Compensation systems on floater rigs
Principles, solutions and contingency systems for hydrocarbons flowing operations

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  - Rig motion compensators: state of art
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  - Conclusions
Project Scope

- Overview of future ENI subsea projects
- Comparison between ENI policies, International Standards and Industry general orientation
- Compensation on floater rigs: available systems and drilling contractors offer
- Market investigation on locked to bottom compensation backup systems
- Conclusions: possible applications for incoming ENI subsea activities
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- Project Scope
- **ENI overview**
- Compensation on floater rigs
- Rig motion compensators: state of art
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- Conclusions
ENI overview: Operative Areas

- Libya - Egypt - Cyprus
- Indonesia
- Australia
- Angola
- Mozambique
- Norway

Operative Vessels:
- Sedco Express
- Saipem 10K
- Scarabeo 7
- Scarabeo 8
- Ocean Poseidon
- DW Pathfinder
- Jack Bates
- Ensco 5004
- Amirante
**ENI overview: Future Subsea Projects**

<table>
<thead>
<tr>
<th>Country</th>
<th>Exploration</th>
<th>Development</th>
<th>Wells N°</th>
<th>Water depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola EH</td>
<td>x</td>
<td></td>
<td>15</td>
<td>500</td>
</tr>
<tr>
<td>Angola WH</td>
<td>x</td>
<td></td>
<td>25</td>
<td>1300</td>
</tr>
<tr>
<td>Indonesia</td>
<td>x</td>
<td></td>
<td>11</td>
<td>500</td>
</tr>
<tr>
<td>Ghana</td>
<td>x</td>
<td></td>
<td>19</td>
<td>1000</td>
</tr>
<tr>
<td>Lybia</td>
<td>x</td>
<td>x</td>
<td>12</td>
<td>300</td>
</tr>
<tr>
<td>Mozambique</td>
<td>x</td>
<td>x</td>
<td>38</td>
<td>2400</td>
</tr>
<tr>
<td>Nigeria DW</td>
<td>x</td>
<td></td>
<td>4</td>
<td>650</td>
</tr>
<tr>
<td>Nigeria UDW</td>
<td>x</td>
<td>x</td>
<td>34</td>
<td>2400</td>
</tr>
<tr>
<td>Nigeria DW</td>
<td>x</td>
<td></td>
<td>4</td>
<td>650</td>
</tr>
<tr>
<td>Norway</td>
<td>x</td>
<td></td>
<td>22</td>
<td>400</td>
</tr>
</tbody>
</table>

- **Total wells number: 180**
- **Hs**: significant wave height, representing meteo-ocean environment
- **ISO 13628**: 100 years return period, for relevant Hs identification.

**Graph:**

- West Africa
- North Sea
- Far East

130 wells in severe environmental conditions
70% of total wells

---

**Diagrams:**

- P10
- P50
- P90
Floater rigs are affected by six different motion components.

Vertical resultant of motion components induces stresses on the string.

Compensation aims to remove string motions and keep it steady, while rig continues to float.
**ENI overview: Why We Need Compensation?**

**Stretch length: software calculation**

### Conservative hypothesis:
- No string internal pressure

**Where Hs > Stretch length**

- Landing string integrity would be lost in case of compensation system lock up, during connected operations
- Extreme hazard to rig personnel
- Hydrocarbons spill

<table>
<thead>
<tr>
<th>ENI PROJECTS</th>
<th>WATER DEPTH</th>
<th>SIGNIFICANT WAVE HEIGHT Hs (m)</th>
<th>WellCat Calculation: STRETCH LENGTH (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>APPRAISAL (3,5” tbg)</td>
<td>DEVELOPMENT (9-5/8” tbg)</td>
</tr>
<tr>
<td>Angola</td>
<td>500 m</td>
<td>3,8</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1300 m</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Cyprus</td>
<td>2200 m</td>
<td>0,8</td>
<td>4,7</td>
</tr>
<tr>
<td>Ghana</td>
<td>1200 m</td>
<td>3,8</td>
<td>-</td>
</tr>
<tr>
<td>Indonesia</td>
<td>500 m</td>
<td>3</td>
<td>1,5</td>
</tr>
<tr>
<td>Mozambique</td>
<td>2400 m</td>
<td>2</td>
<td>4,7</td>
</tr>
<tr>
<td>Nigeria</td>
<td>2400 m</td>
<td>3,8</td>
<td>1,5</td>
</tr>
<tr>
<td>Norway</td>
<td>600 m</td>
<td>8</td>
<td>-</td>
</tr>
</tbody>
</table>

**Legend**
- Hs > stretch length
Company policy and best practices

- **ENI**: Both PHC and AHC are accepted in floater rigs technical specifications. Well testing policy does not require for any special tension protection item in addition of standard long bails or CTLF.

Relevant International Standard

- **ISO 13628/7**: Measures should be taken to avoid damage to the C/WO riser in case of overloading due to accidental load effects, such as inclusion of weak link component in C/WO riser.

- **DNV 101**: Distinguishes between motion compensation systems currently available in rig market. Passive heave compensation trusted for higher reliability respect to active systems.
ENI overview: Industry Practice

Drilling contractors

- **Transocean**: Policy imposes to operator the use high pressure risers tension protection items on rigs equipped with active heave compensation system.

- **Noble**: A dedicated risk analysis prior hydrocarbon flowing operations is required according to well testing policy.

General industry orientation

- **Statoil**: Dedicated risk assessment for lock to bottom operations. Tension protection systems on all rigs performing hydrocarbons flowing operations.

- **ExxonMobile**: No established policy. Rig schedule planning adjusted to perform lock to bottom operations with PHC systems.
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- Compensation methods
  - Rig motion compensators: state of art
  - Backup systems
  - Conclusions
Compensation methods: PHC vs. AHC

In the Industry 2 different types of compensation are used:

- **Passive Heave Compensation:** Hydraulic system based on gas compressibility exploitation.
  
  No electric power supply.

- **Active Heave Compensation:** Electro-hydraulic system.
  
  Continuous power supply.
Compensation methods: PHC

Operating Principle

\[ P_1 V_1 = P_2 V_2 \]

Heave up: \( \downarrow V_1 \uparrow P_1 \uparrow V_2 \downarrow P_2 \)

Heave down: \( \uparrow V_1 \downarrow P_1 \downarrow V_2 \uparrow P_2 \)
Compensation methods: AHC

Operating Principle

Legend
- S1: ship motion [m]
- S2: drill string motion [m]
- e: error value [m]
- u: input control to drawworks [m]
- K: proportional gain
- Ti: integral time [s]
- Td: derivative time [s]

\[ e = S_1 - S_2 \]

\[ u(t) = K \cdot \left( e(t) + \frac{1}{T_i} \int_0^t e(t) \, dt + T_d \frac{de(t)}{dt} \right) \]
## Compensation methods: Comparison

<table>
<thead>
<tr>
<th>Passive system</th>
<th>vs</th>
<th>Active system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>Higher reliability due to system hydraulic nature in fixed load configuration.</td>
<td></td>
<td>Better efficiency on wider range of heave sizes and frequencies.</td>
</tr>
<tr>
<td>Independent from power generation.</td>
<td></td>
<td>Reduced size and installation cost.</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>Weight and size.</td>
<td></td>
<td>Reduced reliability due to electronic components and single item failure modes.</td>
</tr>
<tr>
<td>Tension variation due to inertia.</td>
<td></td>
<td>PLC tuning problems (fixed parameters are used).</td>
</tr>
<tr>
<td>Reduced efficiency, dependent on heave size and period.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resonance affected.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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- **Rig motion compensators: state of art**
  - Backup systems
  - Conclusions
**Rig motion compensators: PHC Systems**

- **Top Drive Motion Compensator**

- **Crown Mounted Motion Compensator**

  - The compensator acts on travelling block.

  - The compensator acts on crown block.
Rig motion compensators: A/P Systems

CMC with active heave compensated cylinder

- Passive system: 454 t
- Active cylinder: 25 t

The active cylinder refines and corrects the inertia of the passive system.

- **Connected operations**: passive compensation.
- **Non connected operations**: passive compensation with active support.

RamRig

The system performs 2 simultaneous functions:

- Hoisting without drawworks. Hydraulic cylinders realise this function.
- Heave compensation with active and passive cylinders.
Active Heave Compensated Drawworks

- Accelerometers spreaded on the rig sense ship movement, calculating resulting vertical motion. PLC processes signals and commands drawworks electro-hydraulic system.

- As the ship heaves up, the winch pays out the work wire.
- As the ship heaves down, the winch heaves in the work wire.
### Rig motion compensators: Market analysis

<table>
<thead>
<tr>
<th>Drilling contractors</th>
<th>Dynamic positioned</th>
<th>Moored</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>P</td>
</tr>
<tr>
<td>Noble</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Ocean Rig</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Saipem</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Seadrill</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Transocean</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td><strong>22</strong></td>
<td><strong>21</strong></td>
</tr>
</tbody>
</table>
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- **Backup systems**
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Backup systems:

Equipment preventing string parting in case of rig compensator lockup.

- Weak Link Bails
- Inline compensator
- Advanced Riser Tension Protector

Alternative compensation:

Equipment providing full string compensation alternatively to rig motion compensator.

- Compensated Coiled Tubing Lifting Frame
Weak Link Bails

- A weak link release mechanism offers string overload protection by mean of shear bolts.
A single air cylinder is pressurized by power air pressure vessels.

As the drilling vessel heaves upward due to wave action, the compensator cylinder extends and the rod moves downward.
Advanced Riser Tension Protector

- Tension frame designed to support C/WO riser with a relief function to protect the riser after a compensator lockup.
- It works for both tension and compression protection.
- System doesn’t require deck spotted APVs and HP hoses.
- Short R/U and R/D time (8 hours, comparable with standard CTLF).
A set of compensating cylinders is mounted vertically on the frame legs and receive energy from a high pressure air/liquid system.

The charge pressure in the dedicated APV bank can be adjusted to provide support tension of various loads.
### Backup system

<table>
<thead>
<tr>
<th></th>
<th>Tension/compression protection</th>
<th>Well access</th>
<th>R/U and R/D times</th>
<th>Rig interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak Link Bails</td>
<td>X</td>
<td>Only slick line/wireline</td>
<td>↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Inline compensator</td>
<td>↑</td>
<td>X</td>
<td>↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Advanced Riser Tension Protector</td>
<td>↑</td>
<td>Full</td>
<td>↑↑</td>
<td>↑</td>
</tr>
<tr>
<td>Compensated Coiled Tubing Lifting Frame</td>
<td>↑↑</td>
<td>Full</td>
<td>↓↓</td>
<td>↓↓</td>
</tr>
</tbody>
</table>

**Legend:**
- ↑ Well
- ↑↑ Optimum
- X Absent
- ↓ Bad
- ↓↓ Worse
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Conclusions

- Oil and gas industry is still not commonly oriented towards one single solution to enhance reliability of standard layout for hydrocarbons flowing on floater rigs.

- Several backup systems are available on market. Only ARTP and CCTLF grant full tension/compression protection and well accessibility for SL/WL/CT.

- ARTP system, even whitout case history is the more attractive. With estimated 8 hrs for R/U and R/D, it ensures 2 days rig time saving respect to CCTLF.

- Passive Heave Compensation is more reliable for fixed loads, reflecting the configuration for completion and hydrocarbon flowing operations. Active/Passive system, joining both principle advantages, is the most diffused for deep water and ultra deep water operations.

- Due to the increasing amount of subsea developments activities, thesis aims to be the starting point for revision and upgrade of the existing policies focused on compensation issue.
I would thank Eni s.p.a. Upstream & Technical Services Division Management for permission to present this work and related results and COMP colleagues for the technical support and needed assistance.