MENCK hydraulic hammer

Forecasting Underwater Noise

Simulation soundly predicts hydro-acoustics during offshore pile driving.

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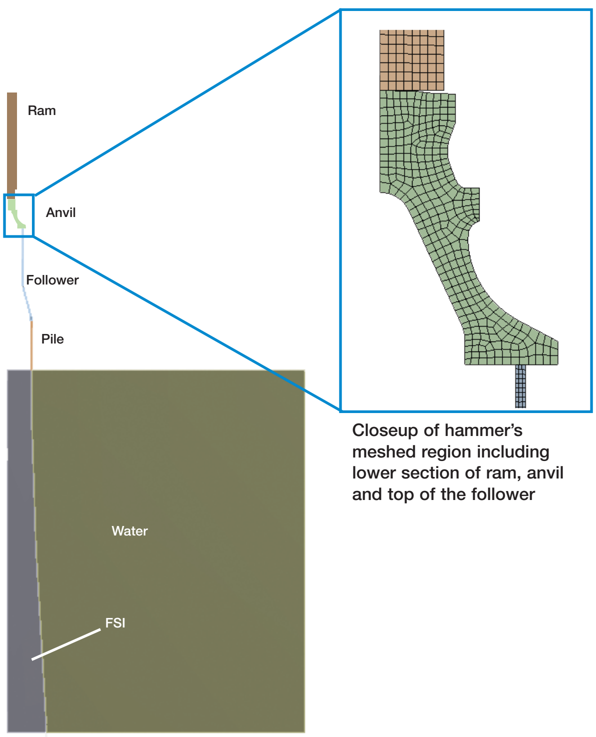
Across the vastness of our planet's oceans, localized sounds originate from many different sources, both natural and man-made. The man-made sources — for example, from ship traffic, drilling, mining and sonar equipment — have significantly added to underwater noise in recent decades. In the growing offshore wind power industry, sound emission related to installation and operation, especially underwater, is a growing concern due to its potential impact on nearby aquatic life.

In most cases, foundations for massive offshore structures such as wind turbines are formed by driving piles into the seabed with hydraulic hammers. The German company MENCK GmbH has a long history of developing, manufacturing and operating such hammers in water depths up to 2,000 meters (1.25 miles). Predicting hydro-acoustics during offshore pile driving is, therefore, of great interest to installation contractors who must comply with tight sound-emission thresholds. For example, the regulatory limit in Germany for underwater sound exposure level at a distance of 750 meters from a construction site is 160 decibels (dB) at a reference pressure of 1 microPascal (1×10^{-6} Pa) [1]. Knowing the sound emission prior to construction helps contractors to select and design noise protection systems — such as air bubble curtains or air-filled cofferdams around the pile — that will meet local project requirements [2]. Reducing underwater noise, however, remains an ongoing subject of research, as no single system is appropriate for all situations.



Closeup of hammer's meshed region including lower section of ram, anvil and top of the follower

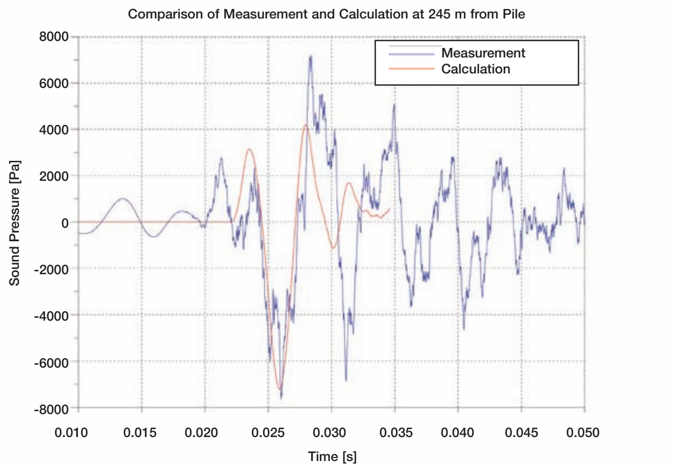
Two-D axisymmetric simulation model in ANSYS Mechanical software. Components of the hammer and pile system along with the water and seabed zones that they inhabit; zone of interest for FSI is indicated with a line.

With this background, a MENCK research team initiated an application project with computer-aided engineering software and services company CADFEM to use ANSYS simulation tools to numerically predict underwater sound emission. Transient structural analysis of the driving impact is commonly performed to evaluate mechanical characteristics of highly loaded hammer components, such as the ram, anvil, adapter plates and followers. MENCK engineers expanded this original simulation to consider noise propagation by two-way coupling of the pile vibrations and water pressure using the acoustic elements in ANSYS Mechanical software.

The two-dimensional axisymmetric simulation consisted of the ram, anvil, follower, pile, soil and water. Coupling the water domain to the structural elements of the pile was made possible via ANSYS Mechanical fluid–structure interaction (FSI). The MENCK team set the ram's initial velocity to achieve the desired impact energy, with all other components being at rest. Boundary conditions included acoustical reflection at the seabed and acoustical absorption at the outer boundary, while the elastic soil properties were modeled as lateral springs. Researchers applied a simple absorption boundary condition because, when only the short-term near-field sound propagation is of interest, reflection is not a crucial issue for transient analysis of acoustics problems. The team additionally approximated the water–air interface as a free surface with zero pressure, which is appropriate for a non-rigid boundary.

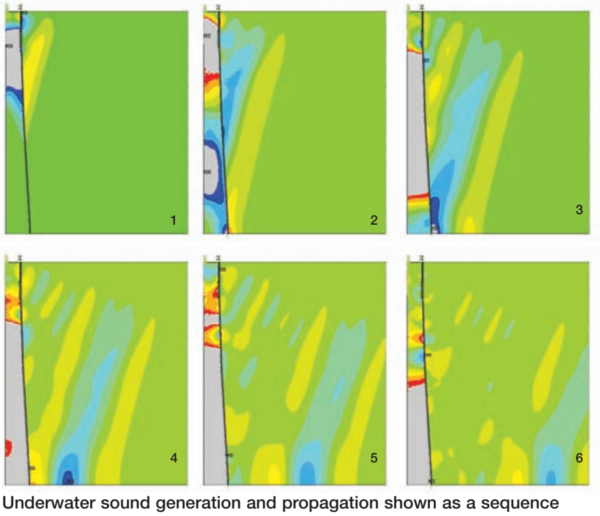
MENCK's engineers set up the simulation in the ANSYS Workbench environment using ANSYS Parametric Design Language (APDL) to control FSI and acoustics parameters. FLUID29 acoustic elements allowed modeling the sound field to cover modal, harmonic and transient solutions. The theory of acoustic waves underlying the FLUID29 element approach is based on the same fundamental equations as computational fluid dynamics (CFD): conservation of mass and momentum. However, assumptions — such as zero-flow velocity and inviscid, compressible fluid properties — were made that result in a linearized acoustic wave equation. A linear equation is reasonable because, even for very high sound pressure levels, the acoustic pressure variations generally represent only about 0.2 percent of ambient pressure.

In concert with the FLUID29 elements, additional displacement degrees of freedom supported the interface to the structural domain. In this way, MENCK could model the full coupling between the fluid (acoustic) and structure domains to account for the sound radiated by a vibrating structure and, at the same time, consider the additional load of this sound pressure field onto the structure [3]. The near-field solution in the vicinity of the pile could then be used to predict the sound pressure level in the far field by means of an additional model that accounts for the effects of prevailing ocean characteristics on sound propagation. For this additional model, the MENCK group used analytical relations based on test data that were available for sound propagation as a function of distance accounting for water depth and seabed properties.



Comparison of measured and calculated underwater sound pressure at a distance of 245 meters from the pile. Knowing the sound propagation law for this region, the sound pressure at 750 meters can be calculated and converted into decibels (dB).

Numerical results from the simulation have been validated for the installation of the monopile on the FINO3, a government-sponsored wind energy research platform in the North Sea [4]. The comparison of measured and calculated sound pressure at a distance of 245 meters from the pile showed good correlation of the first pressure peak's amplitude. Beyond this initial analysis work, however, further validation is required: The peak sound pressure level observed near the pile is relatively high compared to the ambient underwater pressure, which might violate linear wave theory. A full FSI analysis to couple ANSYS Mechanical with ANSYS CFD fluid flow simulation software without the stated typical assumptions of linear acoustics may be applied for this purpose.



Underwater sound generation and propagation shown as a sequence of snapshots in time. Within a steel pile, the speed of sound is about 5,000 meters per second, while the speed of sound in water is about 1,500 meters per second — resulting in radiation patterns and specific inclination angle.

References

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[2] Nehls, G.; Betke, K.; Eckelmann, S.; Ros, M. *Assessment and Costs of Potential Engineering Solutions for the Mitigation of the Impacts of Underwater Noise Arising from the Construction of Offshore Windfarms;* BioConsult SH report on behalf of COWRIE Ltd.: Husum, Germany, September 2007.

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