



Crack identification of the sprocket wheel in sintering machine based on WFEM

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ABSTRACT

In order to identify the crack of the sprocket wheel correctly, the wavelet finite element method is studied in depth. Firstly, the progress of study on the wavelet finite element method is summarized, and then the basic property of wavelet analysis is analyzed, and then the wavelet finite element theory model of sprocket wheel in sintering machine is studied, and the Daubechies wavelet plate element and isoparametric plate element of crack tip are established, and then the theory of constructing crack identification database of the crack for sprocket wheel is studied, and finally the effective of this method is verified by identify the sprocket wheels with five kinds of cracks based on the vibration test, and results showed that this method can identify the crack of the sprocket wheel correctly.

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1. Introduction

Sintering machine is a main device of sintering plant, the movement of the loop wheel machine mainly depends on the rotation of head and end sprocket wheels. The physical model of the sprocket wheel is shown in Fig. 1.

Although the rotate velocity of the sprocket wheel is low, but the loop wheel machine describes the accelerated motion, and the forces between the loop wheel machine and sprocket wheels are very large, therefore the original crack is created in the sprocket wheel, and will be extended with the elapse of time, and finally the sprocket wheel will break down. The cracks of the sprocket wheel will affect the reliability of the loop wheel machine, in extreme cases risk cracks of the sprocket wheel will affect of safety of the loop wheel machine directly, and the catastrophic accidents will happen. Therefore it is important to identify the cracks of the sprocket wheel.

Identification of crack in the structure has drawn many attentions from scientists. Faverjon and Sinou [1] presented a robust damage assessment method for nondestructive and size estimation of open cracks in beams; the identification algorithm could be used for identifying the crack's location and size in a simply-supported beam. Moore et al. [2] proposed a new method to identify the location and presence of a crack in a simple plate undergoing free vibration, which could identify the cracks of various orientations, sizes and locations. A Bayesian system identification methodology was proposed for identifying the crack location, size and orientation in a structure using strain measurements [3]. The Bayesian statistical approach combined information from measured data and analytical or computational models of structural behavior to predict estimates of the crack characteristics along with the associated uncertainties, considering modeling and measurement errors. The effectiveness of the proposed methodologies was illustrated using simulated data from a single crack in a thin plate subjected to static loading. A computational framework was improved to identify the two-dimensional crack in structures [4]. The inverse problem of identification was solved using a genetic algorithm, while each forward problem was solved by the time-dependent extended finite element method, and the effective of this method was verified by experiment. A simple

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Fig. 1. The physical model of the sprocket wheel.

method was proposed to identify the multiple cracks in a beam, and the crack was modeled as rotational springs and the forward problem was solved by FEM [5]. And the locations and sizes of the cracks were solved by Newton–Raphson method. A multi fractal analysis was used to identify the cracks in the rotor [6], and the criteria of the dynamical system were defined by the multiple scaling of the time series to show the damages of rotating shaft. Dahmani et al. [7] proposed a three-dimensional nonlinear finite element model of reinforced concrete beam, and the numerical analyses were carried out by ANSYS 8.0, simulation results showed that this model could identify the regions, loads and deflections in a concrete beam.

The wavelet finite element is a technology which combines the multi-resolution property of wavelet with the traditional finite element method, and the main idea of it uses the wavelet function or scale function as interpolating function, and would overcome the disadvantages of the traditional finite element method in matter of solving the big gradient and strange problems. Wavelet finite element application has attracted many researchers in a wide variety of practical problems. Identification of the crack in the structure was a main research field. Many scientists had done a lot of research works. Dong et al. [8] presented a new method based on high-precision modal parameter identification method and wavelet finite element model to identify the location and depth of a crack in a rotor system. And the correctness and reliability of this method was verified by experiment results. A model was proposed to identification of the crack in the rotor system based on finite element method and *B*-spline wavelet [9]. And the validity of *B*-spline wavelet finite element method for identifying the crack in the rotor system was verified by experimental examples. A methodology was presented to identify the location and size of the crack in structure based on wavelet finite element method, and the experimental results verified the accuracy of this method [10]. A new method was presented to identify the location and size of the crack in the pipe structure based on stress intensity factor and second generation finite element method [11], and the accuracy of this method was verified by experiments.

The wavelet finite element method had a faster convergence speed than the traditional finite element method, and could get the higher numerically computational precision than traditional finite element. The wavelet finite element method was applied to the one-dimension cracked shaft and beam, the crack was simulated by a spring during constructing the model of wavelet finite element method. And identification of the sprocket wheel has almost nobody to study. And the crack of the sprocket wheel is complex, and the spring cannot reflect the singularity of the stress distribution in the tip of the crack effectively, and the natural frequencies and modal shapes of the structure with crack cannot be computed correctly. And the identification precision of the crack in the sprocket wheel was poor. Therefore the triangular singular isoparametric element is established to simulate the crack of the sprocket wheel for avoid the shortage of conventional method.

2. Basic property of wavelet analysis

Wavelet can provide orthogonal basis in $L^2(R)$ that has nice time–frequency local characteristic, multi-resolution analysis, the orthogonal basis can make function in $L^2(R)$ associate with set in $l^2(Z)$, therefore the problems analyzed can be transformed to algebra problems. The main idea of multi-resolution is to establish bases in some subspaces of the finite-mass function space $L^2(R)$ firstly, and then extend the bases in subspaces to $L^2(R)$ through simple operations of dilation and translation [8].

Define 1 $\{V_j\}_{j \in \mathbb{Z}}$ is set as a closed subspace set of space $L^2(R)$, $\{V_j\}_{j \in \mathbb{Z}}$ is called as multi-resolution, if $\{V_j\}_{j \in \mathbb{Z}}$ satisfy the following conditions [9]:

- (1) $\cdots \subset V_{-1} \subset V_0 \subset V_1 \subset \cdots$
- (2) $\bigcap_{j \in \mathbb{Z}} V_j = \{0\}$, $\overline{\bigcup_{j \in \mathbb{Z}} V_j} = L^2(R)$
- (3) $f(x) \in V_j \Leftrightarrow f(2x) \in V_{j+1}$ ($\forall j \in \mathbb{Z}$)
- (4) $\varphi \in V_0$ is presented, which makes $\{\varphi(x-n)\}_{n \in \mathbb{Z}}$ be Riesz base of V_0 , that is to say
 - ① $V_0 = \overline{\text{span}\{\varphi(x-n)\}_{n \in \mathbb{Z}}}$
 - ② $0 < A \leq B < \infty$ is presented, which makes random $\{c_n\}_{n \in \mathbb{Z}} \in l^2(\mathbb{Z})$ satisfy the following condition:

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