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Developing methodology for model tests of floating platforms in low-depth towing tank

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ABSTRACT

The paper presents two different methods of physical modeling of semi-submersible platform mooring system for research in low depth towing tank. The tested model was made in the scale of 1:100 resembling the "Thunder Horse" platform moored in the Gulf of Mexico at a depth of 1920 m. Its mooring system consisted of 16 semi-taut mooring lines (chain-wire-chain) spaced star-shape and attached at the bottom to suction piles. The tests were performed in the towing tank of the Gdansk University of Technology (GUT). The tank depth is 1.5 m and which is about 13.5 times less than that required for typical model tests. This required the development and use of non-standard methods of mooring for the model, which was adapted to the technical conditions existing in the laboratory and material possibilities. Numerical calculations and characteristics of static displacement of the model as a function of the external horizontal load were carried out for both anchoring systems. These characteristics were scaled to the natural conditions and compared with the calculated characteristics of the reference platform. The second method of modeling proved to be much more accurate.

1. Introduction

The ever increasing demand for energy coupled with the shrinking volume of land-based energy resources is stirring a constantly growing interest among coastal countries in making use of vast reserves resting under the bottoms of seas and oceans. Seabed resources have been exploited for many years now, however, due to high costs as well technical and environmental problems the extraction efforts have been largely limited to relatively shallow bodies of water. Drilling and extraction works were initially conducted from fixed, steel or concrete platforms or jack-up rigs. As the depths increased, various floating vessels started to be employed, consisting mostly of semi-submersible or SPAR type platforms, as well as drillships.

In Fig. 1 there are some of the above-mentioned solutions presented along with their anchoring systems.

At the present time, we are witnessing intensive development of this economic sector marked by attempts directed at reaching for less accessible resource deposits. The world's richest countries and major corporations invest enormous amounts into research and development, as well as design and construction of equipment allowing for oil and gas extraction

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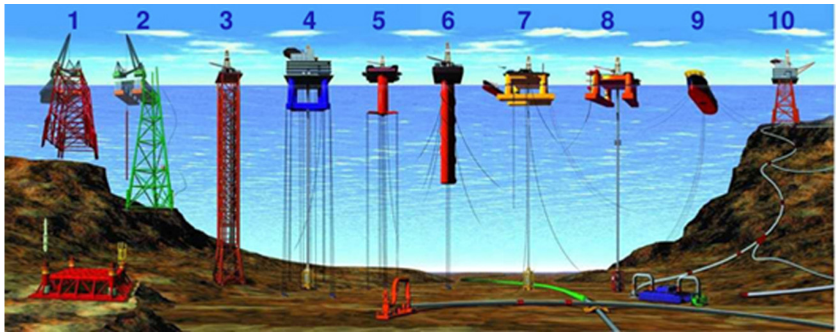

Fig. 1 – Offshore structures: (1, 2) conventional fixed platforms; (3) compliant tower; (4, 5) vertically moored tension leg and mini-tension leg platform; (6) spar; (7, 8) semi-submersibles; (9) floating production, storage, and offloading facility; and (10) sub-sea completion and tie-back to host facility [12].

from seabeds located in zones of more adverse climatic conditions and at increasingly greater depths. One may well take notice of the fact that these challenging depths and weather conditions force constant development of extraction and construction techniques. This includes, the mooring methods, meaning in general, the systems aimed at maintaining the position under varying operating and sea conditions. This area has been explored by a number of leading scientific centers conducting numeric and model based research. The results of these studies, concerning mooring line systems are presented, among others in the works of [2–4].

It should be emphasized, that in case of floating objects, the highest requirements regarding maintaining position relative to seabed must be met by vessels from which drilling works are conducted. According to the requirements of API (American Petroleum Institute) the maximum horizontal displacement during operations may not exceed 5% of the water depth, and 7% for survival conditions. Similarly, the minimum safety coefficients of mooring lines set on the basis of analysis taking into account dynamic phenomena may not be lower than 1.67 for operating conditions and 1.25 for survival conditions.

The most common mooring solutions for semi-submersible platforms and drillships have till now consisted of tethering systems, with chains used for lower depths and chain-ropes for greater ones. Along with increasing mooring depths, the non-tension systems (Cattenery) were abandoned in favor of partially tensed systems usually employing steel cables. Plastic ropes despite their obvious advantages, such as low weight, convenience of service and high elasticity allowing for decreasing the tension member length have till now been employed quite rarely, usually as additional elements working alongside traditional mooring lines. The reason behind this is their ongoing high cost, lack of experience concerning behavior over long periods of operation, as well as excessively high elasticity causing problems in ensuring acceptable range of platform deflection under extreme sea conditions [6].

Another example of anchoring solution is the tension-leg platform mooring system (TLP), where as a rule, the tethers are replaced by columns attached flexibly on the top side to the platform and at the bottom to specially prepared foundations. The system has proved itself to be advantageous for rather moderate depths.

In case of operations executed at significant depths, far from land and for shorter periods of time it is beneficial to use drillships or relatively mobile semi-submerged platforms equipped with dynamic positioning systems. However, for operations planned with long time periods in mind, especially in regions with challenging weather conditions, the tension tether based mooring systems have proved to be most effective.

Among the currently employed floating platforms anchored at large depths one may discern two essential types, as shown in Fig. 1. These are semi-submersible platforms characterized by the cross-sectional area of the hull at the waterline being considerably smaller than in the underwater part, as well as SPAR type platforms in which the entire hull has the shape of a vertical cylinder of practically constant cross-sectional area. Both these types of platforms have recently been the subject to numerical calculations and model tests. The results are shown among others in the publications [1,11,7,8]. SPAR platforms have simpler construction and are less expensive. At the same time, their draught is as much as few times larger than in case of semi-submersible platforms which makes their independent movement practically impossible. Semi-submersible platforms on the other hand, depending on the hull shape below the waterline and equipment level, may move either on their own or using tug boats. This ability makes them a more universal solution, allowing for conducting drilling operations over a certain area or in just a single location, which may be the reason why they continue to remain the most popular rig type in the industry. This fact combined with greater reliability and position stability requirements placed on these structures, explains why this platform type was selected by the authors as the object of numeric and model based research.

The *Thunder Horse* semi-submersible oil platform, anchored in the Gulf of Mexico – one of the largest and most modern examples of this platform type was selected as the standard model for verifying calculations and model tests. Shortly after its installation, following Hurricane Dennis in 2005, the Thunder Horse fell into a 20° list and was under the danger of foundering. This incident resulted in considerable amount of significant and normally unavailable information, appearing in scientific-technical publications on the platform's