Guideline development for offshore structure vibration analysis

ANDRII PISHCHANSKYI

SYNOPSIS

Table 1. Synopsis

Section	Performed work	
1. Special studies	Mesh convergence: • beam; • cylindrical shell; • plate; • stiffened panel.	Parameter sensitivity: • material; • 1D vs. 2D vs. 3D finite elms.; • effective modal mass; • added mass.
2. Simple case	The global response of an electrical motor assembly.	The design of a vibration isolation system.
3. Complex case	The local response of a retractable thruster.	

INTRODUCTION

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

Working Hypotheses:

- Steady state response;
- No stress analysis;
- Periodic loading.

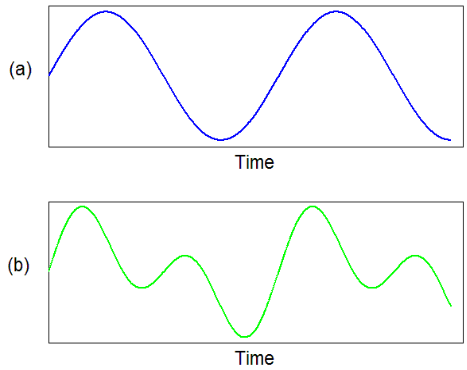


Figure 1. Characteristics and sources of periodic loading: (*a*) simple; (*b*) complex

BASIC SIMPLE STRUCTURES

BASIC SIMPLE STRUCTURES

DEFINITION OF OPTIMAL FINITE ELEMENT SIZE

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

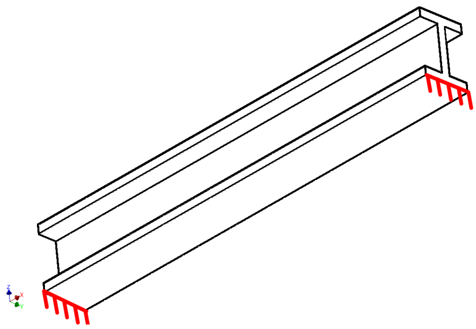
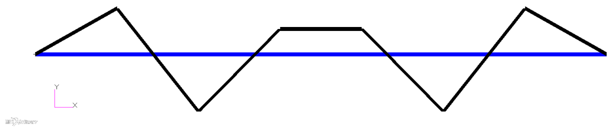
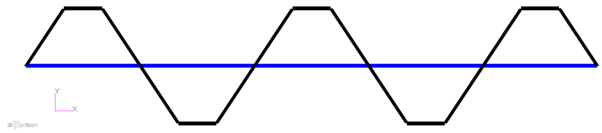


Figure 2. Simply supported beam



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

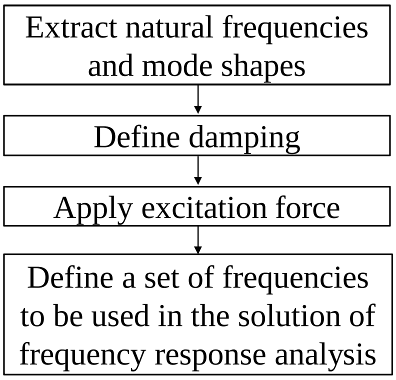


Figure 4. Flowchart of frequency response analysis

SIMPLE REAL CASE

MODAL ANALYSIS

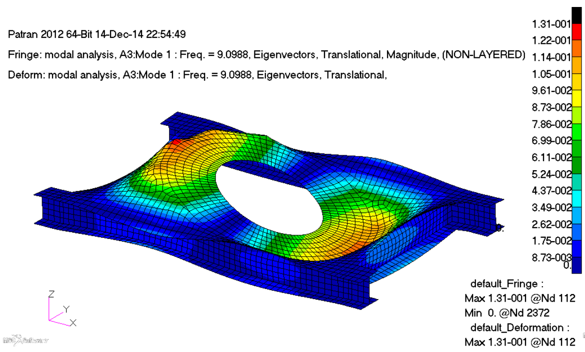


Figure 5. Mode shape 1 of E-motor assembly

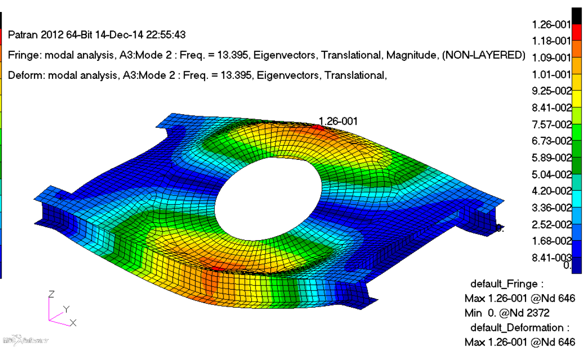


Figure 6. Mode shape 2 of E-motor assembly

SIMPLE REAL CASE

FREQUENCY RESPONSE ANALYSIS PROCEDURE

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

$$F_{unb} = me\omega^2 \qquad (2)$$

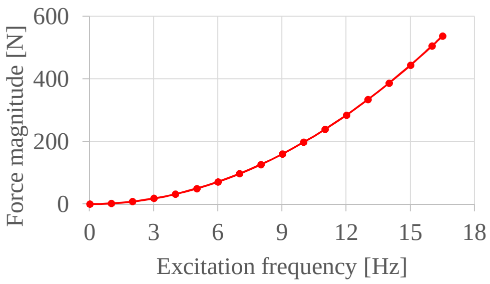


Figure 7. Force magnitude

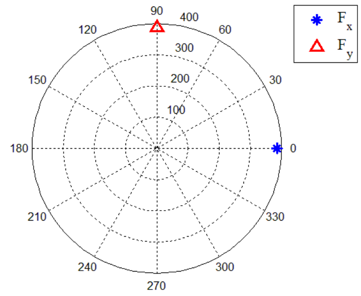


Figure 8. Decomposed force for main continuous rate

SIMPLE REAL CASE

FREQUENCY RESPONSE ANALYSIS. NUMERICAL RESULTS

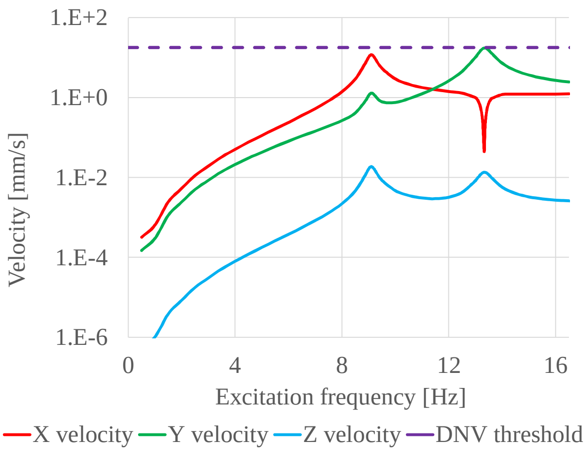


Figure 9. Velocity at COG of E-motor

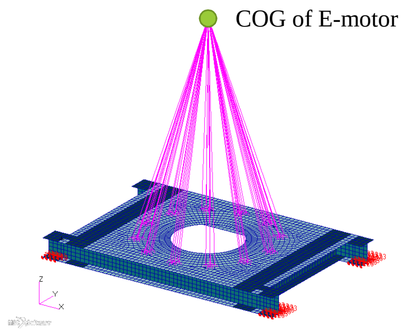


Figure 10. Node for velocity extraction

Conclusion:
Investigation into vibration isolation is reasonable.

SIMPLE REAL CASE

VIBRATION ISOLATION

The problem is solved by so-called force transmissibility:

$$T.R. = \frac{F_T}{F_0} = \sqrt{\frac{1+(2\zeta r)^2}{(1-r^2)^2+(2\zeta r)^2}} \quad (3)$$

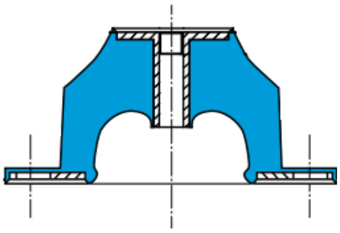


Figure 11. Rubber chock

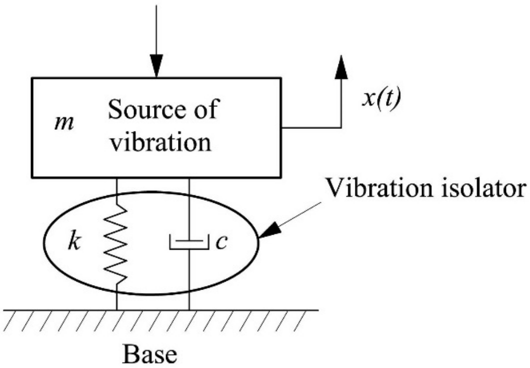


Figure 12. Model of vibration isolation

SIMPLE REAL CASE

VIBRATION ISOLATION

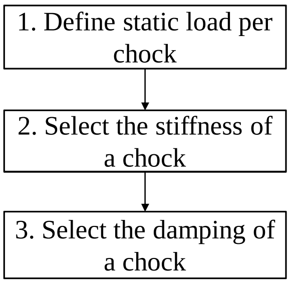


Figure 13. Flowchart of the design of a vibration isolation system

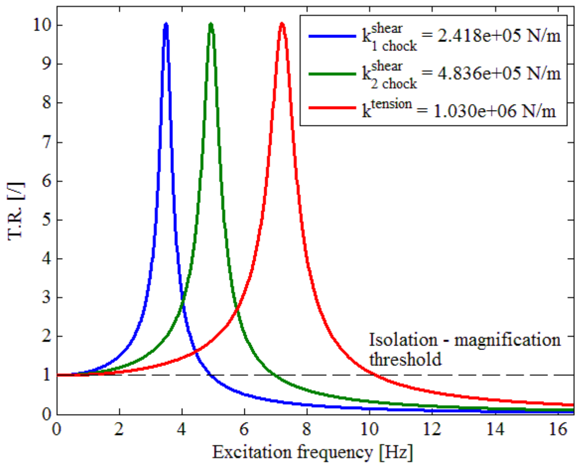


Figure 14. Transmissibility ratio

SIMPLE REAL CASE

VIBRATION ISOLATION

3. Select the damping of a chock witch provides the desired isolation.

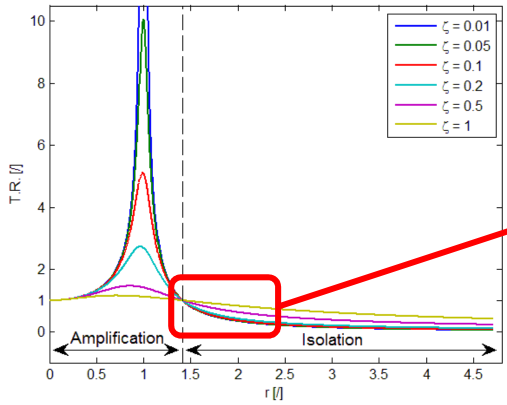


Figure 15. Transmissibility ratio as a function of *r* ratio

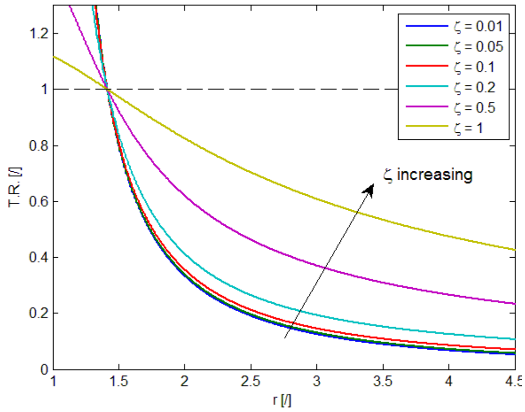


Figure 16. The magnification of isolation area

SIMPLE REAL CASE

NUMERICAL RESULTS

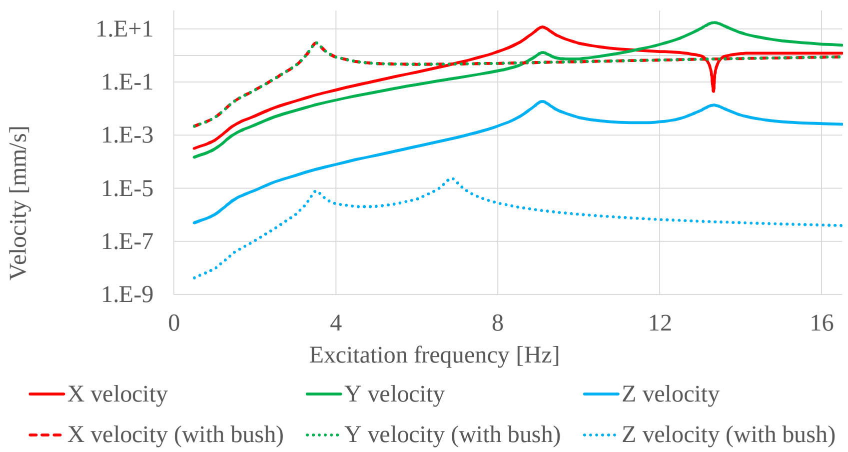


Figure 17. Velocity with and without chocks

Conclusion:

- Resonance frequencies are shifted;
- Velocity with chocks are way below threshold.

COMPLEX REAL CASE

COMPLEX REAL CASE

RETRACTABLE AZIMUTH THRUSTER

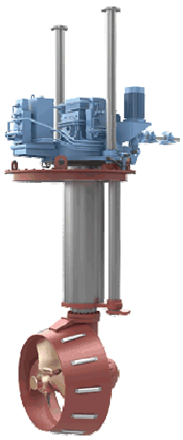


Figure 18. Retractable azimuth thruster

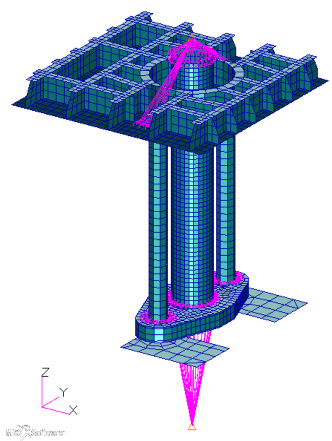


Figure 19. FE modelling

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

COMPLEX REAL CASE

MODAL ANALYSIS

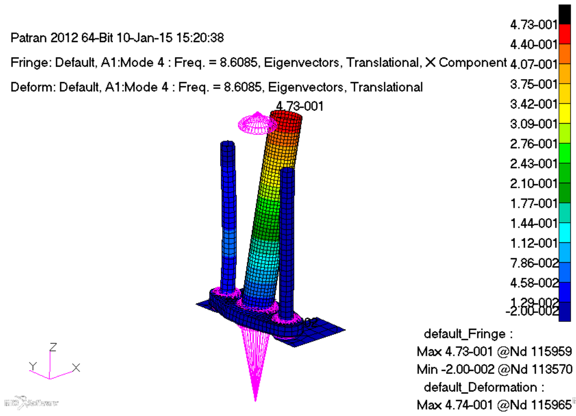


Figure 20. Pendulum mode of stemsection about *y*-axis

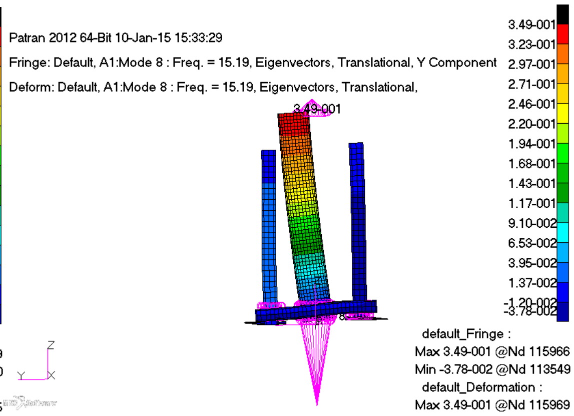


Figure 21. Pendulum mode of stemsection about *x*-axis

COMPLEX REAL CASE

MODAL ANALYSIS

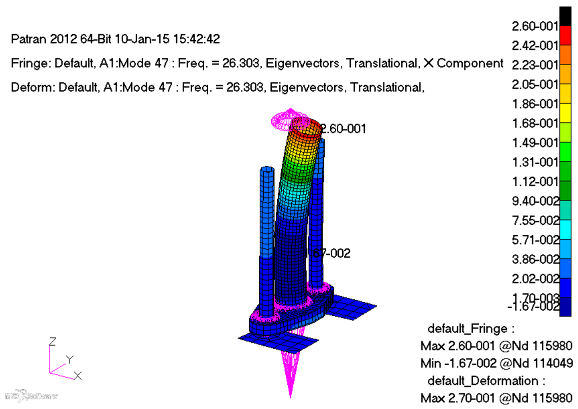


Figure 22. Bending mode of stemsection about *y*-axis

COMPLEX REAL CASE

DYNAMIC LOADING

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

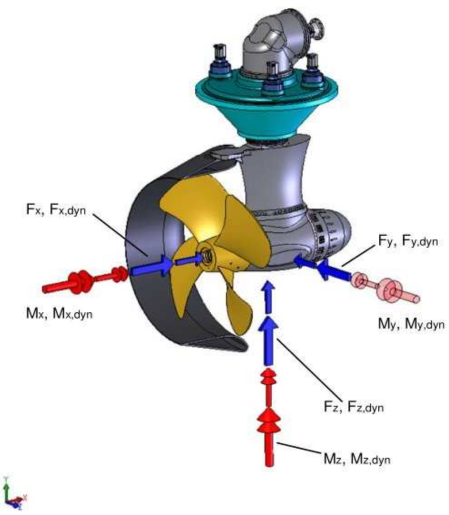


Figure 23. Main static and dynamic forces

COMPLEX REAL CASE

NUMERICAL RESULTS

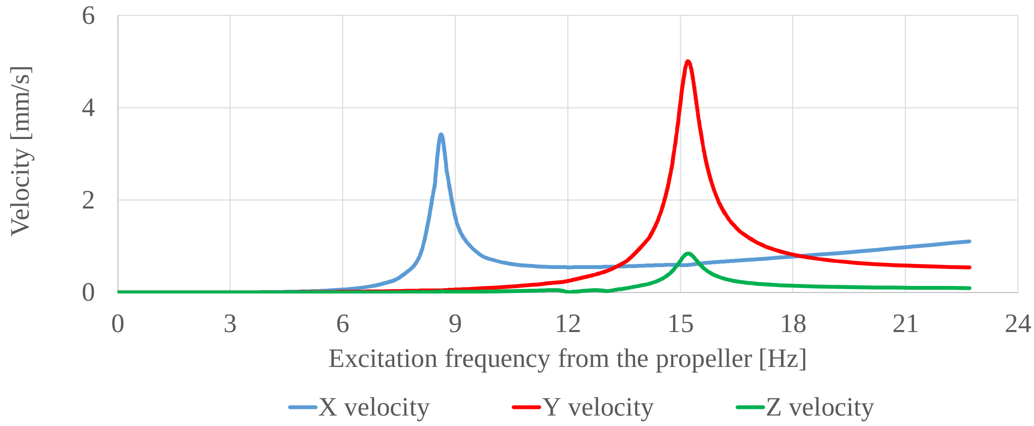


Figure 34. Velocity of COG of gearbox foundation

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.

THANK YOU FOR YOUR ATTENTION

WWW.EMSHIP.EU