The Low Motion Floater (LMF)

Low Motion = Low Cost

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Outline

➢ Pros and Cons of Conventional FPSO

➢ The Low Motion Floater (LMF)
  • Design
  • Performance
  • Construction, Transportation & Installation
  • Risks and Mitigation Measures
  • Main Technical and Economical Advantages

➢ Application to FLNG

➢ Development Status
Pros and Cons of Conventional FPSO

Pros:
- Suitable for remote fields with little or no infrastructures
- High oil storage capacity
- High topside payload capacity
- Quayside integration
- Relatively easy to fabricate and install (except for the turret)
- Most popular FPS with more than 60% market share

Cons:
- Suitable for SCRs in very mild environment and narrow range of water depth only ➔ Limited riser solutions
- Not suitable for TTR and requires a separate Dry Tree Unit if direct vertical access to wells is needed
- Require turret and swivel in medium and harsh environment ➔ Complex component, design limitations, cost and schedule impact
- Most of the above are caused by: High heave, roll and pitch motion

LMF can preserve the pros and eliminate the cons
Benefits of Low Motion

- Enable use of SCRs: reduced limitations on riser size, simplified field layout, and improved integrity
- Enable use of TTRs if desirable on the floater
- Eliminate the need of turret and swivel
- Reduced topside main structural steel due to reduced accelerations
- Reduced sloshing in ballast and storage tanks
- Improved operability: better efficiency in topside processing and better helicopter operability
- Improved habitability: less motion-related effect on offshore personnel
The LMF Design

All Components are field proven

Conventional Topside

Conventional hull

Conventional Mooring

Solid Ballast tank (SBT)

SCRs / Umbilicals

Tendon Top Connector

Courtesy of www.oilstates.com

Short Tendon Pipe
No couplings

Tendon Bottom receptacle
The LMF Design Features

► Square or Rectangular shaped hull provides:
  
  ▪ Flexibility of topside arrangement – more conventional layout, ability to adopt conventional FPSO topside modules
  
  ▪ Control over the hull width ➔ enables large storage capacity, still to fit within dry dock requirements
  
  ▪ Lower VIM response (compared with round shape) ➔ better mooring and riser fatigue

► Modular topside allows for easy quayside integration

► Hull is based on stiffened plate design for easy fabrication

► Tendon system used for Solid Ballast Tank (SBT): robustness, large load carrying capacity, flex-joints at top and bottom connectors
How Are Low Motions Achieved?

- **SBT mass:**
  - Provides high stability (high GM) => less number of compartments, reduced Low Frequency roll / pitch motions
  - Maintains positive tendon tension in all design conditions
  - Ensures full coupling with Hull in heave, roll and pitch (wave frequency)
  - Ensures full coupling with Hull in surge, sway and yaw (low frequency)

- **SBT mass and Added mass**
  - Long heave, roll and pitch natural periods
  - Significantly lower heave, roll/pitch motions

- **Relative motion in surge, sway and yaw**
  - Limited to first order (wave frequency)
  - Much less than TLP hull-to-foundation relative motions

- Low motion is due to mass & added mass of SBT. Independent control of motion and offsets
How Low is Motion Response?

<table>
<thead>
<tr>
<th>Single Amplitude Heave Motion</th>
<th>Motion in 100 year Cyclone</th>
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<tbody>
<tr>
<td>TLP</td>
<td>Heave: 0.4 m SA maximum</td>
</tr>
<tr>
<td>LM FPSO</td>
<td>Pitch/Roll: 2.8° SA maximum</td>
</tr>
<tr>
<td>Spar</td>
<td></td>
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<tr>
<td>Semi</td>
<td></td>
</tr>
<tr>
<td>FPSO</td>
<td></td>
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</tbody>
</table>

LMF motion can be almost as good as TLPs and is adjustable.
Model Testing – Motion RAOs

Surge

Hull Motion RAO, 45deg - X

SBT Motion RAO, 45deg - X

Sway

Hull Motion RAO, 45deg - Y

SBT Motion RAO, 45deg - Y
Model Testing – Motion RAOSs

Heave

Hull Motion RAO, 45deg - Z

- Prediction, Hull
- Model Test, Hull
- Model Test - Regular Wave

SBT Motion RAO, 45deg - Z

- Prediction, SBT
- Model Test, SBT
- Model Test - Regular Wave

Roll

Hull Motion RAO, 45deg - RX

- Prediction, Hull
- Model Test, Hull
- Model Test - Regular Wave

SBT Motion RAO, 45deg - RX

- Prediction, SBT
- Model Test, SBT
- Model Test - Regular Wave
Model Testing – Motion RAOs

**Pitch**

- Hull Motion RAO, 45deg - RY
- SBT Motion RAO, 45deg - RY

**Yaw**

- Hull Motion RAO, 45deg - RZ
- SBT Motion RAO, 45deg - RZ
Model Testing Overview – Green water

100yr 90deg

Test ID: 332
CE_100yr_Realiz 2
Heading angle= 90deg
LMF Fabrication, Transportation and Installation

- Constructability of the SBT and Hull was reviewed and confirmed by a major Korean shipyard
- Optimum construction method: Modular fabrication and dry dock assembly
- Fabrication, transportation and installation sequence
LMF Fabrication, Transportation and Installation

SBT is fabricated in the dry dock

Hull is assembled on top of the SBT in the dry dock

Topside modules are integrated at quayside

The platform is wet-towed to installation site
8 of 16 Moorings and pre-laid risers are installed

8 windlass/chains are used to lower the SBT

Tendons upended and installed
Tendon Lifting – Installation Options

Courtesy of www.jumboship.nl
Risks and Mitigation Measures

➢ Fabrication:
  ▪ Hull width may limit available fabrication facilities
  ▪ Hull width may require crane with extra reach for lifting modules on the hull. Alternatively, skidding may be required
  ▪ Additional fabrication supports needed for fabrication of SBT and Hull at one site
  ▪ If SBT and Hull are fabricated separately, additional arrangement is required to install SBT under the Hull.

➢ Offshore Installation:
  ▪ Lowering SBT on mooring chains: Load equalization at each corner is provided and uneven load sharing between the groups is included;
  ▪ Tendon installation: Installation risks (such as clashing) should be managed and weather window identified.
  ▪ The system is storm safe at any installation step. Operations can be interrupted if necessary.
Technical and Economical Advantages

Main Technical Advantages

- Elimination of turret
- Use of SCRs; simplified field layout
- Elimination of wellhead platform (if used)

Economical Advantages

- Extensive cost estimating performed for FPSO applications around the world
- More than **50% CAPEX savings** could be achieved on hull, mooring and risers in the range of **$500 – 1,000 Million**
Application to FLNG

- LM-FLNG hull: L150m x B100m x D40m = Prelude displacement
- Because of high GM, can build the topside up vertically
- Advantages of LM-FLNG
  - Elimination of turret, one of the main sources of leaks
  - Use of large diameter SCRs even in relatively shallow water
  - Water intake riser can be supported at SBT level, ~ 200m below WL
  - Reduced sloshing in storage tanks, may open to prismatic B-tanks or possibly even membrane tanks
  - Improved operability of topside equipment and helicopter operations
  - Possibility of Side-by-side offloading (compared with round hull shape)
  - Protection of t°-sensitive equipment (can be placed as high as required)
  - Improved Human Factors with better habitability
LMF Development Status

✓ Technical feasibility and economical advantage of the LMF has been studied and demonstrated

✓ Constructability review was completed by a major Korean shipyard. No issues identified

✓ Extensive model tests were completed at KRISO in Nov. 2016 that confirmed the exceptional motion response

✓ Risk workshop with major oil companies was completed in Feb. 2017; no show stoppers identified

✓ Basic engineering package including a method of construction and installation was completed in Feb. 2017 and submitted to Class society

✓ Base case project execution plan is ready; various alternative options are being studied

✓ Approval in Principle granted by DnV

✓ The technology is project ready.
Thank You!

WorleyParsons Group