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Analysis of low-frequency ambient noise measured in shallow sea

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1. Introduction

The low-frequency band of underwater ambient noise contains the fundamental and low-order harmonic components originating from the blade of distant ships. The signals in this band might be important to passive detection and clasification of the underwater targets, but the acoustic measurements in this band might have difficulties due to the non-acoustic pseudo-noise, which is a kind of self-noise caused by the presence of a hydrophone in flow field.[1-3] The flow-induced self-noise could be reduced effectively by screening the hydrophone with porous material.[4-5]

In this paper the characteristics of flow-induced self-noise, which is measured in a shallow sea under the influence of tidal current, are discussed.

2. Experiment and Result

The experiment was conducted in a shallow bay of Korea. The flow field of the bay is controlled by the tidal current which reverses the direction periodically. **Fig. 1** shows the schematic of the experiment.

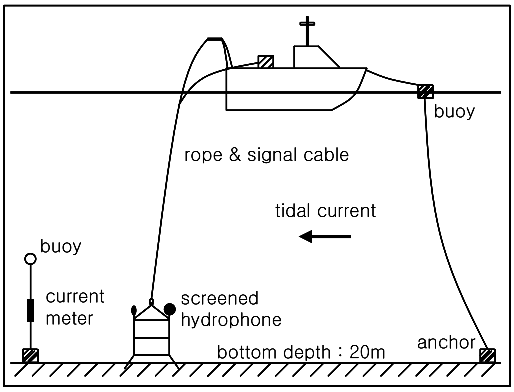

Fig. 1 Schematic of ambient noise measurement .

First, the current meter is deployed and then the hydrophone supporting structure of 1.4 m height and 2 cm diameter is lowered on the bottom. Four hydrophones are attached at the top of the rectangular structure. Three hydrophones are screened with the 10 pore-per-inch open-cell foam of 1, 2, and 3 cm thickness around the hydrophone protection guard and one hydrophone is not screened. The diameters of the hydrophone and hydrophone protection guard are 2.35 and 12 cm. The current meter was moored at the same depth with the hydrophones and separated from the hydrophone supporting structure by 10 - 15 m.

Fig. 2 shows the spectra of ambient noises measured by bare and screened hydrophones at the current speed of 56 cm/s (=1.09 knot). The solid line, which could be approximated as a straight line indicated by a dashed red line, indicates the level of the flow-induced ambient noise measured by the bare hydrophone. The dotted and dash-dotted lines represent the spectra measured by the hydrophones screened with the 2- and 3-cm thick foams. It could be seen from Fig. 2 that the ambient noise measured by the bare hydrophone is affected by the tidal current and could be reduced effectively by screening the hydrophones with foams.

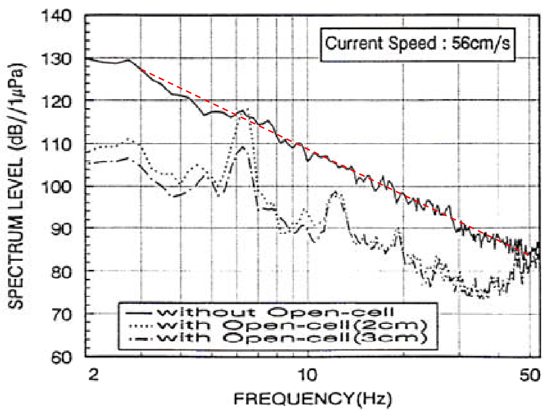

Fig. 2 Spectra of ambient noises measured by bare and screened hydrophones.

3. Analysis and Discussion

The flow-induced noises sensed by a hydrophone are caused in two ways. First, flow around the hydrophone generates turbulent vortices behind the hydrophone which are sensed as pressure fluctuations. Secondly, the pre-existing turbulence in the flow results in pressure fluctuations. The former could be considered as induced turbulence and the latter as intrinsic turbulence.

Strasberg[1-2] derived the expressions for the

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two cases which as follow. When the hydrophone is in non-turbulent inflow, the noise level induced by the turbulent wake behind the hydrophone could be expressed as

$$L_p \approx 135 + 65\log U_0 - 25\log D - 35\log f, \quad (1)$$

where L_p is spectrum level in dB re 1 μPa in 1 Hz band, U_0 is speed in knot, f is frequency in Hz, and D is diameter of hydrophone in cm. If the inflow is already turbulent, the noise level could be written as

$$L_p \approx 119 + 37\log U_0 - 27\log f, \quad (2)$$

for the frequency of (f/U_0) > 2 Hz/knot. Equation (2) was derived by assuming that the hydrophone is small compared with the spatial scale of flow speed variation. So, the applicability of eq. (2) is limited by the frequency corresponding to f < (U_0/2D) knot/cm.

When the hydrophone is placed on the bottom, the hydrophone senses the turbulent pressure fluctuations present in the boundary layer of inflow as flow noises. Webb[3] derived the expression for this case, which could be expressed as

$$L_p \approx 106 + 40\log U_\infty - 15\log f, \quad (3)$$

where U_∞ is the so-called free stream speed, i.e., the speed at a large distance above the bottom.

The current speed in ocean varies logarithmically with height above the bottom, which is given as

$$U(z) = (u_* / \kappa)\ln(z / z_0), \quad (4)$$

where $\kappa \approx 0.4$ is von Karman's constant, z_0 is the roughness parameter, and u_* is the friction speed. The friction speed could be estimated from the relation $C_{1\,m}=(u^*/U_{1\,m})^2$, where $C_{1\,m}$ is drag coefficient of bottom and $U_{1\,m}$ refers to the speed at 1 m above the bottom. **Fig. 3** shows the profile of current speed for the experiment condition, which is estimated using $C_{1\,m}$=0.0025, and z_0=0.0033.[6] $U_{1\,m}$ is assumed to be 54 cm/s. This estimated profile shows $U_{1.4\,m}$=56.38 and $U_{20\,m}$=74.33 cm/s.

Flow noise levels predicted by eq. (1) – (3) for the bare hydrophone of previous section are shown in **Fig. 4**. In applying eq. (3), $U_{20\,m}$ of fig. 3 is used as U_∞. Measured result approximated as a straight line between 3 - 50 Hz is also indicated. Fig. 4 shows that the spectral slope of the measured is most close to the one predicted by eq. (1). That implies that the spectrum measured by the bare hydrophone might be caused by the vortices shed behind the hydrophone. However, there is much difference between the predicted and measured results. The difference from the predicted might be caused by the complex interaction of various vortices shedding from the hydrophones, screens and hydrophone supporting structure.

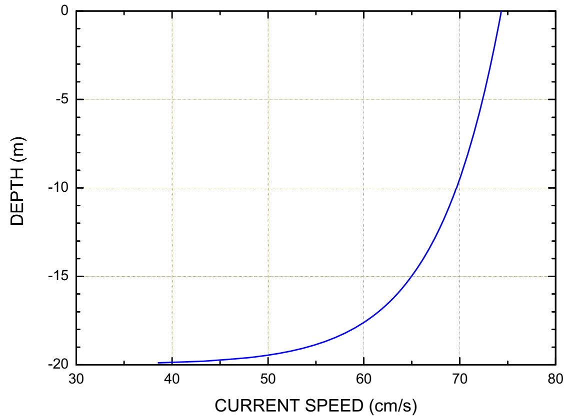

Fig. 3 Current speed profile estimated by eq. (4) for the experiment condition.

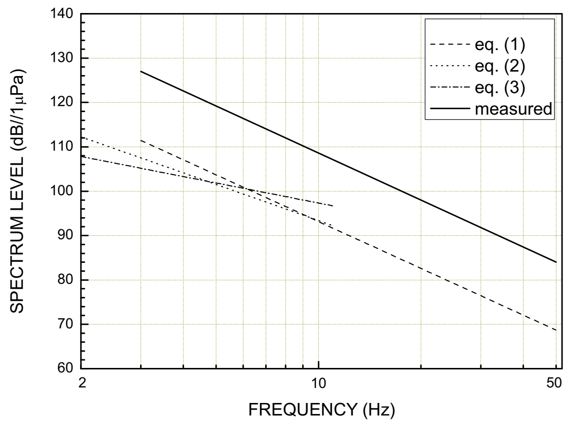

Fig. 4 Spectra of flow noises predicted by eq. (1) – (3) and measured by bare hydrophone.

Acknowledgment

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