THE COMPARISON OF MODAL ANALYSIS BY TWO DIFFERENT EXPERIMENTAL APPROACHES

Yu Zheng         Shibo Xiong
Research Institute of Mechno-Electronic Engineering
Taiyuan University of Technology
No.53 Xikuang Street 030024 Taiyuan, Shanxi, P.R.Chin
e-mail: Zheng1959@163.com

ABSTRACT: This paper presents the comparison of two different methods in the system identification. The experimental modal analysis and operational modal analysis are applied to a local structure of a storage/retrieval machine (S/R machine). The different vibration measurement approach and different theoretic analysis approach give us more information than only one approach. Through the result, the consistence of two approaches is found, and the vibrating integrality that is obtained from measurement under normal operating condition is better than that is obtained from measurement during exciting the structure by a hammer. From the system frequency response functions that obtained by measurement during exciting the structure by a hammer, the high vibration response frequencies are indicated clearly.

On the base of the two experiments, the vibration properties of local structure of a storage/retrieval machine are thoroughly grasped. This is a foundation of structure modification to reduce the vibrating noise of storage/retrieval machine during operating conditions.

1. INTRODUCTION

In large-scale automatic stereoscopic warehouse, the noise produced by storage/retrieval machine during operating conditions especially during high speed operating conditions influence the work environment of user and surrounding life environment of public. Hence, the velocity of storage/retrieval machine is increased, at the same time, the method reducing the noise of storage/retrieval machine must be considered. The main purpose of the test is finding a way to optimize the dynamic design of storage/retrieval machine so that it can work in high quality.

During the S/R machine in operating condition, the vibration behaviors of S/R machine lower beam is one of important factors producing noise. Hence it is necessary to understand lower beam vibration behavior to reduce the noise produced by S/R machine. For this purpose, we make the analysis of S/R machine lower beam modal analysis by two different approaches.

2. TESTING OBJECT

The test object is single mast S/R machine (WJ58DB) made in Taiyuan Gangyu Logistics Engineering Company. (See figure 1).

![Figure 1 Single mast S/R machine](image)
The main structure of single mast S/R machine consists of five parts: upper beam, lower beam, mast, carriage and shuttle.
There are driving wheel device, driven wheel device and traveling guiding wheels device on the lower beam. There are traveling guiding wheels device on the upper beam.

The sizes are list below:

- Total mass: 6917 kg
- Lifting capacity: 200 kg
- Overall height: 19390 mm
- Upper beam length: 1693 mm
- Lower beam length: 3766 mm

3. EXPERIMENT MODAL ANALYSIS

3.1 Experiment test

In order to understand S/R machine lower beam vibration behavior, the local structure experimental modal analysis has be done. The measurement instruments used in experiment are, hammer and accelerometers made in Switzerland KISTLER company, 16 channels SignalCalc Mobilyzer and modal analysis software produced by America DATA PHYSICS CORPORATION company.

The driven wheel is excited by a hammer (100 points), the force direction is vertical downward. Force signal is transferred to lower beam through bearing. 72 accelerometers were placed on lower beam (see figure 2).

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![Figure 2: Experimental modal test points place on the beam](image)

![Figure 3: Frequency response functions of all test points](image)

<table>
<thead>
<tr>
<th>Mode #</th>
<th>Frequency (Hz)</th>
<th>Damping (%)</th>
<th>Mode #</th>
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<th>Damping (%)</th>
<th>Mode #</th>
<th>Frequency (Hz)</th>
<th>Damping (%)</th>
<th>Mode #</th>
<th>Frequency (Hz)</th>
<th>Damping (%)</th>
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<td>10</td>
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<td>4.09</td>
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<td>2</td>
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<td>9.30</td>
<td>11</td>
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<td>4.61</td>
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<td>3.37</td>
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<td>1092.4</td>
<td>1.43</td>
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<tr>
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<td>7.04</td>
<td>14</td>
<td>665.34</td>
<td>3.39</td>
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<td>1174.7</td>
<td>1.62</td>
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<tr>
<td>6</td>
<td>390.92</td>
<td>5.60</td>
<td>15</td>
<td>691.88</td>
<td>3.34</td>
<td>24</td>
<td>1204.1</td>
<td>1.61</td>
<td></td>
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<tr>
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<td>411.88</td>
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<td>737.45</td>
<td>4.38</td>
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</tbody>
</table>

Table 1: Mode frequencies extracted by LSCE
3.2 Test result

In this experiment twelve single dimension accelerometers were used, ten frequency response functions were obtained by DP analyzer. The modal parameters were extracted by experimental modal analysis software with Least Squares Complex Exponential (LSCE) method. Thirty-six mode frequencies were extracted. Depending on identify by Modal Assurance Criterion Matrix (MAC), twenty-five mode frequencies were remained. (See table 1). The ten mode frequencies that have high response behavior were extracted (See table 2). They can be compared with other mode frequencies that were extracted by operational modal analysis software.

4 OPERATION MODAL ANALYSIS

4.1 Experiment test

In order to understand the lower beam vibration behavior during S/R machine under the operating condition, the local structure operational modal analysis was applied to S/R machine. Twenty-four test points were placed on the lower beam (see figure 4).

<table>
<thead>
<tr>
<th>Mode #</th>
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<th>13</th>
<th>15</th>
<th>17</th>
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<td>Frequency (Hz)</td>
<td>411.88</td>
<td>611.40</td>
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<td>773.70</td>
<td>835.74</td>
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<td>Damping (%)</td>
<td>1.19</td>
<td>3.37</td>
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<td>4.12</td>
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<tr>
<td>Mode #</td>
<td>20</td>
<td>21</td>
<td>23</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>921.56</td>
<td>946.56</td>
<td>1092.4</td>
<td>1174.7</td>
<td>1204.1</td>
</tr>
<tr>
<td>Damping (%)</td>
<td>4.09</td>
<td>4.07</td>
<td>1.43</td>
<td>1.62</td>
<td>1.61</td>
</tr>
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</table>

Table 2 High response experimental mode frequencies

<table>
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<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tr>
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<td>408</td>
<td>436</td>
<td>537</td>
<td>608</td>
<td>668</td>
<td>768</td>
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<tr>
<td>Damping (%)</td>
<td>4.1</td>
<td>3.16</td>
<td>4.06</td>
<td>1.337</td>
<td>0.645</td>
<td>2.318</td>
<td>3.637</td>
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<tr>
<td>Mode #</td>
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<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
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<td></td>
</tr>
<tr>
<td>Frequency (Hz)</td>
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<td>945.4</td>
<td>1086</td>
<td>1174</td>
<td>1206</td>
<td>1226</td>
<td></td>
</tr>
<tr>
<td>Damping (%)</td>
<td>2.439</td>
<td>2.295</td>
<td>4.25</td>
<td>1.199</td>
<td>0.9283</td>
<td>1.34</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 High response operational mode frequencies

In the test the three dimension accelerometers made in Switzerland KISTLER company and 16 channels Signal analyzer made in America DP company were used. The operational modal analysis software produced by Danmark B & K company.

The data sets were acquired during S/R machine moving speed above 120m/s. The six data sets were obtained. Then the time domain signal were imported operational modal analysis software and the modal parameters were extracted.

4.2 Test result
The modal parameters were extracted by operational modal analysis software with Enhanced Frequency Domain Decomposition (EFDD) approach (See figure 5). According to the MAC identification result (See figure 6), the thirteen high response mode frequencies were remained (See table 3).

5 Mode shape comparison between two approaches

Because the purpose of the test is reducing the noise produced during S/R machine under operating condition, so the high mode frequencies are interested.

At frequency about 410Hz, two mode shapes are similar. The lower beam is swaying. (See figure 7)

At frequency 611.4Hz, two mode shapes are different. Experiment mode shape is complicated, the some of the beam do same swing, the others do swing in inverse direction.
Operation mode shape is beam do twisty swing. (See figure 8)

At frequency 690Hz, two mode shapes are different. There are two regions in the beam, the experimental mode shape present the beam do same swing in same region. But, mode shape is different in the different region.
The operational mode shape is displayed as a whole vibration. (See figure 9)

At frequency about 773Hz, two mode shapes are similar. (See figure 10)

At frequency 835.74Hz, two mode shapes are similar. The region around exciting point does twisty swing. (See figure 11)

At frequency 920Hz, two mode shapes are different. Experimental mode shape is ruleless, every part of beam do swing is uncorrelation.
Operational mode shape is the sides of beam do same swing and beam body does bending swing. (See figure 12)

At frequency 946.65Hz, two mode shapes are similar. The X axis as a symmetry axis, the region around exciting point does swing oppositely, and beside of exciting point the sides of lower beam do swing in same direction. (See figure 13)

At frequency about 1092Hz, two mode shapes are similar. The main vibration shape is the X axis as a symmetry axis, The sides of lower beam dose swing oppositely. (See figure 14)

At frequency 1174Hz, two mode shapes are similar. The one side of lower beam swing bigger than another side, and the lower beam does twisty swing slightly. (See figure 15)

At frequency 1204Hz, the two mode shapes are different. At the experimental modal frequency, the X axes as symmetry axes, the side of lower beam does swing in same direction. Swing is harmonious.
The operational mode shape present the lower beam does bending swing. (See figure 16)

At frequency 1226Hz, there is only the operational modal frequency. The X axis as symmetry axis, the sides of lower beam dose swing oppositely. (See figure 17)

6 Conclusion

From comparison between two experiment approaches we can find:
(1) The mode frequencies that are extracted by operational modal analysis correspond to the high response model frequencies that are extracted by experimental modal analysis.
(2) Mode shape animation it is evident that in operational modal analysis experiment, the integrality of structure vibration is better than that in experimental modal analysis.
(3) Through mode shape animation it can be observed that main components of vibration shape of lower beam are swing crossed X axis. Hence it is helpful that changing the structure of driving wheel, driven wheel and traveling guiding wheels to reduce the noise produced by S/R machine during it under operating condition.

In sum either experimental modal analysis or operational modal analysis has special advantage in different way. Two approaches are complementary in application. Two approaches are applied at the same time make us understand mechanical structure clearly and completely.

Acknowledgment

The work was financially supported by NSF of Shanxi province (20011064) and NSFC (59975064).

References


Figure 7

Figure 8

Figure 9
Figure 13

Experiment mode shape

Operation mode shape

Figure 14

Experiment mode shape

Operation mode shape

Figure 15

Experiment mode shape

Operation mode shape
Experiment mode shape

Figure 16

Operation mode shape

1205Hz

Figure 17 Operation mode shape

1226Hz