ON THE VIBRATION DAMPING OF NOISE SOURCES ON BOARD SHIPS

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Aiming at the optimization of ship acoustics, many actions have to be implemented on the noise sources present on-board in order to reduce airborne noise emission and structure borne vibration propagation. Among all possible countermeasures, those related to the isolation of the vibration sources are here considered.

Vibration damping has to be applied to all possible joining elements between sources and ship structures aiming at balancing the attenuation performances of one connection with respect to the others.

Considering each equipment as a vibration source characterized by significant vibration levels, which may increase underwater noise radiation and/or jeopardize internal noise comfort, typical connections to be investigated are represented by the resilient mounts (which sustain the equipment), elastic joints between duct/pipes and machinery (such as flexible hoses and bellows) and power supply electric cables.

Basing on proper design criteria, and once the purchased components comply with the defined noise and vibration requirements, an on-board validation is indeed necessary aiming at determining if elastic connections efficiency could be affected by component defects or inappropriate mounting solutions.

Present paper target is to assess the effectiveness of the suitable vibration damping actions through a measurements campaign on the equipment installed on-board without neglecting some technical considerations about the obtained results.

Keywords: Vibration sources damping, elastic connections, on-board validation.

1. Introduction

Ship acoustic signature is a composition of airborne and structure borne levels of each equipment, machinery and component installed on-board.

High masses and relevant noise and vibration levels characterize ship main noise sources and thus, basing on an “energy” principle, significantly affect both vessel underwater-radiated noise and internal comfort. Diesel generating sets, diesel propulsion engines, gas turbines and reduction gearboxes, for instance, fall into this category. All other ship equipment, characterized by a lower effect on the acoustic signature have, in any case, to be optimized from the acoustic point of view in order to maintain their noise and vibration levels as low as possible.

Present paper deals with the isolation of typical vibration sources optimizing and evaluating attenuation performances of all possible connections between sources and ship structures.
2. Vibration sources propagation paths

Considering typical vibration sources, which may affect acoustic behaviour of the vessel, each joining element with ship structures has to be investigated and designed in order to balance the attenuation performances of one connection with respect to the others.

Among all possible vibration sources installed on-board, the study referred to various types of pumps (related to different ship systems) considered and analysed in present paper. As shown in Figure 1, considering the generic equipment (i.e. pump), following main vibration propagation paths have to be investigated:

- **Resilient mounts.** In order to decrease the vibration levels generated by the equipment and transmitted to the structures, soft elastic rubber mounts between machinery feet and ship foundation are installed.
- **Flexible hoses/bellows.** Concerning the vibration transmitted through the inlet/outlet pipes, attenuation properties of the elastic joints between duct/pipes and machinery have to be considered.
- **Electric cables.** Wires attenuation properties have to be increased basing on the position and the on-board integration of the equipment power cables.

The selection of resilient mounts and flexible hoses/bellows, as well as on-board power cables integration, must aim at reducing the vibrations transmitted to the hull since early design stages.

To achieve this goal, since the purchasing phase, suitable technical characteristic for the resilient mounts and the flexible hoses/bellows are imposed to the equipment suppliers.

Concerning the electrical cables selection, metal wires represent, unfortunately, good vibration propagation paths and thus, in order to obtain adequate flexibility values, it is necessary to install cables with an appropriate curvature radius and enough length.

![Vibration propagation paths for generic equipment](image)

Figure 1: Vibration propagation paths for generic equipment
3. On-board damping validation

Once technical characteristic for the elastic connections of the vibration sources are defined, an on-board validation is indeed necessary aiming at determining the efficiency of joining elements between vibration sources and ship structures.

A set of vibration measurements on a significant number of different equipment has been carried out on board of a ship under delivery.

Utilising an accelerometer connected to a portable Analyser (as shown in Figure 2(b)), it has been possible to measure the vibration acceleration levels $L_a$ in dB. In order to have a comprehensive vision of the matter, evaluations can be carried out basing on measurements performed in third octave frequency bands along three directions.

In order to evaluate attenuation performances of the main vibration propagation paths, following parameter has been considered:

$$\Delta[dB] = L_{a,\text{before}}[dB] - L_{a,\text{after}}[dB]$$  (1)

where:

- $L_{a,\text{before}}[dB]$ represents the vibration level measured before (i.e. equipment side) the joining elements considered whatever it is (a resilient mount, an inlet/outlet flexible hose/bellow or a power cable);
- $L_{a,\text{after}}[dB]$ represents the vibration level measured after (i.e. ship structures side) the joining elements considered whatever it is (a resilient mount, an inlet/outlet flexible hose/bellow or a power cable).

$L_{a,\text{before}}$ and $L_{a,\text{after}}$ could be represented by single vibration acceleration level measured before and after the propagation paths connections in one/all direction/s for one equipment, or by a mean value calculated among all equipment and/or all directions and/or all joining elements between equipment and ship structures.

Above-mentioned mean value can be obtained performing an arithmetical mean calculation if the objective is to represent the attenuation trend of the connections or a logarithmical mean calculation if the focus is on the evaluation of the vibration energy transmitted by the equipment to the hull through the connections themselves.

Table 1 describes some possible definitions of $L_a$ levels adopted to evaluate attenuation performances.

As shown in Figure 2, vibration measurements have been performed placing the accelerometer above and below the resilient mounts (Figure 2(a) and (b)), before and after the inlet/outlet flexible hoses/bellows (Figure 2(c) and (d)) and before and after the power cable free section (Figure 2(e) and (f)).

Basing on measurement results, it is possible to assess the attenuation effectiveness of the elastic connections identifying potential component defects or inappropriate mounting solutions.

<table>
<thead>
<tr>
<th>$L_a$ definitions</th>
<th># Equip.</th>
<th># Join. El.</th>
<th>Meas. Dir.</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>single level</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Attenuation value obtained selecting one equipment, one joining element and one measuring direction</td>
</tr>
<tr>
<td>arith-mean</td>
<td>1</td>
<td>all</td>
<td>all</td>
<td>Mean Attenuation value obtained selecting one equipment, all joining elements and all measuring direction</td>
</tr>
<tr>
<td>log-mean</td>
<td>1</td>
<td>all</td>
<td>all</td>
<td>Mean Attenuation value obtained selecting one particular joining element and one/all direction/s</td>
</tr>
</tbody>
</table>

Table 1: Possible definitions of $L_a$ level
4. Validation Results

Aiming at evaluating actual damping grade of on-board vibration sources, several typologies of equipment have been measured. Basing on measurement results it has been possible to pursue following objectives:

- to describe vibration behaviour of single equipment and to evaluate attenuation properties of elastic mount, pipe connections and electric cables;
- to find possible component defects or inappropriate mounting solutions;
- to highlight damping attenuation trends of typical joining elements.
- to verify the compliance of the vibration levels obtained downstream of the connections with the ship noise and vibration requirements;

In order to achieve above-mentioned goals, particular attention has been paid to the following aspects:

- **Background Noise.** If vibration levels measured downstream of elastic connections are comparable or higher than those measured upstream of them, it is possible to erroneously ascribe lower attenuation performances to the connections even if levels measured on the equipment feet or pipes or cable trays are affected by high vibration levels coming from adjacent machinery.
- **Defects.** Once it has been established that vibration levels are not influenced by the background noise, poor connections attenuation performances can be due to possible component defects or inappropriate solutions adopted during the equipment installation that have to be rectified.
- **Damping Trends.** To improve the reliability of possible statistical trends derived by on board validation of the elastic connection attenuations, a large number of measurements are required. It is clear that measured levels shall be considered valid if they are not influenced by the background noise and if possible component defects are excluded. The availability of statistical attenuation data concerning damping behaviour of typical elastic joining elements are useful to perform noise and vibration predictions since early design stages.
- **Noise and Vibration requirements.** On board validation measurements allow to check if the equipment installation has been done correctly in terms of vibration sources damping and, at the same time, to evaluate the compliance with the ship noise and vibration requirements.

5. Conclusions

Among all feasible actions aimed at maintaining ship noise and vibration levels as low as possible, those related to the isolation of the vibration sources are here considered.
Present paper deals with vibration sources damping carried out balancing the attenuation performances of the joining elements installed on the main propagation paths such as resilient mounts (which sustain the equipment), elastic joints between duct/pipes and machinery (i.e. flexible hoses and bellows) and power supply electric cables.

Once damping design requirements for the elastic connections are fulfilled, an on-board validation is performed aiming at determining the efficiency of joining elements selected.

Effectiveness of the suitable vibration damping actions is evaluated performing a set of vibration level measurements before (i.e. equipment side) and after (i.e. ship structures side) the joining elements.

The validation campaign performed on board focuses, among others, on the compliance assessment of the vibration levels obtained downstream of the connections with the ship noise and vibration requirements. In addition, an evaluation of the equipment vibration behaviour finding potential component defects or inappropriate mounting solutions and, by means an extended set of measurements, the opportunity to obtain damping attenuation trends of typical joining elements are possible.

REFERENCES