Controlling Machinery Induced Underwater Noise

Raymond Fischer, Noise Control Engineering, Inc.
NOAA Vessel Quieting Technology
Approach

- How much U/W noise reduction is required?
- Critical sources
  - Machinery
  - Propulsor (covered by others)
- Critical paths
  - Airborne and structureborne
- Noise/Vibration control approaches
- Use NOAA Fisheries R/V as illustration
# Range to achieve 120 dB Level

<table>
<thead>
<tr>
<th>Source Level, dB re 1μPa @1m</th>
<th>range, km Spherical spreading</th>
<th>range, km 1.5 power spreading</th>
<th>range, km Cylindrical spreading</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5-m Zodiac</strong></td>
<td>0.06</td>
<td>0.25</td>
<td>4</td>
</tr>
<tr>
<td><strong>Tug &amp; Barge</strong></td>
<td>0.35</td>
<td>2.5</td>
<td>125</td>
</tr>
<tr>
<td><strong>Supply Ship</strong></td>
<td>1</td>
<td>11.7</td>
<td>1260</td>
</tr>
<tr>
<td><strong>Large Tanker</strong></td>
<td>3</td>
<td>46.4</td>
<td>10000</td>
</tr>
<tr>
<td><strong>Drill ship, rigs, platforms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Drill Ship</strong></td>
<td>0.6</td>
<td>4.6</td>
<td>320</td>
</tr>
<tr>
<td><strong>Conical Drilling Unit</strong></td>
<td>1.8</td>
<td>21.5</td>
<td>3200</td>
</tr>
<tr>
<td><strong>DREDGING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ship 1</strong></td>
<td>0.4</td>
<td>2.9</td>
<td>160</td>
</tr>
<tr>
<td><strong>Ship 2</strong></td>
<td>1.8</td>
<td>21.5</td>
<td>3200</td>
</tr>
</tbody>
</table>
Ocean Attenuation

Attenuation at 10 km
(Spherical spreading = 80 dB)
Cargo Ship Broad Band Noise

Radiated Noise

173 m Direct Drive

173 m Direct Drive
Radiated Noise – Cruise Ship

Radiated Noise - Alaska Cruise Ships
Ship Noise Sources

Propeller Noise Sources
  Cavitation noise & structural re-radiation

Machinery Noise Sources
  Main propulsion system
  Aux. Equipment
    Structural-borne path
    Air-borne path
    Sea-connected system
Direct Radiation, proportional to hull vibration, area and radiation efficiency

Airborne Transmission, proportional to hull thickness, area

First Structureborne Path

2nd Structureborne Path

Airborne Path

Diesel Engine

Ship Structure
Various Drive Vibration Levels
Best Acoustic Design

- Use inherently quiet equipment
  - Rotating rather than reciprocating
- Use (dynamically) stiff foundations
- Place noisier equipment toward centerline
- Use double hulls or tanks outboard of Engine Room
- Diesel-Electric offers greatest opportunity
  - Isolation mounts for gensets, quiet motors
Vibration Isolators

- Best shipboard noise control element.
- Reduces SB path.
- Isolation of Propulsion Engines requires flexible coupling and other components.
- Use only Elastomeric Marine-Grade Mounts.
- Requires dynamically stiff foundations.

Does not eliminate low frequency noise!
Two-stage Genset Isolation System for NOAA FRV
Acoustic Insulation

- Reduces AB & SSB Transmission.
- Typically insulation’s base material is either fiberglass or mineral wool.
- High Transmission Loss (or HTL) material has middle layer of limp mass (usually leaded vinyl).
- Transmission Loss or STC (Sound Transmission Class) defines performance.
## Treatment Effectiveness

<table>
<thead>
<tr>
<th>Treatment</th>
<th>AB</th>
<th>FSB</th>
<th>SSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration Isolation – passive $20-$400/mt</td>
<td>0</td>
<td>10-20</td>
<td>0</td>
</tr>
<tr>
<td>Raft mount equipment</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Steel framing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acoustic Insulation 3 to 8 pcf; $1-$4/ft²</td>
<td>5-10</td>
<td>0</td>
<td>5-10</td>
</tr>
<tr>
<td>Damping; 2-3 psf; $8-$12/ft²</td>
<td>0</td>
<td>5-10</td>
<td>5-10</td>
</tr>
<tr>
<td>Bow Thruster Treatments</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

“Quiet Vessel” approximately 7% to 10% total cost of vessel. Quiet R/V 15% to 20% cost of vessel.

*Values are approximate dB reduction of overall sound.*
Follow Through

All the treatments in the world will not overcome a poor inspection/QA and verification program!

NCE/NOAA Symposium
Advanced Treatments

Air layer (belt forward of engine room)
- Effective mid- to high-frequency (10+ dB)
- Amplifies low freq (-5 dB over 50 Hz bw)
- Holes can clog if not maintained

Hull coating
- Effectiveness depends on material ‘compliance’ and thickness (>10 dB)
- Adherence and damage issues
Advanced Treatments

- Active mount system
  - Improved low frequency performance
  - Cancels tones and multiples

- Keep machinery inside hull (Azipods currently radiate significant mechanical noise)
**Designer NOISE**

- Program for shipboard noise prediction
- Created under US NAVY SBIR Project
- Part of Flagship Designer suite from Proteus Engineering
- Ship specific
  - Modeling, constants, etc.
<table>
<thead>
<tr>
<th>Low Noise Equipment</th>
<th>Propulsion Motor Specially Designed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Double Stage Vibration Isolation</strong></td>
<td>Diesel Gens &amp; Reciprocating Equipment 3512 system – 18,113 kg; 3508 system – 14,770 kg</td>
</tr>
<tr>
<td><strong>Single Stage Isolation</strong></td>
<td>Auxiliary Equipment &amp; HVAC</td>
</tr>
<tr>
<td><strong>Acoustic Insulation</strong></td>
<td>Perimeter of Engine Room and other noisy spaces</td>
</tr>
<tr>
<td><strong>Damping Tiles</strong></td>
<td>Applied to hull and bulkheads (16 tons)</td>
</tr>
<tr>
<td><strong>Hull &amp; Propeller</strong></td>
<td>Specially designed by U.S. Navy (NSWC)</td>
</tr>
</tbody>
</table>

NCE/NOAA Symposium
FRV Radiated Noise – 11 kts
Prediction Tools

DIFFERENCE BETWEEN MEASURED AND PREDICTED RADIATED NOISE - AOE-6

754.5' LOA, 48,800 tons, twin screw
## Range to 120 dB Level

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<th>Source Level, dB re 1 μPa @1m</th>
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<th>range, km Cylindrical spreading</th>
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<tr>
<td><strong>FRV-40</strong></td>
<td>150</td>
<td>.03</td>
<td>.1</td>
</tr>
<tr>
<td><strong>5-m Zodiac</strong></td>
<td>156</td>
<td>0.06</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Tug &amp; Barge @</strong></td>
<td>171</td>
<td>0.4</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Supply Ship</strong></td>
<td>181-20=161</td>
<td>1.1-&gt;.11</td>
<td>12-&gt;.54</td>
</tr>
<tr>
<td><strong>Large Tanker</strong></td>
<td>190-20=170</td>
<td>3.2-&gt;.32</td>
<td>46-&gt;2.1</td>
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<tr>
<td><strong>Drill ship, rigs, platforms</strong></td>
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</tr>
<tr>
<td><strong>Drill Ship</strong></td>
<td>175-20=155</td>
<td>0.6-&gt;.06</td>
<td>4.6-&gt;.2</td>
</tr>
<tr>
<td><strong>Conical Drilling Unit</strong></td>
<td>185-20=165</td>
<td>1.8-&gt;.02</td>
<td>22-&gt;1</td>
</tr>
<tr>
<td><strong>DREDGING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ship 1</strong></td>
<td>172-20=152</td>
<td>0.4-&gt;.04</td>
<td>3-&gt;.1</td>
</tr>
<tr>
<td><strong>Ship 2</strong></td>
<td>185-20=165</td>
<td>1.8-&gt;.02</td>
<td>22-&gt;1</td>
</tr>
</tbody>
</table>
Technology exists to evaluate and control ship noise & should be applied to vessels that operate in environmentally sensitive areas.

Primary noise sources are the propulsion drives – low frequencies and the propulsors – mid to high frequency (can trump once cavitating).

Drives should be selected based on having low vibration source levels and/or utilizing vibration isolation mounts.

Novel treatments show potential but need development.


Active Control of Engine Induced Noise in a Naval Application, M Winberg, S Johansson, T Lag, 8th Intl Congress on Sound & Vib, Hong Kong, 2001.


NCE References

- "Verification of a Hybrid Model for Shipboard Noise Predictions," (with Won-Ho Joo, and Jong-Hyun Park), InterNoise 03, Inst. of Noise Control Engineers, Korea, Aug., 2003.