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Measurements of Underwater Noise from Pile Driving in Southwest Coast of Korea

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ABSTRACT

The interest in underwater noise produced by impact pile driving has been increasing worldwide. Since the impact pile driving noise with extremely high sound pressure level can cause negative effects on marine ecosystem, it is important to measure the noise and to assess possible risks. Recently, offshore wind power generation is being actively developed in Korea and accordingly efforts to assess the environmental impact of pile driving noise are being made. Measurements of pile driving noise were carried out twice in the southwest coast of Korea in 2017 and 2018. The variation of the impact pile driving noise was analyzed for the pile driving noise data measured at a single site. In addition, impact pile driving noise were measured as a function of source-receiver range, which was compared to the theoretical transmission loss curves predicted by a damped cylindrical spreading model and the parabolic equation-based range dependent acoustic model.

Keywords: Impact Pile Driving Noise, Offshore Wind Generation, Noise Propagation

1. INTRODUCTION

Recently, the demand for offshore wind power has been increasing with growing interest in renewable energy development. Most of the offshore construction, including offshore wind power generation, accompany the process of the impact pile driving, which produces extremely high sound pressure levels. This noise may cause physiological effects on fish [1-3] and on marine mammals [4, 5]. The pile driving noise depends on the types of hammer and pile specifications such as materials, size and weight. The main energy created by the piling is radiated at a specific angle toward the seafloor as the sound speed of the pile is faster than that of water, and it has significant energy in a frequency range of 100-2000 Hz [6, 7]. The propagation of the noise is greatly affected by the water depth, sound speed profile, the geoacoustic properties of sediment and stratigraphic structure of the bottom. Propagation of acoustic waves in the ocean is generally described by the practical spreading model expressed as $\mathrm{N}log_{10}(r)$, where the N and r are the spreading-loss constant and propagation range respectively. Because the pile driving noise has directionality and interacts with ocean boundaries, the prediction of piling noise propagation using practical spreading model may be limited and inaccurate. There were several studies on the propagation of impact pile driving noise carried out to predict and evaluate the propagation characteristics [7-10].

In this study, we measured the impact pile driving noise generated during the construction of the offshore wind farm in the southwest Korea. The measured sound pressure levels are compared with the both prediction results of parabolic equation based range dependent acoustic model (RAM) and the damped cylindrical spreading model (DCSM) [8] with the sound speed profile and mean grain size of surficial sediments acquired in the survey.

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2. METHOD

2.1 Field Measurements

Measurements were made in southwest coast of Korea where the offshore wind farm was actively constructed. The site was about 10 km from the Gusipo fishing Port. The twenty offshore wind turbines were under construction. The impact pile driving noise were measured at six points located between about 100 and 2100 m from the source. The water depth decreased from 12 m at the pile driving point to the coast about 10 m. The analysis result of grab samples collected from the surficial sediment indicated a mean grain size of 4 ϕ [where $\phi = log_2(d/d_0)$, in which d is the grain diameter]. Vertical sound speed profiles obtained from conductivity, temperature and depth (CTD) profile exhibited proximal iso-velocity during acoustic measurement. A hydraulic hammer (PILEMER DKH-2016S) and a stainless-steel pile with a diameter of 0.91 m and a length of about 80.705 m (S355ML) were used. Figure 1 shows the photographs taken during the measurements.

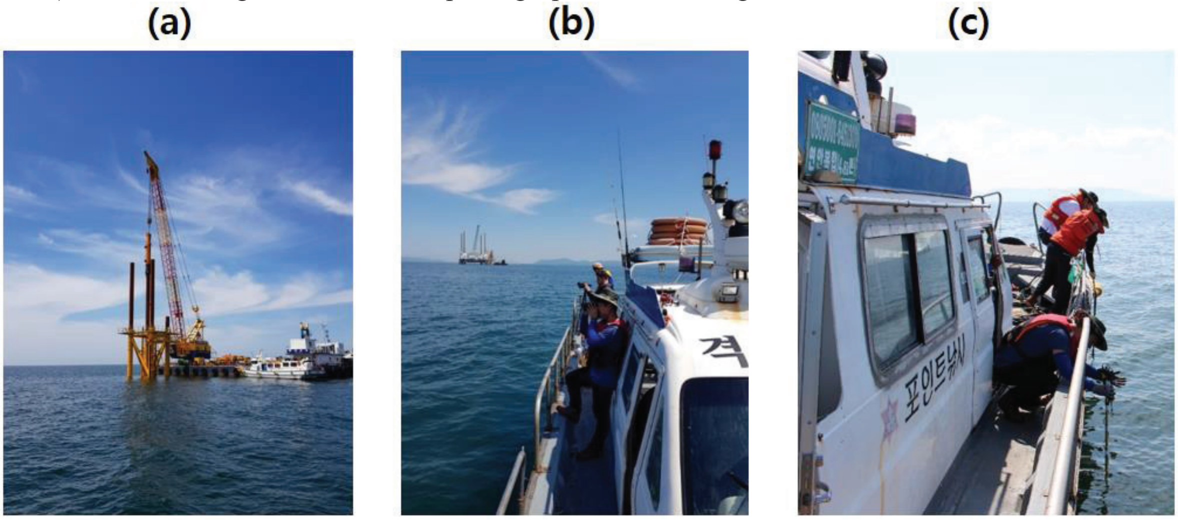

Figure 1 – Photographs taken during the measurements, (a) impact pile driving, (b) range measurements using the laser range finder and (c) hydrophone array deployment

2.2 Measurements System

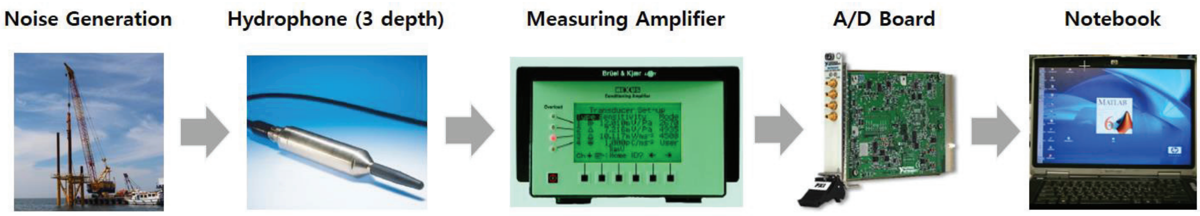

Figure 2 – Noise measurement system

Figure 2 shows a schematic diagram of the noise measurement system. Fishing boat was used to deploy three hydrophones (RESON, TC-4014) at 3, 5 and 7 m above the seafloor. The depth sensors were attached to hydrophone arrays to measure the accurate hydrophone depths. The analogue signal was transmitted to the measuring amplifier, converted into a 16 bit digital signal on the A / D board (NI, PXI-6132) and saved.

Pile driving signals were extracted from acoustic data recorded continuously at several measurement points (112, 288, 520, 695, 884, and 2077 m), and the peak sound pressure level (Peak SPL) and sound exposure level (SEL) were calculated at each point.

3. NOISE PROPAGATION MODELING

3.1 Damped Cylindrical Spreading Model

The DCSM model is given by Equation 1. The decay factor (α) is an environmental representative including the water depth, bottom reflection coefficient and Mach cone angle of the pile driving noise.

The water depth used as an input parameter was 10 m. The compressional wave speed in steel of 5950 m/s was used, which leads to a Mach cone angle of 14.9° in water column. The bottom reflection coefficient was calculated using the impedance ratio between surficial sediment and seawater. Reference range (r_{ref}) was chosen to be 288 m.

$$L_E(r) = L_E(r_{ref}) - 10log_{10}\left(\frac{r}{r_{ref}}\right) - \alpha(r - r_{ref}) \tag{1}$$

3.2 Numerical Model Based on Parabolic Equation

Numerical model was used to simulate the sound propagation in the ocean. In this study, a broadband simulation using a modified RAM with multi-sources was used to simulate characteristics of pile driving noise [6]. The sound sources were distributed vertically from 0.5 m to 20 m at 0.5 m intervals. The propagation of the broadband source was considered by coherently combining the simulation results. The frequency interval was 2 Hz from 50 Hz to 2000 Hz.

4. RESULTS

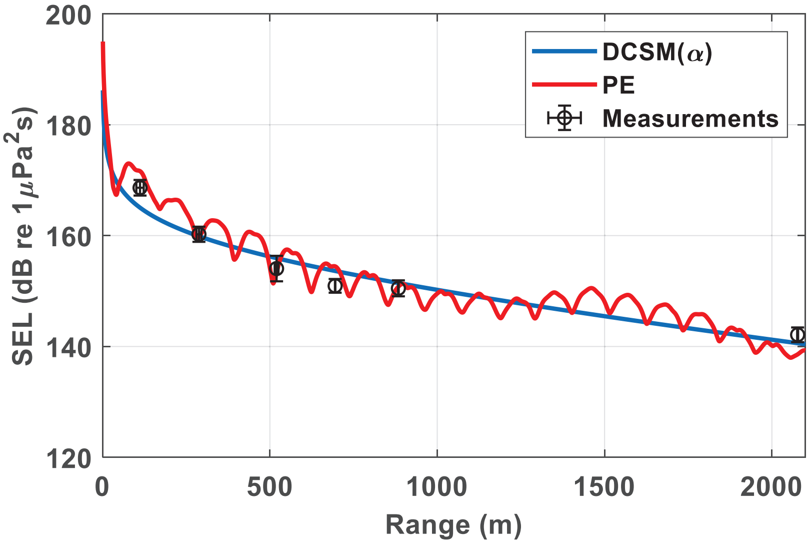

Figure 3 – Measurements of pile driving noise and the comparison with model predictions in SEL.

Figures 3 shows the measurement of pile driving noise and the comparison with model predictions in SEL. The measured SELs as a function of range show differences of peak SPL from 19.5 to 21.9 dB, which are in good agreement with the prediction results. The horizontal error bars represent the range error caused by the drifting of the ship during the measurements. The vertical error bars indicate the standard deviation of the measurements for three depth of hydrophones. The decay factor of 5.9 dB/km is the best fit and the analytical value is 5.1 dB/km. Estimated source levels of pile driving noise from the DCSM and modified RAM were 186 dB and 195 dB in SEL, respectively.

5. CONCLUSIONS

In this study, pile driving noise were measured in southwest coast of Korea and compared with the prediction results predicted using DCSM and modified RAM. Although, the measured noise levels were in good agreement in the model predictions, the source levels predicted by two models showed difference of 9 dB, and accordingly, further study is needed.

ACKNOWLEDGEMENTS

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