CONCEPT AND DESIGN OF A MULTIUSE OFFSHORE FISHFARM FEEDER

[JOSE M. FERREIRA da CRUZ]

CONFERENCIA ANUAL DO CENTRO DE ENERGIA DAS ONDAS MADEIRA – 15.SETEMBRO.2011
THE SEA IN MADEIRA ISLANDS

FROM CALM SEAS
TO HEAVY SEA STATES
AQUAILHA Lda

- STARTED UP PRODUCTION IN OFFSHORE CAGES IN 2006

-In 2011: Plans for production 500 TONS OF GILT-HEAD BREAM

-In 2012: Previsions of 700 TONS OF GILT-HEAD BREAM

-In 2013: Previsions of 1,200 TONS OF GILT-HEAD BREAM
OFFSHORE FEEDING PROCESS

- ACCESSING THE CAGES IN CALM SEA

- TRANSPORTING FEEDING PELLETS BY HAND IN CALM SEAS
SEA IN MADEIRA ISLAND

7-9 METERS WAVES

7-9 m
THE TECHNOLOGY USED BY AQUAILHA

CAGES BUILT WITH FLEXIBLE PVC PIPES

PROTECTION FOR INTRUSION OF SEA BIRDS

HARVESTING THE ADULT FISH

WORKBOAT FOR TRANSPORTATION OF PELLETS AND CAPTURES
OPERATIONAL RESTRICTIONS OF OFFSHORE AQUACULTURE

FEEDING PELLETS LOADED IN PORT

SMALL WAVES CAUSING OPERATIONAL PROBLEMS

6-7 METERS WAVES, MAKING IMPOSSIBLE THE ACCESS AND FEEDING
1. HOW TO FEED MULTIPLE CAGES AND HUNDREDS OF TONS OF FISH, IN A HEAVY SEA STATE DURING WINTER IN ATLANTIC?
2. HOW TO MONITOR THE PHYSICAL PARAMETERS TO DECIDE ON THE RIGHT SPECIFICATION ON FOOD?
THE INITIAL ENGINEERING CONCEPT

<table>
<thead>
<tr>
<th>Structure</th>
<th>Cross section</th>
<th>Description</th>
<th>Value of $C_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright cylinder</td>
<td>Smooth surface; metal, timber, concrete</td>
<td>0.45 0.5 0.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rough surface; round ribs, $h = 2%d$</td>
<td>0.7 0.8 0.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very rough surface; sharp ribs, $h = 8%d$</td>
<td>0.8 1.0 1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smooth surface; sharp edges</td>
<td>1.0 1.2 1.4</td>
<td></td>
</tr>
</tbody>
</table>

**MINIMUM RESISTANCE COEFFICIENT**

$$F_D = C_D q A$$

$$d \sqrt{q} > 2.3 \text{lb}^{1/2}$$

$$A = dh$$

$h/d = 25$

$h/7$

$h/d = 1$
THE INITIAL ENGINEERING CONCEPT (LOADS)

Morison Formula

\[ f = \frac{1}{2} \rho C_D D u |u| + \rho C_M \frac{\pi}{4} D^2 \frac{\partial u}{\partial t} \]
THE INITIAL ENGINEERING CONCEPT

• CAPACITY TO STORE 210 TONS OF PELLETS
• 6 INDEPENDENT SILOS OF 35 TONS EACH
• STORAGE OF 4 DIFFERENT TYPES OF PELLETS

• CAPACITY TO SURVIVE IN SEA STATES UP TO 12m WAVE HEIGHT
• MOORING SYSTEM UP TO 120 m DEPTH
THE GENERAL ARRANGEMENT
THE MODEL

General Arrangement

3D Model
LOAD CONCEPTS
LOAD CONCEPTS

[UNIT] N, m
[DATA] ALIMENTADOR-7 RESTORED direct, TOTAL APPLIED FORCE(v), STEP 1, TIME=0.0
STRUCTURAL RESPONSE (STRESS)

• NUMERIC MODEL OF A QUARTER OF THE ENTIRE STRUCTURE;

• VON MISES STRESSES OBTAINED FROM 120-170 Mpa;
STRUCTURAL RESPONSE (DISPL.)
MOORING CONCEPT

BASIC CONCEPT FOR BUOYS

• POOR SOLUTION FOR HEAVY DYNAMIC MOVEMENTS

• HIGH STRESS CONCENTRATION ON THE ARTICULATED SWIVEL
MOORING CONCEPT
MOORING CONCEPT
INTACT & DAMAGED STABILITY

THE SURVIVAL OF THE UNIT IN HEAVY SEAS, OBLIGES THE STUDY OF THE FEEDER IN THE FOLLOWING CONDITIONS:

• INTACT STABILITY
• DAMAGED STABILITY (FLOODING OF COMPARTMENTS)
INTACT & DAMAGED STABILITY
CONDITION: LIGHTSHIP

Floating Status

Draft FP: 3.409m
Draft MS: 3.409m
Draft AP: 3.409m
Trim: zero
LCG: 0.000

Heel: zero
Equil: Yes
Wind: 0.0 kn
Wave: No
VCG: 1.564 m

Loading Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (MT)</th>
<th>LCG (m)</th>
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</thead>
<tbody>
<tr>
<td>Light Ship</td>
<td>80.00</td>
<td>0</td>
</tr>
<tr>
<td>Deadweight</td>
<td>167.39</td>
<td>0</td>
</tr>
<tr>
<td>Displacement</td>
<td>247.39</td>
<td>0</td>
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</table>

IMO Resolution A.749

Limit
1. Area from 0.00 deg to 30.00
2. Area from 0.00 deg to 40.00 or Flood
3. Area from 30.00 deg to 40.00 or Flood
4. Righting Arm at 30.00 deg
5. Angle from 0.00 deg to MaxRA
6. GM at Equilibrium

<table>
<thead>
<tr>
<th>Limit</th>
<th>Min/Max</th>
<th>Actual</th>
<th>Margin</th>
<th>Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>&gt;0.0550 m-R</td>
<td>0.257</td>
<td>0.202</td>
<td>Yes</td>
</tr>
<tr>
<td>(2)</td>
<td>&gt;0.0900 m-R</td>
<td>0.478</td>
<td>0.388</td>
<td>Yes</td>
</tr>
<tr>
<td>(3)</td>
<td>&gt;0.0300 m-R</td>
<td>0.221</td>
<td>0.191</td>
<td>Yes</td>
</tr>
<tr>
<td>(4)</td>
<td>&gt;0.200 m</td>
<td>1.034</td>
<td>0.834</td>
<td>Yes</td>
</tr>
<tr>
<td>(5)</td>
<td>&gt;25.00 deg</td>
<td>85.00</td>
<td>60.00</td>
<td>Yes</td>
</tr>
<tr>
<td>(6)</td>
<td>&gt;0.350 m</td>
<td>1.793</td>
<td>1.443</td>
<td>Yes</td>
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</tbody>
</table>

Righting Arms vs. Heel

Heel angle (Degrees)
INTACT & DAMAGED STABILITY

CONDITION: FULL LOAD

IMO RESOLUTION A.749

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<th>Margin</th>
<th>Pass</th>
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<tr>
<td>(1) Area from 0.00 deg to 30.00</td>
<td>&gt;0.0550 m-R</td>
<td>0.135</td>
<td>0.080</td>
<td>Yes</td>
</tr>
<tr>
<td>(2) Area from 0.00 deg to 40.00 or Flood</td>
<td>&gt;0.0900 m-R</td>
<td>0.245</td>
<td>0.155</td>
<td>Yes</td>
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<tr>
<td>(3) Area from 30.00 deg to 40.00 or Flood</td>
<td>&gt;0.0300 m-R</td>
<td>0.110</td>
<td>0.080</td>
<td>Yes</td>
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<tr>
<td>(4) Righting Arm at 30.00 deg</td>
<td>&gt;0.200 m</td>
<td>0.538</td>
<td>0.338</td>
<td>Yes</td>
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<tr>
<td>(5) Angle from 0.00 deg to MaxRA</td>
<td>&gt;25.00 deg</td>
<td>88.75</td>
<td>63.75</td>
<td>Yes</td>
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<tr>
<td>(6) GM at Equilibrium</td>
<td>&gt;0.350 m</td>
<td>0.939</td>
<td>0.559</td>
<td>Yes</td>
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</tbody>
</table>

Floating Status

| Draft FP | 6.407m | Heel | zero |
| Draft MS | 6.407m | Equil | Yes |
| Draft AP | 6.407m | Wind | 0.0 kn |
| Trim | zero | Wave | No |
| LCG | 0.000 | VCG | 3.144 m |

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<tr>
<td>Deadweight</td>
<td>384.88</td>
<td></td>
</tr>
<tr>
<td>Displacement</td>
<td>464.88</td>
<td></td>
</tr>
</tbody>
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INTACT & DAMAGED STABILITY
CONDITION: FLOODING LOWER

Floating Status

Draft FP  8.401m
Draft MS  8.400m
Draft AP  8.400m
Trim      0.00 deg.
LCG       0.000

Heel      zero
Equil     Yes
Wind      0.0 kn
Wave      No
VCG       3.144 m

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INTACT & DAMAGED STABILITY
CONDITION: SIDE FLOODING

Floating Status
Draft FP 11.152m
Draft MS 8.802m
Draft AP 6.453m
Trim fwd 26.32 deg.
LCG 0.000

Heel zero
Equil Yes
Wind 0.0 kn
Wave No
VCG 3.144 m

IMO RESOLUTION A.749
Limit
Min/Max Actual Margin Pass
(1) Area from 0.00 deg to 30.00 >0.0550 m-R 0.140 0.085 Yes
(2) Area from 0.00 deg to 40.00 or Flood >0.0900 m-R 0.233 0.143 Yes
(3) Area from 30.00 deg to 40.00 or Flood >0.0300 m-R 0.093 0.063 Yes
(4) Righting Arm at 30.00 deg >0.200 m 0.487 0.287 Yes
(5) Angle from 0.00 deg to MaxRA >25.00 deg 51.29 26.29 Yes
(6) GM at Equilibrium >0.350 m 1.141 0.791 Yes

Righting Arms vs. Heel

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CONDICÃO LEVE

CALADO 3.5m
CONDIÇÃO CARREGADO

CALADO 6.2m
AQUISIÇÃO DE DADOS DE COMPORTAMENTO ESTRUTURAL

EXTENSÓMETROS
OBRIGADO

CONFERENCIA ANUAL DO CENTRO DE ENERGIA DAS ONDAS
MADEIRA – 15.SETEMBRO.2011