A New Extraction Method for the Radiation Efficiency
and Radiation Directional Coefficient

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ABSTRACT

Underwater radiated noise is the key in acoustic stealth performance of modern naval ships. The underwater radiated noise predicted by the hull vibration with radiation efficiency cannot always give the information of radiation pattern which is essential to analyze of detection probability by enemy and to improve the operational performance of the naval ship. The radiation pattern of underwater radiated noise is able to be obtained with radiation efficiency and radiation directional coefficient. In this paper, a new method to extract the radiation efficiency and radiation directional coefficient is suggested and proved with the simulation and experiment by using cylindrical shell of 70 cm diameter in air.

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(directivity) 가
가
(radiation pattern)
(surface patch)

Fig. 1 Patch of structure surface and far-field surface

3

Helmholtz

(radiation directional coefficient)

(μ)

$$\mu_{ki} = \frac{\left(\begin{array}{c} i\text{-번째 표면패치 진동에 의한} \\ k\text{-번째 원음장 패치의 음압파워} \end{array} \right)}{\left(\begin{array}{c} i\text{-번째 표면패치 진동에} \\ \text{의한 원음장 음압파워} \end{array} \right)} \quad (3)$$

$$= (W_{ki} / W_{oi})$$

2.

2.1

Fig. 1

(radiating surface)
R (sphere) (far-field)
(patch) i
 S_i^{RS} , w_i , w_i
R
 W_{oi} , i
 σ_i

$$\sigma_i = \frac{\left(\begin{array}{c} i\text{-번째 표면패치 진동에 의한 원음장} \\ \text{전체 음압파워} \end{array} \right)}{\left(\begin{array}{c} \text{방사체 } i\text{-번째 표면패치의 진동파워} \end{array} \right)} \quad (1)$$

$$= W_{oi} / [\rho c S_i^{RS} (w_i)^2]$$

(1) i

$$W_{oi} = \sigma_i [\rho c S_i^{RS} (w_i)^2] \quad (2)$$

(2)

$$W_{ki} = \mu_{ki} W_{oi} = (\mu_{ki} \sigma_i) [\rho c S_i^{RS} (w_i)^2] \quad (4)$$

$$W_{ki} = \mu_{ki} W_{oi} = (\mu_{ki} \sigma_i) [\rho c S_i^{RS} (w_i)^2] \quad (4)$$

$$W_k = \sum_{i=1}^N W_{ki} = \sum_{i=1}^N (\mu_{ki} \sigma_i) [\rho c S_i^{RS} (w_i)^2] \quad (5)$$

$$W_k = \sum_{i=1}^N W_{ki} = \sum_{i=1}^N (\mu_{ki} \sigma_i) [\rho c S_i^{RS} (w_i)^2] \quad (5)$$

$$W_k = \int_{S_k^{FF}} IdS = [p_k^2(R) / \rho c] S_k^{FF} \quad (6)$$

$$S_k^{FF} = \int_{S_k^{FF}} IdS = [p_k^2(R) / \rho c] S_k^{FF} \quad (6)$$

$$p_k^2(R) = [\rho^2 c^2 / S_k^{FF}] \sum_{i=1}^N (\mu_{ki} \sigma_i) (S_i^{RS} (w_i)^2) \quad (7)$$

(7)

2.2

Brun

5

(1)

5

N

N

N

M

N

M

N

$$\frac{W_o}{\rho c} = (\sigma_i) \left\{ S_1^{RS}(\dot{w}_1)^2 \left(\frac{\sigma_1}{\sigma_i} \right) + S_2^{RS}(\dot{w}_2)^2 \left(\frac{\sigma_1}{\sigma_i} \right) + \dots + S_i^{RS}(\dot{w}_i)^2 (1) + \dots + S_N^{RS}(\dot{w}_N)^2 \left(\frac{\sigma_N}{\sigma_i} \right) \right\} \quad (8)$$

(8)

(ratio)

i

σ_i

(boundary ele-

ment method)

i

$$(\sigma_j/\sigma_i) \simeq (\sigma_j/\sigma_i)_{BEM} \quad (9)$$

(9)

(8)

$$\sigma_i = (W_o) / \left[\rho c \sum_{q=1}^N S_q^{RS}(\dot{w}_q)^2 (\sigma_q/\sigma_i)_{BEM} \right] \quad (10)$$

, N

(10)

$$[z] \{ \sigma \} = \{ W_o / \rho c \} \quad (11)$$

$$, z_{ii} = \sum_{q=1}^N S_q^{RS}(\dot{w}_q)^2 (\sigma_q/\sigma_i)_{BEM} \quad P$$

$$\{ W_o^{(1)} \}, \{ W_o^{(2)} \}, \dots, \{ W_o^{(P)} \}$$

(11)

$$\{ z_1 \dots z_P \}^T \{ \sigma \} = \{ W_o^{(1)} / \rho c \dots W_o^{(P)} / \rho c \}^T$$

또는,

$$[Z] \{ \sigma \} = \{ W_o^P / \rho c \}$$

(12) $[Z]$

$[Z]^T$

$$\{ \sigma \} = ([Z]^T [Z])^{-1} [Z]^T \{ W_o^P / \rho c \} \quad (13)$$

μ_k

N

가

k

W_k

(5)

,

(8)

$$(\mu_{kj} / \mu_{ki}) \simeq (\mu_{kj} / \mu_{ki})_{BEM} \quad (14)$$

k

(15)

,

(16)

$$\mu_{ki} = (W_k) / \left[\rho c \sum_{q=1}^N \sigma_q S_q^{RS}(\dot{w}_q)^2 (\mu_{kq} / \mu_{ki})_{BEM} \right] \quad (15)$$

$$[y] \{ \mu_{ki} \} = \{ W_k / \rho c \} \quad (16)$$

$$, y_{ii} = \sum_{q=1}^N \sigma_q S_q^{RS}(\dot{w}_q)^2 (\mu_{kq} / \mu_{ki})_{BEM} \quad k$$

L

$\{ W_k^{(1)} \},$

$$\{ W_k^{(2)} \}, \dots, \{ W_k^{(L)} \}$$

(16)

$$\{ y_1 \dots y_L \}^T \{ \sigma \} = \{ W_k^{(1)} / \rho c \dots W_k^{(L)} / \rho c \}^T$$

또는,

$$[Y] \{ \mu_k \} = \{ W_k^L / \rho c \}$$

(17) $[Y]$

k

$[Y]^T$

$$\{\mu_k\} = ([Y]^T [Y])^{-1} [Y]^T \{W_k^L / \rho c\}$$
 (18)

(18) N
가 M
 $M \times N$.

$$[\mu]_{M \times N} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \dots \\ \mu_M \end{bmatrix} = \begin{bmatrix} \mu_{11} & \mu_{12} & \dots & \mu_{1N} \\ \mu_{21} & \mu_{22} & \dots & \mu_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \mu_{M1} & \mu_{M2} & \dots & \mu_{MN} \end{bmatrix}$$
 (19)

M i 가 .

$$\sum_{k=1}^M \mu_{ki} = \mu_{1i} + \mu_{2i} + \dots + \mu_{ki} + \dots + \mu_{Mi}$$
 (20)
$$= (W_{1i} / W_{oi}) + (W_{2i} / W_{oi}) + \dots + (W_{Mi} / W_{oi})$$

$$= 1$$

3.

3.1

Fig. 2

mm, 2 mm , 300 mm, 700 mm
100 mm 5 가 , 5 mm

S/W ABAQUS

Fig. 3 (: 11,382,
: 6,192 , :) 3
가

Fig. 2 Ring-stiffened aluminum cylindrical shell

Fig. 4 14 ,
100 m (sphere) ABAQUS

S/W SYSNOISE 5° 2,522
(=35×72+2)

30° 62 가 62 (=5×12+2)가
2,522

3.2

3 가
(1 N) 가 (가 1,
2,3 가 T1, T2, T3)
, (12) (17)

Fig. 3 F.E. Model of cylindrical shell

Fig. 4 Surface patches of cylindrical shell

가 400 Hz, 500 Hz, 650 Hz, 800 Hz, 1000 Hz, 1150 Hz, 1300 Hz, 1550 Hz, 1700 Hz, 1850 Hz
10
3 가 , 2 가
가 3 가 가
(12) (17)
SYSNOISE

Fig. 5

SYSNOISE S/W

Fig. 6
가

3 가

가

(20)

(a) Unit velocity

(b) T1

(c) T2

(d) T3

(e) T1+T2

(f) T1+T2+T3

Fig. 5 Radiation efficiency of structural surface patch

(a) Unit velocity

(b) T1

(c) T2

(d) T3

(a) 400 Hz

(b) 1000 Hz

(c) 1550 Hz

(d) 1850 Hz

Fig. 6 Radiation directional coefficient for far-field patch

Fig. 7 Acoustic sound pressure level for far-field patch

$$\mu_{1i} = \mu_{2i} = \mu_{62i} = (1/62), \text{ or } (\mu_{kj}/\mu_{ki})_{BEM} = 1 \quad (21)$$

Fig. 5 Fig. 6

SYSNOISE S/W

Fig. 7

가

		. Table 1	set 1	가	1
가	(T1)				
(σ)		(μ)		, 가	3
가	(T3)				
			, set 2	σ, μ	T1
가	2	가	(T2)		
,		T3			
, set 3	σ, μ	T1, T2, T3			
,		T3			
. Table 1			case		

Fig. 8

Fig. 8

10 12

7 cm

MFC(micro fiber composite) (70 mm × 60 mm × 1 mm) 1

Table 1 Cases of sound prediction in far-field

Set no.	Excitation case	Vibration for radiation pattern
Set 1	T1	T3
Set 2	T1+T2	T3
Set 3	T1+T2+T3	T3

(a) 400 Hz

(b) 1000 Hz

(c) 1550 Hz

(d) 1850 Hz

Fig. 8 Prediction of acoustic sound pressure level for each far-field patch with different excitation cases

Fig. 9 The near-field acoustic pressure sensor array

Fig. 10 Experimental set-up for the measurement of near-field acoustic pressure

Fig. 11 Regeneration of experimental acoustic pressure level for each far-field patch

4.

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