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Research on the identification of structural adhesive damage of hidden frame glass curtain wall based on EMD

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Abstract
With the increase of the service life of the hidden frame glass curtain wall and the continuous aging of the structural adhesive, the glass panel detachment caused by structural adhesive damage occurs frequently, this paper focuses on the damage identification of the structural adhesive of the hidden frame glass curtain wall, adopts the damage identification method based on the EMD to obtain the instantaneous frequency of the model, and then performs the straight-line fitting of the instantaneous frequency, and realizes the damage identification of the structural adhesive of the curtain wall by utilizing the magnitude of the instantaneous frequency straight-line fitting value, and verifies it on a hidden frame glass curtain wall model. Damage identification is realized by using the magnitude of the linearly fitted value of the instantaneous frequency to realize the damage identification of the structural adhesive of the curtain wall, and the results are verified on a hidden frame glass curtain wall model, which shows that the method can effectively identify the damage of the hidden frame glass curtain wall, so as to ensure the healthy operation of the hidden frame glass curtain wall.
Keywords: *Damage identification, Hidden frame glass curtain wall, EMD.*

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I. INTRODUCTION

In recent years, with the continuous development of China's economy and the rapid development of construction technology, large-scale buildings and ultra-high-rise buildings continue to emerge. Hidden frame glass curtain wall has the advantages of light weight, beautiful appearance, etc., which is widely used in large-scale buildings, CBD and office buildings, and has become a beautiful landscape of the city. China's architectural glass curtain wall started late but developed rapidly, is now the world's first glass curtain wall production and use of the country, but with the large number of applications of glass curtain wall, some safety hazards are slowly emerging. Hidden frame glass curtain wall for a long time to withstand crosswinds, rain, dust and other external factors, ultra-high-rise building curtain wall structure is always subjected to the role of strong winds, these external factors will lead to micro-vibration of the curtain wall and corrosion, which in the long run will lead to the failure of the bonding of the glass curtain wall and connectors loosening, and more serious will lead to the curtain wall falling off, seriously jeopardizing the safety of people's lives.

EMD method is a time-frequency signal processing method, which has significant advantages for the processing of nonlinear and nonsmooth signals. EMD method is able to decompose the complex nonlinear signals into a number of intrinsic modal functions (IMFs) according to the time scale parameters of the structural response signals. These intrinsic modal functions can well reflect some characteristics of the original signals, which helps to analyze the health of the structure. Therefore, in this chapter, the EMD method is used to investigate the damage identification of the structural adhesive of the hidden frame glass curtain wall.

II. EMD THEORY

1.1.1 Instantaneous Frequency

Instantaneous frequency is an important concept in signal processing, which is used to describe the variation of the frequency of a signal in time. For smooth and linear structural response signals, their instantaneous frequencies are considered to be stable, and thus can be obtained by Fourier transform [57]. However, for non-smooth and nonlinear structural response signals, their instantaneous frequencies vary with time,,for non-smooth and nonlinear structural response signals, some advanced time-frequency analysis methods, such as the short-time Fourier transform, wavelet transform, etc., can be used to obtain the signal's localized characteristics in time and frequency, so as to obtain the changing instantaneous frequencies. One of the most representative is the definition of instantaneous frequency in the proposed EMD method by Huang.

1.1.2 Instantaneous Frequency

The emergence of instantaneous frequency facilitates the study of single-component functions, but it is difficult to utilize instantaneous frequency to study complex structural response signals due to the complexity of structural response signals, which do not meet the definition of single-component functions. The emergence of the intrinsic modal function solves this problem. The intrinsic modal function (IMF) decomposes the complex structural response signal into a number of single-component signals, which can better understand and analyze the time-frequency characteristics of the signals and better reflect the existence of a variety of vibration modes in the signals, which solves the problem of analyzing complex structural response signals using the instantaneous frequency, and makes the time-frequency analysis of the signals more accurate and feasible. The intrinsic modal function must satisfy the following two conditions:

(i) In the entire signal length range, the number of extreme value points (including the great value, the small value) and the number of zeros must be the same or differ by 1.

(ii) In the entire signal length range, for any point of the local extreme value of the envelope and the envelope of the local extreme value, the mean value is required to be zero.

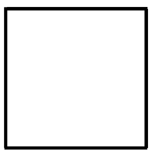
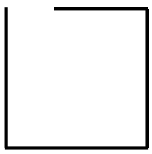
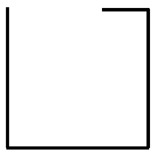
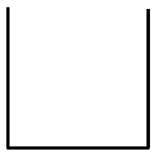
For condition **(i)**, it is more common in traditional signal analysis methods, while condition **(ii)** is to make the decomposed signal waveform more stable and prevent large fluctuations in instantaneous frequency.

III. STRUCTURAL ADHESIVE DAMAGE RECOGNITION

3.1.1 Introduction To The Experiment

This test investigates the health state of the model by obtaining the modal parameters of the glass panels under different structural adhesive damage states. The test simulates the damage of structural adhesive at different locations by manually cutting different lengths of structural adhesive at different locations on each side of the hidden frame glass curtain wall model. The working condition is set to be continuous damage on one side, and the four sides are divided into A, B, C and D in a clockwise manner, and the glass panel is divided into 49 measurement points. The specific working conditions are shown in Table 1.

Table 4: Unilateral Sustained Damage Working Condition Setting Table

Experimental Group	Working Condition 1	Working Condition 2	Working Condition 3	Working Condition 4
	No Injury	Damage 200mm	Damage 400mm	Damage 600mm
Unilateral Sustained Injury				

3.1.2 Analysis Of Results

The EMD decomposition of the structural response signals under the four working conditions of structural health, damage 200 mm, 400 mm, and 600 mm can obtain a number of order intrinsic modal function (IMF) components of the hidden frame glass curtain wall model, and the first-order IMF components can be obtained by performing the Hilbert transform of the first-order IMF components to obtain the first-order instantaneous frequency under each working condition, and the results are shown in Fig. 1.

From Figure 1, it can be seen that the first-order instantaneous frequency of the hidden frame curtain wall model fluctuates overall on a horizontal straight line. Linear fitting of the instantaneous frequency can obtain the center instantaneous frequency. The straight line fitting value under structural health condition is 374.085 Hz, while the straight line fitting value for A edge damage of 200 mm is 360.077 Hz. By comparing the straight line fitting values, it can be found that when the structure is damaged, its instantaneous frequency will decrease accordingly. Therefore, damage identification of structures can be carried out through instantaneous frequency.

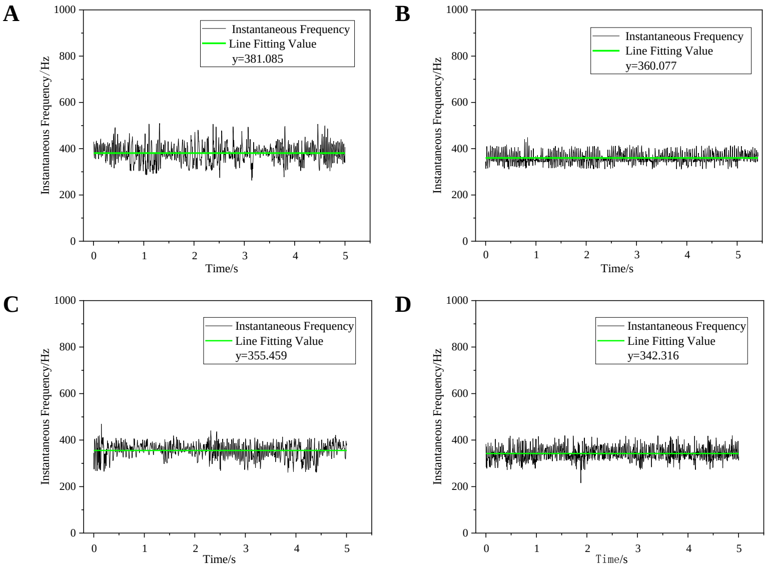


Figure 1:Instantaneous Frequency Map of Unilateral Sustained Damage Health Status. (A) Health Status, (B) Damage 200mm, (C) Damage 400mm and (D) Damage 600mm

IV. CONCLUSION

Empirical Mode Decomposition (EMD) method can effectively decompose non-stationary and nonlinear signals, without the need to define a basis function in advance for the signal to be processed. It has good adaptability, orthogonality, and completeness. The first-order instantaneous frequency can identify the degree of damage to the structural adhesive of the hidden frame curtain wall. When the structural adhesive is damaged, the instantaneous frequency will decrease accordingly. For unilateral continuous damage, the instantaneous frequency shows a linear decreasing trend, while for multilateral damage, the instantaneous frequency will decrease with the deepening of the damage degree, but will not maintain a linear decreasing trend. Once the structure is damaged, the instantaneous frequency will decrease to a certain extent, and when the degree of damage worsens, the decrease in instantaneous frequency will decrease. This is suitable for health monitoring research on hidden frame curtain walls.

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