Implementing Self-upending for lightweight Jackets in Persian Gulf

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ABSTRACT: Steel-structured jacket or template platforms have been extensively installed in Persian Gulf offshore oil & gas fields. For the jackets in the water depth range of 40 meters in this region, utilizing the self-upending concept has been investigated. It has been concluded that designing the light weight jackets, implementing the self-upending process for their installation operations, are economically and practically more convenient than the usual crane-assisted up-ending methods. Two methods of self-upending for light weight jackets have been presented in this paper. In first method self-upending is implemented without using ballast systems and in second model self-upending is implemented with ballast systems. Considering the required number of new installations for the “new” as well as “brown-bag” projects, and considering the existing problems and difficulties for the available marine spread, especially ready-to-work heavy floating cranes, utilizing this concept in the offshore industry for light weight jackets seems to be a considerable break-through.

Keywords: lightweight jacket; upending; launch; installation

INTRODUCTION

“Jacket” or “template” platforms have been used successfully and extensively in the Persian Gulf oil & gas platforms. Each platform structure is composed of two parts, namely sub-structure and super-structure. The equipment and the facilities required in the processing of the extracted hydrocarbons (crude oil or gas) are generally supported by the super-structure. This part of the platform structures is located well above the seawater surface, so that the installed machinery, equipment and facilities as well as their operating personnel could safely work on it.

Super-structure is supported by the lower portion of the platform structure, namely sub-structure. Hence sub-structure transfers the loads from the super-structure, as well as the loads imposed on itself, to the seabed. For the platforms concerned in this study, the sub-structures are composed of a space frame constructed of welded structural-steel tubes, in the form of a prismatic or conical three-dimensional space truss, supporting the super-structure. This frame is composed of several (3 to 8) numbers of legs, extending from the seabed all the way to top of the sea surface. This pre-fabricated space frame is supported on the seabed by means of tubular steel piles driven into them, from the specialized marine spread. The driven piles are extended well-enough into the seabed and to the pre-determined depth, so that all the structural loads of the platform could be safely transferred to the seabed subsoil. Generally the super-structures have the same number of legs as the sub-structures supporting them; and they are coincident at the upper-ends of the sub-structure (jacket) legs.
MATERIALS AND METHODS
As the super-structures of the platforms could have different functions, shapes and dimensions, and the main investigations in this study concern the jacket installation, this report will concentrate merely on jacket sub-structures.
A typical jacket sub-structure and the different stages of its fabrication and installation, has been depicted in Fig. 1. The different stages of the jacket construction are:

1. Fabrication in fabrication yard;
The jackets are generally fabricated in a horizontal position at the fabrication yards. If the jacket is meant to be launched into the water, there will be a pair of “launch trusses”, on which the jacket will be fabricated, as well as facilitating the launch of the jacket from the launch barge into the water.

2. Load-out to the carrier or launch barge;
If the jacket is of the launch-type, the launch trusses enable the load-out of the jacket into the launch barge. In this case the jacket is pushed towards the skid-ways on the launch truss, by means of the pulling mechanisms (located either on the launch truss in the form of “push-pull systems”, or by means of pulling winches on the shore side connected with proper rigging to a pair of sheaves blocks on the barge). Other pushing devices such as tractors or winches located on the barge could also be employed.
At the other hand if the jacket is not required to be launched, it is designed to be lifted or transported (by bogies with especial synchronized wheel axles) to the carrier barge. In both of the said cases specialized machinery with rather expensive hiring rates are required. Also in this case at least four pieces of specialized pad-eyes, for lifting the jacket, is required to be welded to the proper places on the outermost top legs of the jacket.

3. Transportation of the jacket to the installation site;
After the completion of a proper sea-fastening and lashing of the jacket to the launch barge or carrier barge, the barge is towed to the offshore installation site. In general for the jackets that are loaded out over the skid-ways of the launch barges, much less material is required for the sea-fastening.

4. Launching or lifting the jacket into the water;
When the carrier or launch barge at installation site, if the jacket is required to be launched into the sea, the launch riggings from the barge winches will be connected to the jacket launch lugs (on the launch trusses), and after the launch barge assumes a certain pre-determined trim, the sea-fastenings are caught and the launching process will proceed.
If the jacket is not of the launch type, generally heavy floating crane(s) shall be mobilized to the installation site, and after connecting the lifting riggings to the jacket, lifting from the barge and lowering into the seawater will proceed.

5. Up-ending process of the jacket and putting it on the pre-determined location of the seabed;
When the jacket is launched / lifted to the sea, generally it assumes a horizontal position (due to its own reserve buoyancy). Hence the floating crane(s) (the same mobilized to the offshore installation site for the jackets to be lifted from the carrier barge, or another floating crane to be mobilized in case of a launch type jacket) will assist the jacket for upending while controlled ballasting is carried on.

6. Driving the piles and fixing the jacket to the seabed;
7. Complementary and commissioning works. Of all the above stages of jacket installation, stages 2.4 and 2.5 will be combined into a single stage and stage 2.5 will be omitted, if the “upending concept” is utilized in the design and construction of the jackets. Nevertheless omission of this single stage will result in a considerable saving in the expenditure of the project, as will be explained below.

Description of “Self-Upending Concept”
What is meant by self-upending is to add removable buoyancy tanks in the quantity and pre-determined locations, so that the launching trajectory of the jacket in the water will end up in a near-vertical floating jacket.

Implementing the” self-upending” concept for some existing jackets
In this section two actual cases have been investigated as follows.
RESULTS AND DISCUSSION

1. Example A: Jacket in 37.6 m water depth

Method 1

Self-upending concept has been implemented for a 662-ton Jacket in Persian Gulf (Amid, 2016); the Software Sacs is implemented to perform 3-D Time-domain Launch and Self-upending Analysis (Bentley Systems Incorporated, 2014). In this method jacket is self-upended without ballast systems and it launches in water depth of 40 meters with orientation of 82 degrees. Fig. 2 shows the trajectory of the jacket as has been calculated in Launch Analysis. Buoyancy tanks with dimensions of 2 m outside diameter and wall thickness of 1.5 cm with total weight of 86 Tons are used to assist the jacket up-ending. Four phases are considered in the launch analysis, tipping position occurs at time 113 sec. Table 1 depicts the involved time-steps and their corresponding positional quantities for the center-of-gravity of the jacket, where at the last time-step (final up-ending position), the associated bottom clearance and inclination angles for the jacket in 40m water depth could be observed. The minimum bottom clearance during the launching process is 5.45 meters occurring 150 seconds after the launch is commenced. Whereas the jacket upended position, assumes a greater clearance than the minimum criteria, which is 5 m. Fig. 3 shows the final upended free floating Position of Jacket in water depth of 37.6m. As it could be examined, the transverse as well as longitudinal metacentric heights are 4.46 m and 6.53 m correspondingly, which are well above the minimum criteria of 0.5 m and 0 (Noble Denton Marine Services, 2015). In order for the jacket to assume its vertical position, two legs of the jacket have
been flooded with the ratio of 60%. Fig. 4 shows the final vertical position of the Jacket ready to be positioned on the seabed. Longitudinal and Transverse metacentric heights during flooding the legs with ratio of 60% are shown in Fig. 5 and 6. As it could be examined, the transverse as well as longitudinal metacentric heights are 0.69 m and 4.49 m correspondingly before positioning the jacket on the seabed which are well above the minimum criteria of 0.5 and 0 (Noble Denton Marine Services, 2015). Fig. 12 shows jacket model with buoyancy tanks.

2. Example A: Jacket in 37.6 m water depth
Method II
Self-Upending concept has been implemented for this jacket in Persian Gulf. In this method jacket is self-upended using ballast systems and it launches in water depth of 37.60 meters with orientation of 46 degrees. The Software Sacs is used for the launch analyses (Bentley Systems Incorporated, 2014). Fig. 7 shows the launch trajectory of the jacket, and Fig. 8 depicts the free-floating position of the jacket in water depth of 37.6 m. As it could be observed, the transverse and longitudinal metacentric heights are 1.44 m and 2.07 m accordingly, which are greater than the required minimum values of 0.5 m and 0 (Noble Denton Marine Services, 2015). Table 1 shows the jacket launch analysis results in 37.6 m water depth. Two legs of the jacket need to be flooded with a ratio of 100%. Fig. 9 depicts the final position of the jacket ready to be placed on the seabed. Longitudinal and Transverse metacentric heights during flooding the legs with ratio of 100% are shown in Fig. 10 and 11. As it could be examined, the transverse as well as longitudinal metacentric heights are 3.14 m and 4.73 m correspondingly, before positioning the jacket on the seabed which are well above the minimum criteria of 0.5 m and 0 (Noble Denton Marine Services, 2015). Buoyancy tanks with outer diameters of 2 m and wall thickness of 1.5 cm with a total weight of 104 Tons are implemented in the design. Fig. 13 shows jacket model with buoyancy tanks.

3. Design of Buoyancy Tanks
Two types of buoyancy tanks are designed according to DNV-RP-C202 (DNV Recommended Practice, 2013) as stiffened circular cylindrical shells for jackets and are stiffened by ring frames. Table 2 depicts dimensions and weight of each buoyancy tanks. Three main buckling modes for stiffened cylindrical shells are controlled, shell, panel ring and column buckling. Buoyancy tanks are designed for a depth of 60 meters for both examples.

<table>
<thead>
<tr>
<th>Table 1: Launch results</th>
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<tbody>
<tr>
<td><strong>Jacket Example A Model I</strong></td>
</tr>
<tr>
<td>Time (sec)</td>
</tr>
<tr>
<td>139</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>164</td>
</tr>
<tr>
<td>171</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2: Buoyancy tanks specifications</th>
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</thead>
<tbody>
<tr>
<td><strong>Example A Type 1</strong></td>
</tr>
<tr>
<td>Outside diameter (mm)</td>
</tr>
<tr>
<td>Wall thickness (mm)</td>
</tr>
<tr>
<td>Average unit weight (Kg/m)</td>
</tr>
<tr>
<td>Total weight (Tons)</td>
</tr>
</tbody>
</table>
Fig. 2: Launching trajectory of the jacket, example A

Fig. 3: Free floating position for the jacket, example A, at the installation depth

Fig. 4: Jacket ready to be placed on the seabed
Fig. 5: Longitudinal Metacenter during upending, jacket example A

Fig. 6: Transverse Metacenter during upending, jacket example A

Fig. 7: Trajectory of jacket example A Model II
Fig. 8: Floating position of the jacket at the end of the launch model II

Fig. 9: Ready to be placed on the seabed Model II

Fig. 10: Longitudinal Metacenter during upending, jacket example A model II
Comparison of Self-upending Method and the Conventional Methods (Crane-Assisted Upending)

The considered jackets in the above examples (designed with the self-upending concept) are compared with the conventional (crane-assisted upending) cases in Table 3 below. The following assumptions have been made:

- 4.00 USD cost each kg of the fabricated structures;
- Each buoyancy tank is assumed to be used in at least four projects, hence only 25% of their fabrication costs for the above example have been considered;
- Minimum rental duration of 10 days for hiring of the floating cranes, for performing the up-ending process (including Mob./Demob., bad weather and etc.), has been assumed;
- For the smaller jacket a daily rental rate of 120'000 USD, has been assumed.

Buoyancy tanks are selected and designed in an optimal as well as modular manners, so that they could be used for other projects as well, (total weights of BT for example A= 86 tons). Please refer to Fig.s 12 and 13 below.

CONCLUSION

Implementing the self-upending concept, in the design of the jackets is quite attractive due to the following reasons:

I. This method is quite economical for lightweight jackets (it should be noted that in the above example, we utilized the jackets that were not meant to be launched and self-upended. If the self-upending concept was to be employed from the first stages of their designs, definitely more economical gains could have been resulted). Please refer to Table 3, for comparison.

II. Two methods of self-upending have been presented for lightweight jackets. In model I jacket must be launched in water depth of 40 meters, in model II jacket should be launched in water depth of 37.60 meters

As it could be clearly observed, it is more economical to design the jackets with self-upending concept, rather than implementing the conventional crane-assisted up-ending operations.
Table 3: Cost comparison

<table>
<thead>
<tr>
<th>Costs</th>
<th>Example A Model I</th>
<th>Example A Model II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional B/L Weight</td>
<td>21.5 Tons</td>
<td>26 Tons</td>
</tr>
<tr>
<td>Cost</td>
<td>86'000$</td>
<td>104'000$</td>
</tr>
<tr>
<td>Additional L/T Weight</td>
<td>106 Tons</td>
<td>106 Tons</td>
</tr>
<tr>
<td>Cost</td>
<td>424'000$</td>
<td>424'000$</td>
</tr>
<tr>
<td>Total Cost</td>
<td>510'000$</td>
<td>528'000$</td>
</tr>
<tr>
<td>Benefits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crane Saving Duration</td>
<td>10 days</td>
<td>10 days</td>
</tr>
<tr>
<td>Cost</td>
<td>1'200'000$</td>
<td>1'200'000$</td>
</tr>
<tr>
<td>Total Saving</td>
<td>690'000$</td>
<td>671'000$</td>
</tr>
</tbody>
</table>

Fig. 12: Jacket model example A Model I, with the proposed buoyancy tanks

Fig. 13: Jacket model example A model II, with the proposed buoyancy tanks
REFERENCES

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