IDENTIFICATION METHOD OF PLURAL SOUND SOURCES BY USING MEASURED VALUES WITH ERROR AND POWER SPECTRA IDENTIFICATION

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Abstract

This experimental study presents an inverse analysis method for the identification of plural unknown sound sources in the three-dimensional free sound field using the boundary element method and the optimization technique. In the previous reports, an algorithm that analyses the observation point importance was given and was used as a weight in the evaluation function in the optimization process. The vibration velocity amplitudes at different frequencies as well as the locations of plural sound sources were simultaneously identified whose sound spectra are different from one sound source to another. As a result of this report, it was effective to use the observation point importance for the accurate identification of sound sources. The sound spectra of sound sources could be identified accurately for the remote diagnostics of machinery.

1. INTRODUCTION

In order to reduce the noise generated from machinery in a factory, it is important to search the sound source and to investigate the characteristics of noise. In diagnostics of machinery the identification of sound source location and other sound information are necessary. To identify the sound information the inverse problem which obtains the location or other information from the measured data is used. Many studies use the optimization technique to treat the inverse problem [1],[2],[3],[4],[7].

In this paper, the identification of the location and the vibration velocity of plural sound sources which have the different frequency components is tried. Then the frequency components of plural sound sources are identified. This technique will be applied to the remote diagnostics of machinery.

2. IDENTIFICATION METHOD

The sound source field model used for identification of sound sources is shown in Fig.1. And the co-ordinates of observation points are given in Table 1. There are plural sound sources on the x-y plane, and the microphone arrays are set on two planes at Z=0.5 and 1.0m.

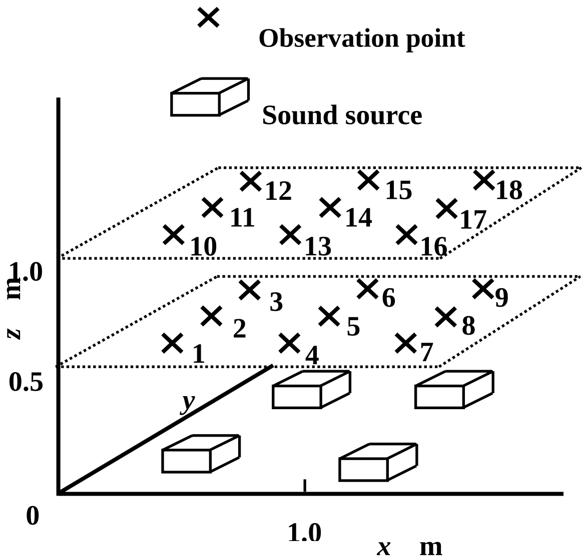


Fig. 1 Sound field model for identification

Table 1 Locations of observation points in Fig. 1

No.	*x, y, z* m		No.	*x, y, z* m
1	0.3, 0.3, 0.5		10	0.3, 0.3, 1.0
2	0.3, 0.8, 0.5		11	0.3, 0.8, 1.0
3	0.3, 1.3, 0.5		12	0.3, 1.3, 1.0
4	0.8, 0.3, 0.5		13	0.8, 0.3, 1.0
5	0.8, 0.8, 0.5		14	0.8, 0.8, 1.0
6	0.8, 1.3, 0.5		15	0.8, 1.3, 1.0
7	1.3, 0.3, 0.5		16	1.3, 0.3, 1.0
8	1.3, 0.8, 0.5		17	1.3, 0.8, 1.0
9	1.3, 1.3, 0.5		18	1.3, 1.3, 1.0

The sound sources are identified by minimizing the difference between the measured sound pressure and the calculated sound pressure at the assumed sound source locations and by changing the identified parameters. The boundary element method is used to calculate the sound pressure at the observation point based on the assumed sound source. The changing of the identified parameters becomes the minimization problem of the objective function which is composed of the measured sound pressure and the calculated one. The conjugate gradient method is used to minimize the objective function.

2.1 Sound field analysis by using boundary element method

To detect sound sources, sound field analysis is carried out by the boundary element method. The sound pressure at arbitrary location can be obtained by the sound field analysis. In this study, the sound pressure at the measuring point is treated as known information, and the some information of sound sources are obtained as the inverse problem.

2.2 Optimization method and objective function

In this study the locations of sound sources are also treated as unknown information. At first, sound pressure information is calculated from the assumed sound source information (i.e. location and vibration velocity). Next, the sound source information is renewed according to the calculation algorithm to minimize the difference between the measured and calculated sound pressure. The objective function is defined as the difference between the calculated sound pressure at the observation point by the boundary element method and the measured one at the observation point.

So far two kinds of the evaluation function were defined and applied to the identification problem. Those are (1) the fundamental evaluation function method [7] and (2) the selection method of observation point based on the observation point importance [4].

2.3 Weighted method based on observation point importance

In the weighted method the following two evaluation functions are used alternatively.

$$W = \frac{1}{M}\sum_{i=1}^{M}(p_{ci} - p_{mi})^2 \tag{1}$$

$$W_2 = \frac{1}{M}\sum_{i=1}^{M}w_i(p_{ci} - p_{mi})^2 \tag{2}$$

where W is the fundamental evaluation function, M is the number of observation points, p_{ci} and p_{mi} are the calculated sound pressure at observation point i using the assumed sound source location and the measured sound pressure at observation point i. w_i in Eq.(2) is given by

$$w_i = (p_{fi} - p_{mi})^2 \tag{3}$$

The algorithm of the weighted method based on observation point importance is composed of the followings (a) – (c).

(a) By using the fundamental evaluation function W of Eq.(1) the calculation of identification is continued till reaching to convergence.

(b) By using w_i of Eq.(3) which is the weighted value based on the observation importance, the calculation W_2 of Eq.(2) is continued till reaching to convergence.

(c) Eq.(1) which is not weighted is calculated till reaching to convergence. Then Eqs.(2) and (1) are alternatively used for identification till convergence.

3. IDENTOFIED RESULTS AND DISCUSSINS

The identified results by the weighted method based on observation point importance are given. The identified parameters are the location and the sound spectra of each sound source.

3.1 Experimental apparatus

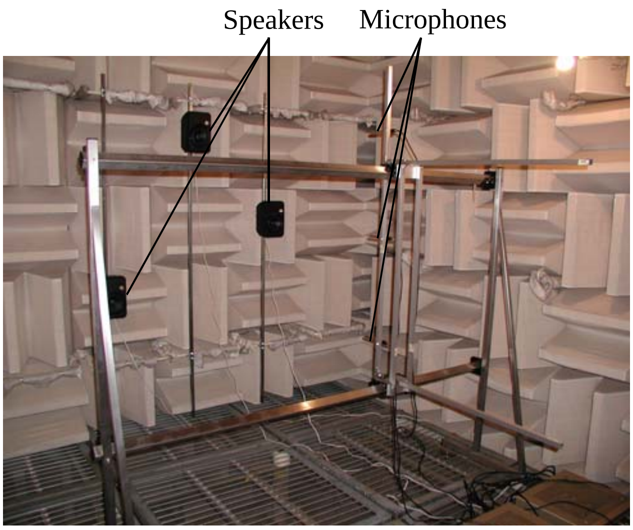


Fig. 2 Experimental apparatus

The experimental apparatus is shown in Fig.2. The loudspeakers are used as the sound source and the microphones are set at the location given in Table1. The each loud speaker radiates the sound composed of the different sound spectrum from 100 Hz to 1000 Hz. It is assumed that the sound source is a hexahedron 64 x 64 x 32 mm in boundary element analysis and that only the upper plane is vibrating.

3.2 Identified results of sound source location and vibration velocity

In this section the identified results are given and discussed for the frequency component of 300 Hz. The identified results of sound source location and vibration velocity are shown in Fig.3 and Table 2. In Fig.3 the initial and final sound source location and the locus are indicated. It is found that the sound source locations are identified accurately and that the vibration velocity is identified not so well.

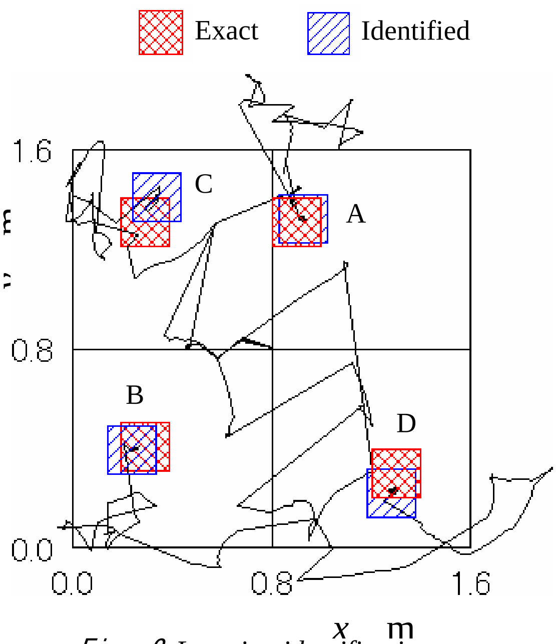
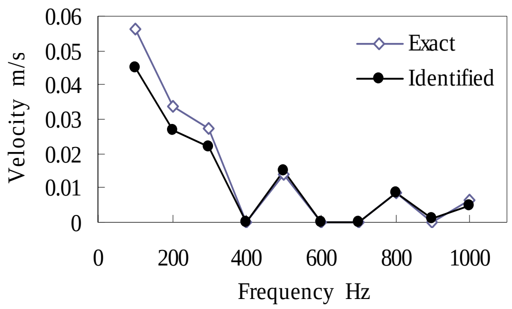


Fig. 3 Location identification

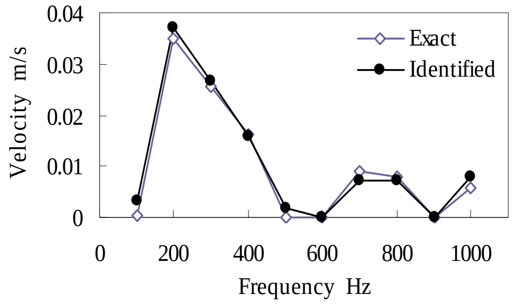
Table 2 Identification result

Sound source	Exact		Weight method	
	x, *y* m	*v* m/s	*x*, *y* m	*v* m/s
A	0.900, 1.300	0.0275	0.928, 1.317	0.0217
B	0.300, 0.400	0.0237	0.243, 0.388	0.0207
C	0.300, 1.300	0.0255	0.343, 1.405	0.0259
D	1.300, 0.300	0.0243	1.282, 0.215	0.0221

The identified results of the vibration velocity are indicated in Figs. 4 and 5 for all frequency components. In this case, the identified sound source location for 300 Hz is used also for other frequency components. Figure 5 gives the sound pressure level, which is calculated by using the results of Fig.4, at the distance 4 m from the sound source. It is found that the distribution of frequency components is obtained accurately for not only 300 Hz but also for other frequency components and that this method is useful for identification of the sound source location, vibration velocity, and the sound pressure spectrum.

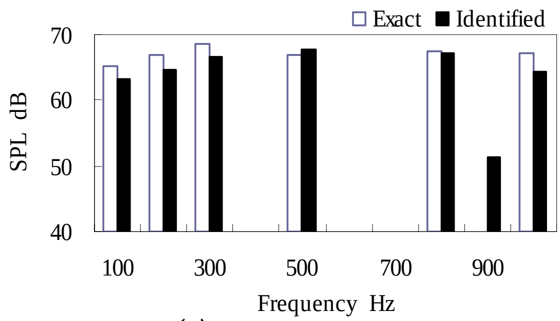


(a) Sound source A

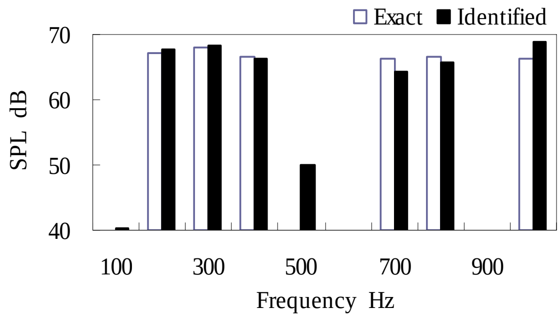


(b) Sound source C

Fig. 4 Velocity identification



(a) Sound source A



(b) Sound source C

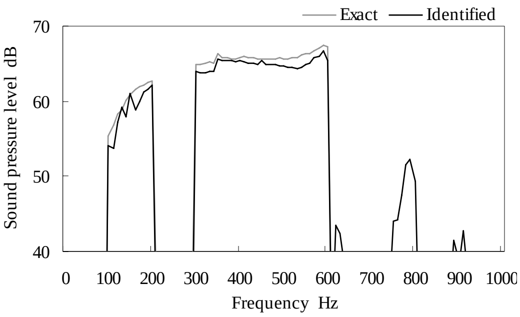
Fig. 5 SPL identification

3.3 Simultaneous identification of power spectra for plural sound sources

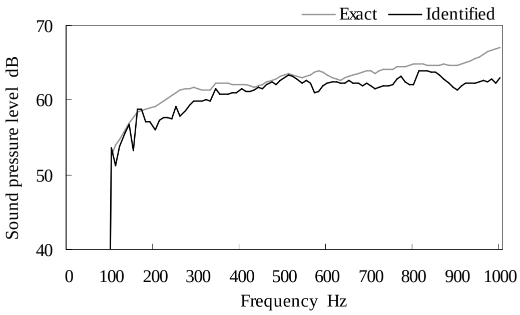
Next the complicated sound sources, which have the spectrum peaks at each 10 Hz from 100 Hz to 100 Hz, are identified. The measured and identified power spectra are shown in Fig.6. The power spectra of sound sources can be identified fairly well.

CONCLUSIONS

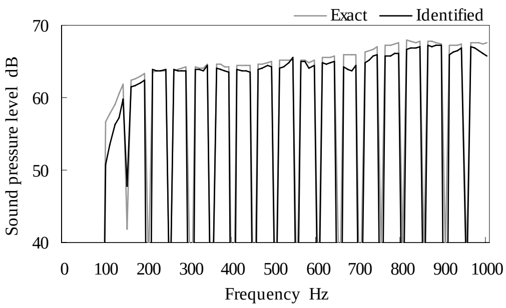
The identification method of sound source location and sound information was proposed and discussed by using sound pressure values obtained from the microphone array. This identification method becomes the optimization problem to minimize the difference between the measured and the calculated vales. It was found that this method is useful to identify the sound source locations, sound velocity, and the frequency components of sound velocity.



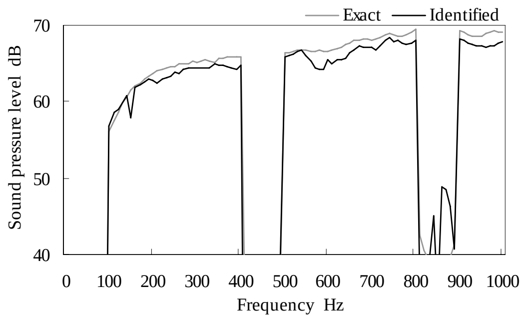
(a) Sound source A



(b) Sound source B



(c) Sound source C



(d) Sound source D

Fig. 6 Sound spectrum identification

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