Full-Scale Modal Analysis of a Ro-Lo Vessel in Operation

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MOTIVATION
The ship building industry faces the challenges to improve transportation capability, lower fuel consumption or increase speed, often in combination. Generally, this means lower weight and increased flexibility of the ship structures. Nevertheless the ships still have to fulfill the demands of classification societies concerning vibration levels and sustain a long service life.

A ship is exposed to a complex vibration environment, influenced by the sea as well as by operational conditions. Particularly, the hydrodynamic load effects are difficult to estimate analytically. Experimental results are therefore important to verify the analytical models. In the present poster preliminary results from a full-scale modal test of a Ro-Lo vessel (Figure 1) are presented.

EXPERIMENTAL SETUP AND EQUIPMENT
The measurement points (26 in total) were spread out on the main deck of the vessel, two points on the deck house (fore), and two points on the flume tank (aft) as shown in Figure 2.

The following equipment was used:
- 3x National Instrument 4497, 16 channel, 24bit analog inputs cards
- 45x Dytran 3097A3 accelerometers, 500mV/g
- Up to 300 meter coaxial cables, in total more than 5 kilometers of coaxial cable
- In-house software for DAQ control, based on MATLAB DAQ-toolbox

All measurement points were measured simultaneously. The presented results are obtained from a 30 minutes record under which stationary conditions can be justified.

The cruising speed was 10 knots and the sea was very calm.

**Table 1: Estimated natural frequencies and damping ratios**

<table>
<thead>
<tr>
<th>Mode #</th>
<th>Freq. [Hz]</th>
<th>Damping [%]</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.004</td>
<td>0.394</td>
<td>1. vertical bending mode</td>
</tr>
<tr>
<td>2</td>
<td>1.861</td>
<td>0.634</td>
<td>1. horizontal bending mode</td>
</tr>
<tr>
<td>3</td>
<td>1.890</td>
<td>0.328</td>
<td>2. vertical bending mode</td>
</tr>
<tr>
<td>4</td>
<td>2.249</td>
<td>0.687</td>
<td>1. torsional mode</td>
</tr>
<tr>
<td>5</td>
<td>2.751</td>
<td>0.399</td>
<td>3. vertical bending mode</td>
</tr>
</tbody>
</table>

**Figure 1:** The investigated Ro-Lo vessel, by Flensburger Shipyard

**Figure 2:** Overview drawing of the vessel, including Measurement points.
RESULTS
Until now only preliminary results are obtained, which are presented here.

In Table 1 the natural frequencies and damping ratios are shown for the first five flexible modes. The corresponding mode shapes are shown in Figure 3.

Most important from these preliminary results is that it is possible to extract the first modes with current state-of-the-art parameter extraction techniques.

FURTHER WORK
The sea trail under which the measurement was performed gave other operation condition than the one presented here.

The modal dependency of these different condition needed to be studied, e.g. to verify scale model experiments. 
Soon (Feb 2014) we publish a conference paper on this dependency.

Another important factor for the usefulness of operational modal analysis to validate analytical models of ship structures are clear guidelines on the required measurement condition and analysis parameters to obtain consistent modal estimates.

CONTACT
The presented result is a part of the Ph.D. project by Esben Orlowitz (eo@iti.sdu.dk) within Operational Modal Analysis, supervised by Anders Brandt (abra@iti.sdu.dk).

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Figure 3: Mode shapes for the first five modes of the vessel. (a) 1. vertical bending mode, (b) 1. horizontal bending mode, (c) 2. vertical bending mode, (d) 1. torsional mode and (e) 3. vertical bending mode.