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Hydrodynamic response simulation of Catenary mooring in the spar truss floating platform under Caspian Sea conditions

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ABSTRACT

Nowadays, oil platform's moorings failure one of the most important challenges of the drilling industry in deep seas for the establishment and stability of the platform during operation. The behavior of these moorings plays an important role in the preservation of the platform with interaction by waves and environmental forces. In this regard a sample of non-classical Spar Truss platform was analyzed using Moses software in the Caspian Sea. Also hydrodynamic analysis of mooring system based on three-dimensional diffraction method was used; this analysis is based on time dependent and six degrees of freedom motion. Therefore response amplitude operator (RAO) of platform moorings was obtained by incident wave. The effect of removing a platform mooring was studied. The results indicate a high gradient change in Surge Movement. Also the results of this study can be used as a benchmark for spar platforms design in Caspian sea.

1. Introduction

Nowadays, sea engineering sciences in the area of oil and gas and construction of offshore structures is progressing rapidly. Iran has about 34 trillion cubic meters underground gas reserves and is ranked as the second largest gas reserves in the world. Also Iran's petroleum reserves are classified in the top five countries in the world. The major part of these resources lies in the seas of this country. Thus, the extraction of this national wealth is essential for the country's growth and development. In addition, 90% of the offshore undiscovered hydrocarbon resources are in water depths greater than 3000 feet. For this reason, the use of technologies such as Spar is very important. The Caspian Sea in the north of Iran with a surface area of 436,000 km^2, 1200 km length, 220–550 km width and the volume over 77,000 km3 is the world's largest lake having many non-extracted oil and gas reserves. The depth of the Sea is 10–12 m in the northern part, up to 770 m in the middle part and the deepest point in the southern part reaches to 1000 m (Zeraatgar and Hajiarab, 2003). Because of the deep sea in the vicinity of Iran and the need to exploit the God-given resources, the use of drilling rigs capable of operating at these depths is inevitable. Spar platforms are one of these platforms that is divided into three classic Spar, Truss Spar and Cell Spar and connected to the seabed by Catenary and Clamped moorings. Classic Spar are the first generation of the platforms and the tendency to construct truss spar platforms have been made by the progress of construction technology and more recognition of this type of platform such that out of 17 spars operating so far, 3 are classic, 13 are truss and 1 is cell spar. The use truss spar platform in the Caspian Sea with the characteristic wave height of 7.20 m in a 10-year returning period is an option for the sea. Because at first it is easy to transport platform between different drilling sites. Secondly, these platforms always maintain their flotation because the Center of Buoyancy is on the Center of Mass. Thirdly; Spars have slight Heave movement due to the endpoint of the platform under the wave impact zone. According to research conducted by Ketabdari and Hatami, Truss Spar platform with heave and pitch motions less than other floating platforms (Hatami and Ketabdari, 2012).

One of the areas in need of research on this type of platform is restricting the movement of these platforms to 6° of freedom and therefore optimal operation of the platform. Therefore, extensive studies have been made on the mooring of floating platform especially spar platform; including mooring cable analysis using the finite element method by Veenesh. MV and colleagues in 2014 (Vineesh et al., 2014).Another research by S.H.Jeon and colleagues in 2013 investigated spar-type offshore wind Turbine with catenary Mooring Cables in the face of environmental forces in which the stress and angles of Mooring cables under these forces have been studied (Jeeon et al., 2013). In another study conducted in 2015, Hanis. V validated and controlled Mooring response outputs in the face of wave energy using numerical method (Harnois et al., 2015). Nielsen and Bindingbo in 2000 investigated the maximum force damped by mooring using the finite element method and laboratory method (Nielsen and Bindingbo,

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2000). In the researches above, there was no injury in the analyses carried out on the moorings. The present research after proposing the Catenary mooring for Truss Spar platform in the Caspian Sea and mooring analysis, the damage (rapture) of the moorings was also analyzed because of the importance of stability and safety of the deck and maintenance of the platform. The damage will occur due to various reasons such as cable fatigue, wave vortices created behind the Spar platform, the accumulation of marine products and so on. In this regard, Dongsheng Qioa, Gongwei Yan in 2014 investigated the damage of mooring on the spar platform in deep water (Dongsheng and Gongwei, 2014). Mohamed et al. (2012) proposed a code in MATLAB as TRSPAR and investigated the wave impact on the rapture of Truss Spar Platform Mooring (Mohamed et al., 2014). In the following, truss Spar platform was modeled in Moses software using statistical information of the Caspian Sea and the use of JONSWAP spectrum which have similar conditions to the Caspian Sea, and then the statics and dynamics of the platform after removing mooring is studied in order to operate this platform through more information and more complete experiments under critical condition.

2. Materials and methods

2.1. Catenary moorings of platform

Mooring lines are responsible to deal with the impact of environmental forces on the platform and thus maintaining its stability. Environmental forces applied in the horizontal plane, as well as the stress caused by the surge motion of the platform and wind should be transferred to the seabed. So these forces create a torque, which depends on the depth of water. The system should be such to allow the floating platforms move by the waves. However, some motions of the platform are limited in some cases. Generally, mooring systems in offshore structures are classified into three tensile, Catenary and Clamped moorings (Mo'ayyeri, 1996).

Mooring line which is comprised of cable and chain cannot transfer the torque. The torque generated must be balanced by a vertical force. The difference between tensile, Catenary and clamped moorings is in the balance of the torque. The ductility of the mooring against the waves is provided by the geometrical shape and axial elasticity. The geometrical ductility of this system leads to a complicated dynamic behavior against environmental forces. Tensile moorings are usually used in base tensile plat forms and is not applicable in the Spar platform. Catenary and clamped moorings are used in Spar platform to maintain balance. Fig. 1 shows a part of a cable as an element separate from the seabed. In order to determine the differential equation governing the deformation of the cable, it is sufficient to write equations balance of forces for free-diagram of cable:

$$\sum F_y = 0 \ \rightarrow w.\ \delta s + \frac{d}{ds}(T.\ \sin\theta).\delta s = 0 \tag{1}$$

$$\sum F_x = 0 \ \rightarrow \frac{d}{ds}(T.\ \cos\theta).\delta s = 0 \tag{2}$$

where w is the weight per unit length, and T is the tension of cable, as well we have:

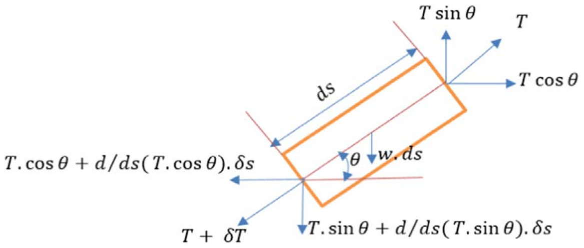

Fig. 1. Mooring element from the ground up.

$$\sin\theta = dy/ds \tag{3}$$

$$\cos\theta = dx/ds \tag{4}$$

$$\mathrm{T.}\ \cos\theta = H \tag{5}$$

H is the horizontal component of mooring force which is fixed along the length. The horizontal component of mooring force is fixed along with the length, because no external horizontal force is not applied on the mooring in calm water.

With the insertion of 4 and 5 in Eq. (1):

$$H.\ \frac{d^2y}{dx^2} + w.\ \frac{ds}{dx} = 0 \tag{6}$$

$$ds = (dy^2 + dx)^{1/2} \tag{7}$$

By inserting 7 in 6, we have:

$$H.\ \frac{d^2y}{dx^2} + w.\ \left[1 + (\frac{dy}{dx})^2\right]^{1/2} = 0 \tag{8}$$

With the integration of Eq. (8):

$$\frac{dy}{dx} = -\sin h(\frac{w.\ x}{H} + \sin h^{-1}(\tan\theta_0)) \tag{9}$$

Re-integrating of Eq. (9) and applying boundary conditions give the following relationships:

$$Y = \frac{H}{w}.\left[\cos h(\frac{w.\ x}{H} + \sin h^{-1}(\tan\theta_0)) - \cos h(\sin h^{-1}(\tan\theta_0))\right] \tag{10}$$

$$l = \frac{H}{w}.\left[\sin h(\frac{w.\ x}{H} + \sin h^{-1}(\tan\theta_0)) - \tan\theta_0\right] \tag{11}$$

Fig. 2 shows the free-diagram of cable so we have:

$$V_b = V_t - w.\ s \tag{12}$$

$$V_b = H.\ \tan\theta_b \tag{13}$$

As a result, we have:

$$\tan\theta_b = (V_t - w.\ s)/H_t \tag{14}$$

Changes in cable length is also calculated on the basis of the strain relation:

$$S = S_0 + \Delta S \rightarrow \Delta S = \frac{S_0(T - T_0)}{EA} \tag{15}$$

As a result, we have:

$$S = S_0 + (1 + \frac{(T - T_0)}{EA}) \tag{16}$$

Catenary mooring system comprised of cables or chain lines which are connected to the surface of the platform on one side and connected to the mooring installed on the sea floor on the other side. Catenary moorings installed at a certain distance from the platform on the sea

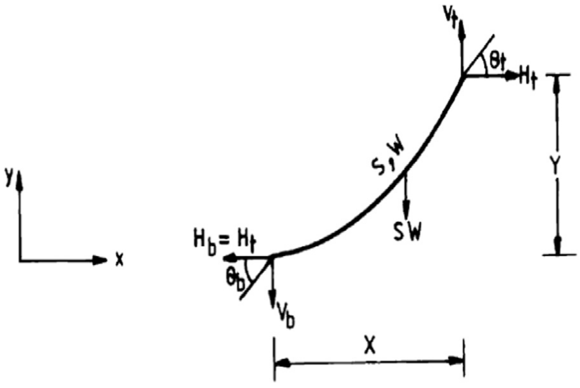

Fig. 2. Free-diagramof mooring cable.