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INTRODUCTION

- Offshore Industry moving to the deeper and harsher environments in search of oil and gas resources
- Motion response of the Offshore Structure is a critical factor for a lot of operations and maintenance work
- Challenge to ensure the structural integrity of the offshore platform being capable of withstanding the impact of extreme environmental wave loading

OBJECTIVE

- To develop a global structural model of a case study semisubmersible platform
- Analyze of motions response of the platform
- Quantify the impact of extreme wave load on the offshore floating structure in terms of element average Von mises stress & identify critical structural regions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Technical data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of pontoon</td>
<td>92.3m</td>
</tr>
<tr>
<td>Height of pontoon</td>
<td>8.45m</td>
</tr>
<tr>
<td>Width of pontoon</td>
<td>14.3m</td>
</tr>
<tr>
<td>Height (Deck Structures)</td>
<td>19.5m</td>
</tr>
<tr>
<td>Height of each Column Leg</td>
<td>52.5 m</td>
</tr>
<tr>
<td>Overall Width of the Structure</td>
<td>74.1 m</td>
</tr>
</tbody>
</table>
**METHODOLOGY**

**Approach**
- Global Structural FE Modelling of Beam & Shell Elements
- Hydrodynamic Analysis in HydroD(Wadam)
- Post Processing Global Motion Response Variables
- Post Processing Global Quasi Static Structural Strength Analysis

**Software Tool Used**
- **Sesam GeniE**
- **Sesam HydroD**
- **Postresp**
- **Xtract**

**DESIGN CODES AND STANDARDS**

- **Det Norske Veritas (DNV) Offshore Standards**
  - DNV-OS-C101
  - DNV-OS-C103
  - DNV-OS-C201
  - DNV-OS-C205
  - DNV-OS-C103

- **American Petroleum Institute (API) Offshore Standards**
  - API RP 2A-WSD
  - API RP 2FPS

- **Norwegian (NORSOK) Offshore Standards**
  - NORSOK -N-001
  - NORSOK -N-003
  - NORSOK -N-004

- **International Standard Organisation (ISO) Offshore Standards**
  - ISO19901
  - ISO19902
  - ISO19904_1
ANALYSIS OVERVIEW : Structural Modelling

- Global structural model made of combination of beam and shell elements representing the stiffness similar of the actual structure
- Key sub-assemblies of the semisubmersible platform: Pontoons, Column, Deck & Bracing
- Longitudinal stiffness of the pontoons, Stiffness of the braces in axial direction, Stiffness in vertical direction of the columns, Stiffness of the main bulkheads as well as the shear and bending stiffness of the upper hull
- Modelling with the help of structural technical drawing provided by DNV Gdynia Office

ANALYSIS OVERVIEW : Structural Modelling

- Simplified structural model
- Local details such as brackets, buckling stiffeners, smaller cut-out like doors neglected
- Bracing System modelled using pipe section with geometrical diameter and thickness
- Connections between the upper hull/columns, column/braces and column/pontoons etc. are modelled along with bulkheads and decks frames as they are vital to the global stiffness
- Boundary condition as super nodes primarily with vertical spring stiffness to avoid stress concentration around support points
**ANALYSIS OVERVIEW : Structural Modelling**

- Finite Element Model of the Panel, Morison and Global structure required to set up the Global Response analysis
- 8-noded quadrilateral elements have been used for meshing the structure, 6-noded triangular elements have been used sporadically in areas
- The structural model of the shell structures of pontoons, columns exposed to the water surface have been used for the panel model
- The Morison model is a structural finite element model that consists of the cross bracing beam elements

**ANALYSIS OVERVIEW : Hydrodynamic Analysis Set up**

- Frequency domain analysis using the 3D potential theory program SESAM HYDRO-D Wadam
- Hydrostatic calculations, in which the hydrostatic and inertia properties of structure are calculated
- Load calculations, in which the detailed pressure distribution on element level calculated is transferred to the structural FEM model for analysis
- One set of wave loading and one mass distribution with the operating condition draft 13.33m analyzed.
- Wind & current loading assumed negligible
- Semisubmersible analyzed as a free floating body without considering effect of the mooring lines and risers on the structure response
- Loading with no heel and trim of the platform
ANALYSIS OVERVIEW: Extreme Environmental Wave Loading

- Design wave parameter selected for one of most extreme climates i.e. in the North Sea with 100 year return period
- Water depth to be uniform 300 m
- Sea state defined for 3 hour duration
- Wave period/frequency applied 4 sec to 24 sec with an interval of 2 sec
- 8 Wave heading at regular interval of 45 deg considered with respect to the Platform
- Wave spectrum was modelled as Bretschneider spectrum which is denoted as a 2 parameter Pierson-Moskowitz spectrum with the significant wave height being 13.6m and peak period being 16 sec

ANALYSIS OVERVIEW: Global Motion Response Analysis

- Response of the platform measured in terms of (RAOs) for the 6 DOF
- The natural heave period resulting in resonance

$T_H = \frac{\sqrt{(M+A_A)} \cdot 2\pi}{\sqrt{(P+g\cdot A_W)}} = 7.95 \text{ sec}$
ANALYSIS OVERVIEW : Pressure Loading

- Hydrodynamic & hydrostatic pressure loading response of the platform
- Pressure distribution on element level calculated is transferred to the structural FEM model

ANALYSIS OVERVIEW : Global Structural Response

- Hydrodynamic loads with mass inertia loads applied
- Structural integrity checked based on shell von Mises stress
- ULS-b limit state from WSD/LRFD synonymous with the present loading case & empirical formulation to quantify the environmental load contribution
Standards give two different strength design philosophies, the WSD (Workable Stress Design) or the LRFD (Load Resistance Factor Design).

**LRFD**

<table>
<thead>
<tr>
<th>Combination of load designs</th>
<th>Load Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULS a</td>
<td>1.3 1.0 0.7</td>
</tr>
<tr>
<td>ULS b</td>
<td>1.0 1.0 1.3</td>
</tr>
</tbody>
</table>

\[
(\Sigma \gamma G + \Sigma \gamma Q + \Sigma \gamma E) \leq \phi Ru
\]

\( \gamma = \text{Load Factor,} \)
\( \phi = \text{Resistance Factor} \)
Typical Value for Steel Structure = 1/1.15

\[ FS = \frac{Ru}{\phi} \]

**WSD**

<table>
<thead>
<tr>
<th>Limit state</th>
<th>Action combination factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULS a</td>
<td>1.0 1.0 -</td>
</tr>
<tr>
<td>ULS b</td>
<td>1.0 1.0 1.0</td>
</tr>
</tbody>
</table>

\[ \Sigma G + \Sigma Q + \Sigma E \leq Ru / FS \]

\( \gamma = \text{Load Factor,} \)
\( \phi = \text{Resistance Factor} \)
Typical Value for Steel Structure = 1/1.15

\[ UF_{WSD} = (\sigma V - m) / (\sigma V / 1.67) \times 1.33 \]

\[ UF_{LRFD} = (\sigma V - m) / (\sigma V / 1.15) \times 1.3 \]
CONCLUSION

- Maximum stress due to wave induced loading occurs in frequency range \((T = 8-10 \text{ sec}, f = 0.125-0.1\text{Hz})\). Result in accordance with theoretical behaviour of structure as the natural resonance period of motion response of the vessel lies in the same frequency range.
- Connection column/pontoons & bracing/column/pontoons have been found critical to wave loading. Worst case scenario in terms of stress distribution (344 MPa) to occur in beam sea.
- LRFD as compared to the WSD approach based on Von Mises Stress produces 16 % higher values for yield utilization in the structural elements for extreme environmental wave loading.

RECOMMENDATIONS AND FUTURE SCOPE OF WORK

- Global structural might have stress concentration caused by the modelling simplifications or lack of the local reinforcements.
- Detailed local non-linear finite element analysis recommended for precise information regarding structural strength in the critical zones.
- Case studies of different environmental loading scenarios including wind, current effects and effects of mooring lines/riser system would add considerable value to the global response analysis.
- Similar set of concepts could be used to perform the global response analysis on other types of offshore floating structures like TLP, Spars and FPSO etc.
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- Effects of Hydrodynamic Modelling in Fully Coupled Simulations of a Semisubmersible Wind Turbine by I. Kvittem, E. Bachynskib, T Moan
- A Deep Draft Semisubmersible with a Retractable Heave Plate by J. Halkyard, J. Chao, P. Abbott, J. Dagleish, H. Banon
- Static and dynamic analysis of the Semisubmersible type floaters for Offshore wind turbine by C. Mayilvahanan and R.P. Selvam
- Technical drawings of the Semisubmersible Platform by DNV Poland, Gdynia Office (Confidential)