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Mega Bubble Curtain

For noise mitigation of offshore wind piling operations

Offshore windmill installation involves pile driving, which generates high-decibel noise, disturbing marine life. Our proposed method suggests using larger site and pipe diameters for better noise mitigation and easier handling, making it a viable option for the Norwegian Continental Shelf.

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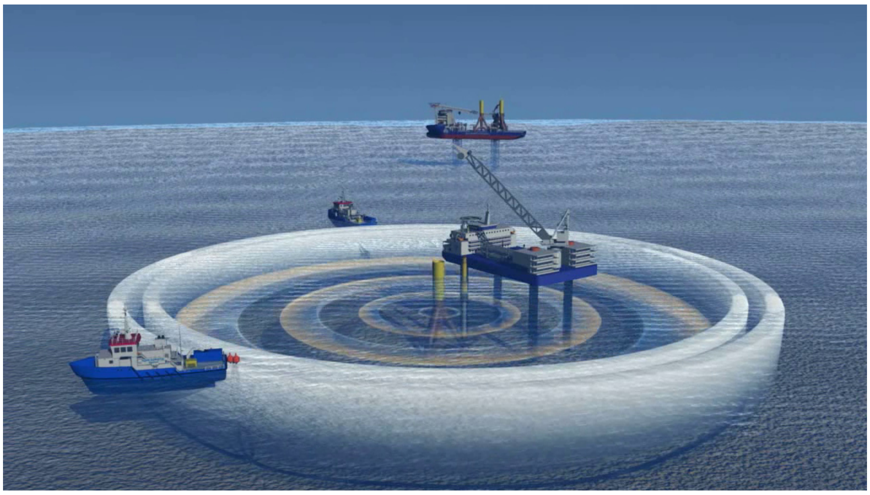
Introduction

In the context of climate change, it is imperative that initiatives to integrate green energy into the energy mix take into account the effects on the local environment. The installation of offshore wind turbines involves the use of pile driving to embed the monopile into the seabed. This process generates high-decibel noise that propagates through the water, disrupting various marine life forms. It is essential that legislation be enacted to minimize this noise to the lowest possible levels.

The primary method currently employed to address this issue involves creating a bubble curtain around the piling site. This technique utilizes an air-filled pipe placed on the seabed, which is perforated to produce a curtain of bubbles. However, the established method has limitations in terms of noise mitigation and logistical challenges. An improved noise abatement system is proposed, featuring an increased site diameter and larger pipe diameter. This solution not only enhances noise reduction but also simplifies handling during operations and addresses additional challenges. It presents a viable option for the environmentally friendly construction of fixed wind turbines on the Norwegian Continental Shelf.



Courtesy: Mship

Environment

Sound propagates more rapidly and over greater distances in water compared to air. Numerous underwater species depend on underwater sounds and possess exceptional hearing abilities. In regions where offshore pile driving occurs, there is particular concern for harbour porpoises, which can suffer hearing loss due to these high-impact sounds. Behavioral changes observed up to 25 kilometers away indicate that harbour porpoises are disturbed by the noise even at considerable distances. The avoidance of the area due to the sound can persist for several days. The impact on marine animals is not confined to harbour porpoises but also affects whales, pinnipeds, cetaceans, and fish.

AI Generated Image

Legislation

The EU Directive 2008/56/EC, known as the Marine Strategy Framework Directive (MSFD), sets forth requirements for achieving Good Environmental Status (GES). Among the descriptors for GES is the stipulation that underwater noise must be at levels that do not adversely affect the marine environment. Several countries, including Germany, the Netherlands, Denmark, the United States, and Taiwan, have developed specific regulations or recommendations for noise reduction or sound exposure levels (SEL). Germany has been a pioneer in this field, initiating regulations and noise measurements in 2008, along with government sponsorship for the development of the big bubble curtain.

OSPAR, a commission dedicated to protecting the marine environment of the northeast Atlantic, has issued an inventory of measures to mitigate the emission and environmental impact of underwater noise. This inventory identifies the big bubble curtain (BBC) as the state-of-the-art solution for limited water depths and pile dimensions.

In ST meld 20 (2019-2020), Norway's integrated ocean management plans state that the government will establish pressure indicators for underwater noise and harmonize them with the OSPAR system. The licensing rules for offshore wind projects require an impact assessment that includes considerations for underwater noise.

State of the technology

The big bubble curtain (BBC) concept was developed by the German company Hydrotechnik Lübeck, which remains a leading entity in this field. Sponsored by the German government, the concept was designed to comply with noise regulations. The BBC system comprises flexible hoses with perforations, which are placed on the seabed around the piling site and supplied with air from compressors on a vessel's deck. These hoses, with an inner diameter of 100-150 mm, are stored on a drum aboard the ship and deployed in circles with a radius of up to 150 meters at depths of 15-50 meters. The optimal overpressure is 3-4 bar, with applied pressures reaching up to 10 bar and flow rates ranging from 0.11 to 0.5 $m^3/min*m$ [a)].

This concept has demonstrated noise reduction of up to 15 dB SEL for a single application and 18 dB SEL for a double BBC.

Courtesy: Hydrotechnik Lübeck GmbH

a) https://www.hydrotechnik-luebeck.de/portfolio-items/compressed-air-hydro-sound-mitigation/

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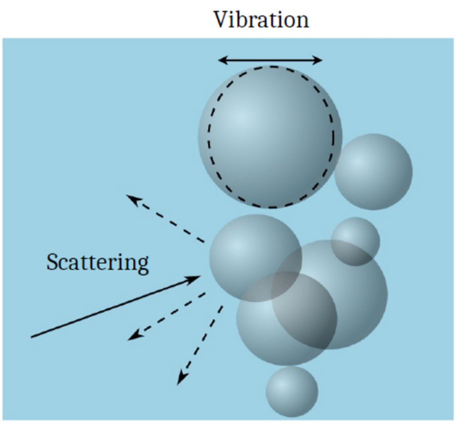
Noise mitigation

A veil of bubbles dampens underwater sound through two primary effects. First, the difference in density and speed of sound between water and the bubbly water mix causes sound waves to bend, leading to reflection and scattering in various directions. Additionally, sound pressure decreases logarithmically with distance, further reducing as it is refracted and travels within the bubble curtain. For higher frequencies, noise absorption becomes the dominant effect. When the size of the bubbles matches the sound frequency, they begin to resonate, effectively absorbing the sound by transforming the energy.



Courtesy: Tale Egeberg Aasland

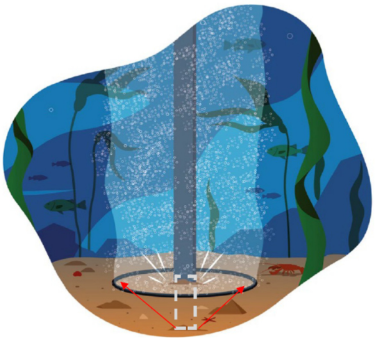
Challenges

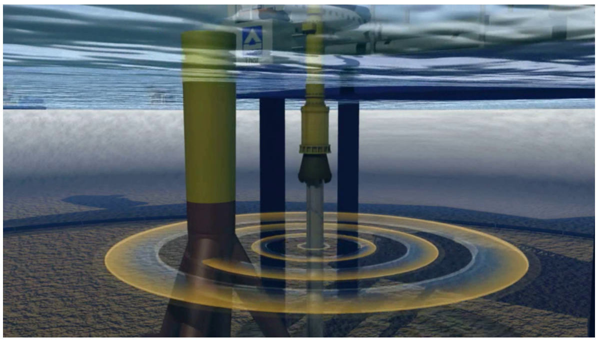
The effectiveness of noise mitigation increases with a higher volume of air and a larger distance within the ring, allowing sound to travel farther. Sound is also transmitted through the soil, reflecting upwards at an angle from the bottom of the pile and entering the water column at a distance from the pile, depending on the piling depth.

Currents can also affect the bubbles, causing them to drift from their origin, move closer to the source, or even pass it.

A large radius around the pile is beneficial for volume, distance, and seismic sound mitigation, provided no marine creatures are trapped inside. The large diameter results in a long length, leading to a pressure drop over the length. This necessitates applying higher pressure at the start of the pipe to maintain sufficient pressure at the end, which can cause uneven bubble distribution if not compensated for by varying nozzle sizes. Overpressure at the beginning of the pipe will cause bubbles to expand more as they rise to the surface, altering their sound mitigation properties with depth. This effect is more pronounced at greater depths. As bubbles rise and grow, they may merge, creating larger bubbles and leaving spaces of water between them for sound to travel through. Deeper water also allows for further drift due to currents.

Deeper waters are also associated with larger piling diameters, which produce lower frequencies and higher energy levels. In the Sørlige Nordsjø II area, with an average depth of 60 meters, bottom-fixed structures involving piling operations may be an option. Currently, no major Norwegian players are addressing this environmental challenge, nor has the government imposed any restrictions on these operations.

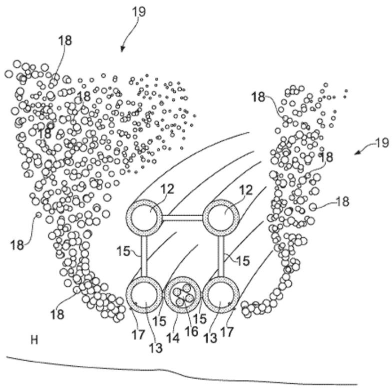

Courtesy: EBM-FSB7, 2021


Courtesy: Mship

Large cross section – low pressure

A potential solution to these challenges is to use a pipe with a larger cross-section and circumference. This design accommodates currents in deep waters by maintaining a significant distance from the source.

To address the issue of varying bubble sizes throughout the water column, the pipe can feature two rows of holes, one on each side of the large cross-section pipe. The pipe's diameter should be sufficient to prevent the two rows from merging. Additionally, the two rows can produce bubbles of different initial sizes, ensuring that the bubbles are neither too small initially nor too large by the time they reach the surface.



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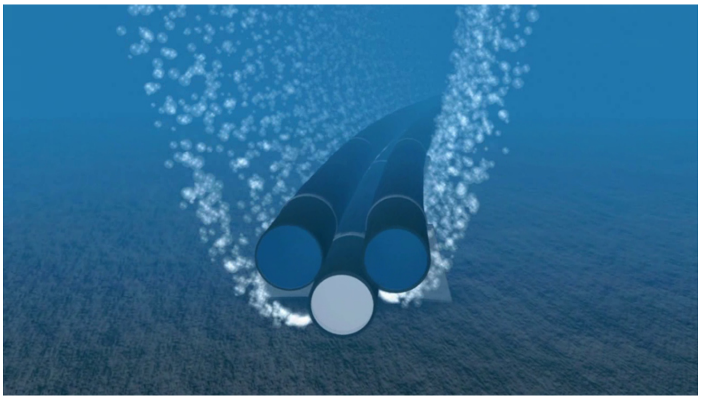

Courtesy: Mship

A larger cross-section also facilitates more even pressure distribution along the length of the pipe, resulting in consistent bubble production. With uniform pressure, there is no need for higher overpressure at the beginning of the pipe, which would otherwise cause excessive bubble expansion upon release.

Additionally, a larger circumference and cross-section allow for greater volumes of air and increased distance from the source, both of which enhance acoustic damping.

Pipelife in Brevik has successfully produced large-diameter PE pipes directly into the sea, demonstrating their effectiveness in various applications, including subsea installations worldwide.


Courtesy: Mship

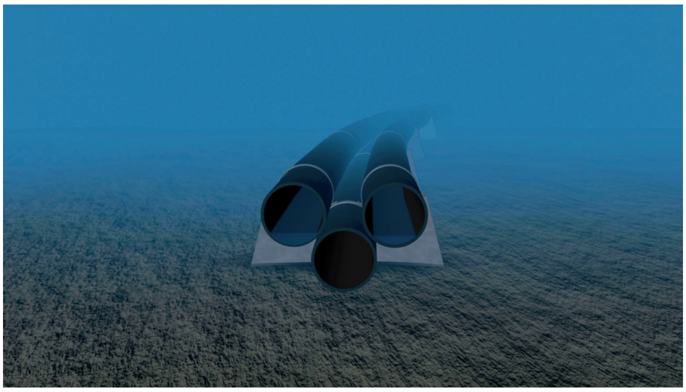
Handling and configuration

The proposed solution introduces additional practical challenges and necessitates new solutions. Large diameter pipes cannot be stored on a drum onboard; instead, they may be towed behind the vessel in several lengths, thereby saving deck space.

These pipes can also be stored on the seabed, although PE pipes will float due to their density being lower than water. A stacked configuration of four pipes in a square can address this issue: two pipes can serve as ballast, filled with a chain and water to ensure they sink, while the other two pipes supply air to the bubble curtain, providing additional distance between the two bubble rows on opposite sides. This method eliminates the need for a winch during the laying operation, as the pipes are ballasted with seawater to sink and then floated by expelling the seawater with a compressor.

Increased air volume requires more compressor power. Instead of renting over 20 compressors, a more permanent, high-capacity compressor is recommended. For instance, a Centac 5CII can provide over 450 m³ of oil-free air per minute at pressures suitable for depths greater than 30 meters, with a footprint of 26 m² and a weight of less than 10 tons.

Courtesy: Pipelife



Courtesy: Mship

Conclusion

We must not harm the environment while addressing climate change; therefore, the construction of wind turbines should incorporate noise mitigation strategies to protect marine animals from excessive sound during foundation installation. Since Germany's pioneering regulations and measurements in 2008, the technology has advanced significantly. Currently, the Big Bubble Curtain (BBC) is the leading method, offering up to a 15 dB SEL reduction in noise levels.

However, this technology has not been proven in deeper waters and with larger pile diameters. For the development of offshore wind in Norway, deeper areas are being considered, but there is a lack of specific rules and recommendations. The challenges posed by seismic noise, currents, and the combination of greater depths and larger pile diameters can be addressed by increasing the circumference, cross-section, and air volume. The additional challenges of handling and air capacity are resolved with the benefit of using less deck space.