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Ship-Radiated Noise Reconstructed Based On FIR Filter

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Abstract

Based on the mechanism of the ship radiated noise analysis, ship radiated noise is generated by using FIR filter excitation Gaussian white noise. The FIR filter combined with statistical ROSS empirical model to keep simulation similar. In order to detect the noise similarity, it is effective to use the correlation coefficient as a judgement. Furthermore, The comparison about the time cost and the similarity between FIR method the bispectrum method were calculated. Simulation results shown that FIR method has high accuracy and less time-consuming features.

Keywords: *ship-radiated noise; FIR ; Bispectrum; simulation*

1. Introduction

With the importance of the maritime strategy repeatedly raised, the sound of water against application used in many areas. The ship radiated noise as the main carrier of Hydroacoustic technology has been widespread concern in recent years. Ship Radiated Noise [1-3] mainly consists of three parts, Which are mechanical noise, propeller noise and hydrodynamic noise. Mechanical noise and propeller noise are major components of the radiated noise, which noise is more important depends on the speed, length, displacement and the frequency of the ship noise. Typically, once the propeller cavitation occures [4], the propeller noise become the main source of noise, especially in the high frequency band. When ship moving at low speed, the mechanical noise tends to rise as the main source of noise. Therefore, It is obvious that the ship radiated noise consist of lines spectrum[6] and the broadband continuous spectrum. Meanwhile, various modeling reconstruction methods have emerged to fit the mechanism of the ship radiated noise analysis.

The method about the spectral structure modeling: Liu Gang [7] and other people using bispectrum analysis and processing the ship radiated noise strong bands. Liu can effectively extract the higher-order spectra and reconstruct ship noise of Ship Noise according to it magnitude. This modeling approach is mainly using the higher-order cumulant spectrum and higher moment spectrum to analysis ship radiated noise High-precision. Furthermore, the reconstructed spectrum target can be reconstructed high simulation accuracy ultimately. However, this method is very time-consuming, where ever-changing battlefield changes, It will encounter serious consequences if the right noise can't quickly generate; therefore a ship radiated noise method depend on equation modeling attracted wide attention due to its rapid and systematic. The classic ROSS empirical model [8] from the mathematical statistical modeling, which is assumes that a ship noise excitation spectrum is proportional to the baseline spectrum. This proportionality constant is determined by the speed of the ship and the length exponent of ship. Therefore, the size of the sound source level can be represented by function expression. This modeling approach can guarantee the speed of simulation. However, due to its age-old empirical models can only apply to old-fashioned small vessel. Using this model will lead to the accuracy of reconstruction insufficient. Therefore, it is necessary to develop a fast and high precision modeling method to meet modern needs. As we all know, the Filter is a tool which can filter the signal to obtain the desired signal. So the method of filter is widely used in construction ship radiated noise . Liang Mingzan et al. [9] found continuous spectrum is regularity and used filter simulated continuous spectrum of ship radiated noise. According to analysis Continuous spectrum having dB / octave characteristics, which can be obtained by setting filter coefficients from the equation. The equation make ship radiated noise continuous spectrum become a formula. However, It is not effective enough because not only the continuous spectrum noise had but also the line spectrum noise had as well. Therefore, the line spectrum should reconstructed at the same time. Liu [10] and other people used FIR frequency response simulated the ship radiated noise spectrum (line spectrum majority concentrated in the low frequency band) at low frequency line, where the line spectrum has a new method to reconstruct. However this method focuses on low frequency line spectrum reconstruction, which ignore the other bands ship radiated noise characteristics. It is our target to achieving a more complete ship radiated noise spectrum in this paper.

2. Ship radiated noise noise generation modeling

Adaptive FIR filter used in this paper having the desired method of constructing a frequency response (FIR) filter

which is similar to ship radiated noise. The desired similar ship radiated noise obtained through FIR excitation Gaussian white noise. Theoretical analysis shown that, when using the adaptive method can make FIR filter frequency response more in line with design specifications, the stability of the numerical method can be avoided, which make reconstruction become more flexible.

The working principle of FIR filter based on minimum mean square error shown as follows：

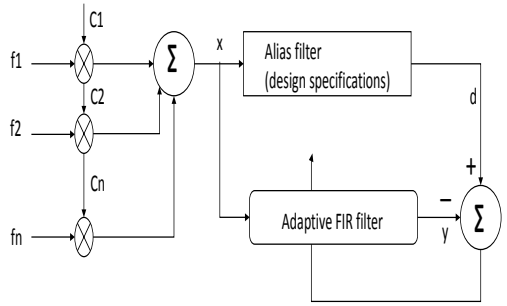

Fig. 1 The Adaptive Block Diagram of FIR filter

The specific algorithm: First interpolating in vector form according to a desired amplitude frequency response. Then the unit impulse response of the ideal filter obtained by inverse Fourier transform. Finally the units ideal filter impulse response truncation by this obtained coefficients of the digital filter by using window function. Pseudo-adaptive filter output is expected response of the filter. It should be noted that input signal is not the actual signal, but added in order to artificially the filter design. Adaptive process may be any kind of adaptive iterative algorithm is applied to the horizontal structure of the filter, such as the least mean squares method. So the specified frequency response get when the adaptive filter convergence based on the pseudo amplitude response.

In order to obtain a desired frequency response it is necessary to know the source level function of ship radiated noise.Ship radiated noise spectrum consist of line spectrum and continuous spectrum by the composition. Therefore, according to the current ROSS statistical functions, the sound source level function S (t) shown as follows:

$$S(t) = SL_f + S_i(t) \quad (1)$$

Where f is a continuous spectral function, $S_i(t)$ is the function of linear spectrum. Continuous spectral function of the form are as follows:

$$\begin{cases} SL_f = SL_s + 20 - 20\log(f_0) & f \le f_0 \\ SL_f = SL_s + 20 - 20\log(f) & f > f_0 \end{cases} \quad (2)$$

SLs is the total source level above 100Hz, f_0 is the peak frequency. Wherein the total level of the sound source function is:

$$f_0 = 1000 - 900\frac{V}{V_{max}} \quad (3)$$

$$SL = 112 + 50\log\frac{V}{10} + 15\log T - 1.5 * 10^{-5}T \quad (4)$$

V is the speed of the ship, T is tonnage. The center line spectrum Si (t) in equation (1) as a function of the expression:

$$S_i(t) = \sum_{n=1}^{n_i} a_{in}\sin[n(2\pi f_i t + \emptyset_i(t) + r_{in})] \quad (5)$$

n is the number of i-order harmonic components harmonic group contains; r_{in} uniform random quantity on [0,2π]; Each group has a separate random drift harmonic phase $\emptyset_i(t)$; f_i and a_{in} is specific parameters setting with Vessels.

3. Modeling and Simulation

Based on the above filter modeling, the modeling of the FIR filter order selection for the 2000 Order, the hull parameter is the actual speed of 15 knots, a maximum speed of 25 knots, the hull tonnage of 400t. Original sampling frequency noise is 48000Hz. Frequency response shown in Figure 2:

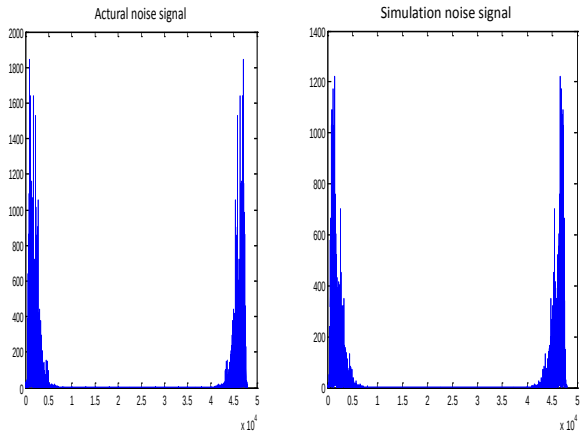

Fig. 2 The comparison of frequency between original and simulated ship radiated noise

In order to better see the difference between the original ship radiated noise and simulation ship radiated noise, this article will focus on observation 100Hz-5000Hz frequency band, mainly because the line spectrum almost full located in this band. It is easy to found from Figure 3

that the line spectrum in the band mainly between 100Hz-1000Hz. There Almost no high-energy line spectrum exists above 1000H. It can be seen in the continuous spectrum and line spectra superimposed effect from the original Record Ship radiated noise spectrum. Although there are some towering line spectrum exist in low frequency but due to different sea conditions, measuring line device receives at different times have a greater spectrum access, and energy were quite different. Further more, because the line spectrum often appear random drift phase and therefore requires a more scientific judgment mechanism to evaluate the simulation ship radiated noise and the original ship radiated noise similar or not(or prove whether they are the same boat).

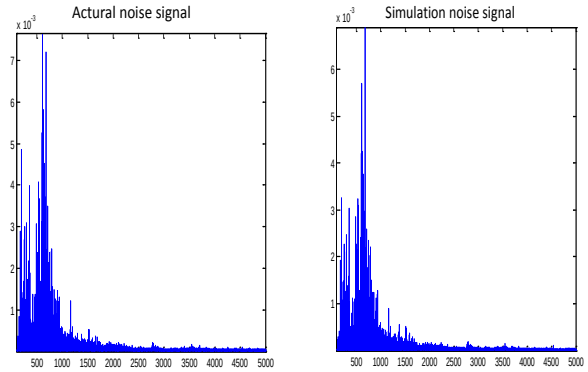

Fig. 3 The frequency domain of original and simulated ship radiated noise

4. Ship simulation results analysis

In order to judge FIR and double spectroscopy noise simulation are similarities with the original ship radiated noise. In this paper, we are taking the above mentioned methods in the frequency range 100Hz-5000Hz as the main section of the comparison, while the two methods are the same frequency range measured noise autocorrelation coefficients. According fidelity above evaluation criteria. The simulation results of the two methods were compared with the original radiation noise, which is a method to generate FIR ship radiated noise signal, and the other is a two-spectroscopy radiation generated noise signal. In this paper, the correlation coefficient were calculated results in the table below:

Method	Actual Ship Radiated Noise
FIR simulation method	0.9428
Bispectrum simulation method	0.9534

Table 1:The comparison of signal between simulated noise with other noise

It can be found the correlation coefficient in the table that the ship radiated noise generated signal simulated from FIR method and the original ship's ship radiated noise signal is 0.9428. The correlation coefficient indicating that the noise signal simulation with the original noise signal is high correlation. Furthermore, the ship sailing in the complex surroundings, so this distance is considered to be a high degree of simulation performance. To further examine the degree of simulation bispectrum method is reliable, In this paper, we calculated the correlation coefficient between original ship radiated noise and the ship radiated noise simulated by double spectroscopy .

It was found that the correlation coefficient difference between FIR and Bispectrum simulated ship noise signal is 0.0106. The results shown that both the ship radiated noise simulated by FIR method and ship radiated noise simulated by Bispectrum method distance difference is very small. The results show that the method generates FIR ship radiated noise and Bispectrum ship radiated noise signals generated both have a high degree of similarity.

This paper compares the FIR method and the Double spectroscopy method[6] and calculate them which is faster. Experiments in this paper using the same computer and the same matlab version. After 20 experiments were averaged to one decimal place, in order to facilitate see the difference between two methods. The FIR method average time processed a standard time, double time spectrum method time is 2.5 where shown in Figure 4. This can be found in many ways faster than previous methods, the proposed method is verified more rapid.

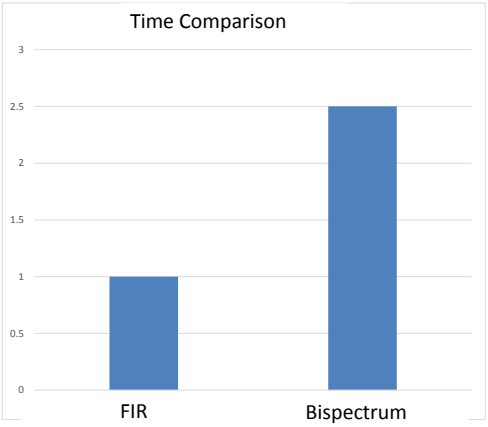

Fig. 4 : The comparison of two experimental methods

5. Conclusion

Based on the mechanism of the ship radiated noise analysis, combined with statistical ROSS empirical model

designed ship radiated noise generation and adaptive modeling method based on FIR filters, and more with the current application of double spectra were compared. Experimental results show that the FIR and Double spectroscopy similarity reduced compared to little but greatly increases efficiency. Thus demonstrating the effectiveness of the method.

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Tian Wen was born in 1992, currently studying at the Jiangsu University of Science and Technology. He majored in control engineering and his research direction is Acoustic Warfare.