# The application of the Morlet wavelet on response filtering of the helicopter cannon' s recoil

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## Abstract

The Morlet wavelet is a complex-exponential function with gauss function wave . Making use of the frequency character of "bell shape", the paper presented the response filtering method of the helicopter cannon's recoil and ensured that the phase did not distort after filtering. The paper studied the validity of the way through the numerical simulation. The project application indicated that the method could get rid of the noise of the recoil response effectively and had great application potential on the dynamic loading identification of the helicopter cannons.

## Introduction

The measurement of the helicopter cannon's recoil is one of the most important contents for dynamic load identifying of the helicopter cannons launch. It will provide the test data for the consistency design of the cannon and the helicopter's configuration, in addition, It can provide the data for shock absorption of the cannons.

The cannons launch is the wide frequency-band impulse exciter. The signal-noise ratio of the test data in the flight flutter test is poor because of test condition、test environment、engines and atmosphere turbulence. In order to improve the accuracy of the test result, when identifying the helicopter cannon's recoil, it is necessary to process the test signal. Because of the uncertainty of the cannon launch, the test signal can not be measured repetitively. The ecumenic reprocessing method can not be suitable for the method of the cannon launch.

The Morlet wavelet is a complex-exponential function[1] with gauss function wave, whose mathematic form is the gauss function in both frequency and time domain. Making use of the frequency character of "bell shape", the paper constructed the appropriate filter and completed the filtering of the impulse response. The numerical simulation indicated that the method could ensure that the phase did not distort after filtering.

The Morlet wavelet is a complex-exponential function with gauss function wave[1] ,when $\omega_0 \geq 5$,the approximate mathematic expression is:

$$h(t) = \frac{\beta}{\sqrt{2\pi}} e^{-\frac{\beta^2 t^2}{2}} e^{-ift} \qquad (1)$$

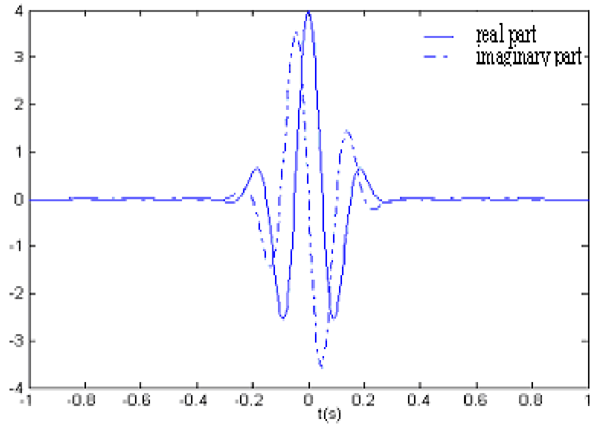
The Fourier transform is

$$h_f(\omega) = e^{-\frac{(\omega - f)^2}{2\beta^2}} \qquad (2)$$

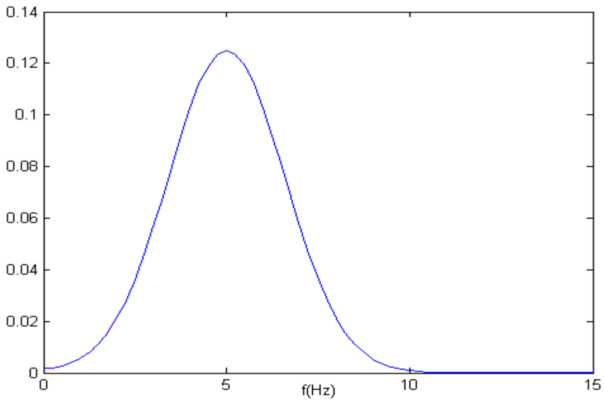
The above expression shows that the single Morlet wavelet consists of real part and imaginary part in the time domain, and it is a gauss function with "bell shape" with the center frequency being $f$ in the frequency domain. If $\beta$=20, $f$=5Hz, then the Morlet wave expression is:

$$h(t) = \frac{20}{\sqrt{2\pi}} e^{-\frac{20^2 t^2}{2}} e^{-i5t} \qquad (3)$$

Figure 1 shows the curve of the above Morlet wavelet expression.




a) real part and imaginary part of the Morlet wavelet




b) the Fourier transform of the Morlet wavelet real part

Fig.1 the Morlet wavelet

The express (1) is the plural mother wavelet and the filtering can induce phase distorting in time domain. In order to avoid the problem, only the morlet wavelet real part was used to construct filter, which made the reconstructing signal and original signal having the same phase. The Fourier transform of the morlet wavelet real part is :

$$H_f(\omega) = e^{-\frac{(\omega - f)^2}{2\beta^2}} + e^{-\frac{(\omega + f)^2}{2\beta^2}} \quad (4)$$

$$H_f(\omega) \equiv H(\omega, f) \quad (5)$$

Through the an inverse Fourier transform, the coefficient of the wavelet transform in the time domain is obtained:

$$\mathrm{CWT}(t, f) = \mathrm{IFFT}(X(\omega) \bullet H_f(\omega)) \quad (6)$$

Where, $X(\omega)$ and $H_f(\omega)$ were Fourier transforms of the response and the morlet wavelet real part respectively. The real part provide a FIR linear phase filter for every center frequency, which makes the reconstructing signal and original signal having the same phase.

If there are n mother wavelets for reconstructing signal, FIR wavelet filter groups can come into being by making use of the expression(4) [2].

For the given frequency $\omega_0$, the relation of the wavelet coefficient an the original signal is:

$$\begin{bmatrix} W(\omega_0, f_1) \\ \vdots \\ \vdots \\ W(\omega_0, f_n) \end{bmatrix} = \mathrm{X}(\omega_0) \begin{bmatrix} H_{f_1}(\omega_0) \\ \vdots \\ \vdots \\ H_{f_n}(\omega_0) \end{bmatrix} \quad (7)$$

$X(\omega_0)$ can be obtained through the generalized inverse transform from the above expression,

$$\hat{X}(\omega_0) = \begin{bmatrix} H_{f_1}(\omega_0) \\ \vdots \\ \vdots \\ H_{f_n}(\omega_0) \end{bmatrix}^{\mathrm{T}} \begin{bmatrix} W(\omega_0, f_1) \\ \vdots \\ \vdots \\ W(\omega_0, f_n) \end{bmatrix} \quad (8)$$

$\hat{X}(\omega_0)$ can be obtained according to every frequency $\omega_0$ ,then the reconstruction signal also can be obtained through the inverse transform. The method can be used to get rid of the response distorting and noise, further, the more important signal character can be obtained.

## 2 The numerical simulation

In order to validate the validity of the method, the paper studied the morlet wavelet filtering methodg application on signal de-noising through the numerical simulation.

For a multiple dimension of freedom system, the impulse response was simulated by designing the mathematic model, namely,

$$x(t)=\sum_{j=1}^{M} e^{-\zeta_j \omega_j t}\sin(\omega_j t+\phi_j)+BN(t) \qquad (9)$$

Where, $\omega_j = 2\pi f_j$, $f_j$ and $\zeta_j$ are thecorresponding mode frequency and damping respectively, and $\phi_j$ is the initial phase, B is the noise coefficient, $N(t)$ is additional gauss white noise, $x(t)$ is the response signal, M is the mode ranks of the signal. Selecting the mode parameter $f_1$=8Hz、$\zeta_1$=0.03, $f_2$=15Hz、$\zeta_2$=0.06.The sampling rate is 256Hz,and the signal length is 4s.Figure2 shows the response time history, Figure 2 shows the response time history with 20% white noise. The response was processed using the above method. The bottom of the figure2 shows the time history of the filtered simulation signal, We can see that the filtering effect of the Morlet wavelet is very obvious. The signal-noise ratio was improved effectively through the Morlet wavelet filtering.

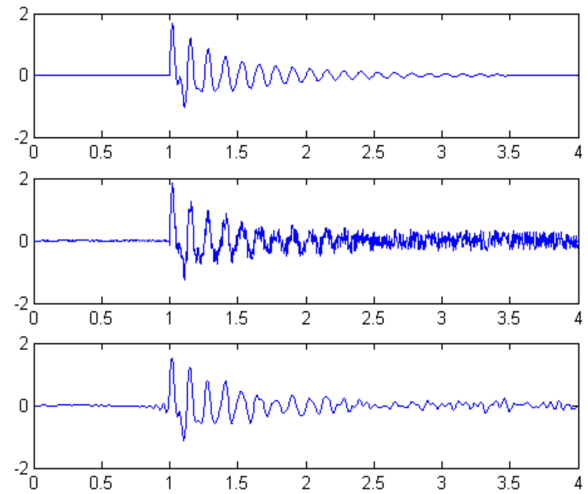


Fig.2 the time history of the simulation signal with noise before and after filtering

## 3 The project application

The dynamic load identifying of the helicopter cannon's recoil is very important. There are single launch and continuous launch when launching the helicopter cannons. Because there is aerodynamic noise when the helicopter is flying, so the measurement signal is polluted by the noise all the time. For the purpose we studied the filtering method for improving the signal-noise ratio. In order to validate the application effect of the method, the real test response data of the helicopter cannon launch were analyzed as followed.

The above curve of the figure 3 shows the response history of the single cannon launch when the helicopter is hovering in the sky. The measured signal is polluted by the noise. The response was processed using the above method. The bottom of the figure 3 shows the time history of the filtered signal, We can see that that the filtering effect of the Morlet wavelet is very obvious for the single cannon launch. The Morlet wavelet filtering is a very effect method for reprocessing the signal of the single cannon launch and the needed data in the post-processing can be obtained.

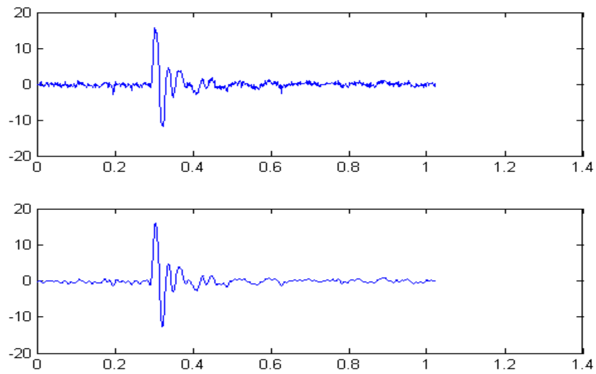


Fig.3 the time history of response for single cannon launch before and after filtering

The above curve of the figure 4 shows the response history of ten cannons continuous launch when the helicopter is hovering in the sky. The measured signal is polluted by the noise. he response was processed using the above method. The bottom of the figure4 shows the time history of the filtered signal, We can see that that the filtering effect of the Morlet wavelet is very obvious for ten cannons continuous launch. The Morlet wavelet filtering is a very good reprocessing method for getting rid of noise for ten cannons continuous launch .

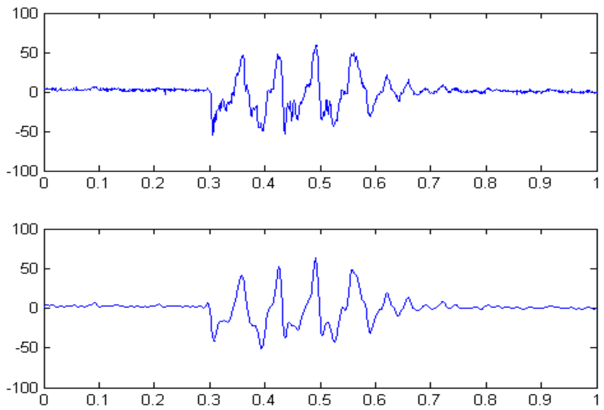



Fig.4 the time history of response for continuous cannon launch before and after filtering

## 4 Conclusions

The Morlet wavelet is the complex-exponential function with gauss function wave, whose imaginary part is the Hilbert transform of the real part. Making use of the frequency character of “bell shape”, the paper designed a filtering method based on the Morlet wavelet and the satisfied filtering effect was obtained. The numerical simulation and the project application indicates that the method can get rid of noise effectively and improve the signal-noise ratio. so the method has better application potential.

## References

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