A General Approach for DP Weathervane Control

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Introduction to Weathervane

Weathervane is an instrument for showing the direction of the wind

It is based on the principle that a body with a fore-end pivot aligns with the wind incident direction
This principle can be extended to a FPSO moored by a **PASSIVE turret system** at the bow.

This angle guarantees minimum mooring forces.
Introduction to Weathervane

Turret at bow
Current=1.6m/s from N
Introduction to Weathervane

Turret at bow

Weathervane Basic Principle

Stabilizing forces
Introduction to Weathervane

Turret at bow

Weathervane Basic Principle

Stabilizing forces
However, if the pivot point (Turret) is astern from the force application point, the equilibrium is not aligned with the environment.
However, if the pivot point (Turret) is astern from the force application point, the equilibrium is not aligned with the environment.
Introduction to Weathervane

Turret at mid-ship
Current=1.6m/s from N

The non-weathervane angle leads to high loads in the mooring system.
The same principle can be extended to a **ACTIVE DP** vessel.

**Passive Turret Mooring**
*with weathervane capacity*

**Active DP Shuttle**
*with weathervane capacity*
Introduction to Weathervane

Simulation of a environmental Direction variation

Control Reference Point
Close to the bow “artificial” Pivot Point

Active DP Shuttle
with weathervane capacity
This idea was introduced by **J.A. Pinkster and U. Nienhuis** (OTC, 1986)

They proposed only one propeller at the bow, and to control a reference point close to the forward end of the vessel

No heading control! Maybe dangerous

Unstable behavior for reference control point close to the midship
No heading control! Maybe dangerous.

Green safe zone
From NE to S

Environmental change

Weathervane control must be switched off by the DPO.
Introduction to Weathervane

Solution - “Manual”
Weathervane control based on DPO Experience

Actual Operation
2009 (Brazilian Basin)
Introduction to Weathervane

T.I. Fossen and J.P. Strand (Automatica, 2001)

They proposed the Wheather Optimal Heading Control (WOHC)  **ABB Patented**

Control of a forward bow point

Circle reference point is changed to keep position of vessel reference point
This work presents a novel methodology for weathervane control.

It is based on the Zero Power Control Technique.

Originally developed for Maglev Magnetic Levitation.
**Zero Power Control**

**Traditional control:**
Monitoring the system output

**Zero Power Control:**
Monitoring the controller output and the system output
Zero Power Control Weathervane

• How it works?

Control Action is used to change the position, seeking the minimum consumption
Zero Power Control
Weathervane

- Application to DP System: **Sway Control Force is used to change the Heading Set-point**
Zero Power Control
Weathervane

U=1m/s

Start:
Ψ = 30°
Ψ_{SP} = 30°

After t_1:
Ψ = 30°
Ψ_{SP} = 20°

After t_2:
Ψ = 21°
Ψ_{SP} = 10°

After t_3:
Ψ = 11°
Ψ_{SP} = 0°

Speed of set-point change depends on K1
Zero Power Control

Current

Wind

2 equilibriums
Bow incidence is stable
Stern Incidence is unstable

Stable

Unstable
Advantages of ZPC Weathervane control

- Can control any reference point

- Heading is controlled, so limits can be imposed

- All horizontal plane controllers maintain the same control structure and same tuning
Numerical Results
Numerical Results

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length (m)</td>
<td>121.92</td>
</tr>
<tr>
<td>Length entre perpendiculars L_{PP} (m)</td>
<td>121.92</td>
</tr>
<tr>
<td>Beam B (m)</td>
<td>30.48</td>
</tr>
<tr>
<td>Draft T (m)</td>
<td>5.18</td>
</tr>
<tr>
<td>Mass M (ton)</td>
<td>17092</td>
</tr>
<tr>
<td>Moment of Inertia I_{Z} (ton.m^{2})</td>
<td>2.4×10^{7}</td>
</tr>
</tbody>
</table>

DP Barge with 6 azimuth thursters

Numerical Offshore Tank – TPN Simulator

Time Domain Simulator
Condition 1 - Aligned

- Current: 0.7 m/s
- Wind: 9 m/s
- Wave: Hs=2m
- Period (Tp): 8s

Initial position and Final position are shown.

- Midship control
- Side-point control
Simulation: Brazilian Typical Environment #1

- Current: 0.7 m/s
- Wind: 9 m/s
- Wave: Hs = 2 m, Tp = 8 s

Graphs showing:
- Final position
- Initial position
- Pos X [m] and Pos Y [m]
- FY [kN]
- Yaw angle [°] and Yaw Set-point [°]

Time [s]:
- 1000 to 7000
Experimental Results
Vessel Properties

1:125 Reduced Scale DP Tanker

<table>
<thead>
<tr>
<th>Property</th>
<th>Real value</th>
<th>Model Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length</td>
<td>277m</td>
<td>2.22m</td>
</tr>
<tr>
<td>Length between Perpendiculars ([L_{pp}])</td>
<td>262m</td>
<td>2.10m</td>
</tr>
<tr>
<td>Beam [B]</td>
<td>46m</td>
<td>0.37m</td>
</tr>
<tr>
<td>Draft [T]</td>
<td>8m</td>
<td>0.064m</td>
</tr>
<tr>
<td>Mass [M]</td>
<td>80,617 ton</td>
<td>41.3 kg</td>
</tr>
<tr>
<td>Inertia ([I_z])</td>
<td>(4.85 \times 10^7) ton m(^2)</td>
<td>1.59 kg m(^2)</td>
</tr>
</tbody>
</table>
Laboratory Facilities

Wind Generation System:
• Adjustable Angle
• Adjustable Speed

Wave Generation System:
• Adjustable Frequency
• Adjustable Height
Comparison: Midship control

Simulation

Experiment

Final position

Initial position

Wind 22m/s
Comparison: Port side control

Simulation vs Experiment

Wind 16 m/s
Comparison: Stern control

Simulation vs. Experiment

Wind

[Charts and graphs showing comparisons between simulation and experiment results for various parameters such as position, force, angle, and sway.]
Midship control
Bow control
Port side control
Stern control
Experiments Summary

- Midship control
- Ahead point control
- Lateral point control
- Stern point control
• For the stern control point, the large heading oscillation is responsible for the power amplification. The Figure shows that the average DP sway force reduces after the ZPC-W is turned on. So, the weathervane action is working properly, and the oscillation problems may be mitigated by a fine tuning of the control gains.
CONCLUSIONS

- Satisfactory results so far, decreasing DP utilization (Except stern control)
- Successfully controlled the vessel bow, midship and port side and variable environment condition
- More studies need to be conducted, but the results of this paper shows that this controller is commercially viable, with great advantages over simpler weathervane controllers, specially for offshore applications
FUTURE WORK

• More simulations
• Deeper stability analysis
• Real time simulation
• Implementation
THANKS
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