2Pa2-6

Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 83-84
8-10 November, 2011

Estimation of Spatial Averaging in Near Field Measurement Using a Hydrophone for Deriving Mechanical Index

Mechanical Index 算出における
近距離音場での音圧空間平均の影響

Masahiro Yoshioka[†] and Tsuneo Kikuchi (NMIJ/AIST)
吉岡 正裕[†]，菊池 恒男（計測標準研究部門／産業技術総合研究所）

1. Introduction

International standard IEC62539 describing methods for the derivation of thermal and mechanical indices (*TI*, *MI*) related to diagnostic ultrasound was revised in 2010.[1)] Acoustic pressure measurement in near field is now required for deriving *MI*.

The requirements for the hydrophone to be used in the derivation is given in IEC62127-1.[2)] One important hydrophone property is active element size. Because a hydrophone output voltage is proportional to the spatial average of acoustic pressure on the active element of the hydrophone, when amplitude and phase distributions of an ultrasonic field are not flat in the region of the active element, a significant uncertainty might occur in the acoustic pressure measurement.[3,4)]

Even though the maximum hydrophone active element size for far and focused fields is given as a simple expression in IEC62127-1, that for near fields is unclear. To resolve this problem, a method for estimating the effect of spatial averaging in near field measurement using numerically calculated ultrasonic fields is investigated.

2. Derivation of Mechanical Index

When a distribution of pulse intensity integral $pii(z)$ (J/cm^2), which is a time integral of instantaneous acoustic intensity,[2)] on a beam axis is measured in water, attenuated pulse intensity integral $pii_\alpha(z)$ (J/cm^2) is given as

$$pii_\alpha(z) = pii(z) \times 10^{-\alpha z f_{\mathrm{awf}}/10}, \quad (1)$$

where z (cm), f_{awf} (MHz), and α = 0.3 dB/(cm·MHz) are the depth from the sound source, the ultrasonic frequency, and the acoustic attenuation coefficient of tissue, respectively.[1)] Depth for *MI* z_{MI} (cm) is the z at which $pii_\alpha(z)$ is maximum. *MI* is defined as

$$MI = \frac{p_{\mathrm{r},\alpha}(z_{MI}) \times f_{\mathrm{awf}}^{-1/2}}{C_{MI}}, \quad (2)$$

$$p_{\mathrm{r},\alpha}(z_{MI}) = p_{\mathrm{r}}(z_{MI}) \times 10^{-\alpha z f_{\mathrm{awf}}/20}, \quad (3)$$

where C_{MI} = 1 MPa·MHz$^{-1/2}$ and $p_{\mathrm{r}}(z)$ (Pa) is peak-rarefactional acoustic pressure, which is the maximum modulus of the negative instantaneous acoustic pressure, on the beam axis.

Therefore, the measurements of $pii_\alpha(z)$ and $p_{\mathrm{r},\alpha}(z)$ using a hydrophone are required for the derivation of *MI*.

3. Estimation of Spatial Averaging

When the center of a hydrophone active element is aligned with the beam axis, the effect of spatial averaging by the hydrophone on sound pressure measurement $K_{\mathrm{sa}}(z)$ can be estimated as the ratio of sound pressure along the beam axis $p_{\mathrm{c}}(z)$ to that spatially averaged over the region of the hydrophone active element $p_{\mathrm{sa}}(z)$:

$$K_{\mathrm{sa}}(z) = \frac{p_{\mathrm{sa}}(z)}{p_{\mathrm{c}}(z)}. \quad (4)$$

Sound pressure distributions to determine $p_{\mathrm{c}}(z)$ and $p_{\mathrm{sa}}(z)$ are calculated numerically using a model of a baffled piston.[5)] Deviations of $K_{\mathrm{sa}}(z)$ from 1 indicate the effect of the hydrophone spatial averaging.

4. Experiment

An ultrasonic field of 3.4 MHz radiated from a plane circular ultrasonic transducer 13 mm in diameter was measured using two hydrophones with different active element sizes: a membrane hydrophone (MHB500B, NTR Systems, Inc.) with an 0.5 mm square active element and a needle hydrophone (0.2 mm probe, Precision Acoustics Ltd.) with a 0.2 mm diameter active element. Measurement results of $pii_\alpha(z)$ are shown in **Fig. 1**. The depth of maximum $pii_\alpha(z)$ is around z = 3 cm for both hydrophones.

$K_{\mathrm{sa}}(z)$ calculated for each hydrophone is shown in **Fig. 2**. They demonstrate that the spatial averaging of a hydrophone with a large active element size is more effective than that with a small one, and that this effect increases with decreasing z, as expected.

Measurement results of $p_{\mathrm{r},\alpha}(z)$ in a neighborhood of the depth of maximum $pii_\alpha(z)$ are shown in **Fig. 3**. The $p_{\mathrm{r},\alpha}(z)$ corrected by dividing by $K_{\mathrm{sa}}(z)$ to remove the hydrophone spatial averaging

----
masahiro.yoshioka@aist.go.jp

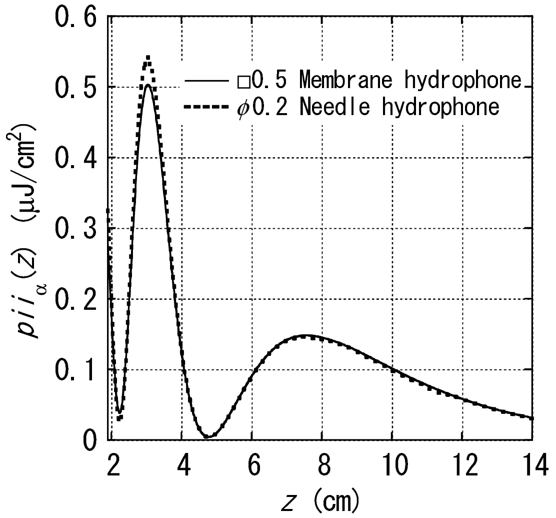

Fig. 1 Measurement results of attenuated pulse intensity integral $pii_{\alpha}(z)$ using two hydrophones with different element sizes ϕ0.2 and □0.5.

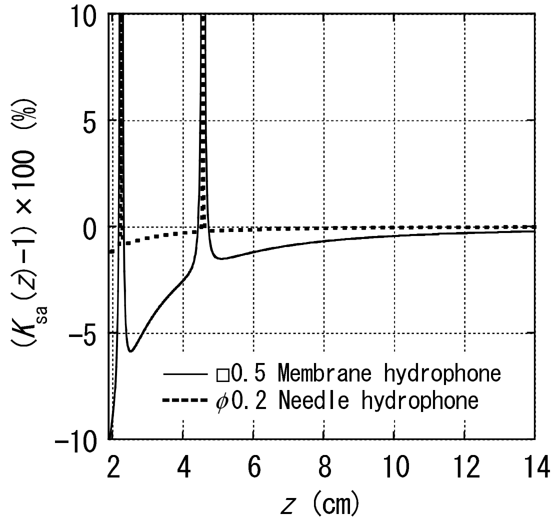

Fig. 2 Estimates of spatial averaging effect $K_{sa}(z)$ for the two hydrophones used in the experiment.

effect is shown in **Fig. 4**. As shown by comparing Figs. 3 and 4, correcting $p_{r,\alpha}(z)$ using $K_{sa}(z)$ reduces the difference between the measures obtained for the hydrophones with two different active element sizes. For example, the ratio of the $p_{r,\alpha}(z)$ values as measured by the two hydrophones at the respective depths of maximum $pii_{\alpha}(z)$ are 3.7 % for the uncorrected $p_{r,\alpha}(z)$ (Fig. 3) and 0.3 % for the corrected $p_{r,\alpha}(z)$ (Fig. 4).

5. Summary and Discussion

The results of the experiment confirmed that the effect of spatial averaging on the measurement of $p_{r,\alpha}(z)$ using hydrophones in the near field can be estimated quantitatively from $K_{sa}(z)$ calculated numerically using a model of a baffled piston. In addition, the measurement uncertainty by the spatial averaging of a hydrophone would be reduced by correction using $K_{sa}(z)$. However, when $K_{sa}(z)$ deviates significantly from 1, it should be noted that the large uncertainty in the $K_{sa}(z)$ calculation might arise in the process for determining the hydrophone active element size (whether nominal or measured size is used[3]) and the effect of the circular assumption on the active element size measurement[4]), as shown in our previous investigations.

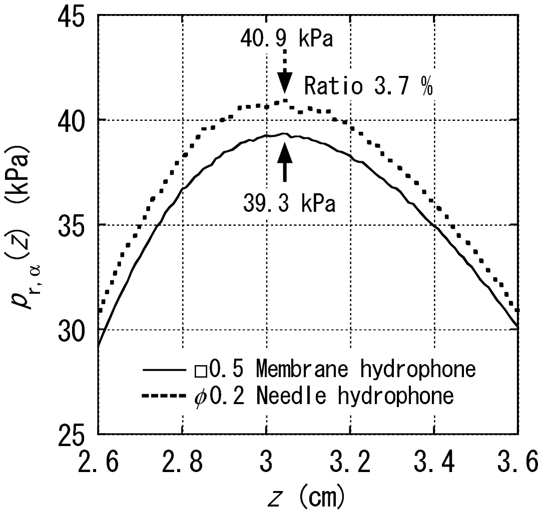

Fig. 3 Measurement results of attenuated peak-rarefactional acoustic pressure $p_{r,\alpha}(z)$ around the depth of maximum $pii_{\alpha}(z)$.

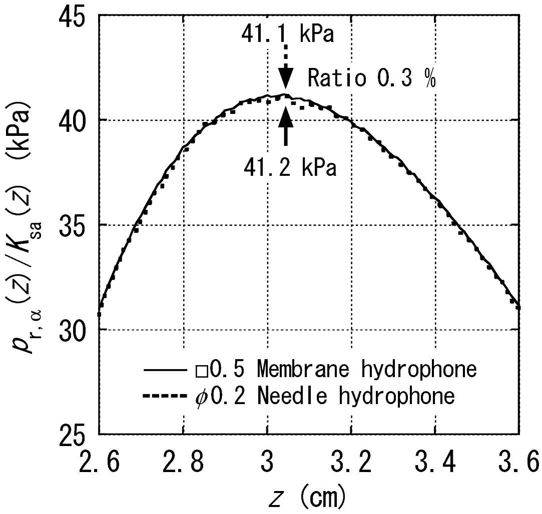

Fig. 4 Attenuated peak-rarefactional acoustic pressure corrected using $K_{sa}(z)$ around the depth of maximum $pii_{\alpha}(z)$.

References

1. IEC62359:2010.
2. IEC62127-1:2007.
3. M. Yoshioka: Jpn. J. Appl. Phys. **47** (2008) 3926.
4. M. Yoshioka, Y. Matsuda, and T. Kikuchi: Jpn. J. Appl. Phys. **49** (2010) 07HC01.
5. G. R. Harris: J. Acoust. Soc. Am. **70** (1981) 10.