is equal to half of depth of the water around the platform. Total time of modeling is considered to half a second (500 milliseconds). Due to the salinity, density of sea water is a little greater than the density of fresh water. In the present model, the density of seawater is averagly considered equal to 1025 kilograms per square meter. Speed of sound in water is also considered equal to 1500 meter per second that almost is five times bigger than the speed of sound in the air. Given to the proximity of explosive material to platform, changes of blast wave is spherically defined from the the source of the explosion. Density of TNT is equal to 1600 kg per square meter and its mass is 100 kg. Dynamic analysis was performed in explicit method with variable time steps. This time steps is determined based on the stability of dynamic analysis stepwise method. Six dynamic analyses were totally done to investigate the effect of underwater explosion. Weight and distance of explosive material was changed in any analysis. Finite element model of platform consisted of 1106 nodes and 1144 elements. 340 elements is related to deck and 804 beam element is related to deck.

Findings

To investigate the stability of the platform, dynamic response was studied which includes the base shear and deformation of platform at different times after the explosion that the results are being observed for two explosions of 100 kg and 50 kg.

Explosion of 100 kg explosive material at distance near to platform **N-100**

The effect of near explosion has been investigated by putting 100 kg TNT of explosive material at 10 meter distance from platform. Model of platform and position of explosive material shown in Figure 1.



1- underwater explosion

Figure 1: platform model and explosive material at 10 meter distance from its surrounding

PEEQ[2] contour and deformation of platform shown in figure 2 in the last step of analysis. Most equivalent plastic strain happened in an alignment that explosive material placed in it and is equal to 200 percent. The durability of platform was also 66 seconds and after that the continuous of analysis will be ceased because of instability of platform.

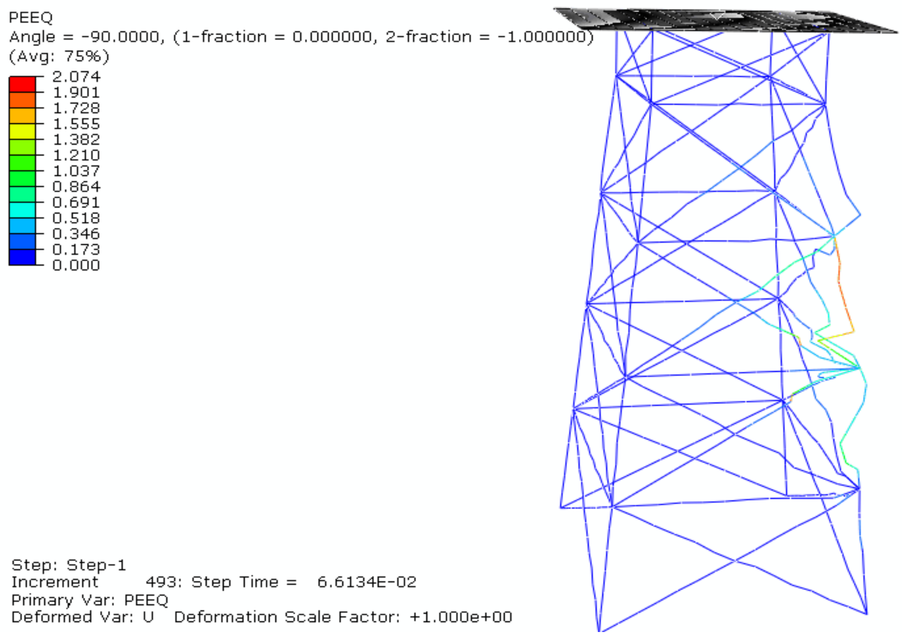
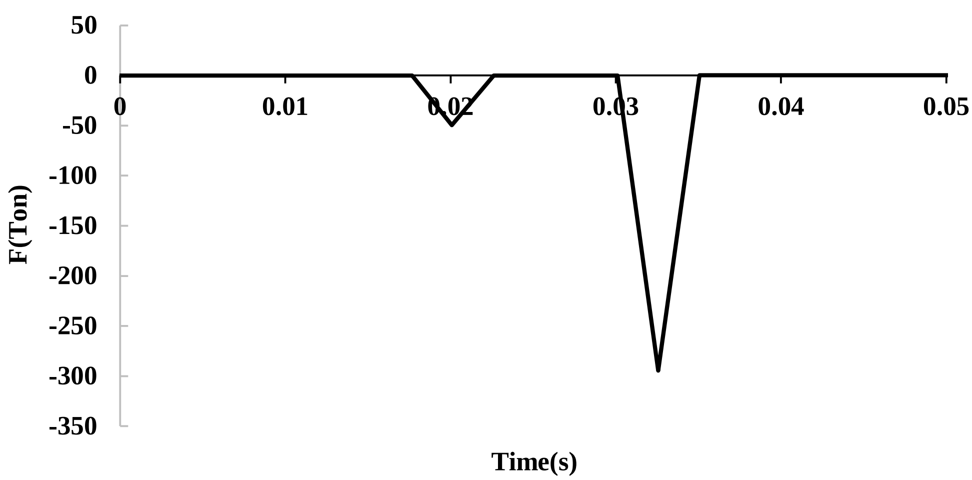


Figure 2: plastic strain contour and deformation of platform in the last step of analysis

The base shear occurred in result of explosion of platform in its bases. The changes of base shear shown in figure 3. The most of base shear occurred at the base in side of explosive material and the maximum of base shear is obtained equal to 200 tone which is obtained at 0/03 seconds (30 milliseconds) after explosion and then it goes to zero.



2- Equivalent Plastic Strain

Figure 3: time history of platform base shear force

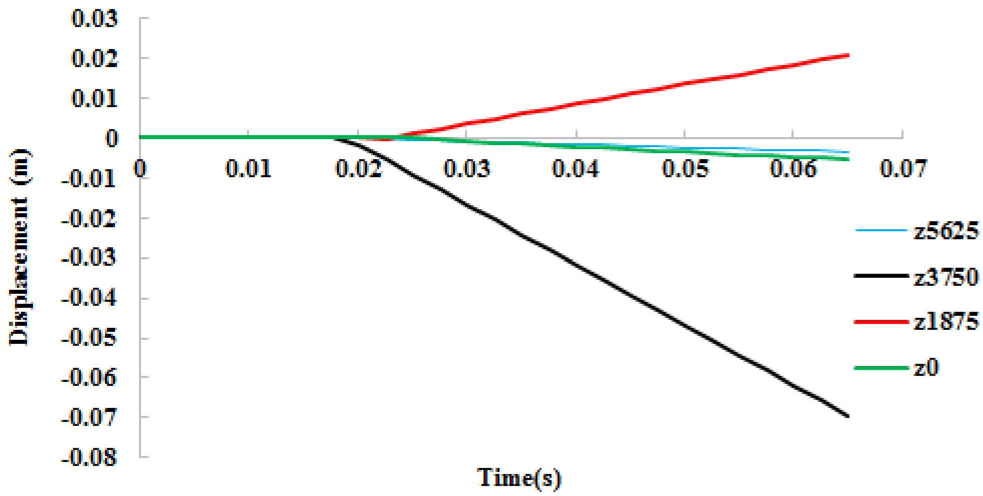


Figure 4: time history of deformation of different levels of the platform base

Explosion of 50 kg explosive material at distance near to platform **N-50**
In this part the effect of explosion of 50 kg TNT explosive material is investigated at 10 meter distance from platform. Model of platform and position of explosive material shown in Figure 5.

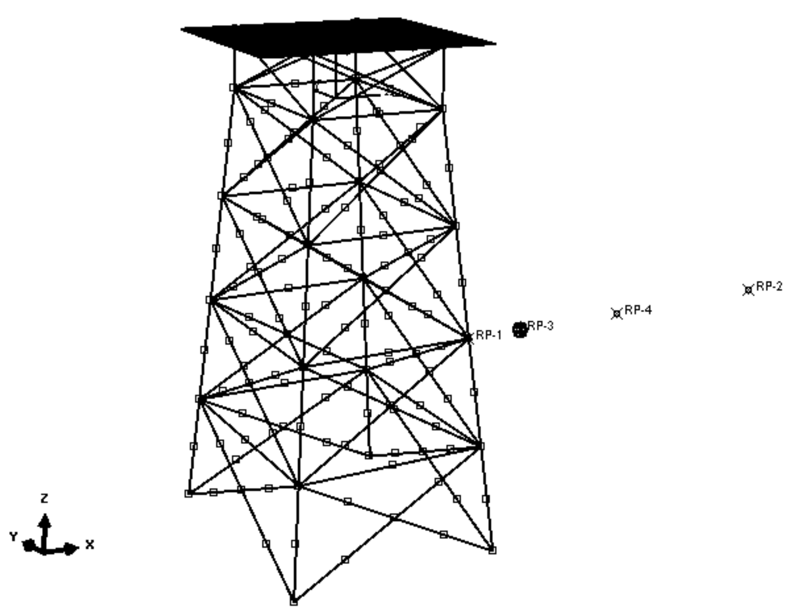


Figure 5: Model of platform and explosive material at 10 meter distance from its surrounding

The total shear force exerted on the base of the platform shown in Figure 6. In base shear force diagrams a small pulse is seen about 20 milliseconds after the explosion and a great pulse is seen in shear diagram at time of 35 milliseconds. The maximum base shear has been obtained equal to 180 tons.

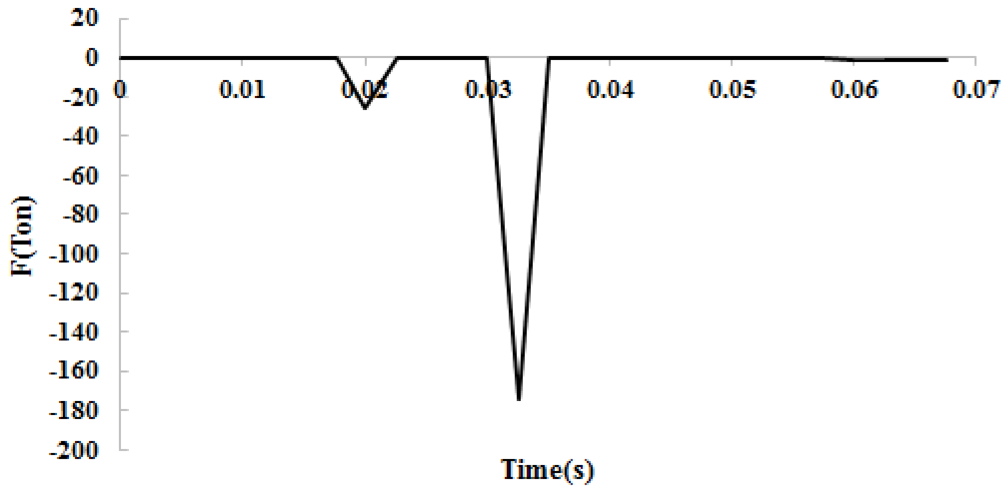


Figure 6: time history of shear force of platform base

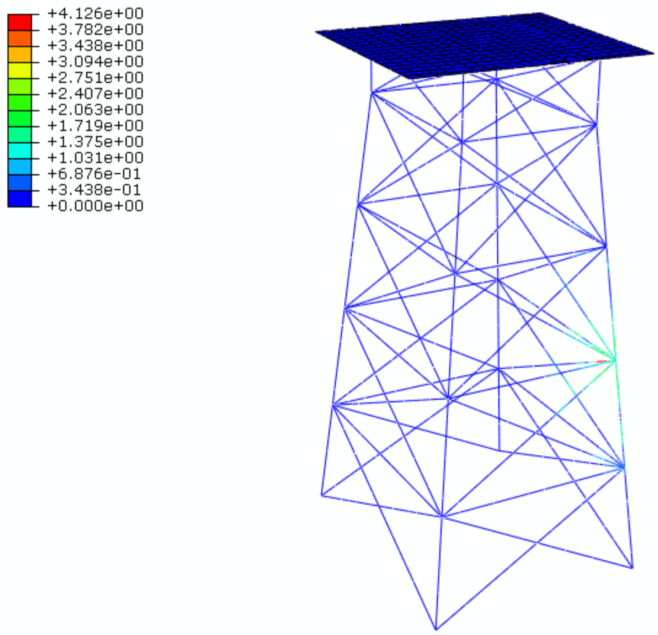


Figure 7: deformation contour at the last step of analysis

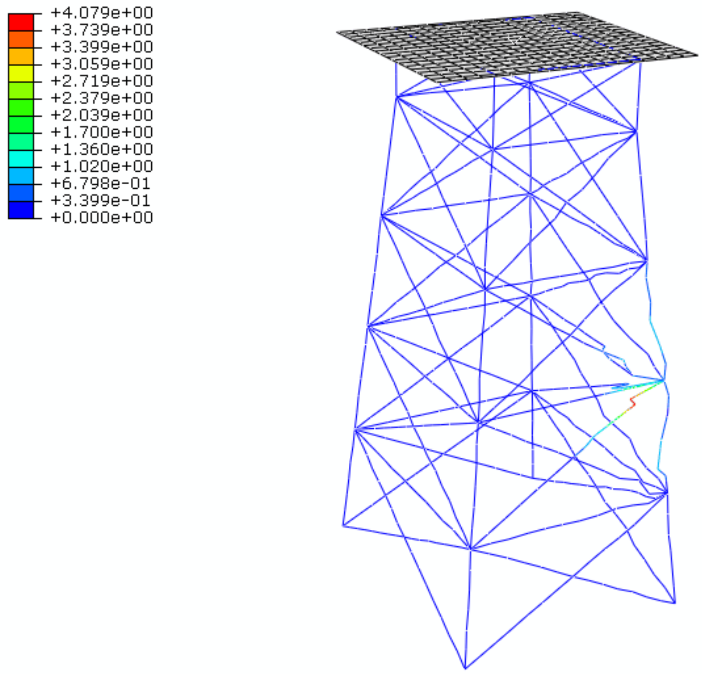


Figure 8: plastic strain contour at the last step of analysis

Discussion and conclusion

The main aim of the present research, was simulation of fixed base marine platforms behavior against underwater explosions and its possible sunsequent events. For this reason the effect of underwater explosions on fixed base marine platforms was evaluated. Explosive material was put on near the platform. For modelling the water around the platform the added mass was used and after the construction of the finite element model of issue, the governed dynamics equations was analyzed by explicit stepwise method in the time domain. In order to reach the object, a sample case of marine platforms in the Persian Gulf region was studied against different explosive conditions. In summary it can be said that in near field the local destruction was more observed. After modelling and numerical analysis of a sample case of marine platform constructed in Persian Gulf region, the numerical results were analyzed and the results are as follows.

A part of the platform which placed in the vicinity of explosive material may have been damaged and in a short time, deformation, speed and acceleration of this part of the platform is increased. The impact of the explosive material and its distance from the platform in value of equivalent plastic strain is significant so that, for example, to explode 100 kg TNT in near distance the maximum equivalent plastic strain occurred in an explosive material level and equal to 200 percent. To explode 50 kg TNT in near distance the maximum equivalent plastic strain occurred in a level which explosive material placed in it and equal to 407 percent. Durability of platform was very low before destruction and destruction is quickly done so that, for example, to explode 100 kg TNT in near distance the durability of platform is 66 seconds and after that due to the instability of the platform, the continuous of analysis is ceasead. By collecting conducted studies in the field of research it was observed that most of studies regarding underwater explosion is mainly related to warships, ships and submarines. The researches found that the effect of explosion was more localized and only a range of structure located in the near of explosive material was destroyed. For example, the studies of

Yong S. Shin (2002) can be mentioned on the effects of underwater explosion on the ship (Shin, 2002). The speed of prow of the sheep was investigated in conducted research. In the present study, deformation was used instead of speed due to the discreteness of deck truss structure to continuous of shell structure of body of the sheep. Because after destruction of members of platform, a very high speed achieved from these members which was not in accordance with reality. Recently, the results of dynamic analysis of a concrete dam against underwater explosion has been published by Tian Tong Yu (Tiantang, 2009). In this analysis, the relations governed on reservoir of dam has been writtened in view of Euler and dynamic equations of body of dam in view of Lagrange. In the analysis, shock wave propagation and interaction between the dam and reservoir have been considered to involve by Euler-Lagrange method. LS-DYNA software was used for numerical calculations. In conducted research, local destruction was observed at the upstream of the dam body. This result is similar to obtained results for the destruction of platform caused by the underwater explosion. In studied platform model, it was observed that a number of the platform base truss members has had a large deformation and has been destructed.

In relation with the results of research, in order to complete and development of the research it is suggested that the verification of obtained results to do with definition of case study of same platform. It is suggested to make a laboratory model from case study of marine platform of present research and a definition of a malfunction indicator for platform. As well as, in order to complete and development of present research the following cases is suggested for future researches to study the response of platform to shallow, medium and deep blast.

Resourses

[1] Sprague, M.A.; Geers, T.L. "A Spectral-Eement/Finite-Element Analysis of a Ship-Like Structure Subjected to an Underwater Explosion"; *Comput. Methods Appl. Mech. Engng*. 2006; 195, 2149-2167, **2006**.

[2] Aman, Zhang et al. "Dynamic Response of the Non-Contact Underwater Explosions on Naval Equipment." *Marine Structures* 24.4 (2011): 396–411. Web.

[3] Zhang A. M., Yao X. L., Yu X, B. (2008). The dynamics of three-dimensional underwater explosion bubble, *Journal of sound and vibration*, 311, 1196-1212.

[4] Continental Shelf Associates Inc. "Explosive Removal of Offshore Structures - Information Synthesis Report. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS App., Study MMS 2003-070." (2004): 188. Print.

[5] EmamZadeh, S. S, "an adaptive finite element method for structural interaction of water and underwater explosion caused by a doctoral thesis", tips Mohammad Taghi Ahmadi and Mohammad Sohail, Tarbiat Modarres University, Tehran, **2008**.

[6] Cole, R.H. "Underwater Explosions"; *Princeton University Press*, **1948**.

[7] American Petroleum Institute (API). "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms-WSD"; 20th Edition; Chapter 18; **2002**.

[8] Y.S. Shin, "Ship Shock Modelling and Simulation for Far-Field Underwater Explosion", in B.H.V. Topping, Z. Bittnar, (Editors), "Proceedings of the Third International Conference on Engineering Computational Technology", Civil-Comp Press, Stirlingshire, UK, Paper 36, 2002. doi:10.4203/ccp.76.36

[9] Tiantang, Y. (2009, March 31 2009-April 2 2009). *Dynamical Response Simulation of Concrete Dam Subjected to Underwater Contact Explosion Load.* Paper presented at the Computer Science and Information Engineering, 2009 WRI World Congress on.