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II SIMPÓSIO DE MODELAGEM COMPUTACIONAL EM CIÊNCIA E TECNOLOGIA DO PIAUÍ

Passive Mitigation of Vibration Frequencies on Offshore Structures

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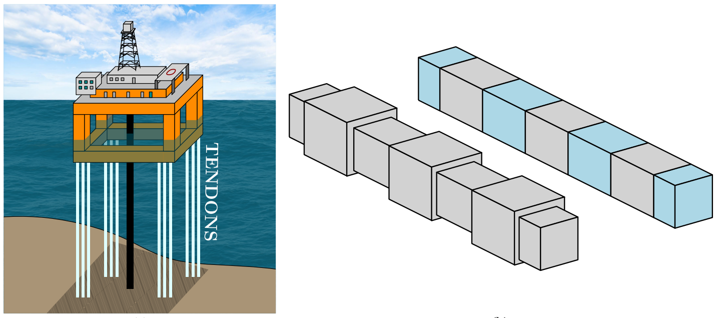
Introduction

Offshore platforms operate in environments subject to constant wave action, which induces dynamic loads on structural components, particularly the support legs or tendons (Fig. 1a). These loads propagate as mechanical vibrations throughout the structure and may compromise its integrity, performance, and service life.



(a) (b)

Fig. 1: Tension-Leg Platform (a) and tendons represented as stepped and bimaterial periodic beams (b).

Among passive vibration mitigation strategies, periodic structures have attracted increasing interest due to their ability to generate **band gaps**—specific frequency ranges where the propagation of waves is naturally attenuated. This behavior is directly influenced by the geometry and material distribution along the structure (Fig. 1b). This study investigates the vibrational behavior of stepped and bimaterial periodic beams, focusing on how geometric variations influence wave attenuation.

Methodology

The periodic beams were modeled using **Euler–Bernoulli theory**, with unit cells composed of three segments—two identical outer sections and a central one. Two configurations were analyzed: **stepped beams**, with variations in cross-sectional geometry, and **bimaterial beams**, alternating materials along the length (Fig. 2).

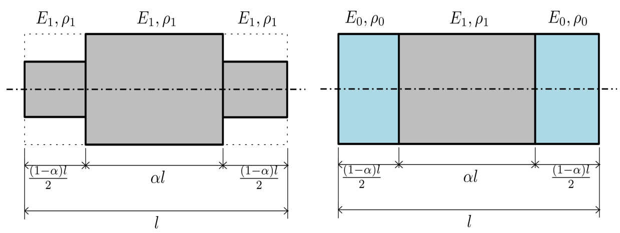


Fig. 2: Unit cells for stepped and bimaterial beams.

The relative length of the central segment is governed by a saturation parameter α, ranging from 0 to 1. Values of $\alpha = \{0, 1\}$ correspond to prismatic beams. Each segment is modeled individually and assembled by enforcing compatibility at interfaces. The vibrational behavior was analyzed in the frequency domain using the Finite Element Method (FEM). A MATLAB® script was developed to assemble the global stiffness and mass matrices of the periodic structure and solve the resulting generalized eigenvalue problem, enabling the construction of dispersion curves.

Numerical Results and Discussion

Numerical simulations were performed for both stepped and bimaterial beam configurations, considering hinged-hinged boundary conditions. Initially, the natural frequencies corresponding to modes 1 through 22 were calculated for a fixed saturation parameter of $\alpha = 1/2$, which defines the relative length of the central segment within each unit cell. The geometric and material properties adopted in the simulations are illustrated in Fig. 3, while the resulting frequency spectra for each mode are presented in Fig. 4.

These results serve as a basis for analyzing the emergence of band gaps and assessing how the different periodic configurations influence vibrational behavior and wave attenuation performance.

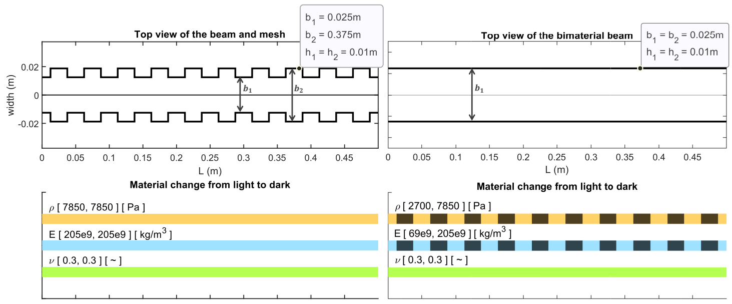


Fig. 3: Stepped and bimaterial beam parameters.

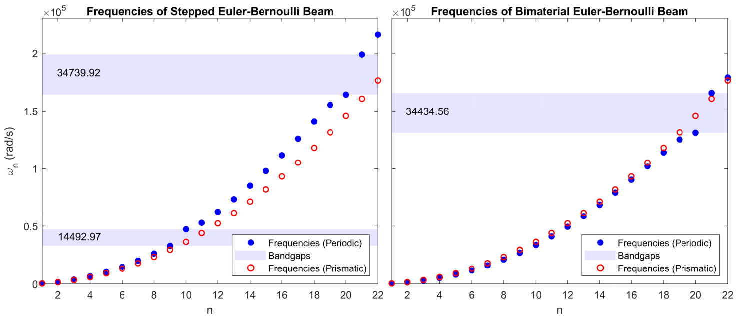


Fig. 4: Natural frequencies and band gaps for $\alpha = 1/2$ for stepped and bimaterial beams.

By varying the saturation parameter α, it is possible to adjust the relative lengths of the beam segments and, consequently, shift the band gap position. Natural frequencies for modes 18 to 22 were computed for α values of 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, and 7/8, and the results are shown in Fig. 5.

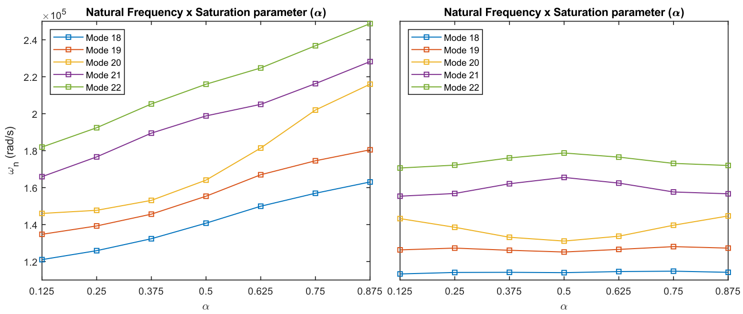


Fig. 5: Natural frequencies by saturation parameter for stepped (left) and bimaterial beams (right).

Conclusion

The study demonstrated that the dynamic behavior of periodic Euler-Bernoulli beams, including stepped and bimaterial configurations, can be effectively controlled by adjusting the saturation parameter α. Numerical simulations showed that varying α influences the relative segment lengths within the unit cell, allowing for the tuning of band gaps within desired frequency ranges. This passive approach offers a promising strategy for vibration mitigation in offshore platforms and other structural systems subjected to dynamic loads.

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