ABSTRACT

There are some offshore oilfields that have comparatively low shear strength cohesive soils in China, which means very deep penetration for most of the jack-ups. To develop these fields more efficiently, a kind of big-foot jack-up is introduced. A larger spudcan may result in shallower penetration but larger extraction resistance, which may make the jack-ups difficult to pull out. To evaluate the operating capability of the big-foot jack-up, both the penetration and extraction capability at all well sites of offshore China are calculated. It is shown that larger spudcans enable the rig to penetrate much shallower in soft soils, and the possibility of punch-through in all fields is reduced too. To improve the extraction capability of the rig, the jetting system is redesigned based on finite element simulation and lab experiment. By investigating the structural strength with environmental data, it can be concluded that big-foot rig could be operated at most of China’s offshore fields in moderate weather.

KEY WORDS: big-foot jack-up; penetration; extraction; operating capability

INTRODUCTION

After decades of development, jack-up drilling units are now widely used in shallow water for its reliability and economic efficiency. And with support of diverse kinds of spudcans, jack-ups gain great operating capability at sites ranging from soft to strong soil layers. However, there also exist great challenges for jack-ups to install on some very soft clay sites, such as field DF. Field DF is a great gas field operated by China National Offshore Oil Company Limited and located at western South China Sea. China Oilfield Services Limited (COSL) owns 29 jack-ups, but few of them are able to install there. HYSY941, a JU2000E rig and one of COSL’s most advanced offshore rigs, failed to install at DF in 2006.

To meet the requirements of field DF, it is necessary to design and build a new jack-up rig to operate at sites of very soft soil. A special big-foot jack-up is designed. It is a three legs cantilever jack-up, with a maximum operating depth of 121.9m (400ft). The rig has very large rectangular spudcans, cross-sectional area of each spudcan being 395m$^2$ and the ultimate bearing pressure being 250kPa. However, large spudcan may result in large extraction difficulties. So, is it possible to uplift successfully from the soft soil?

More than 20 sites from several offshore oil fields are chosen for the evaluation of the big-foot jack-up’s operational capability. Both the penetration depth and extraction resistance of the rig are evaluated. Penetration depth is calculated based to Bulletin 5-5A of Society of Naval Architects and Marine Engineers (SNAME) and Chinese industrial specification of SY/T 6707. The penetration process is also simulated with ABAQUS (ABAQUS, 2010). The extraction resistance is calculated theoretically and numerically. At all the sites, the penetration depth and extraction resistance of the big-foot jack-up are compared with those of other two jack-ups, i.e. HYSY937 and HYSY941. Quoted from the operating manuals, the equivalent cross-sectional diameters of the spudcan, the maximum preload and uplift capacity of the three units are listed in Table 1.

Table 1 Basic information of the three jack-up units

<table>
<thead>
<tr>
<th>Unit</th>
<th>HYSY937</th>
<th>HYSY941</th>
<th>Big-foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>GustoMSCCJ46</td>
<td>Freddie &amp; Goldman JU 2000E</td>
<td>--</td>
</tr>
<tr>
<td>Equivalent spudcan diameter (m)</td>
<td>13.82</td>
<td>18.0</td>
<td>22.4</td>
</tr>
<tr>
<td>Maximum preload per leg (t)</td>
<td>7900</td>
<td>11200</td>
<td>9900</td>
</tr>
<tr>
<td>Uplift capacity per leg (t)</td>
<td>5000</td>
<td>6100</td>
<td>6440</td>
</tr>
</tbody>
</table>

PENETRATION DEPTH

Theoretical Method

Numerous researches have been done to study the bearing capacity of spudcan foundation (Skempton, 1951; Vesic AS, 1975; Young AG et al., 1984). And some classical and robust results have been adopted in widely used specifications. A brief introduction of main methodology used is presented in this section.

$SY/T\ 6707$. $SY/T\ 6707$ recommends Eq. 1 to calculate the overall bearing capacity of the spudcan foundation.

$$Q = q_s A + \gamma V$$

(1)

where $Q$ is the overall bearing capacity of spudcan, $q_s$ is the unit bearing capacity, which has different formulas for cohesive and noncohesive soil, $A$ is the maximum cross-sectional area, $\gamma$ is the average effective unit weight of the soil replaced by spudcan, and $V$ is the volume of the spudcan. It can be seen that Eq. 1 is similar with that of API RP 2A-WSD(R2010).