“Ship design and scientific platforms— PART I”

Presentation by

Dr. – Eng. T. P. Mazarakos

Naval and Ocean Architect and Marine and Arctic Engineer, M.Sc., Ph.D.
Senior Engineer Laboratory for Floating Structures and Mooring Systems, School of Naval Architecture and Marine Engineering, National Technical University of Athens (NTUA).
Adjunct Assistant Professor, TEI of Athens, tmazarakos@naval.ntua.gr

7th FerryBox Workshop, 7-8 April Heraklion Crete, Greece
**What is Ferry Box**

**FerryBox** is an autonomous, low maintenance metrology system which has been developed especially for permanent deployment on ships, metrology platforms and river measurement points for long-term in situ monitoring of rivers, estuaries, coastal zones and open sea.
The figure shows as an example the scheme of the German FerryBox system.

The FerryBox Principle (1/2)

The water is pumped from a subsurface inlet into the measuring circuit of multiple Sensors. A debubbling unit removes air bubbles, which may enter the system during heavy seas. At the same time coarse sand particles which may be introduced in shallow harbors and which settle and tend to block the tubes are removed as well. Coupled to the debubbler there is an internal water loop in which the seawater is circulated with a constant velocity of about 1 m/s. This already decreases the tendency for building bacterial slimes on sensors and tube surfaces. A small part of the water is filtered by a hollow-fibre cross-flow filter module for automatic nutrient analysis.
FerryBox Principle (2/2)

Ferry Box (open system)  Ferry Box (closed system)
Pictures of commercial available FerryBoxes
# FerryBox Sensors

## Operational Standard Sensors
- Temperature
- Salinity
- Oxygen
- Turbidity

## Sensors that need major improvements
- Chlorophyll-a-concentration
- pH/pCO2
- Nutrients-Nitrate
- Nutrients-other
- Phytoplankton- Groups
- Phytoplankton and zooplankton by morphology

## Sensor systems that are “on the horizon”
- Algal species by genetic sensors
- Organic micro-pollutants by genetic sensors
FerryBox Ship Routes

- North Sea & Atlantic
- Baltic Sea
- Northern Atlantic
- Mediterranean Sea
Ship Type

Ship type and its primary use will influence where and how easily a Ferrybox can be installed and operated.

- All ships tend to be different even ships of the same class supplied to the same company.
- Ships need to be inspected carefully to find the most appropriate location for equipment.
- The category of regulations applied on board varies.
- Water inlet must be ahead of outlets for black and grey water from the ship (sewage and other contamination).
- Work by the crew or for the ship’s operators may interfere with the Ferrybox installation.

**Ship types:** Cargo ships, car/ passenger ferry, Ro/Ro Ship, Container ship, Merchant ships
Inlet (1/2)

The source of water used should be as close as possible to the Ferrybox installation. This is to avoid contamination both by heat, fouling of the line and other potential changes in water properties. Some sensors like inlet temperature or oxygen can be placed just after the inlet valve.

Different ships may present different opportunities for obtaining water depending on the size and design of the ship.

A direct intake with a penetration through the hull may be possible this will require the Ferrybox system to have a dedicated pump to drive or pull water through the system and then return it through a hull outlet to the sea. If the Ferrybox is above the ship’s water line the ship’s drainage system can be used.
Inlet (2/2)

Water can also be drawn in from the sea chest. This may be more accessible than a simple hull penetration and the sea chest is designed to reduce air bubbles being pumped into the ships internal cooling water systems.

Connection to internal ship circuits system is possible and can be made at any time the expertise available. Suitable designs can avoid the installation of dedicated water pumps. A key point is to know the quality of the water.
Pumps and Valves

Pumps

If the system is designed with an independent water take off point different types of pump are available, for example peristaltic or impeller pumps.

Valves

For direct penetrations through a hull or into the sea chest the use of ball valves at the inlet and outlet are recommended, as these make it possible to clean the parts through the hull when the ship is in dry dock.
Choice of System

A basic design point which affects where and on what ship a system can be installed is if the water circuit is open or closed.

In a **closed** circuit, water is pumped through the system using a single pump and no free water surface is involved reducing the risk of leaks and flooding. The system is more acceptable to a wider range of ship operators.

In an **open** system, water is pumped into the ship’s systems such as CO2 equilibrator form where it flows into a reservoir tank which then has to emptied and pumped out of the ship using a second pump. This generates a higher risk of leaks and flooding and may be less acceptable to some shipping companies.
Sensors

Temperature

In most cases the sensors for temperature and salinity operated without major problems.

Salinity

The salinity sensor requires a high accuracy and long-term stability, for instance to discriminate between different water masses which differ only little in salinity (<0.1).

Turbidity

For optical turbidity measurements the signal is very sensitive to biofouling.
Ships and Sensors

1. Ultrasonic Type Water Ingress Alarm
2. Air Purge Type Level Gauge
3. Magnetic Float Type Level Gauge
4. Magnetic Float Type Level Switch
5. Board PC
Ships and Sensors

Stabilizers
Ships and Sensors

Sea Water Line

TF - Tropical Fresh Water
F - Fresh Water
T - Tropical Seawater
S - Summer Temperate Seawater
W - Winter Temperate Seawater
WNA - Winter North Atlantic
Ships and Sensors

An ADCP mounted under the keel of the ship is an effective tool to monitor water and sediment transport through channels/straits.

The instrument is attached to the hull of the ferry 30 cm below the hull itself to prevent problems with air bubbles and interference with the turbulence of the ship. This technique measures the current field below the moving ferry.
Ships and Sensors

Bow thrusters
Ships and Sensors

Ballast tanks
Ships and Sensors

Fresh water tanks
Cooling water intake (water jet)
Ships and Sensors

Anti fouling systems
Ships and Sensors

Ship Propeller and Rudder
Ships and Sensors

Ship Propeller
Ships and Sensors

Cavitation
Ships and Sensors

Shells
Algae
Other floating bodies ...

Wadden Sea Pole (and censors)
Other floating bodies ...

Underwater glider

The underwater glider, is an autonomous underwater vehicle. It works buoyancy driven and is extremely energy efficient.

The underwater glider, is a relatively new measurement platform and originally developed as a low-cost, long-endurance device for observing the oceans.
Other floating bodies ...  

Waverider buoy

Data from the buoy are: wave height, wave length and wave period.

A Waverider buoy follows the movements of the sea surface, and determines the wave height by measuring the vertical acceleration of the buoy. At the heart of all Waverider buoys is an accelerometer, mounted on a horizontal, stabilised platform suspended in a fluid filled sphere in the bottom of the Waverider buoy.
Other floating bodies ...

HCMR buoy
Near shore

Monopiles

Tripod

Offshore Structures...
Conclusions

All marine science has an important practical side in relation to overcoming the problems of working in the often harsh environment of the sea. Sea worthiness requires robust systems that work well in harsh physical conditions. Relaying data to users also requires a robust supply chain. Added to these demands are the extra ones associated with working with shipping companies and their commercial constraints and on ships that were not designed as scientific laboratories.
“Ship design and scientific platforms—PART II”

T.P. Mazarakos* and S. A. Mavrakos**

*Laboratory for Floating Structures and Mooring Systems, School of Naval Architecture and Marine Engineering, National Technical University of Athens, Greece
tmazarakos@naval.ntua.gr

#Hellenic Centre for Marine Research, Director, Anavissos, Greece
mavrakos@naval.ntua.gr

Presentation by

Dr.–Eng. T. P. Mazarakos

7th FerryBox Workshop, 7-8 April Heraklion Crete, Greece
“Multi – Purpose Floating Structure for Offshore Wind and Wave Energy Sources Exploitation”
Selection of installation positions: Water Depths 60, 120 and 200m (ARISTEIA1, ARISTEIA2, ARISTEIA 3, ARISTEIA 4, ARISTEIA 5, ARISTEIA 6)

**Aristeia4:** N35.43°, E26.80° (200m)  
Rocky - semi-rocky soil formations

**Aristeia6:** N40.05°, E25.20° (120m)  
No rock formations soil
### Environmental Conditions - HCMR

<table>
<thead>
<tr>
<th></th>
<th>$N$</th>
<th>$m$</th>
<th>min</th>
<th>max</th>
<th>$s$</th>
<th>$CV$</th>
<th>$Sk$</th>
<th>$Ku$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_s$ (m)</td>
<td>29218</td>
<td>1.0147</td>
<td>0.0900</td>
<td>7.140</td>
<td>0.6176</td>
<td>60.8678</td>
<td>1.7833</td>
<td>5.7311</td>
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<tr>
<td>$T_p$ (s)</td>
<td>29218</td>
<td>5.3824</td>
<td>1.6800</td>
<td>13.660</td>
<td>1.5200</td>
<td>28.2398</td>
<td>1.0460</td>
<td>1.5926</td>
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<tr>
<td>$U_w$ (m/s)</td>
<td>29218</td>
<td>6.4672</td>
<td>0.1100</td>
<td>20.570</td>
<td>3.3328</td>
<td>51.5339</td>
<td>0.3513</td>
<td>-0.3352</td>
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</table>

**Basic statistical characteristics of the time series of wind and wave**

**Aristeia 4 (200m)**

<table>
<thead>
<tr>
<th></th>
<th>$N$</th>
<th>$m$</th>
<th>min</th>
<th>max</th>
<th>$s$</th>
<th>$CV$</th>
<th>$Sk$</th>
<th>$Ku$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_s$ (m)</td>
<td>29218</td>
<td>0.4074</td>
<td>0.000</td>
<td>4.500</td>
<td>0.402</td>
<td>98.699</td>
<td>2.7925</td>
<td>12.0299</td>
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<tr>
<td>$T_p$ (s)</td>
<td>29218</td>
<td>3.2296</td>
<td>1.260</td>
<td>7.710</td>
<td>0.945</td>
<td>29.2723</td>
<td>1.0385</td>
<td>1.7451</td>
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<tr>
<td>$U_w$ (m/s)</td>
<td>29218</td>
<td>4.1412</td>
<td>0.060</td>
<td>20.680</td>
<td>2.924</td>
<td>70.605</td>
<td>1.2027</td>
<td>1.5689</td>
</tr>
</tbody>
</table>

**Basic statistical characteristics of the time series of wind and wave**

**Aristeia 6 (120m)**
Floating System Properties

Top view of floating structure and basic characteristics of its parts.

Side view of floating structure and basic characteristics of its parts.
Floating Platform Geometry

**Geometrical Dimensions of each OWC device**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of inner concentric cylindrical body</td>
<td>5m</td>
</tr>
<tr>
<td>Draft of inner concentric cylindrical body</td>
<td>20m</td>
</tr>
<tr>
<td>Outer &amp; inner radius of the oscillating chamber in each device</td>
<td>14–14.5m</td>
</tr>
<tr>
<td>Oscillating chamber’s draft</td>
<td>8m</td>
</tr>
<tr>
<td>Spacing between offset columns</td>
<td>50m</td>
</tr>
<tr>
<td>Length of Main column (tower base)</td>
<td>20m</td>
</tr>
<tr>
<td>Diameter of pontoons and cross braces</td>
<td>1.6m</td>
</tr>
<tr>
<td>Draft</td>
<td>20m</td>
</tr>
<tr>
<td>Elevation of main column (tower base above SWL)</td>
<td>10m</td>
</tr>
</tbody>
</table>

**Mass Characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Platform Mass (including ballast)</td>
<td>2.183x10^6kg</td>
</tr>
<tr>
<td>Displacement</td>
<td>6086.3t</td>
</tr>
<tr>
<td>KG (below SWL)</td>
<td>4.05m</td>
</tr>
<tr>
<td>Platform roll inertia</td>
<td>1.5x10^9kgm^2</td>
</tr>
<tr>
<td>Platform pitch inertia</td>
<td>1.5x10^9kgm^2</td>
</tr>
<tr>
<td>Platform yaw inertia</td>
<td>2.7x10^9kgm^2</td>
</tr>
</tbody>
</table>

**Mooring System**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of mooring lines</td>
<td>3</td>
</tr>
<tr>
<td>Mooring line diameter</td>
<td>130mm</td>
</tr>
<tr>
<td>Mooring line Mass per unit length</td>
<td>104kg/m</td>
</tr>
<tr>
<td>Mooring line mass in water</td>
<td>888.6N/m</td>
</tr>
<tr>
<td>Young’s modulus of elasticity (E)</td>
<td>200GPa</td>
</tr>
<tr>
<td>Equivalent mooring line extensional stiffness (EA)</td>
<td>2646MN</td>
</tr>
<tr>
<td>Total Restoring coefficient Kxx (depth 200m)</td>
<td>180KN/m</td>
</tr>
<tr>
<td>Total Restoring coefficient Kzz (depth 200m)</td>
<td>44.1MN/m</td>
</tr>
<tr>
<td>Pretension</td>
<td>32.4MN</td>
</tr>
</tbody>
</table>
### Wind Turbine Geometry

#### WT masses and center of mass

<table>
<thead>
<tr>
<th>WT components</th>
<th>Mass [t]</th>
<th>Zcg [m]</th>
<th>Length [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower</td>
<td>250</td>
<td>43.3</td>
<td>77.6 (+10)</td>
</tr>
<tr>
<td>Nacelle</td>
<td>240</td>
<td>89.45</td>
<td>-</td>
</tr>
<tr>
<td>Hub</td>
<td>50</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>Blade x 3</td>
<td>17.74</td>
<td>~90</td>
<td>61.5 (+1.5)</td>
</tr>
</tbody>
</table>
Formulation of the problem

- **Analytical Method** (Computer Code: HAMVAB- S. A. Mavrakos, 1995)

- **Reduce Order Model of the WT** (Mavrakos, 2015, Mazarakos, 2015)


\[
\begin{bmatrix}
M_{ij} + A_{ij}(\omega) + M^{WT}
\end{bmatrix} \ddot{x} + \begin{bmatrix}
B_{ij}(\omega) + B_{ij}^{WT}
\end{bmatrix} \dot{x} + \\
\begin{bmatrix}
C_{ij} + C_{moorings} + C_{ij}^{WT}
\end{bmatrix} x = F(\omega)e^{i\omega t}
\]
Hydrodynamic Studies and coupled hydro- aero- elastic analysis of the moored multi- purpose floating platform

Hydrodynamic Calculations for the Floating Platform POSEIDON (120m)

- Exciting Wave Forces
- Motions
- Air Pressure
- Volume Flow
- Drift Forces
- Added Mass/ Damping
- Wave Drift Damping
- Shear Forces
Experimental Campaign
Experimental Campaign
Experimental Campaign
Surge motion of the TLP combined floating platform, 3 OWC’s and wind turbine system. Wave heading 0 degrees.
Multi-Purpose Floating Structure for Offshore Wind and Wave Energy Sources Exploitation - Sensors
Multi-Purpose Floating Structure for Offshore Wind and Wave Energy Sources Exploitation—Sensors