Offshore platforms have been used since the 60’s (and impulse in the 70’s by the oil crises) in the exploration and production of oil and gas in the North Sea. Offshore structures are usually fixed platforms supported on pile foundations, built primarily on steel. These structures have not been economical feasible to explore marginal fields in the North Sea, mainly due to its high costs of installation and removal. Thus, an innovative self-installing platform, capable of being easily relocated when the field runs dry, was designed and built for the Dutch sector of the North Sea.

However, as usually occurs in the developing projects, the self-installing platform still faces some engineering issues, mainly when it comes to support the impact of cyclic environmental loads, such as winds and waves. The lack of legs bracing and the fact that the entire structure (topside and legs) work together as a portal frame results in: (a) a decrease of the first frequency modes that affects the structure fatigue life; and also that (b) the fatigue loads go through to the structure topside.

This study presents and analysis several variant structural solutions for the self-installing platform, using the F3-FA platform project layout, both the design basis and the geometrical configuration; and incorporating different key structural solutions in the design with the aim of improving its dynamic behaviour and, by consequence also, its fatigue performance.

1. INTRODUCTION

1.1. GENERAL CONSIDERATIONS

Offshore platforms are supporting structures placed in marine environment. The most common type of offshore platform is a fixed platform that extends from the seabed to a certain height above the sea surface, often consisting of a steel tubular structure called the jacket (Figure 1.1a).

The F3-FA\textsuperscript{1} platform is a pioneer fixed platform, one of a kind in the North Sea, built to be a re-usable gas production platform, using an innovative structural concept for offshore structures called the self-installing platform (SIP) (Figure 1.1b). The company IV-Oil & Gas [1] has developed a self-installing platform for the F3-FA project with the topside of 4,000 mT, in a total weight of 9,000 mT, including legs and foundations. This structure was designed for 40 meters water depth, for the severe environmental conditions of the North Sea and being prepared for re-usage.

\textsuperscript{1}The offshore platform name came from its initial design location site.

The F3-FA platform is already in service after its successful installation.

1.2. GOAL OF RESEARCH

Due to the innovation of the solution combined with the tight planning of the original project, the F3-FA design of the SIP has not been developed fully efficiently. The structural layout and the dynamic behavior are the main aspects under investigation in the
master thesis; the two combined may significantly improve the fatigue performance of the structure.

The impact of environmental loads in an offshore structure will generate considerable time-variable stresses, which may lead ultimately to fatigue failure. Indeed, the dynamic behavior is decisive in the fatigue performance and design of the structure.

Therefore, the main objective of the master thesis is to improve the dynamic behavior of the F3-FA platform, by proposing solutions to its design layout that can minimize the dynamic effects due to wave loading and therefore, at the end, reduce fatigue issues of the platform.

To achieve the main objective:
1) The F3-FA platform layout is used: basis of design, structural model build with SACS software [12] and as-built structural drawings;
2) A simplified structural model of the F3-FA is re-built based on the original F3-FA SACS model;
3) The re-built F3-FA SACS model is compared with the original model, to guarantee the feasibility of the study;
4) Different key structural alternative solutions are incorporated, in the geometric structure configuration of the re-built model, with the aim of improving the dynamic sensitivity of the platform to wave loading;
5) The re-built F3-FA model is used as a model of reference to compare the different structural solutions, and two main results are compared: frequency modes and structural weight.

2. SELF-INSTALLING PLATFORM (SIP)

The F3-FA platform main components are shown in Figure 2.1.

2 SACS Offshore Platform Structural Design & Analysis Software and abbreviated to SACS [12] is a structural engineering software that supports the design and analysis of offshore structures.

2.1. STRUCTURE

Topside

The F3-FA topside is a three dimensional portal frame structure. The main steel structure comprises two longitudinal frame trusses, in row 1 and row 3, and five transversal ones in the rows A1, A, C, E and F (Figure 2.2). The three important decks, cellar deck, main deck and top deck, complete the horizontal elements of the primary framing.

The decks consist of welded beam grids made of main HEB profiles and IPE stringers, both supporting a orthotropic steel plate on the upper flange.

The integration of the legs with the topside is made by four tubular sleeve sections incorporated between the top and the main deck, at the corners of the topside.

Topside key dimensions (Figure 2.2):
- Length = 40.630 m (dist. between rows A1 and F);
- Width = 25.250 m (dist. between columns);
- Height = 20.5 m (between cellar deck and helideck);
- Long. spacing between legs axis = 36.430 m;
- Lateral spacing between legs axis = 20.750 m.

Substructure

Large 3250 mm diameter tubes formed the four legs on the platform corners. The legs are named after their close position to the inter-section of rows A1, A3, E1 and E3 (Figure 2.2).

At the sea bottom, each leg is connected to a suction bucket. A transition frame (also known as knuckle joint) allows the bucket circumference to be eccentric from the leg axis, by distributing the platform loads to the buckets (Figure 2.3).
Substructure key dimensions:

- Leg’s diameter = 3.25 m;
- Leg’s height = 78.020 m;
- Knuckle joint height = 18.370 m.

iii. The pressure inside the caisson will drop causing a massive suction force downwards;
iv. This suction force, caused by the difference between the bucket inside pressure and the hydrostatic pressure, induces the bucket to penetrate further into the seabed.

When the bucket penetrates the soil, the skin friction is mobilized along the bucket wall surface and the soil tip resistance in the wall sleeves toe. Under tension, the suction bucket resistance is given by the skin friction resistance mobilized along the bucket wall surface and the bucket self-weight \(^3\). By simply reversing the process, the bucket can be rapidly removed by putting pressure inside the caisson, the overpressure created will cause a vertical lifting force and the suction bucket is removed intact to be reused.

**Leg-topside connection**

The F3-FA platform is connected in two different elevations between the topside and the substructure, as shown in Figure 2.5. On the top, legs are rigid connected to the topside using pretension bolts – known as superbolts\(^3\). These particular bolts, due to their considerable size, are fixed by a number of 36 smaller bolts, known as jackbolts, to ease the necessary torque force and ensure a stiffer connection.

To guide the legs, from the top to the main deck, tubular sleeves are bonded to the topside by four vertical shear plates transferring the vertical loads to the deck framing.

On the cellar and lowest deck, due to restrictions on the space available, a connection offshore is accomplished with a simple clamp, to avoid lateral movements of the legs due to the wave impact and transferring only horizontal loads.

**2.2. CONSTRUCTION, TRANSPORT AND INSTALLATION**

Topside and legs were built separately and attached together on the yard. Similar procedure was followed with the knuckle joint and suction buckets.

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\(^3\) Superbolts or multi-jackbolt tensioners are an alternative safe solution to a single enormous size bolted joint by the use of several smaller jackbolts reducing the torque force and size. For the F3-FA platform 16 superbolts M240 were used to support the topside.
Figure 2.6: Legs installation

Afterwards, the topside was transported to the barge, in a process known in the offshore industry as loadout. The Heerema H-541 was used as an intermediate barge from where the platform could roll over to the final transport barge BOA 35, as shown in Figure 2.7.

Figure 2.7: F3-FA platform moving to the H-541 barge

The final part in completing the F3-FA platform is to add the suction buckets to the platform. This phase is called mating and required the use of the floating crane Matador 3. The lifting vessel picks up the suction bucket with the knuckle joint from the quay and transported to the exact position in the F3-FA where they were welded together, as presented in Figure 2.8.

Figure 2.8: Matador 3 with suction bucket and knuckle joint

The platform was then transported to the final destination. The barge was positioned, with the help of tug boats, the suction pumps were installed on the caissons and the platform legs were lowered into the seabed using the strand jacks, after the sea fastenings were released (Figure 2.9). Once the suction buckets were fixed the topside was jacked to its final elevation.

The final stage was the installation of the superbolts and setting up of the clamp system filled in with rubber blocks to absorb wave impact loads (Figure 2.10).

Figure 2.9: F3-FA platform installation sequence

Figure 2.10: F3-FA clamp system installation

The F3-FA platform was installed in September 2010 and in the following month the first well was opened with the drilling rig Noble Scott Marks and the first gas came on January 2011.

2.3. ADVANTAGES

Important benefits can be obtained by using the SIP platforms, such as:

a) the no need of expensive heavy lift vessels for transportation and installation of the platform;

b) the easy installation of the platform (substructure and topside) in only one piece in a short time;

c) the use of suction technology instead of piles for the foundation execution, reducing environmental issues concerning both the energy consume and noise creation;

d) the potential of re-use of the self-installed platform, transforming the cost-effective panorama of the offshore oil and gas field industry, and reclassifying the so called “marginal fields”.

2.4. ENGINEERING ISSUES

One of the main differences of the SIP platforms with respect to the traditional installed platforms is the fatigue loads going through the topside of the structure.

In a traditional jacket platform the vertical loads due to weights and live loads are transmitted throughout the legs to the sea floor and the lateral horizontal loads, mainly due to waves, are supported by leg bracings, which in turn will transmit them to the sea floor. Admitting that the topside is stress free for lateral

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4Marginal fields refers to an oil or gas fields that may not produce enough net income to make them worth developing at a given time, special due to technical and economic conditions.
loading, only the legs and braces are designed for the dynamic horizontal loads affecting the fatigue life of the jacket.

In a SIP platform, however, the entire structure (topside and legs) will work together in a behavior similar to a portal frame with no stabilizing braces. This means that also the topside is loaded with cyclic wave loads which result in a fatigue design required also for the topsides.

Figure 2.11 presents a very simple static example and the resulting bending moment diagram (BMD), comparing the behavior of a traditional offshore structure with a SIP platform, when submitted to lateral loads. The topside of the portal frame will be subjected to stresses, due to a horizontal force applied, unlike the cantilever structure (simulating the behavior of the jacket platform).

![Figure 2.11: a) Jacket platform; b) SIP platform](image)

Last but not least, the lack of braces restraining the legs (substructure stiffness is lower) will decrease the first frequency modes of the structure resulting in a lower fatigue life when compared to a jacket platform. As a result SIP platforms are more likely to be sensitive to fatigue issues and therefore need a careful design with respect to this important structural design requirement.

3. RE-BUILT F3-FA MODEL

3.1. MODEL GEOMETRY

The re-built F3-FA model geometry is based on the F3-FA as-built drawings and original SACS model. All primary steel structure is modelled with line members and the deck plating as plate elements.

The main difference between both models is the mezzanine deck and intermediate deck, modelled in the original model but not in the re-built model.

3.2. DESIGN ACTIONS

All relevant design loads, such as permanent loads, live loads and environmental loads are considered.

In a practical and conservative approach, the environmental loads are considered collinear, combined with their maximum values and cover eight different directions around the wind rose.

Special attention is given to the hydrodynamic loads responsible for the biggest stresses and fatigue assessment for the overall platform.

The hydrodynamic loads are caused by waves and currents, plus they are represented by distributed load diagrams, applied to the platform substructure legs, which increase exponentially with the water column elevation (Figure 3.2). The wave loads are calculated based on a theoretical wave model that best describes the sea state motion. The current velocities are collected on site, per elevation, and added to the wave velocities.

![Figure 3.2: a) Hydrodynamic loads diagram](image)

The F3-FA structure response to wave loading is more sensitive than a typical jacket platform. Due to a less stiffer substructure the platform has a higher natural period, closer to the wave period, resulting in greater deformations and stresses due to the wave forces.

The dynamic amplification factor (DAF) accounts the structure dynamic response, measuring the ratio between the dynamic response and the static response of the structure. In the F3-FA project, the dynamic load effect is considered through the structure modal response.

3.3. BASIS OF ANALYSIS

**In-place analysis**

The in-place analysis covers the stress and buckling check of all structural members and the strength and stability integrity of the global structure for operational and survival conditions.

The normal operating condition covers the 1 year return period and the survival condition the 100 years return period for wind, current and wave actions.
The topside permanent and live loads are combined with the environmental actions. All structural members are checked according to API [7/] and AISC [10/]. Particular attention is given to the legs design, and an example of the buckling and stress check for cylindrical members, is given in [1/].

**Fatigue analysis**

The fatigue analysis evaluates the damage caused by the cycling wave loads for the overall main structure F3-FA critical welded joints of the leg butts. A spectral fatigue analysis considers the stochastic properties of the waves.

The fatigue assessment is based on a stress analysis of the structure and can be summarized as follows:
1) For a given cyclic load a certain stress range can be determined;
2) The number of cycles for failure can be specified based on a logarithmic relation with the stress range, known as S-N curve;
3) The expected damage is given by the ratio between the number of cycles likely to occur for the cyclic load in a year and the number of cycles for failure;
4) The total damage is obtained by the sum of the expected damage for all cyclic actions considered;
5) The design fatigue life is known by multiplying the structure design lifetime by the inverse of the total damage.

The fatigue assessment is performed on the offshore structure joints and welds, where the material imperfections are critical. To account for stress concentrations the nominal stress ranges are multiplied by a stress concentration factor (SCF).

### 3.4. COMPARISON RESULTS

Three parameters of high importance for the study are presented for comparison of the original with the re-built F3-FA SACS models: frequency modes, loads and fatigue analysis results.

**Loads**

The loads applied in the re-built F3-FA SACS model present minor differences to the original model.

**Frequency modes**

The frequency modes comparison results are presented in Table 3.1 and indicates irrelevant differences between both models.

**Fatigue analysis results**

Table 3.2 presents a comparison between the original and the re-built F3-FA SACS model for the fatigue analysis results of the welded joints considered in this study, i.e. substructure butt weld joints.

<table>
<thead>
<tr>
<th>Mode shape</th>
<th>Natural period</th>
</tr>
</thead>
<tbody>
<tr>
<td>--</td>
<td>Re-built F3-FA model</td>
</tr>
<tr>
<td>1</td>
<td>2.67 s</td>
</tr>
<tr>
<td>2</td>
<td>2.64 s</td>
</tr>
<tr>
<td>3</td>
<td>1.91 s</td>
</tr>
<tr>
<td>4</td>
<td>1.43 s</td>
</tr>
<tr>
<td>5</td>
<td>1.41 s</td>
</tr>
<tr>
<td>6</td>
<td>0.76 s</td>
</tr>
<tr>
<td>7</td>
<td>0.72 s</td>
</tr>
</tbody>
</table>

**Figure 3.3: Re-built F3-FA SACS model 3 first mode shapes**

**Table 3.2: Maximum fatigue lives [yrs.] comparison between the Original and the Re-built F3-FA SACS model**

<table>
<thead>
<tr>
<th>JOINTS</th>
<th>WALL THICKNESS</th>
<th>FATIGUE LIVES</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Elevation (m)</td>
<td>t1 (mm)</td>
<td>t2 (mm)</td>
</tr>
<tr>
<td>xx09</td>
<td>-35.670</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>xx11</td>
<td>-31.870</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>xx12</td>
<td>-29.310</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>xx13</td>
<td>-26.750</td>
<td>85</td>
<td>135</td>
</tr>
<tr>
<td>xx14</td>
<td>-24.325</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>xx15</td>
<td>-21.900</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>xx20</td>
<td>-26.000</td>
<td>95</td>
<td>135</td>
</tr>
<tr>
<td>xx21</td>
<td>-17.300</td>
<td>75</td>
<td>95</td>
</tr>
<tr>
<td>xx22</td>
<td>-13.300</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>xx23</td>
<td>-9.300</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>xx24</td>
<td>-5.300</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>xx25</td>
<td>-1.300</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>xx26</td>
<td>2.700</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>xx27</td>
<td>6.700</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>xx28</td>
<td>10.700</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>xx29</td>
<td>14.700</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>xx30</td>
<td>18.700</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>xxCD</td>
<td>20.305</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>xx40</td>
<td>22.700</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>xx41</td>
<td>26.700</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>xx42</td>
<td>30.700</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>xx43</td>
<td>34.700</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>xxTD</td>
<td>36.305</td>
<td>45</td>
<td>80</td>
</tr>
</tbody>
</table>

xx = A1, A3, E1 and E3, for legs A1, A3, E1 and E3 respectively.

**Conclusions**

The main conclusion is that the re-built F3-FA SACS model is a good reference model of the F3-FA platform, based on the comparison results with the original F3-FA SACS model.
4. STUDY OF POSSIBLE STRUCTURAL IMPROVEMENTS

Two key goals were established:
i) to improve the dynamic behaviour of the platform by increasing its natural frequencies for a better performance to fatigue loading;
(ii) to come up with structural alternative solutions to design features that faced some issues during the F3-FA construction / installation.

The main alternative design solutions studied are:
a) the exclusion of the transition frame (also known as knuckle joint) existing between the legs and the suction buckets. Will allow a better geometric configuration in the leg-topside connection, due to the restraints necessary during transport for the knuckle joint, over the smaller leg buckling length existing;
b) the increase of legs diameter, to increase the frequency modes of the structure that will affect the fatigue behavior of the platform;
c) a new leg-topside connection, to provide a more stiffer and robust link between the substructure and the topside, avoiding many expensive hours of offshore work to accomplish the present connection in the F3-FA platform.

4.1. KNUCKLE JOINT

The knuckle joint was primarily required to avoid a deep water seaport during the platform assembly and transport, trough eccentric buckets. Plus it provided the following benefits to the platform:
1) Increase the legs strength and stiffness, by decreasing their unbraced length;
2) Improve the F3-FA structure dynamic behaviour, through stiffness and lateral support.

During the F3-FA construction and installation, the knuckle joint proved not to be the desirable structural solution. The disadvantages of the knuckle joint were:
1) Extensive steel weight, welding work and lift requirements, resulting in considerable construction time and cost;
2) Substantial expensive offshore work, for the current F3-FA leg-topside connection to be compatible with the knuckle joint;
3) Fatigue critical tubular weld joints in the chord and brace members of the knuckle joint, according to the fatigue analysis report [6].

The re-built F3-FA SACS model was then adapted without the knuckle joint and with a centric suction bucket. For the buckets to be centred with the legs, and without changing the transportation, two structural alternatives are possible, as shown in Figure 4.1:
A) Buckets underneath the barge and shifted position to be centric with the legs;
B) Buckets side by side with the barge (as before) keeping the position, since the legs shifted to be centred with the buckets;

4.2. LEG SIZE DIMENSIONS

To match or reduce the structure periods without the knuckle joint, the leg diameter and wall thickness are changed; three different models are studied using leg diameters of 4000, 4500 or 5000 mm.

4.3. LEG-TOPSIDE CONNECTION

Considerable offshore hours were required to assemble the clamp connection, due to the dimensions of the elements and the conditions available, turning out to be an expensive activity. The new leg-topside connection will attach the topside main trusses directly with the legs, through the sleeves, and the sleeves will expand to the lowest deck.

5 21 meters water depth = 5 meters barge under water + 14 meters bucket + at least 2 meters for gap and tidal changes.
Since the legs are located outside the barge, an extra column is added on the edge of the barge and connected to the sleeves through plates that will transfer the topside loads to the barge during sea transport. In order to maintain the platform compatibilities with the barge BOA 35, the legs are shifted apart to maintain the original distance between the sleeve and the barge.

4.4. RESULTS

The natural periods and frequencies of the first mode shapes are compared with the re-built F3-FA model in Table 4.1. The models analysed revealed a successful decrease on the natural periods with the increase of the legs diameter and with the selected wall thickness for the fatigue calculations. Also, the variant solutions had a considerable reduction on the structural steel weight, as shown in Table 4.2.

Table 4.1: Natural period: Variant solutions / Re-built model

<table>
<thead>
<tr>
<th>Models</th>
<th>Structural weight</th>
<th>Natural period</th>
<th>Mode shapes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-built F3-FA</td>
<td>4654 mT</td>
<td>2,42 s</td>
<td>1,74 s, 0,61 s, 0,58 s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Joint numbers</th>
<th>Member type</th>
<th>Maximum UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topside beams</td>
<td></td>
<td></td>
<td>3250 mm</td>
</tr>
<tr>
<td>Cellar deck</td>
<td>156-168</td>
<td>HE1000A</td>
<td>0,82</td>
</tr>
<tr>
<td>Main deck</td>
<td>208-205</td>
<td>HE1000A</td>
<td>1,09</td>
</tr>
<tr>
<td>Top deck</td>
<td>327-333</td>
<td>HE1000A</td>
<td>1,12</td>
</tr>
<tr>
<td>Heli deck</td>
<td>427-403</td>
<td>HE500A</td>
<td>0,58</td>
</tr>
</tbody>
</table>

Based on the variant solutions proposed for the F3-FA platform, the in-place and fatigue analysis were checked considering the operational and survival conditions.

In-place analysis

The critical topside members with maximum Unity Check ratio (UC) reported, per location, for all models are presented in Table 4.3.

Table 4.3: Maximum topside members UC’s – comparison between models with different leg diameter

<table>
<thead>
<tr>
<th>Location</th>
<th>Joint numbers</th>
<th>Member type</th>
<th>Maximum UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topside beams</td>
<td></td>
<td></td>
<td>3250 mm</td>
</tr>
<tr>
<td>Cellar deck</td>
<td>156-168</td>
<td>HE1000A</td>
<td>0,54</td>
</tr>
<tr>
<td>Main deck</td>
<td>208-205</td>
<td>HE1000A</td>
<td>0,64</td>
</tr>
<tr>
<td>Top deck</td>
<td>327-333</td>
<td>HE1000A</td>
<td>0,67</td>
</tr>
<tr>
<td>Heli deck</td>
<td>427-403</td>
<td>HE500A</td>
<td>0,51</td>
</tr>
</tbody>
</table>

The values differ with a higher leg diameter, due to an increase of the wave forces and are more visible in the tubular sections of the main trusses.

In the substructure leg the higher stresses values came from the bending moment. Figure 4.4 presents the critical bending moment diagram for the leg when submitted to the worst load combination.
One can conclude that, the larger the legs section diameter the bigger will be the hydrodynamic loads. Even, considering that the structure excitation from the wave motion for the models with smaller legs diameter is greater and, as a consequence, the quasi-static wave loads will have a higher dynamic amplification factor. However, in Figure 4.4 the bending stresses are also shown to demonstrate that, the increase of the legs section resistance is bigger than the increase of the hydrodynamic loads in the models with a bigger leg diameter, since the bending stresses are lower.

**Fatigue analysis**

The fatigue analysis is the decisive design check in the F3-FA substructure design also for the variant solutions. Table 4.4 presents the critical fatigue life, per butt weld joint elevation, for the F3-FA re-built model and the variant solutions. The leg wall thickness was changed in order the leg butt weld joints present at least 100 years of fatigue life. The maximum wall thickness adopted was 150 mm.

The variant model with the original 3250 mm leg’s diameter, present two joints where the 100 years fatigue life could not be achieved, even with a considerable increase of the leg wall thickness. The models with leg’s diameter increase were able to satisfy the fatigue requirements in all joints.

Looking back to the results of Table 4.1, the first three mode shape natural periods of the variant solution with the original leg diameter are considerably higher than the re-built F3-FA model. While, for the other models a better dynamic behaviour of the structure was obtained. Thus, the models leg wall thickness was optimized based on the fatigue analysis results to reduce the structural main steel weight, as shown in Table 4.4.

**Conclusions**

All final variant models have a total structural weight lighter than the original F3-FA platform, mostly due to the removal of the knuckle joint. Based on Table 4.2 and Table 4.4 a final table for the overall results is presented below.
In Table 4.5 the design fatigue life is based on the lowest fatigue life estimation from the substructure butt weld joints and the structural steel weight on the rebuilt F3-FA SACS model values. From the overall results, presented in Table 4.5, the models with the leg diameters 4000 and 4500 mm are the most recommended for a variant solution of the F3-FA platform.

5. MAIN CONCLUSIONS

The main aim was to improve the structural layout and the dynamic behaviour under wave loading of the F3-FA platform by proposing different structural solutions to be adapted in future updates of platform design.

The first aspect investigated was the possibility of adopting a structure without the knuckle joint. With this improvement, considerable structural steel weight is reduced (around 1000 mT). But this improvement has a direct impact in reducing the first structure frequency modes due to an increase of the flexibility of the overall structure and, consequently, a lower fatigue performance.

To solve the reduction of the first natural structure frequencies, three alternative solutions were investigated by enlarging the legs diameter. Besides the original leg diameter (3250 mm), leg’s diameter of 4000, 4500 and 5000 mm were considered. Also, new leg wall thickness was proposed to optimize the weight and improve the structural stiffness. The first frequencies therefore increase, with respect to the original design, with the increase of the leg diameter and wall thickness redesign.

An alternative solution for the leg-topside connection was also proposed. In this new solution, a straight connection is accomplished with the sleeve going through the entire topside. The corner trusses are also replaced with truss rows directly connected to the legs and compatible with the transport barge used. This connection required less steel and no significant change was observed in the structure frequency modes.

With these design improvements the variant solutions were analysed and checked for in-service and fatigue performance. For the most demanding fatigue analysis, the legs joints proved to satisfy the fatigue requirements, except when using the original leg diameter size.

Therefore, it can be concluded that the structural solutions proposed contain improvements that can be included in future design updates of the F3-FA platform, being the models with a leg diameter 4000 or 4500 mm the more rational solutions, with respectively 450 or 100 mT structural steel weight reduction to the present design (9% or 2% of the total structural steel net weight used on the F3-FA platform, if buckets are excluded).

6. REFERENCES

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