Development of Self-Installing Deepwater Spar

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February 2017
Contents

• Introduction & Background
• ACE Spar breakdown
• Installation Sequence
• Main particulars, Hull design and Weight control
• Stability & Motion response
• Construction advantages
• Cost break-down
• Further work
• Summary
Arup’s ACE platforms

- Arup has successfully designed and installed the award winning ACE (Arup Concept Elevator) range of fixed platforms.
Arup’s ACE platforms

- Self-installing fixed platforms
- Re-locatable
- Less intensive offshore campaign
- Strand Jacks used for lifting and lowering
- Comprehensive offshore solution
- Drilling, production, wellhead facilities, offshore wind
Conventional Spar platforms

- Classic type
- Truss type
- Cell type

The main components of a Truss Spar platform are:

- Topsides
- Hard Tank
- Truss structure
- Soft Tank
Arup’s Deepwater solution

The best of both worlds!

• **ACE platform**
  - Enhanced Project Economics due to various reasons
  - Self-installing and re-locatable
  - Minimal requirement of a specialist heavy lift vessel
  - Lifting and lowering system proven in harsh installation conditions
  - Vertical stacking construction for ease of fabrication

• **Spar platform**
  - Supports dry and wet trees
  - Low heave motions
  - Suitable for deep to ultra-deep water depths
  - Provide product storage
Contents

• Introduction & Background
• **ACE Spar breakdown**
• Installation Sequence
• Main particulars, Hull design and Weight control
• Stability & Motion response
• Construction advantages
• Cost break-down
• Further work
• Summary
ACE Spar breakdown

Barge deck
- Primary support for the Topsides
- Buoyancy during the wet-tow

Hard Tank
- Providing buoyancy or tanks for ballast during Installation & In-place condition
- Store product in the Operational phase

Soft Tank
- Forms the heave plate
- To be used for water ballast + solid ballast if required to maintain a positive GM during Transportation, Installation and In-place condition
Installation Sequence

The **Self-Installing** sequence for ACE Spar platform will utilize Strand Jacks and can be divided into three main stages:

- *Float-out*
- *Lowering*
- *Deck raising*
Float-out
Deck-raising
In-place
Installation sequence (cont.)

**Float-out**
Ballasting Hard Tank, Soft Tank and Truss

**Lowering**

**Deck raising**
De-ballasting Hard Tank

**In-place**
Hook-up & Commissioning
Contents

• Introduction & Background
• ACE Spar breakdown
• Installation Sequence
• Main particulars, Hull design and Weight control
• Stability & Motion response
• Construction advantages
• Cost break-down
• Further work
• Summary
Main Particulars

A typical deep-water Spar platform has been considered to estimate the initial sizing of the sub-structure for meeting the following criteria:

- **Topsides weight:** ~18,500t Topsides (with supporting barge)
- **Storage capacity:** up to 18,000 bopd capacity
- **Operational water depth:** up to 1,500m water depth
- **Centre well slot:** 15m x 15m centre well slot
- **Air-gap:** Minimum ~25m in operational condition and remain positive in storm condition
- **Metacentric height (GM):** Positive in all conditions including Operational, Transportation & Installation
Spar Hull design

The basic hull dimensions have been calculated for the concept:

- **Barge deck (and sponsons if required)**
  - Designed to form the primary support for the topsides modules
  - Provide adequate buoyancy during the Float-out stage and maintain appropriate freeboard

- **Hard Tank & Soft Tank**
  - **Hard Tank**: Provide adequate buoyancy during Operational condition to maintain sufficient air-gap
  - **Soft Tank**: Provide sufficient ballast (water or solid) during the Operational condition in order to maintain a positive GM.
Hull Dimensions

Barge Deck

- Length/width: ~75 to 80m
- Height: 10 to 15m
- Well-bay to sit inside deck’s slot OR a moon-pool

Hard Tank

- Diameter: 30 to 35m
- Length: 100 to 120m
- 15-20 sq. m center well slot for buoyancy cans, conductors & risers

Soft Tank

- 60-70 sq. m, 3-10m high
- 20-25 sq. m center well slot to accommodate the risers

Truss Structure

- 30-35 sq. m, 30-40m high
### Weight control

Current ACE Spar configuration designed to handle a total payload of ~25,000t.

<table>
<thead>
<tr>
<th>Description</th>
<th>Weight (t)</th>
<th>XCG (m)</th>
<th>YCG (m)</th>
<th>ZCG* (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsides</td>
<td>9,000</td>
<td>0.00</td>
<td>0.00</td>
<td>174.00</td>
</tr>
<tr>
<td>Barge Deck</td>
<td>~9,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wellhead bay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard Tank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft Tank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>~34,000</td>
<td>0.00</td>
<td>0.00</td>
<td>128.23</td>
</tr>
</tbody>
</table>

*From bottom of the Soft Tank*
Hull Design features

Various factors affecting the Hull design:

- **Type of Topsides facility** (production, drilling or both)

- **Number of conductors** (will dictate the center well and hence Soft tank and Deck size)

- **Need for storage capacity** (will drive the size of the Hard tank)

- **Type of tensioning** to be used for the risers (buoyancy cans, hydro-pneumatic, ram type)

- **Presence of VIV strakes** on the Hard tank (might lead to change in deck design)

- **Fabrication method** to be used (Vertical stacking preferred)

- **Installation sequence** (load-out or float-off)

- **Fabrication location & capability** (dry-dock, shipyard etc.)

- **Well-head bay size & layout**
Contents

• Introduction & Background
• ACE Spar breakdown
• Installation Sequence
• Main particulars, Hull design and Weight control
• Stability & Motion response
• Construction advantages
• Cost break-down
• Further work
• Summary
Stability

As per ABS Rules for Floating Production Installations, Part 5B, Ch3 Sec 2,

the GM should remain positive during the Installation phase. GM achieved during different Installation stages:

- **Float-off**  GM = 33m  Freeboard: 10m  Floating stability range: 32°
- **Lowering**   GM = 57m  Freeboard: 7m
- **In-place**   GM = 3m  Draught: 130m  Air-gap: 25m
Float-out model (DNV Sesam)

- Structural model prepared in DNV Sesam module, Genie. The model comprised of barge deck, ballast compartments and auxiliary buoyancy aids in form of Sponsons
- Meshing done in Genie
- Stability check in HydroD
- Hard Tank accounted for as a point mass
- Trim ballast used to level the platform
- Required freeboard, stability range and positive GM achieved
Lowering model

- Structural model was prepared in Genie. Model comprised of hard tank, barge deck, ballast compartments and auxiliary buoyancy Sponsons
- Stability check done in HydroD
- Trim ballast used to level the platform
- Required freeboard and positive GM achieved
In-place model

- Structural model was prepared in Genie. The model comprised of hard tank and ballast/product compartments
- Meshing done in Genie
- Stability check in HydroD
- Required air-gap and positive GM achieved
- Only Hard Tank was modelled to get the correct water-plane area
Motion Response

Frequency domain analysis was carried out to estimate the natural frequencies and the peak response of the platform using DNV Sesam modules Hydro and Wadam.

Natural Frequency:

- Roll: 92.4 sec
- Pitch: 92.3 sec
- Heave: 32.1 sec
Motion response checked in a Gulf of Mexico 100 year RP storm condition. Similar or less worse met-ocean conditions for WA region.

\[ Hs = \sim 16 \text{ m} \quad Tp = \sim 15 \text{ sec} \]

Heave natural frequency is sufficiently far from crest of the wave spectrum and hence gives a peak response of up to 0.6 m.

Pitch and Roll motion response are minimal.
Motions model

- Genie model was used with Soft Tank for In-place condition
- Total mass of the structure was distributed using point masses to account for the inertia including the Topsides, barge deck and truss members
- Permanent water ballast in soft tank has been modelled in HydroD
Contents

• Introduction & Background
• ACE Spar breakdown
• Installation Sequence
• Main particulars, Hull design and Weight control
• Stability & Motion response
• Construction advantages
• Cost break-down
• Further work
• Summary
## Construction advantages

<table>
<thead>
<tr>
<th>Conventional Spar</th>
<th>ACE Spar</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Built in half or quarter sections and joined before transporting to the offshore site.</td>
<td>• Vertical stacking construction configuration similar to what is used for constructing oil terminal/refinery oil storage tanks.</td>
</tr>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>• Top-tensioned riser system or buoyancy cans hook-up and commissioning offshore.</td>
<td>• Top-tensioned riser system or buoyancy cans can be pre-commissioned during the fabrication stage onshore, saving significant costs for offshore installation.</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>• Conventional fabrication method used of connecting structure blocks horizontally.</td>
<td>• Strand Jacks to be used to construct and erect the hard tank vertically.</td>
</tr>
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Contents

• Introduction & Background
• ACE Spar breakdown
• Installation Sequence
• Main particulars, Hull design and Weight control
• Stability & Motion response
• Construction advantages
• **Cost break-down**
• Further work
• Summary
Cost break-down

A bottom-up cost estimation and comparison has been carried out for the ACE Spar platform.
Cost – Transportation & Installation

The T&I costs can be reduced significantly compared to a conventional deep-water spar platform.

<table>
<thead>
<tr>
<th>T&amp;I phase</th>
<th>Conventional Spar</th>
<th>ACE Spar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-structure tow</td>
<td>Semi-submersible vessel</td>
<td>Semi-submersible vessel</td>
</tr>
<tr>
<td>Sub-structure installation</td>
<td>Semi-sub vessel, tugs</td>
<td>Semi-sub vessel, tugs</td>
</tr>
<tr>
<td>Topsides load-out</td>
<td>Barge</td>
<td>Semi-sub vessel</td>
</tr>
<tr>
<td>Topsides tow</td>
<td>Barge</td>
<td>Semi-sub vessel</td>
</tr>
<tr>
<td>Topsides installation</td>
<td>Barge, HLV, tugs</td>
<td>Semi-sub vessel, tugs</td>
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Contents

• Introduction & Background
• ACE Spar breakdown
• Installation Sequence
• Main particulars, Hull design and Weight control
• Stability & Motion response
• Construction advantages
• Cost break-down
• Further work
• Summary
Further work..

- *Model Testing* for motion response assessment and moorings
- *Effect of viscous drag* (soft tank & additional heave plate if required) on the motion response of the Spar
- *Mooring design* including dynamics of mooring lines and a coupled analysis to estimate the spar motions due to mooring stiffness
- *Effect of different type of TTRs* (top-tensioned riser) on the design of Spar
- *Transportation motion response* of the Spar
- *Refine the Structural design* to reduce the amount of steel required
- Stability & motion assessment for a *CG offset*
- Sensitivity checks on *Auxiliary buoyancy* requirement in form of Caissons
- Effect of current; requirement & design of *VIV strakes* on overall Spar design
Summary – Why ACE Spar?

- Self-Installing
- Less intensive offshore campaign
- Improved constructability
- Reduced requirement of specialist vessels
- Re-locatable De-commissionable
- Un-interrupted deck space
- Enhanced Project Economics
Thank you

Questions?