Research Progress of Structural Damage Identification Based on Wavelet

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ABSTRACT

In recent years, many scholars begin to study the identification of structural damage based on wavelet analysis technology. The experimental research and application are introduced from different structure types, function types and the combination of wavelet analysis technology and other disciplines, most of these theory and methods have been verified through laboratory model and engineering practice. Finally through the research and analysis of the present situation, the development direction of the application of wavelet technology in structural damage identification is put forward.1

INTRODUCTION

Due to various reasons, the structure may happen varying degrees of damage, such as substandard construction quality, material failure or aging, steel corrosion, overload and so on. In recent years, accidents caused by structural damage occur frequently, which have caused great economic losses to the country. Therefore, it is a pressing task to identify structural damage as soon as possible. In recent years, scholars have applied various disciplines to structural damage identification, for that the dynamic response index of the structure can conveniently and quickly reflect the overall health state of the large-scale structure, around the various dynamic response parameters, scholars introduced modal parameters, neural networks, vector machines and other methods to identify structural damage. Wavelet analysis, as a very good signal conversion and processing method, has attracted extensive attention.

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**PRINCIPLE**

The basic principle of structural damage identification method based on wavelet transform is as follow. Firstly, wavelet transform is used to extract modal parameters which are sensitive to structural damage, then the change of the modal parameters is compared with the index in the damage sample library, and the closest damage condition is chosen as the actual damage state of the structure. Therefore, the core role of wavelet transform in this method is to extract the modal parameters of the structure.

The formula of continuous wavelet transform is as follow[1].

\[ W_x(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t) \phi^*(\frac{t-b}{a}) dt \]  

(1)

Where, \( a \) is the scaling parameter associated with frequency scaling, \( a \) and \( b \) are real number, \( b \) is the time translation parameter. \( \phi \) (t) is basic wavelet function, \( \phi^* \) (t) is its conjugate function.

**DIFFERENT STRUCTURAL FORMS**

Different structural forms are different in material selection, work load and working environment, scholars have studied the damage identification of frame structures and beam structures etc., by wavelet analysis. Cao Yilong uses wavelet packet analysis to deal with the seismic shaking table test data of an eight-story frame model[2], then the acceleration response of structures is obtained in different frequency bands. The wavelet packet energy variance maximum index of each sensor under different working conditions is calculated respectively by the data. Then the damage location and damage degree of the structure are identified.

Liu Chuncheng selected the 500kV ZB21 transmission tower as an analytical model[3]. The multi - scale modeling of the upper and lower curved arm joints of the straight tower is carried out to identify the cracks in the tower. Then the wavelet packet energy curvature difference is taken as the damage degree index parameter. According to the known working conditions and index trained, the prediction model is obtained, and the predicted damage degree is close to the target value.

Liu Xi-jun improved the wavelet packet energy and used wavelet packet transform technique to extract the response of the structure to the particular frequency band[4], and obtained the single order modal response of the structure. Then, he uses the model (shown in Figure 1) to validate the method. By contrast, the damage sensitivity of wavelet packet energy of node curvature response is stronger, so the index used for structural damage identification is reasonable.
DIFFERENT FUNCTIONS

Different types of wavelet functions have great influence on the accuracy of damage identification, scholars have selected a variety of wavelet functions to test their effects. Zhan Huajun chooses mexh wavelet to analyze the modal parameters of the portal frame[5]. The wavelet coefficients are obtained by wavelet transform of the corner signal, and the maximum value is found at the crack.

Wang Xin uses Daubechies as wavelet function. Then, taking the Xi’an bell tower as the engineering support[6], the damage simulation analysis of ancient wood structure under environment excitation is carried out by Ansys software, it is found that the first 8 components of the wavelet packet energy curvature difference can identify the damage location of the ancient wood structure.

Fan Zhe proposed a transitivity function in wavelet domain[7], namely a function describing the relationship between degrees of freedom in the frequency domain. Damage sensitive index was constructed, combined with outlier analysis, the health status of the structure is identified.

COMBINED WITH OTHER METHODS

For large structures, they have many components, the establishment of sample library is very complicated and the efficiency of the test result’s comparison is very important. Many scholars use wavelet analysis technology and other methods to combine together, it bringing better practice. Liu Wenbo proposed an unsupervised damage identification method based on discrete wavelet transform (DWT) and fast independent component analysis (FastICA) [8]. The structural response is pretreated by discrete wavelet transform, and the processed mixed signal is used as the input signal of FastICA to extract independent damage feature signals. Then, the structural damage time and location are identified according to the isolated characteristic component signals.

Using wavelet analysis and neural networks, GUAN De-qing uses the rotation mode and the natural frequency to carry out the continuous wavelet transform and construct the neural network for the damage structure[9]. Wavelet analysis is used to locate the structure damage, and the wavelet transform of the corner mode of the damaged frame structure is carried out to obtain the wavelet coefficients. It is found that singular points exactly correspond to damage positions. Then, the natural frequency is used as the input parameter of the neural network, and the neural network is used to identify the damage degree of the structure.
CONCLUSIONS

(1) Modal parameters of structural response signal can be extracted through the method of wavelet transform, and it can also transform the signal into the time-frequency domain space, compare with only in time or frequency domain, this identification method can more accurately identify structural modal parameters.

(2) Wave analysis technology has a wide application, suitable for structural damage identification of various materials and different structure forms, and it is expected to carry out the research in more extensive field, and it can also make scholars from different industries work together closely.

(3) Some research models are simple, and there are many differences between them and the actual structure boundary conditions. How to build a model closer to the actual situation and to do more actual testing is a future research direction.

ACKNOWLEDGMENTS

Projects: China and Australia cooperation research projects (16394507D Hebei Funded Projects of Introducing Overseas Scholars(CL2017073)

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