Guideline development for offshore structure vibration analysis

ANDRII PISHCHANSKYI

SYNOPSIS

Table 1. Synopsis

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<td>1. Special studies</td>
<td>Mesh convergence: • beam; • cylindrical shell; • plate; • stiffened panel.</td>
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<td>Parameter sensitivity: • material; • 1D vs. 2D vs. 3D finite elms.;</td>
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<td>• effective modal mass; • added mass.</td>
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<td>The design of a vibration isolation system.</td>
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<td>3. Complex case</td>
<td>The local response of a retractable thruster.</td>
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INTRODUCTION

- Service limit state;
- High structural complexity;
- Modal analysis.

**Working Hypotheses:**
- Steady state response;
- No stress analysis;
- Periodic loading.

![Figure 1. Characteristics and sources of periodic loading: (a) simple; (b) complex](image)

BASIC SIMPLE STRUCTURES
BASIC SIMPLE STRUCTURES

DEFINITION OF OPTIMAL FINITE ELEMENT SIZE

Discrepancy, \( \Delta = \frac{\text{numerical} - \text{analytical}}{\text{analytical}} \) (1)

Figure 2. Simply supported beam

a). 7 elements, \( \Delta = -6.09\% \)

b). 15 elements, \( \Delta = -1.16\% \)

Figure 3. Mode shape with 5 half-waves

SIMPLE REAL CASE
SIMPLE REAL CASE

FREQUENCY RESPONSE ANALYSIS PROCEDURE

- Extract natural frequencies and mode shapes
- Define damping
- Apply excitation force
- Define a set of frequencies to be used in the solution of frequency response analysis

Figure 4. Flowchart of frequency response analysis

SIMPLE REAL CASE

MODAL ANALYSIS

Figure 5. Mode shape 1 of E-motor assembly
Figure 6. Mode shape 2 of E-motor assembly
SIMPLE REAL CASE
FREQUENCY RESPONSE ANALYSIS PROCEDURE

- Modal damping ratio $\zeta = 0.02$ is suggested for all modes to be conservative.
- The magnitude of unbalance excitation force:

$$ F_{unb} = me\omega^2 $$

(2)

![Figure 7. Force magnitude](image)

Figure 7. Force magnitude

![Figure 8. Decomposed force for main continuous rate](image)

Figure 8. Decomposed force for main continuous rate

SIMPLE REAL CASE
FREQUENCY RESPONSE ANALYSIS. NUMERICAL RESULTS

![Figure 9. Velocity at COG of E-motor](image)

Figure 9. Velocity at COG of E-motor

**Conclusion:**
Investigation into vibration isolation is reasonable.
SIMPLE REAL CASE

VIBRATION ISOLATION

The problem is solved by so-called force transmissibility:

$$T.R. = \frac{F_R}{F_0} = \frac{1 + (2\zeta^2)^2}{(1 - \zeta^2)^2 + (2\zeta)^2}$$  \hspace{0.5cm} (3)

$$F(t) = F_0 \sin(\omega t)$$

1. Define static load per chock
2. Select the stiffness of a chock
3. Select the damping of a chock

Figure 13. Flowchart of the design of a vibration isolation system

Figure 12. Model of vibration isolation

Figure 14. Transmissibility ratio
3. Select the damping of a chock which provides the desired isolation.

Figure 15. Transmissibility ratio as a function of $r$ ratio

Figure 16. The magnification of isolation area

Conclusion:
- Resonance frequencies are shifted;
- Velocity with chocks are way below threshold.
COMPLEX REAL CASE

RETRACTABLE AZIMUTH THRUSTER

Conclusion:
Vibration influences structural design in the vicinity of the azimuth thruster.

Figure 18. Retractable azimuth thruster
Figure 19. FE modelling
**COMPLEX REAL CASE**

**MODAL ANALYSIS**

Figure 20. Pendulum mode of stem section about y-axis

Figure 21. Pendulum mode of stem section about x-axis

Figure 22. Bending mode of stem section about y-axis

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**COMPLEX REAL CASE**

**MODAL ANALYSIS**

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**GUIDE DEVELOPMENT FOR OFFSHORE STRUCTURE VIBRATION ANALYSIS**

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**EMSHIP**
COMPLEX REAL CASE

DYNAMIC LOADING

- Only $F_{x,\text{dyn}}, F_{y,\text{dyn}}, F_{z,\text{dyn}}, M_{x,\text{dyn}}$ are used.
- A modal damping of 2% is considered.

Figure 23. Main static and dynamic forces

COMPLEX REAL CASE

NUMERICAL RESULTS

Figure 34. Velocity of COG of gearbox foundation
CONCLUSION AND FUTURE PROSPECTS

CONCLUSION

• The flowchart of vibration analysis and the instructions for its implementation are given;
• The suitability of analysed analytical solutions for the definition of optimal FE size is investigated;
• Required sensitivity studies are performed;
• Modal analysis as a means to identify resonance beforehand is described;
• Static FE model is adapted for the purpose of vibration analysis;
• Local and global vibration responses are obtained;
• Vibration isolation system is designed.
FUTURE PROSPECTS

- Specify the local response of azimuth thruster with the precise mean values of loading as the functions of steering angle and ship speed;
- Consider hydrodynamic added mass for the submerged surfaces.

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