DYNAMIC POSITIONING CONFERENCE
October 15-16, 2013

DESIGN AND CONTROL SESSION II

Automatic Heading Control for Dynamic Positioning in Ice

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AUTOMATIC HEADING CONTROL FOR DYNAMIC POSITIONING IN ICE

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Contents

- Introduction, motivation
- The need for automatic heading control with DP in ice
- Proposed structure of the control system
- Numerical simulation tool and setup
- Simulation results
- Discussion
Considerable amount of resources

- 25% of undiscovered gas
- 16% of undiscovered oil
  - M. Naseri and M. Barabady, 2013
Introduction, motivation

- Decrease of the arctic ice cover

Hajime Yamaguchi, “Sea ice prediction and construction of an ice navigation support system for the Arctic sea routes”, POAC 2013

- Even more important in 2012
Introduction, motivation

**Stationkeeping is required**
- Dynamic Positioning Systems are considered as a possible solution

**DYPIC project** ([dypic.eu](http://dypic.eu))
- European collaborative research program
- Development of a model DP system for the HSVA large ice tank (presented in Houston in 2012)
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The need for automatic heading control with DP in ice

State of the art – general learnings

- Deficiencies of open water DPS in ice conditions
- Ice loads very different from open water efforts
- Ice Management crucial for success
The need for automatic heading control with DP in ice

**Recents technological progress**

- Demonstration of feasibility of stationkeeping in certain ice conditions
- Extensive model testing campaigns in 2011 and 2012 at HSVA

![Diagram showing ship position in the plane with set points and circle of 5m full scale radius.](image)
The need for automatic heading control with DP in ice

- Projection to operations
  - Maximal abilities expected when aligned with the ice drift
  - Demonstrated by the first capability plots in ice

\[ \text{0°} \quad 30° \quad 60° \quad 90° \quad 120° \quad 150° \quad 180° \quad 210° \quad 240° \quad 270° \quad 300° \quad 330° \]

0.25kt
0.5kt

Kerkeni, Metrikin and Jochmann, “Capability plots of dynamic positioning in Ice”, OMAE 2013

Zhou, Riska and Moan, “Station Keeping Capacity of a Moored Structure with Heading Control in Level Ice”, IAHR 2012
Ice drift direction estimation?

- Complex and non-trivial (sudden changes, loops, etc.)
- Task of the IM
  - Drifting buoys data => not real time!

Marchenko et al., “Characteristics of ice drift in the western Barents sea reconstructed by the data of Ice trackers deployed on drifting ice of the Barents sea in 2008 and 2010”, POAC 2011
The need for automatic heading control with DP in ice

Ice drift direction estimation?
- Significant on-going research
  - Aerial observations with unmanned technologies

Ice drift direction estimation?

- Significant on-going research
  - Aerial observations with unmanned technologies
  - Underwater observations

_Jørgensen and Skjetne_, “Dynamic estimation of drifting ice topography over a 2D area using mobile underwater measurements”, POAC2013
Ice drift direction estimation?

• Significant on-going research
  • Aerial observations with unmanned technologies
  • Underwater observations
• => Current technologies not effective

Possible function proposed by DPS?

• Keeping the vessel aligned with the ice drift
• Reduce ice loads
• Improve performances
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Proposed structure of the control system

- Based on successful algorithms tested in DYPIC
- Enhancement with a new block called «Automatic Heading Controller»
Proposed structure of the control system
Proposed structure of the control system

- Estimator
- Controller
- Thrust allocation

Positions → Automatic Heading Controller → Thrusters command

- Thrusters Feedback
- Heading
- Wind
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Numerical Model

**NTNU simulator**

- Non-smooth Discrete Element Method
- Based on NVIDIA PhysX engine
- Level and managed ice conditions
- Collision detection
- Contact dynamics
Use of a conceptual Arctic drillship

- 3 azimuths bow
- 3 azimuths stern

Froude scaling with a factor of 30


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length in design waterline</td>
<td>198.73 m</td>
</tr>
<tr>
<td>Length between perpendiculars</td>
<td>184.00 m</td>
</tr>
<tr>
<td>Breadth, moulded</td>
<td>41.33 m</td>
</tr>
<tr>
<td>Draught at design waterline</td>
<td>12.00 m</td>
</tr>
<tr>
<td>Stem angle at design waterline</td>
<td>45°</td>
</tr>
<tr>
<td>Displacement volume</td>
<td>68457 m³</td>
</tr>
<tr>
<td>Centre of gravity from aft perp.</td>
<td>95.34 m</td>
</tr>
<tr>
<td>Block coefficient</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Numerical simulation tool and setup

**Scenario**

- Simulation of stationkeeping

![Fixed Heading (FDPS)](image1)

![Automatic Heading (ADPS)](image2)
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## Simulation results

### Simulated scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Drift angle (°)</th>
<th>Ice drift velocity model scale (m/s)</th>
<th>Ice drift velocity full scale (knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>10</td>
<td>0.047</td>
<td>0.5</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>30</td>
<td>0.094</td>
<td>1</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>50</td>
<td>0.094</td>
<td>1</td>
</tr>
</tbody>
</table>
Simulation results

Scenario 1 (10°, 0.5kt)
Scenario 2 (30°, 1kt)
Simulation results

Scenario 3 (50°, 1 kt)
### Results summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FDPS</td>
<td>ADPS</td>
<td>Ratio</td>
</tr>
<tr>
<td>Median of the transversal force [kN]</td>
<td>567.4</td>
<td>323.2</td>
<td>43%</td>
</tr>
<tr>
<td>Median of the power consumption [kW]</td>
<td>4371</td>
<td>3913</td>
<td>10%</td>
</tr>
</tbody>
</table>
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Discussion

- Validation of the behaviour of the automatic heading controller

- Enhancement of stationkeeping performances and abilities

- Only tested in simulation
  - Model limitations
  - Constant ice drift

- New asset for the development of DP in Ice technology
Discussion
Thank you for your attention