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ANALYSIS OF NATURAL OSCILLATIONS OF THE OFFSHORE FIXED PLATFORM

R.M. Ostapenko,
Assistant

I.D. Kara,
PhD

V.P. Andriievskyi,
PhD

R.P. Kravchuk,
Master student

Kyiv National University of Construction and Architecture,

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The analysis of natural oscillations of the offshore fixed oil production platform with the research of the impact of the pile foundation flexibility on values of dynamic parameters was performed. Two discrete idealized models of the platform were used for the dynamic analysis.
Keywords: offshore platform; discrete model; frequency of oscillations, period of oscillations.

Introduction. Among the large nomenclature of technical means used in mastering oil and gas resources on the continental shelf there are offshore fixed drilling platforms. At the same time, such structures are one of the most difficult, expensive and largely problematic. In the modern world the development of marine deposits of hydrocarbons increases because of gradual depletion of oil and gas deposits on land [1].

The composition of structures on the shelf expands continuously due to the development of new areas. Offshore fixed platforms are the main hydrotechnical structures for the development of marine oil and gas deposits. Fixed are structures that remain in place throughout the operation period. They are designed to accommodate on them drilling, oil industrial and necessary equipment that provides drilling wells, the oil and gas extraction and preparation as well as a number of other works: the pumping water into a layer, the wells repair, the preparation of raw materials for the transportation etc. Besides emergency rescue equipment and household premises are placed on such platforms.

The purpose of the offshore hydrotechnical structure usually defines the minimum area value and the weight of the platform that must be installed in the certain place. The economy of the design of the platforms supporting part is determined, first of all, by the way of setting it at the place of the operation, by the action of the external environment as well as local conditions. The action of the external environment that are the influence of wind, flows, waves as well as the action of ice fields and earthquakes on the strength of the structure must be studied previously. The depth of water and characteristics of the soil basis belong to local conditions moreover the last of them is particularly important to the analysis of the foundation of the structure.

Further ensuring safe working conditions of staff, the environmental protection, the protection of property, minimizing the consequences of emergency situations are important when designing offshore platforms [2]. Methods of the analysis of strength of elements of offshore structures that are under the action of external loads are given in [3]. Modelling of the ice load and determination of offshore platforms characteristics for the ice destruction efficiency were performed in [4]. Some aspects of the dynamical analysis of offshore structures are presented in [5, 6]. Considering the transition to more deep-water areas and the nascence of new technical solutions problems of designing of structures for exploration and development of hydrocarbons deposits on the continental shelf remain.

The purpose of the article. The purpose is the analysis of natural oscillations and the research of the impact of the flexibility of the pile foundation on dynamical parameters values of the offshore fixed oil production platform. Under the action of periodic wave load the platform performs periodic oscillations. The frequency of oscillations of the platform can be close in the value to the value of the wave load frequency. Therefore, there is the threat of the resonance that is accompanied by the sharp increase in the oscillation amplitude that negative affects the work of the platform. That's why it's very important to know values of periods and frequencies of natural oscillations of the structure.

The main part. The object of the research is the offshore platform that represents the steel technological platform on piles. The intended region of construction is the shelf of Bay of Kazantyp of Sea of Azov at the depth of 11 m from the water level in the calm state. As the mark 0.000 is accepted the water surface level.

This platform consists of two parts. Conditionally, it can be divided into above-water and underwater-supporting parts. The above-water part consists of the lower deck block, the upper deck block, two moorages, the flambeau, the connection mast with equipment. Deck blocks are connected with each other by staircases and transition platforms. The upper deck block consists of the platform for wells repair and the helicopter platform. Protective enclosures for safe operation are provided along the outline of the deck.

The underwater part represents the supporting metal spatial carcass. This carcass consists of two supporting columns, the piped grillage and piles. The lower deck block attaches to these columns with the help of angle braces. In the place of icing of the column is provided the icebreak casing in the form of three sheets of steel that are welded to four pipes of the column. To enhance the rigidity of the protective casing additional elements are welded between sheets and the internal volume is concreted between external sheets. Inside the icebreak drum diaphragms of rigidity of sheets and rods are provided. The grillage attaches to seabed with the help of 24 piles that are scored through guides in the grillage. Piles represents metal pipes upper parts of which are fixed in the grillage with the help of cementation of inter-pipe space. The length of piles is 50 m. Piles are filled along the entire length with the solution. The weight of the structure and forces are transmitted through piles to ground foundation completely.

Technological equipment which includes wells and the gas pipeline is placed on the platform. Four wells are drilled under the left column. The platform works in automatic mode, i.e. there is no service personnel. The platform is equipped with two moorages for the approach of ships and landing and releasing of people. By-products should be burned outside the platform for fire-fighting purposes. To do this, the flambeau is taken beyond the platform on the console truss 25 m long. The flambeau is located on the leeward side of the platform according to the predominant direction of wind.

Throughout the operation period of the structure constant and variable loads act on it. Variable loads and impacts according to duration of continuous action can be prolonged, short-term end episodic [7]. Loads and impacts that act on the platform are: the own weight; the hydrostatic pressure on members that are underwater permanently; the weight of equipment, technological stocks, ballast; loads that arise when moving, drilling equipment is operating; loads that occur during production, transportation, assembling of structures, landing of helicopters, mooring of ships; loads that are caused by hydrometeorological conditions (wind, snow, waves, stream, ice fields); loads that are related to a sharp violation of the technological process; seismic impacts; loads that that are caused by soil blurring, uneven soil deformation; seismic, temperature impacts and dynamic loads from explosions. These loads can act not simultaneously and do not combine with their maximum values. That's why combinations of loads are accepted for consideration these influences on hydrotechnical structures.

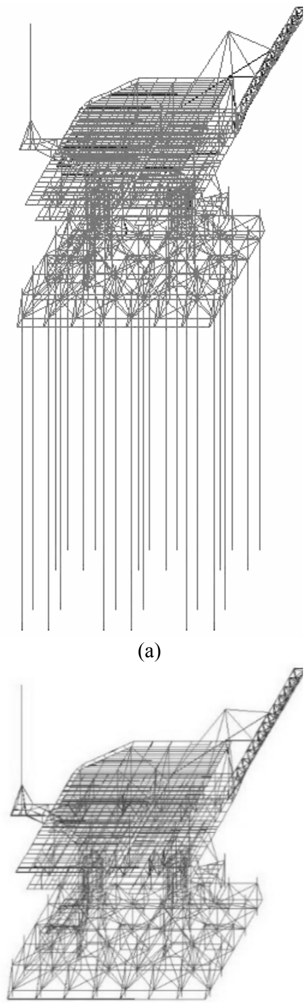
There is a great variability of stream in Sea of Azov. The average stream velocity is 0,6-0,8 m/s, the maximum velocity reaches the value 1,4 m/s. The average wave height is 2,2-2,5 m, the maximum height is 4,3 m. Most storms have duration 6-8 h, strong storms can last 25-28 h. The ice mode is characterized by repeated appearance and disappearance of ice even complete freezing of the entire surface of sea. The velocity of drift floating ice reaches the value 3,6 km/h, the average thickness of ice is 25-35 sm. Ice stuffing to the bottom of sea arises almost every year in shallow bays. The wind mode is characterized by the average annual wind velocity that is equal 4,5-6,5 m/s, in open sea the wind velocity can be 40 m/s.

The analysis of natural oscillations of the platform on piles was performed using its two discrete finite-elements idealized models: the flexibility model (Fig. 1,a) and the rigid model (Fig. 1,b).

In the first discrete model (Fig. 1a) the interaction of soil foundation and piles was implemented by using of finite elements that simulated the elastic connection between joints. The reaction of elastic soil basis under the action of external loads was replaced by the system of non-dimensional concentrated elastic-flexible links that modeled discretely the resistance of foundation to linear displacements of a pile and its twisting around the longitudinal axis. Links formed special non-dimensional elastic-flexible supporting elements that connected joints of the bar finite-elements model of a pile with the immovable absolutely rigid body [8, 9].The water media was rejected conditionally during the analysis of this model. Thus, it was thought that the platform is in air media and the impact of water media was modelled in the form of connected masses that have been distributed additionally at joints of the platform. This discrete model consisted of 3125 joints and 6215 members.

Piles were rejected in the second model (Fig. 1b) and the platform was considered to be rigidly attached to the absolutely immovable rigid body. This discrete model included 1757 joints and 4823 members.

For every model first twelve basic natural form of oscillations were analyzed: the first model – transverse-bending oscillations of the connection mast in the plane *YOZ*; the second model – analogical oscillations in the plane *XOZ*; the third model – transverse-bending oscillations of the flambeau console; the fourth model –bending oscillations of bearing structures of the entire platform in the plane *YOZ*; the fifth model – transverse-bending oscillations of bearing structures of the entire platform in the plane *XOZ*; the sixth model – rotating oscillations around the vertical axis *Z*; the seventh – bending-rotating oscillations in the plane *YOZ*; the eighth model – the higher bending form of oscillations of the connection mast in the plane *XOZ*; all other forms are higher order and have the complex nature. Results of comparative modal analysis of above forms of the platform are given in Tables 1, 2.



(a)

(b)

Fig. 1. Discrete idealized models of the platform (a) – flexible, (b) – rigid

Table 1

Values of oscillations forms frequencies for different models(ω, s^{-1})

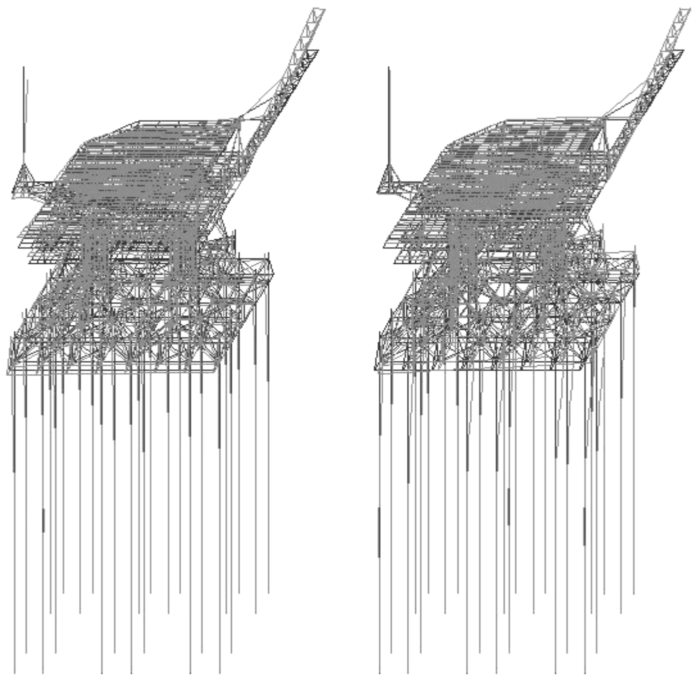
The number of the form	The first model	The second model	The absolute value of the difference, %
1	7,098	7,11	0,17
2	7,734	7,73	0,05
3	11,125	11,663	4,84
4	12,133	14,848	22,38
5	15,634	22,787	45,75
6	16,179	23,201	43,4
7	16,742	27,922	66,78
8	22,657	29,495	30,18
9	23,204	34,809	50,01
10	28,149	36,01	27,93
11	29,42	36,408	23,75
12	34,258	43,644	27,40

Table 2

Values of oscillations forms periods for different models(T, s)

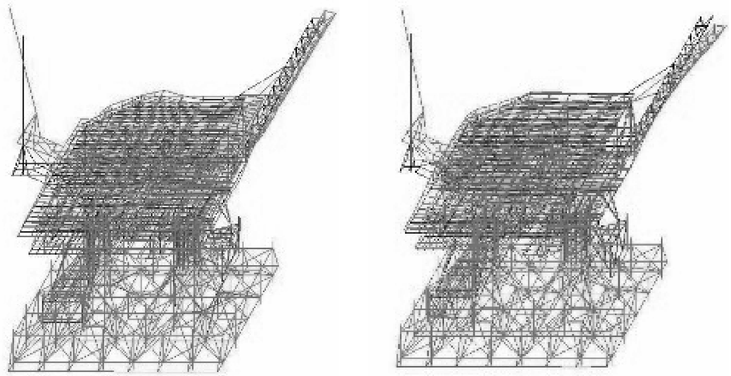
The number of the form	The first model	The second model	The absolute value of the difference, %
1	0,885	0,883	0,23
2	0,812	0,812	0,00
3	0,565	0,538	4,78
4	0,518	0,423	18,34
5	0,402	0,276	31,34
6	0,388	0,271	30,15
7	0,375	0,225	40,00
8	0,277	0,213	23,10
9	0,271	0,18	33,58
10	0,223	0,174	21,97
11	0,213	0,172	19,25
12	0,183	0,144	21,31

The modal analysis showed that in first two models of natural oscillations of the platform took part only the flexible connection mast basically therefore parameters of natural oscillations (the frequency of oscillations ω and the period of oscillations T) didn't depend on the flexibility of the supporting foundation of the platform. The similar behavior was also characteristic of the third form of natural oscillations of the platform where took part basically only another flexible structure of the platform – the flambeau console. In all other forms of natural oscillations, especially in fifth (Fig. 2a, Fig. 3a)and seventh (Fig. 2b, Fig. 3b)models, taking into account the flexibility of the supporting foundation changed values of dynamic parameters of 1,25-1,5 times that is quite significant.



(a) (b)

Fig. 2. Forms of natural oscillations of the first model platform: (a) – the fifth form, (b) – the seventh form



(a) (b)

Fig. 3. Forms of natural oscillations of the second model platform: (a) – the fifth form, (b) – the seventh form

Obtained results indicate the importance of taking into account the flexibility of the pile foundation during analyzing of members of the offshore fixed platform.

Conclusion. The analysis of natural oscillations of the offshore fixed platform showed that in first three models of oscillation stook part basically only flexible structures of the platform: the connection mast and the flambeau console and in other forms of oscillations taking into account the flexibility of the pile foundation changed values of dynamic parameters almost half. Respectively, taking into account this factor when analyzing of stress-strain state of members of the hydrotechnical oil production structure is very important.

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Остапенко Р.М., Кара І.Д., Андрієвський В.П., Кравчук Р.П.

АНАЛІЗ ВЛАСНИХ КОЛИВАНЬ МОРСЬКОЇ СТАЦІОНАРНОЇ ПЛАТФОРМИ

Морські стаціонарні платформи є основними гідротехнічними спорудами для облаштування морських нафтогазових родовищ. Вони призначені для буріння свердловин, добування і підготовки нафти і газу, для закачування води в пласт, ремонтні роботи, підготовкисировини до транспортування. Споруди для розробки підводних родовищ є найбільш чисельною групою споруд на шельфі. Водночас такі конструкції є одними з найбільш складних і багато в чому проблематичних. Для уникнення загрози резонансу, який супроводжується різким зростанням значення амплітуди, дуже важливо знати періоди і частоти власних коливань споруди. В роботі досліджувався вплив піддатливості пальової основи на значення динамічних параметрів морської стаціонарної платформи з глибиною занурення 11 м. Аналіз власних коливань платформи на палях був проведений для двох її розрахункових скінченоелементних моделей: піддатливої, в якій взаємодію основи та пальового фундаменту реалізовано з використанням скінчених елементів, що моделювали пружний зв'язок між вузлами, та жорсткої, в якій палі були відкинуті, а платформа вважалась такою, що жорстко прикріплена до абсолютно нерухомого диска. Для кожної моделі досліджувалось перші дванадцять власних форм коливань. В перших двох формах власних коливань платформи приймала участь, в основному, тільки гнучка щогла зв'язку, в третій формі коливань приймала участь, в основному, лише консоль факелу, тому значення кутової частоти і відповідного періодуколивань не залежали від піддатливості опорної основи платформи. Для всіх інших форм власних коливань платформи врахування піддатливості опорної основи змінювало значення динамічних параметрів в 1,25-1,5 рази, що свідчить про необхідність врахування цього фактора при дослідженні напружено-деформованого стану елементів нафтовидобувної споруди.

Ключові слова: морська платформа, дискретна модель, частота коливань, період коливань.

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ANALYSIS OF NATURAL OSCILLATIONS OF THE OFFSHORE FIXED PLATFORM

Offshore fixed platforms are the main hydrotechnical structures for the development of marine oil and gas deposits. They are designed for drilling wells, the oil and gas extraction and preparation, the pumping water into a layer, the wells repair, the preparation of raw materials for the transportation.Structures for development of marine deposits are the most numerical group of offshore structures. At the same time, such structures are one of the most difficult and largely problematic. To avoid the threat of the resonance that is accompanied by the sharp increase in the oscillation amplitude it's very important to know values of periods and frequencies of natural oscillations of the structure. In this article the impact of the flexibility of the pile foundation on values of dynamic parameters of the offshore fixed platform with the depth of immersion 11 m were analyzed.The analysis of natural oscillations of the platform on piles was performed using its two discrete finite-elements models: the flexibility model,wherethe interaction of soil basis and piles was implemented by using of finite elements that simulated the elastic connection between joints,and the rigid model,where piles were rejected and the platform was considered to be rigidly attached to the absolutely immovable rigid body.For every model first twelve basic form of natural oscillations were analyzed. In first two models of natural oscillations of the platform took part basically only the flexible connection mast, in the third form of natural oscillations took part basically only the flambeau consoletherefore values of frequencies and periods of oscillations didn't depend on the flexibility of the supporting foundation of the platform. In all other forms of natural oscillations of the platform taking into account the flexibility of the supporting foundation changed values of dynamic parameters of 1,25-1,5 times that indicates the need to take into account this factor when analyzing of stress-strain state of members of the oil production structure.

Keywords: offshore platform, discrete model, frequency of oscillations, period of oscillations.

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Аналіз власних коливань стаціонарної нафтовидобувної платформибув виконаний з дослідженням впливупіддатливості пальового фундаменту на значення динамічних параметрів.
Табл. 2. Іл. 3. Бібліогр. 9 назв.

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The analysis of natural oscillations of the fixed oil production platform was performed with the research of the impact of the pile foundation flexibility on values of dynamic parameters.
Tab. 2. Fig. 3. Ref. 9.

Автор (науковий ступінь, вчене звання, посада): асистент кафедри будівельної механіки ОСТАПЕНКО Роман Миколайович.
Адреса робоча: 03037 Україна, м. Київ, проспект Повітряних Сил, 31, Київський національний університет будівництва і архітектури
Роб. тел. + 38(044) 2415412
E-mail: ostapenko.rm@knuba.edu.ua
ORCIDID: https://orcid.org/0000-0003-3770-9913

Автор (науковий ступінь, вчене звання, посада): кандидат технічних наук, доцент, доцент кафедри будівельної механіки КАРА Ірина Дмитрівна.
Адреса робоча: 03037 Україна, м. Київ, проспект Повітряних Сил, 31, КНУБА
E-mail: karaidknuba@tutanota.com
ORCIDID: https://orcid.org/0000-0002-6172-8797

Автор (науковий ступінь, вчене звання, посада): кандидат технічних наук, доцент, доцент кафедри будівельної механіки АНДРІЄВСЬКИЙ Віктор Петрович.
Адреса робоча: 03037 Україна, м. Київ, проспект Повітряних Сил, 31, КНУБА
E-mail: andriievskyi.vp@knuba.edu.ua
ORCIDID: https://orcid.org/0000-0003-4700-997X

Автор (науковий ступінь, вчене звання, посада): магістрант кафедри будівельної механіки КРАВЧУК Роман Петрович.
Адреса робоча: 03037 Україна, м. Київ, проспект Повітряних Сил, 31, КНУБА
E-mail: kravchuk_rp@knuba.edu.ua