# Correlation between FEM calculated and on site measured natural frequencies

**Ing. Valter Cergol Ph.D.,** Cergol Research s.r.l. Director, Trieste, Italy email: cergol@cergolresearch.com

**Ing. Alessandro Toson MSc.,** Naval architect and marine engineer, Cergol Engineering Consultancy s.r.l. technical department, Trieste, Italy email: toson@cergolengineering.com

**Ing. Romualdo Di Giovanni MSc.,** Naval architect and marine engineer, Cergol Engineering Consultancy s.r.l. technical department, Trieste, Italy email: digiovanni@cergolengineering.com

## ABSTRACT

This paper describe a comparative analysis between the FEM calculated and on board measured natural frequency measurements for different typology of ships. From the analysis of the researched data, the accuracy of the results obtained with the numerical calculations and on situ measurements is assessed and discussed.

## NOTATION

| | |
|---|---|
| F.E.A. | Finite element analysis |
| RMS | Root Mean Square |
| mm/s | Millimeters per second |
| mld. | Moulded |
| o.a. | Over all |

## INTRODUCTION

The scope of this presentation is to evaluate the accuracy of the FEM analyses, comparing the calculated results with the natural frequencies measured on board.
A Dynamic F.E.A., to predict the natural frequencies of the ship structure, have been performed for different areas of the investigated ships;

The description of the natural frequency measurement methodologies and the features of the investigated ships, are included in dedicated chapters.

The results of the numerical calculation are compared with the values measured on board.

## IMPACT HAMMER METHODOLOGY FOR NATURAL FREQUENCY ASSESSMENT ON BOARD

The on-site tests have been performed by using the impact methodology. With this procedure it is possible to excite the structures of interest and, by using high sensitivity transducers, it is possible to record the signal.

Dedicated instrumentation is used for this typology of measurement:

- Force-acceleration instrumented
- High sensitivity transducers

**Figure 1 Sensors-Intentionally masked**

In order to correctly investigate the structural behavior of the investigated items, the following procedure has been followed:

1. The testing surface has been carefully cleaned in order to eliminate residual dust, metallic grains or other material that could affect the reading of the transducers;
2. All the collected data have been post-processed.

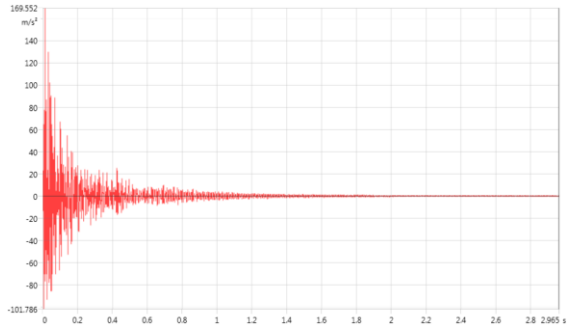

**Figure 2 Typical response signal**

## MAIN FEATURES OF THE INVESTIGATED VESSELS

The study is performed on four different type of ships. The vessels considered in this study are characterized by the following main features:

| | |
|---|---|
| Length o.a. | between 70 and 230 m |
| Breadth mld. | between 13 and 31 m |
| Draught | between 6.3 and 8.2 m |
| Cruising speed | between 14 and 23 kn |

In this document, the vessels used for the analyses are named as Ship 01, Ship 02, Ship 03 and Ship 04.

For each ship, dedicated F.E.A. models are developed considering the structural layouts of decks, bulkheads and beams as per the scantling and general arrangement plans. All vessels are built in steel and part of the superstructures are in light alloy.

## NUMERICAL MODELING

In this chapter, the F.E.A. model descriptions are shown.

In order to generate the structural model of the hull of the vessel, a three-dimensional mathematical representation is developed using a finite element model (3D – F.E.A. model). The provided scantling plans and general arrangement plan are used as modeling guide line.

The generated F.E.A. models used in the study are shown in Figure 3.



**Figure 3. F.E.A. models -Intentionally masked**

## NUMERICAL MODEL ANALYSIS RESULTS

### F.E.A. for mode shape calculation

The natural frequencies and mode shapes of the model are obtained solving for the eigenvalues of the following equation:

$$[M]\{\ddot{u}(t)\} + [C]\{\dot{u}(t)\} + [K]\{u(t)\} = 0 \qquad [2]$$

In case also the dynamic response can be calculated by the equation [3]:

$$[M]\{\ddot{u}(t)\} + [C]\{\dot{u}(t)\} + [K]\{u(t)\} = \{f(t)\} \qquad [3]$$

Where:

$[M]$is the mass matrix
$[C]$ is the damping matrix
$[K]$ is the stiffness matrix
$\{\ddot{u}(t)\}$ is the acceleration vector
$\{\dot{u}(t)\}$ is the velocity vector
$\{u(t)\}$ is the displacement vector
$\{f(t)\}$ is the force vector

Typical F.E.A. outputs are shown from Figure 4 to Figure 7. In each figure, only the area of interest is shown and the right-side legend shows the eigenvectors levels.

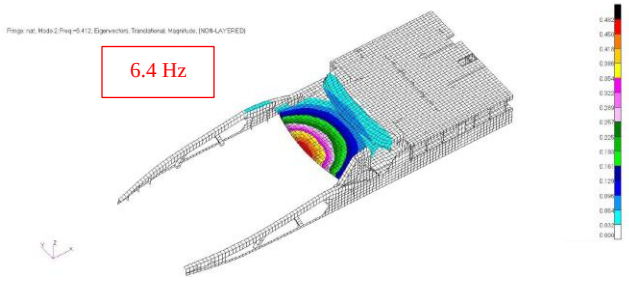


**Figure 4. Mode shape analysis results – Ship 01 aft area view**

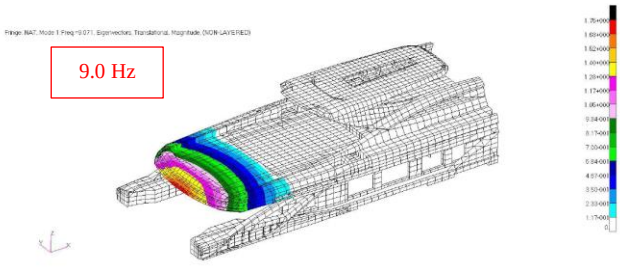


**Figure 5. Mode shape analysis results – Ship 02 aft area view**

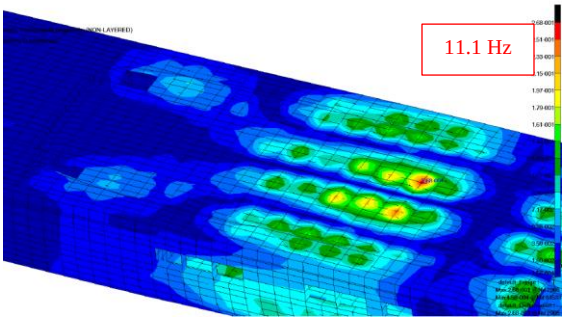


**Figure 6. Mode shape analysis results – Ship 03 main deck view**

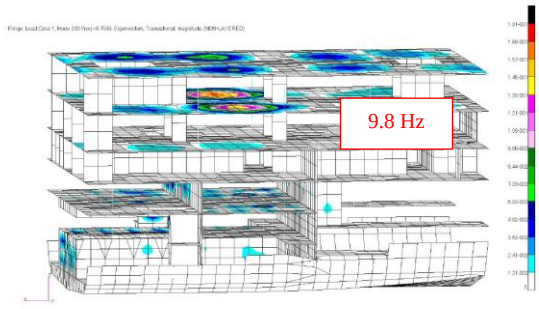


**Figure 7. Mode shape analysis results – Ship 04 engine frame**

The F.E.A. results are summarized from Table 1 to Table 4. In each table, the investigated area and the calculated natural frequency value are listed.

| Area | Natural frequency [Hz] |
|---|---|
| Aft main deck | 6.4 |

**Table 1. F.E.A. calculated natural frequency – Ship 01**

| Area | Natural frequency [Hz] |
|---|---|
| Aft upper deck | 9.0 |

**Table 2. F.E.A. calculated natural frequency – Ship 02**

| Area | Natural frequency [Hz] |
|---|---|
| Main deck center | 11.1 |

**Table 3. F.E.A. calculated natural frequency – Ship 03**

| Area | Natural frequency [Hz] |
|---|---|
| Main propulsion engine frame | 9.8 |

**Table 4. F.E.A. calculated natural frequency – Ship 04**

## ON BOARD MEASURED NATURAL FREQUENCIES

For each investigated ship, a dedicated natural frequency measurement campaign is performed on board. An executive summary of the measured natural frequencies is shown from Table 5 to Table 8. The same locations and conditions analyzed in the F.E.A. calculations are considered.

| Area | Natural frequency [Hz] |
|---|---|
| Aft main deck | 6.1 |

**Table 5. F.E.A. calculated natural frequency – Ship 01**

| Area | Natural frequency [Hz] |
|---|---|
| Aft upper deck | 10.2 |

**Table 6. F.E.A. calculated natural frequency – Ship 02**

| Area | Natural frequency [Hz] |
|---|---|
| Main deck center | 10.5 |

**Table 7. F.E.A. calculated natural frequency – Ship 03**

| Area | Natural frequency [Hz] |
|---|---|
| Main propulsion engine frame | 11.0 |

**Table 8. F.E.A. calculated natural frequency – Ship 04**

The measured natural frequency spectra are shown from Figure 8 to Figure 11. The spectra are presented in different formats due to the fact that the measurements have been performed with different instrumentation.

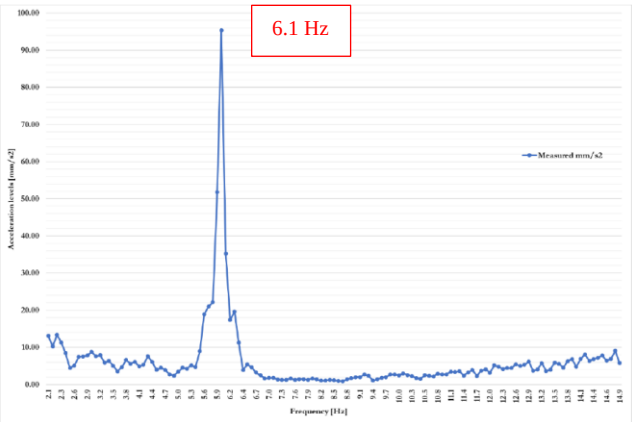


**Figure 8. Measured natural frequency spectra – Ship 01**

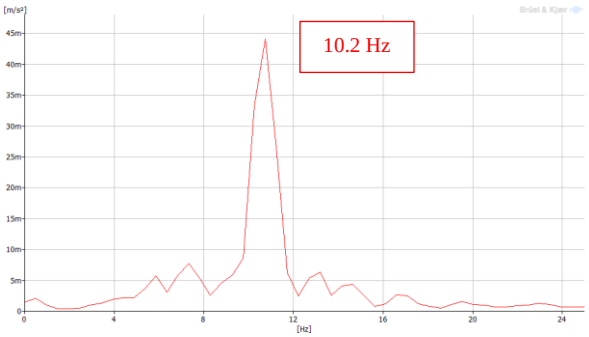


**Figure 9. Measured vibration levels spectra – Ship 02**

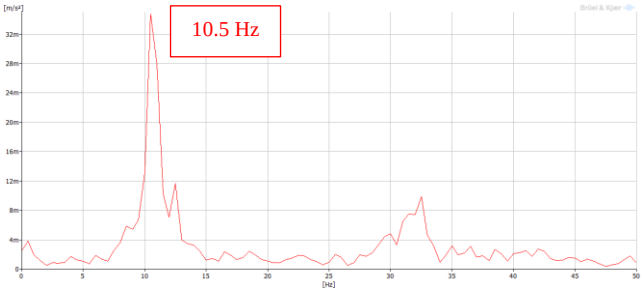


**Figure 10. Measured vibration levels spectra – Ship 03**

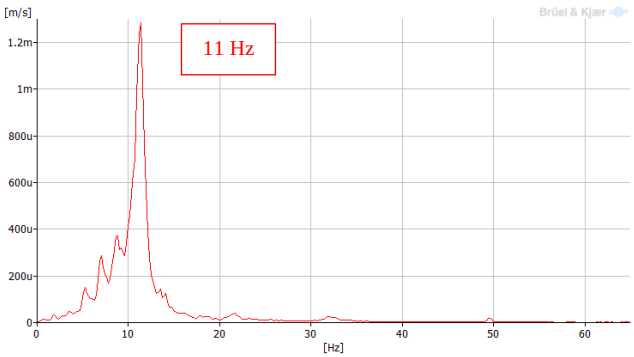


**Figure 11. Measured vibration levels spectra – Ship 04**

## COMPARISON ANALYSIS BETWEEN NUMERICAL CALCULATIONS AND MEASUREMENTS ON BOARDS

The results obtained from F.E.A. calculations are compared with the measurements taken on board the vessels.

### Comparison between F.E.A. calculated and on board measured natural frequency

The F.E.A. calculated and on board measured natural frequency values are summarized in Figure 12.

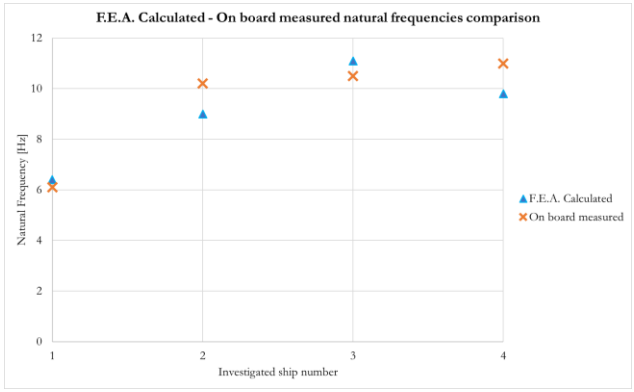


**Figure 12. Comparison diagram**

## CONCLUSIONS

Based on the numerical calculation results and the measurements performed on board, the following can be stated:

- Comparing the calculated and measured natural frequency, an average difference of 8% is evaluated.

Based on the comparative analysis results, the used methodology can be considered adequate and the accuracy of the performed calculations and measurements sufficient for this typology of investigations. The performed study is a confirmation of how the numerical modeling is a very reliable predictive calculation methodology.

Considering the obtained results, it is authors suggestion to apply a 8-10% correction on the F.E.A. predicted natural frequency.


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