Study on the Way of Tracking the Rotating Point Noise Source Identification Based on Beamforming

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ABSTRACT

For the problem of rotating noise source identification, the paper will propose a new beamforming algorithm which includes reasonable filter and rotating angle. The method studies on rotating point source and is based on assumption of the discretization of rotating and steady sound field. The advantage of the algorithm will have a high resolution, fast calculation, well tracking noise source location and so on. Compared to the result of cross-spectral beamforming algorithm software, it can find that the algorithm can obviously enhance resolution and be able to find rotating noise source location at any time. Effectiveness and truth of the new algorithm can be verified by practical example. It can be an accurate method to obtain the rotating impeller noise source information.

Keywords: Beamforming; Rotating Point Noise Source; Noise Source Identification; Tracking.

1. INTRODUCTION

Beamforming is a kind of spatial acoustic field visualization technology and has been widely applied in the field of sound source identification. Beamforming has more advantage of rapid measurement, higher calculation precision and more resolution than traditional sound source identification technology and is used to measure the medium and far distance. It can be used to identify the steady, transient and mobile noise source[1,2]. However, the application of beamforming algorithm on the sound source trailing is little. Liu Yun Tao[3] from Inner Mongolia university of technology used comb array to identify the aerodynamic noise of horizontal axis wind turbine with winglet in 2013. Rakesh C. Ramachandran[4] applied the advanced...
de-convolution beamforming algorithm to identify 1.5MW horizontal axis wind turbine noise source. The results proved that the algorithm could be better to identify the mechanical noise caused by tower and aerodynamic noise caused by blades. In 2012, Gwang-Se Lee[5] used the 48 microphone array to identify 660 kW wind turbine noise source and the results demonstrate that noise generates in the downstream of the blades.

The paper is based on Fu Jian’s assumption of discrete spatial rotating point source and Wu Jiu Jiang’s research that is the low rotational frequency is little impact on the harmonic distribution. The paper write spherical wave beamforming algorithm program with wave filter and rotation angle to research on the Way of Tracking the Rotating Point Noise Source via matlab. The purpose of this approach is to get real rotating turbo- machinery noise location at any time and provide a reference on sound source position.

2. Near Field Traditional Beamforming Algorithm

Noise source identification is based on beamforming signal processing techniques, the received pressure signal for each microphone do delay processing with a reference microphone received signal, so that all the received microphone signal is the same phase. Then do sum these delay signals to keep output the maximum [8]. Then the pressure signals $P_m$ are individually delayed and summed:

$$B(\vec{r}, \omega) = \frac{1}{M} \sum_{i=1}^{M} P_m(\omega)e^{-j\Delta_m(\vec{r})}$$

(1)

$$\Delta_m(\vec{r}) = \frac{|\vec{r} - \vec{r}_m|}{c}$$

(2)

Where $M$ is a number of the microphone, the individual time delays $\Delta_m(\vec{r})$ are chosen with the aim of achieving selective directional sensitivity in a specific direction, $\omega$ is the temporal angular frequency.

When the focal point position is same as location of real sound source, the result of delay and sum is the largest, we name it main-lobe; however, when the focal point position is not on location of the real sound source, the result of delay and sum is side lobe. Side lobes are superimposed to form "ghost", the relationship of side lobe and the main lobe peak size will affect the accuracy of sound source identification.

3. Establishment of Experimental Programs and Models

3.1 Experimental Projects

Experimental equipment is shown in figure 1. Under laboratory conditions, the plane of rotation is taken place of 1.2m diameter. Turbo machinery is simulated by the
type of triple-phase asynchronous motor driving disk. Because the type of beeper’ sound position is too small, it can be considered as point source. Three different beepers are fixed on rotating disc and each of beeper’s angle is 120° and the distance between the disk center and beeper is 0.4m. The center of the array surface is opposite the center of rotating disk and distance between two flat is 1.5m. The acoustic signal is obtained by an optimized 60 channel comb array and hardware acquisition card.

![Experimental equipment](image)

**Figure 1. Experimental equipment.**

3.2 Software Modeling

When a rotating point source passes $\Delta \tau$ at the low speed, the location of rotating noise source is not beyond the scope of array resolution. Based on this assumption, a rotating point source can discrete a series of point source and this method can identify noise source at any moment.

The program is as follows: first of all, radius of the 0.6m circle plane is divided into $360 \times 7$ Circular field point calculation model and the real sound source is a certain point in the model. Secondly, according to the traditional beamforming algorithm, we should only do phase compensation without spherical wave amplitude correction of the near field sound source identification algorithm which designs a reasonable filter and loads the corresponding rotating angular to identify rotational point source information. Finally, in the laboratory conditions, the acoustic pressure data from the time date recorder should be imported into programs to identify the static or rotational sound source location.

4. Comparison of Results

4.1 Analyzing the Results of Stationary Point Source Identification

The point source is located at 90°; the radial distance is 0.4m; frequency of the beeper is 2464Hz. Acoustic imaging results are shown as figure 2.
In the dynamic range of 3dB, figure 2a is calculated by traditional beamforming algorithm with filter and figure 2b is also calculated by cross-power except self-spectrum beamforming. The results of figure 2 are shown as follows:

(1) The sound source main lobe width of figure 2a is significantly narrower than figure 2b, the main lobe width is more narrow, the sound source identification resolution is better, it proves that the algorithm’ spatial resolution is better than cross-power except self-spectrum beamforming.

(2) The average sound pressure level of sound source in figure 2a is less than figure 2b, but it did not affect the sound source identification results, there are two reasons accountable for it. Firstly, the algorithm only makes phase compensation, but not do amplitude correction for microphone received sound pressure signal; Secondly, band-pass filter can be attenuated SPL.

4.2 Moving Point Source Identification Result Comparative Analysis

The speed of disc is respective 80r/min and 120r/min. The beeper is fixed on the rotating circular surface of radius 0.4m. Figure 3 is the result of acoustic imaging processing software in a certain schematic acoustic array.

As the figure 3 is shown, the sound source frequency is 2592Hz. We get following conclusion from figure 3 in the dynamic range of 3dB.

(1) Sound source position is a circular track in the peripheral surface, the reason is the use of steady state calculations beamforming algorithm.

(2) Figure 3a and figure 3b have a "ghost" in the rotation center disk, but the
ghost of figure 3a is smaller than figure 3b, the reason for this phenomenon is the change of rotating frequency. When the rotating frequency increases, the sound source location of the side-lobe values will also increase, however the side-lobe there will be noise pollution source imaging, so the ghost of figure 3a is less than figure 3b;

(3) According to figure 3, it can be found that the location and size of the sound source identification are almost identical, which shows that the change of rotation frequency has little effect on the harmonic distribution, when the rotation frequency is low.

4.3 Simulation Calculation Results

We can find from figure 3 that the image of sound source identification result is difficult to identify the sound source which is issued by certain buzzer. In order to solve this problem, when rotating point source is steady speed, rotating point source can disperse into distributed along the rotation trajectory of a series of static sound source. The trigger is arranged on the 1st sound source angle of 90°. The position of sampling data to trigger the first time $\Delta \tau$ is same as a benchmark. When $\Delta \tau$ is smaller, the forward-looking source location in the rotating process does not change, according to the frequency resolution and frequency rotation, the $\Delta \tau$ is equal to 0.03s and the sampling rate is 8192Hz, so the number of 245 points sound pressure signal data are used to calculate. When motor speed is 120r/min and 1st trumpet sound source frequency is 2592Hz, we use filtering beamforming algorithm to calculate sound source image, such as figure 4.
As the figure 4 shown, the radial position of identification from point sound source is 0.42m. The recognition results and the actual installation radial position deviation rate is 5% and the range of deviation is small. The angle of sound source position corresponds to 192°, the reason for sound source location inaccurate angle is software itself acquisition delay, so the sound source is driven by the motor from 90° along the clockwise rotation to 192° and across 258°. Rotating point source is based on steady-state sound field condition; the triggering time is after first $\Delta \tau$ in sound source localization results were based on 36° to rotate along the clockwise, so the rest of sound source recognition images can obtain. The figure 4a to figure 4i shows that this kind of sound source discrete method can constantly locating, identifying sound source location information and achieve the sound source of the trailing under the known conditions of the revolution. The comparison of sound pressure level from figure 3 to figure 4 show as follow.

(1) The sound source pressure level of figure 4 is less than figure 3. There are two reasons accountable for this phenomenon. Firstly, the main reason for the phenomenon is selection of sampling points; secondly, the algorithm does not amplitude correction and the algorithm using the technique of filter;

(2) The process of sound source localization from figure 3 appears ghost in the center of the disc, but figure 4 does not appear. So the algorithm can be better positioning the sound source in specific information and effective attenuation side lobe.

5. CONCLUSION

The beamforming algorithm is based on the loading of the filter and rotational angle to verify the sound source planar sound source imaging software. The conclusions are shown as follows:

(1) The algorithm can identify the location information of the rotating point sound source in the condition of near field beamforming algorithm and the steady of rotating sound field;

(2) The algorithm does not modify the amplitude, it will change the SPL from sound source identification, but it does not affect the location of sound source recognition;
(3) Under the assumption of spherical wave, the acoustic imaging software was developed to better trail moving sound source. Beamforming algorithm with respect to a cross power spectrum has a fast computational speed, higher resolution and obvious side-lobe suppression effect. It can provide a kind of method to obtain the rotating impeller’s position of sound source.

6. REFERENCE

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