Design and Control

Dynamic Positioning System for Deep Ocean Drill Ship “CHIKYU”

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Dynamic Positioning System
for
Deep Ocean Drill Ship
“CHIKYU”

Mitsui Engineering & Shipbuilding Co., Ltd.
Japan Agency for Marine-Earth Science and Technology
Background

International Scientific Research Program by Ocean Drilling

- ODP (Ocean Drilling Program) 1985〜2003
  - Riser-less Drilling Vessel: JOIDES Resolution (USA)

- IODP (Integrated Ocean Drilling Program) October 2003〜
  - Riser-less Drilling Vessel: JOIDES Resolution (USA)
  - Riser Equipped Drilling Vessel: Japan

OD-21
(Ocean Drilling in the 21st. Century)

Drill to the Mantle!

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Appearance and Azimuth Thruster

Azimuth Thruster 6
Tunnel Thruster 1

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Dimension of “CHIKYU”

- Length (L_{PP}) : 192.0 (m)
- Breadth : 38.0 (m)
- Draft : 9.2 (m)
- Gross Tonnage : 57,087 (ton)
- Speed : 10 (kt)
- Accommodation : 150 (personnel)
- Generator (Main) : 5,000 (kw) \(\times\) 6
  (Auxiliary) : 2,500 (kw) \(\times\) 2
- Thruster (Azimuth type) : 4,200 (kw) \(\times\) 6
  (Tunnel type) : 2,550 (kw) \(\times\) 1
- Derrick (Hook Load) : 1,250 (ton)
  (Height) : 121 (m)
- Drill String Length (Future Plan) : 10,000 (m)
  : 12,000 (m)

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Characteristics of DPS for “CHIKYU”

- **Position Keeping Ability**
- **Positioning Stability** and **Various Conditions**
- **Redundancy**
  - Safety and Long-term Drilling Operations
- **DP Functions**
  - Ship Handling and Variety of Operations
### Specification

**Positioning Accuracy in Design Conditions**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Drilling</th>
<th>Stand-by I</th>
<th>Stand-by II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>1.5</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Wind</td>
<td>23</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>Wave</td>
<td>4.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>(m)</td>
<td></td>
<td>(m)</td>
<td>(m)</td>
</tr>
<tr>
<td>(sec.)</td>
<td>8.2</td>
<td>9.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Direction: 30(deg.) against the Heading.

**< Drilling Condition >**

If any single failure occurs in kinetic equipment, DP operation has to be continued.

\[ 2P \] has to be less than 1.5% of water depth or 15(m) whichever is larger.

**< Stand-by Condition >**

All equipment for DP is available.

\[ 2P \] has to be less than 3.0% of water depth or 30(m) whichever is larger.

Position keeping accuracy is specified using 2 \( P \).

( \( P \) : Standard deviation of vessel’s deviation from the DP point.)
Controlling Theory of DPS

Feed Back Forces and Moment
Forces and Moment to minimize the Deviation from the DP Point and Target Heading.

Feed Forward Forces and Moment
Forces and Moment against the External Disturbances (Wind, Wave, Current etc.).

Control Forces and Moment
Distribute to Available Thrusters
(Considering to Save the Total of Generating Thrust)
Concept of MDPS
(Mitsui Dynamic Positioning System)

The Characteristics of “CHIKYU”
- Tank Tests
- Wind Tunnel Tests etc.

Static / Dynamic Simulations
- Select / Arrange Thrusters
- Check the Effect Sensor’s Noise
- Design the most Suitable Controlling Method etc.

Suitable Configuration for DPS
- Position Keeping Ability
- Redundancy etc.

Check the Position Keeping Ability
Simulation and Measured Data
Tank Test
( Position Keeping Test )

Current: 2.5 (kt)
Wind: 2.3 (m/s)
Wave: 5.5 (m)
Measured Data and Dynamic Simulation
(Time Histories and Trajectory)

- Wind Spd.: 19.8 m/s
- Wind Dir.: 300 deg.
- Current Spd.: 0.5 kt
- Current Dir.: 215 deg.
- Wave Height: 2.3 m
- Wave Dir.: 310 deg.

- Simulated Thrust: 60.6 ton
- Measured Thrust: 57.7 ton

- Simulated Deviation from DP Point:
  - 0 m
  - 5 m
  - 10 m
  - 15 m
  - 20 m
  - 25 m
  - 30 m

- Simulated Target Heading:
  - 310.0 deg.

- Simulated Position (Latitude):
  - 2.7 m
  - 2.2 m

- Simulated Position (Longitude):
  - 500 m
  - 700 m
  - 900 m
  - 1100 m
  - 1300 m
  - 1500 m
  - 1700 m
  - 1900 m
  - 2100 m
  - 2300 m
  - 2500 m

- Simulated Heading (deg.):
  - -70 deg.
  - -60 deg.
  - -50 deg.
  - -40 deg.
  - -30 deg.

- Simulated Target Wind:
  - 500 m
  - 700 m
  - 900 m
  - 1100 m
  - 1300 m
  - 1500 m
  - 1700 m
  - 1900 m
  - 2100 m
  - 2300 m
  - 2500 m

- Simulated Target Wave:
  - 500 m
  - 700 m
  - 900 m
  - 1100 m
  - 1300 m
  - 1500 m
  - 1700 m
  - 1900 m
  - 2100 m
  - 2300 m
  - 2500 m

<table>
<thead>
<tr>
<th>Wind Spd.</th>
<th>Simulation</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Spd.</td>
<td>0.5 kt</td>
<td>0.5 kt</td>
</tr>
<tr>
<td>Current Dir.</td>
<td>215 deg.</td>
<td>215 deg.</td>
</tr>
<tr>
<td>Wave Height</td>
<td>2.3 m</td>
<td>2.3 m</td>
</tr>
<tr>
<td>Wave Dir.</td>
<td>310 deg.</td>
<td>310 deg.</td>
</tr>
</tbody>
</table>

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Measured Data and Dynamic Simulation (Position Keeping Ability)

- 2 \( \Delta_p \) (m) from Dynamic Simulations
- 2 \( \Delta_p \) (m) from Measured Data at Sea Trials

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Position Keeping Ability Check

<table>
<thead>
<tr>
<th>Condition</th>
<th>Drilling</th>
<th>Stand-by I</th>
<th>Stand-by II</th>
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<tbody>
<tr>
<td>Current</td>
<td>1.5 kt</td>
<td>1.5 kt</td>
<td>2.5 kt</td>
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<tr>
<td>Wind</td>
<td>23 (m/s.)</td>
<td>30 (m/s.)</td>
<td>23 (m/s.)</td>
</tr>
<tr>
<td>Wave</td>
<td>4.5 (m)</td>
<td>5.5 (m)</td>
<td>5.5 (m)</td>
</tr>
</tbody>
</table>

The maximum allowable \(2p\) from specification

The results of numerical simulations under design conditions.
Characteristics of DPS for “CHIKYU”

Position Keeping Ability
Positioning Stability and Various Conditions

Redundancy
Safety and Long-term Drilling Operations

DP Functions
Ship Handling and Variety of Operations

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Characteristics of DPS for “CHIKYU”

Redundancy

The Engine Room and High Voltage Switchboard Room is partitioned by Watertight and Fireproof Bulkhead. The key instruments for DPS (Thrusters, Generators etc.) are installed in Double Hull section.

DPS System Configuration

- All signal and electric power source lines are doubled.
- Hot Back-up
- There are 3 Control Consoles and CPU for DPS.
- Triple Voting System
- Several sensors are equipped to measure the same kind of data.

<table>
<thead>
<tr>
<th>Sky-Fix DGPS</th>
<th>2 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS-GLONASS Hybrid System</td>
<td>2 units</td>
</tr>
<tr>
<td>Position Sensors</td>
<td></td>
</tr>
<tr>
<td>Acoustic Position Reference System</td>
<td>2 units</td>
</tr>
<tr>
<td>Gyro Compass</td>
<td>3 units</td>
</tr>
</tbody>
</table>

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Characteristics of DPS for “CHIKYU”

Position Keeping Ability
Positioning Stability and Various Conditions

Redundancy
Safety and Long-term Drilling Operations

DP Functions
Ship Handling and Variety of Operations
DPS Functions

Controlling Function

DP Mode
- Auto Heading Mode
- Joystick Mode
- Stand-by Mode
- Lever Mode (Grouped, Individual)
- Hand Mode
- Auto Pilot Mode
- Tracking Mode
- NFU Mode

Controlling Function (Addition)
- Alarm Monitoring Function
- Self Diagnosis Function
- Indicating Function
- Recording Function

Update DP Point
- DP Tracking
- Fix Azimuth Angle
- Power Up
- Control Gain Select
- Min. Thrust Heading

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Update DP Point

- Update the DP point to **Minimize the Riser Pipe’s tilt Angle** (top and bottom).

  **Riser Angle Control System (RACS)**

- Estimate the vessel’s position using the Riser’s tilt angles (Top and Bottom) without any other position sensor.
This DPS is designed considering the operation of “CHIKYU”.

**Position Keeping Ability**

Sea Trials & Simulation

Confirmed the Complete Position Keeping Ability under Various Conditions.

**Redundancy**

Enough Redundancy to Assure for Long Term Drilling Operation.

**DP Functions**

Highly Adaptable Ship Handling Functions for a Variety of Operations.

Scientific Drilling Operation will start in 2007