Wave emissions from pile installation via axial and torsional vibrations in a layered acousto-elastic medium

Tsetas, Athanasios; Tsouvalas, Apostolos; Metrikine, Andrei

Publication date
2024

Document Version
Final published version

Citation (APA)
Tsetas, A., Tsouvalas, A., & Metrikine, A. (2024). *Wave emissions from pile installation via axial and torsional vibrations in a layered acousto-elastic medium*. Abstract from 11th European Nonlinear Dynamics Conference 2024, Delft, Netherlands.

Wave emissions from pile installation via axial and torsional vibrations in a layered acousto-elastic medium

Athanasios Tsetas*, Apostolos Tsouvalas* and Andrei Metrikine*
**Faculty of Civil Engineering and Geosciences, Delft University of Technology Stevinweg 1, 2628 CN Delft, The Netherlands*

Summary. This paper studies the underwater sound and seabed vibrations generated from pile installation via axial and/or torsional vibrations, namely the "Gentle Driving of Piles" (GDP) method. A non-linear pile-soil-water model is utilized in this numerical study, where the pile vibrations and the resulting fluid-soil wave motion are analyzed. A semi-analytical finite element approach is used for pile-soil-water modelling and the pile-soil interaction is based on Coulomb friction enhanced with a memory mechanism. The comparison between classical axial vibratory driving and GDP is considered, investigating the effect of torsion in noise abatement as well as the presence of super-harmonic resonance-like phenomena.

Extended abstract

The global demand for renewables is steadily increasing in recent years, in view of the global targets towards decarbonization of the energy sector [1]. Offshore wind is growing remarkably, yet these rapid developments are accompanied by technical challenges on various fronts, such as foundation installation. The primary support structures for offshore wind turbines are bottom-fixed foundations, with the monopile being the most preferred concept for shallow to intermediate water depths [2]. The conventional installation method for monopiles is impact hammering, a robust and efficient technique which has raised significant environmental concerns due to the high levels of underwater noise generated during the process and the associated threats to marine species [3]. To tackle this challenge, alternative and environmentally friendly pile installation methods are gaining traction, with an increasing number of research projects focusing on driving methods that can mitigate the environmental impact of offshore wind farm construction. Among the available techniques, vibratory pile driving offers a promising alternative to impact hammering. The focus herein lies in classical vibratory driving and an innovative technique utilizing simultaneous axial and torsional vibrations, i.e. the "Gentle Driving of Piles" (GDP) technique [4, 5].

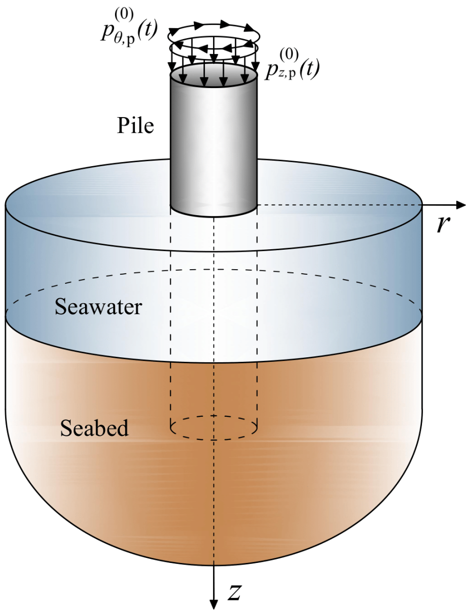
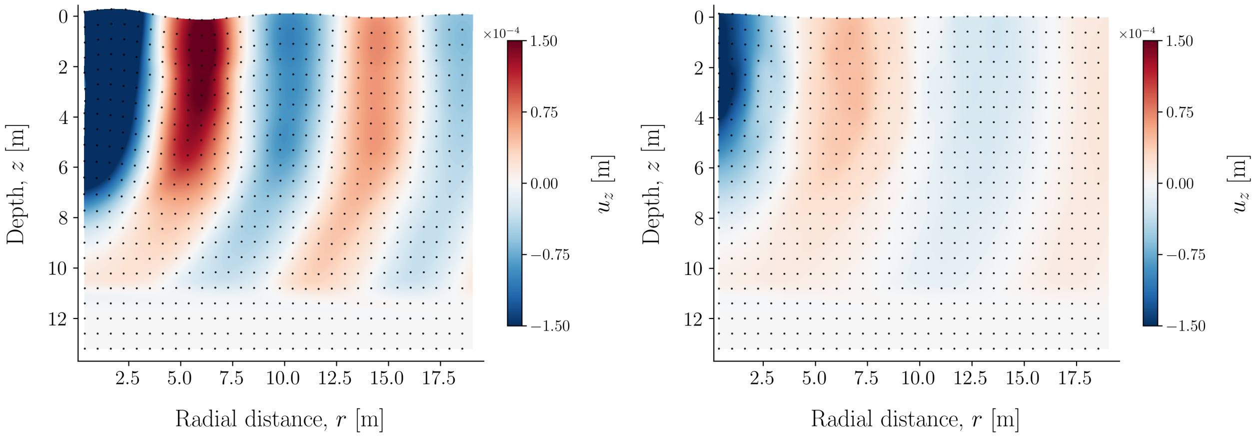


Figure 1: A numerical model for tubular pile installation in a layered acousto-elastic medium via axial and/or torsional vibrations.

In this paper, we study the underwater sound and seabed motion induced by vibratory pile installation via axial and/or torsional vibrations. For that purpose, a 3-D non-linear pile-soil-water model is developed for the analysis of pile vibrations and wave motion in the surrounding seawater and seabed. In particular, the model is comprised of a thin cylindrical shell (pile) according to the Love-Timoshenko theory [6], an acoustic fluid layer (seawater) and a linear elastic layered half-space (soil). The former component is modelled via the Semi-analytical Finite Element (SAFE) method [7] and a discrete version of the normal modes approach is introduced in this work for the dynamic analysis of the layered acousto-elastic domain, namely the Thin-Layer Method (TLM) [8]. The pile-soil contact is based on a history-dependent frictional interface, thus rendering the full system non-linear and allowing for pile slip relative to the soil. The dominance of super-harmonic components leading to high levels of underwater sound (resonance-like phenomena) is studied and the comparison with classical vibratory driving is also considered (see Fig. 2). Conclusively, the present study aims to elucidate the complex dynamics associated with underwater noise generation during monopile installation via the GDP method, with a view to high installation performance and low levels of underwater noise emissions.



(a) VH_1 (b) GDP_1

Figure 2: Comparison of soil displacement fields for pile installation via (a) axial vibratory and (b) GDP methods.

References

[1] International Energy Agency (2023) World Energy Outlook 2023. Tech. rep., Paris, France

[2] Musial W, Spitsen P, Duffy P, Beiter P, Shields M, Hernando DM, Hammond R, Marquis M, King J, Sathish S (2023) Offshore Wind Market Report: 2023 Edition. Tech. rep., National Renewable Energy Lab.(NREL), Golden, CO (United States)

[3] Tsouvalas A (2020) Underwater noise emission due to offshore pile installation: A review. Energies 13(12):3037

[4] Tsetas A, Tsouvalas A, Gómez S, Pisanò F, Kementzetzidis E, Molenkamp T, Elkadi A, Metrikine A (2023) Gentle Driving of Piles (GDP) at a sandy site combining axial and torsional vibrations: Part I - installation tests. Ocean Engineering 270:113453

[5] Tsetas A, Tsouvalas A, Metrikine AV (2023) The mechanics of the gentle driving of piles. International Journal of Solids and Structures 282:112466

[6] Leissa AW (1973) Vibration of shells, vol 288. Scientific and Technical Information Office, National Aeronautics and Space Administration

[7] Tsetas A, Tsouvalas A, Metrikine AV (2023) A non-linear three-dimensional pile–soil model for vibratory pile installation in layered media. International Journal of Solids and Structures 269:112202, DOI https://doi.org/10.1016/j.ijsolstr.2023.112202

[8] Kausel E (1999) Dynamic point sources in laminated media via the thin-layer method. International Journal of Solids and Structures 36(31-32):4725–4742