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Perceptible Grouping of Cracks in nuclear piping using wavelet transformation

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***Abstract*—This paper presents an application of the wavelet transform for damage detection or crack detection based on digital image processing measurements. A number of important issues that need to be considered when image sequences are used for vibration analysis are discussed. These include: correspondence of image features from image to image, image calibration and spatial resolution. The principles of image edge detection are discussed and a comparison between the wavelet approach and the classical method is presented. A digital image damage detection method based on converting image to data, then filtering and converting from 2D to 3D data measured. The method is illustrated using a simple programming for matlab and Fortran for image to data and wavelet transformation model. The major advantage of the method is the significantly increased number of discrete points used to describe mode shapes. This is in contrast to classical techniques where in practice a small number of measurement points are obtained from a limited number of sensors.**

***Keywords*—Crack detection, Wavelet transformation**

I. INTRODUCTION

This paper brings together recent developments in image edge detection and proposes a novel approach by which wavelet coefficients are used to locate or detect damage in a structure. The main objective of the paper is to present a damage detection procedure using image sequences. Edge contours are obtained from image sequences using the classical wavelet-based approach [2]. This provides a number of measurement points that are significantly larger than in the case of classical accelerometer-based measurements. The novelty of the proposed method is that edge contours, which describe the structure's movement, are utilized for further damage detection analysis. The orthogonal wavelet transform is also applied to damage identification. Preliminary results from this work were initially reported in [10] where the presence of seeded damage in a beam was detected. The work presented in this paper extends the previous results in that more sophisticated equipment has been used for optical measurements and hence higher quality mode shape data were obtained. Additionally, the orthogonal wavelet transform is applied to mode-shapes for damage identification.

Section 2, briefly describes image-processing principles and introduces the wavelet approach used for image edge detection, and terminology and definitions are provided.

Section 3, introduces the proposed damage detection, method based on the Orthogonal Wavelet Transform of mode-shapes. The method is illustrated using a digital image processing.

Section 4, the two-dimensional wavelet transform, Determination of crack location and length, Estimation of crack depth, 3D Image Processing, and Internal Crack Measurements are represented.

Section 5, includes the final conclusion of the paper

II. IMAGE EDGE DETECTION: CLASSICAL METHODS AND THE WAVELET APPROACH

Image edge detection is well known in the image processing community, although the analysis is still a marginal subject of research in engineering applications. Therefore, for the sake of completeness, this section briefly introduces the general concept and the wavelet-based approach to edge detection. The reader is referred to [1] for more detailed analysis.

III. IMAGE EDGE DETECTION

Research in image edge detection shows a wide diversity of proposed techniques. The theory of image detection can be traced back to Marr and Hildreth in 1980. In 1986 Canny proposed he method that today is the de-facto technique used in image analysis [3,5], the use of the wavelet transform expanded to a wide range of areas and Mallat suggested a wavelet transformation that can be implemented in detecting edges both in one dimensional signals and images [5]. Edges in images often appear where large variations in the intensity exist. An edge can be defined as a step discontinuity in a 2D signal (e.g., an image) [9]. The edges can be located by searching for these discontinuities: either as local maximum of the first derivative or as the zero-crossings of the second derivative of the image. Therefore, for a continuous image f(x, y), its derivative assumes a maximum in the direction of the edge.

IV. THE TWO-DIMENSIONAL WAVELET TRANSFORM

In the case of a 1D space, the continuous wavelet transform of a function $f(x)$ is defined as a convolution of the function with a function $\Psi(x)$ called the wavelet function (mother wavelet) in the form

$$W f(u,s) = \frac{1}{\sqrt{s}} \int_{-\infty}^{+\infty} f(x)\Psi^*\left(\frac{x-u}{s}\right)dx, \quad 1$$

Where s and u are the scale and translation variables, respectively, and * denotes the conjugate part.

For constructing a proper wavelet, which reflects the properties on real applications, Mallat [1,7,8] developed the multi-resolution analysis. A scaling function $j(x,y)$ is defined and the wavelet function $\Psi(x)$ is constructed using the scaling function.

The scaling j is associated with a one-dimensional multi-resolution approximation $\{V_i\}_{j\in Z}$ where j correspond to the scale level. Let $\{V^2{}_i\}_{j\in Z}$ be the separable two-dimensional multi-resolution defined by $V_j^2 = V_j \otimes V_j$ where $\otimes$ denotes the tensor product. Considering W_j^2 as the lower resolution approximation space V_j^2 in V_{j-1}^2, we can write

$$V_{j-1}^2 = V_j^2 \oplus W_J^2 \quad , \ldots\ldots\ldots\ldots\ldots 2$$

where $\oplus$ denotes the direct sum of two vector spaces. On the basis of (2), a wavelet orthogonal basis of $L^2(R^2)$ can be constructed by using the scaling function j and the corresponding wavelet Ψ. In particular, three wavelet are defined, as

$$\Psi^1(x,y) = j(x)\Psi(y),$$
$$\Psi^2(x,y) = \Psi(x)j(y),$$
$$\Psi^3(x,y) = \Psi(x)\Psi(y),$$
$$with \quad j(x,y) = j(x)j(y), \quad \ldots\ldots 3$$

For computational purposes, the scale and translation variables are discredited; hence, the three wavelet can be written as

$$\Psi_{j,n,m}^k(x,y) = \frac{1}{2^j}\Psi^k\left(\frac{x-2^j n}{2^j} - \frac{y-2^j m}{2^j}\right), \quad 1 \le k \le 2, \quad 4$$

Consequently, $\left|\Psi^1(w_x, w_y)\right|$ is large at low horizontal frequencies w_x and high at vertical frequencies w_y, where $\left|\Psi^2(w_x, w_y)\right|$ is large at high horizontal frequencies and low at vertical frequencies, and $\left|\Psi^3(w_x, w_y)\right|$ is large at high horizontal and vertical frequencies [7]. Wavelet edges, which are respectively horizontal and vertical. The wavelet Ψ^3 produces large coefficients at the corners (diagonal direction). The wavelet family $\left\{\Psi_{j,n,m}^1(x,y), \Psi_{j,n,m}^2(x,y), \Psi_{j,n,m}^3(x,y)\right\}_{(j,n,m)\in Z^3}$ is an orthogonal basis of $L^2(R^2)$.

The three wavelets extract signal details at different scales and orientations. The separable wavelet expressions of Eq. (3) imply that

$$\Psi^1(w_x, w_y) = f(w_x, w_y)\Psi(w_x, w_y),$$
$$\Psi^2(w_x, w_y) = \Psi(w_x, w_x)f(w_x, w_y), \quad \ldots\ldots 5$$
$$\Psi^3(w_z, w_x) = \Psi(w_x, w_y)\Psi(w_x, w_y),$$

Where f and $\Psi^k \; k=1,2,3,$ denote the Fourier transformations of j and Ψ^k, $k=1,2,3$, respectively.

A. Determination of Crack Location and Length, Estimation of Crack Depth

To determine the location and length of the crack the two-dimensional discrete wavelet transformation is applied to the model of digital image data. The data are available on 147 x 160 sample grid, which is dense enough for detection purpose. For the analysis, level one of decomposition was used, as this provides coefficients of finest detail. The first level approximation is essentially a smoothed version Fig.(a_i) where i = 1,2,..,8 a small change of the (D^i) (where i =2,..,8). In the previous section an effective diagnostic method for finding finite size cracks in piping images has been laid out , Having detected the crack length, the analysis presented in this section aims at finding an estimate of the crack depth. From Fig(b_i) (where i = 1,2,..,8) a small change of the (L^i) (where i =2,..,8) amplitude is noticed due to the change of the contour lines in the graph the data 3D.

B. 3D Image Processing

3D image data is produced from a wide range of sources. Everything from surveying and weather studies down to radiography and nuclear magnetic resonance creates volumetric data, all of which is readily thought of as 3D images. The data that we are examining are 3D images of concrete created with high-resolution tomography (Landis 99). We are using several tools to extract information from 3D images. Some of these tools are traditional image processing techniques, while others have been developed specifically for this project

The areas that we have been investigating include fracture energy, pore structure and permeability of concrete. Fracture energy has been studied extensively using many 2-D and 3D techniques. None of these have been able to produce the level of resolution in three dimensions that x-ray micro tomography is capable of.

They did demonstrate that a two-dimensional model cannot be used effectively to investigate concrete, a highly anisotropic material that exhibits complex 3D fracture surfaces. There have also been many previous studies of permeability using such techniques as mercury intrusion proximity penetration and nitrogen absorption. By using 3D imaging techniques, we hope to relate these older studies to the actual microstructure of concrete.

C. Internal Crack Measurements

In order to accurately measure fracture energy in concrete, it is essential to be able to analyze the fracture surfaces in a true 3D fashion. We have developed two techniques to relate the change.

V. Conclusion

A new method for identification of cracks in piping structure based on the two-dimensional wavelet transform was presented. This work presented provides a foundation for using the two-dimensional wavelet analysis as model for efficient damage detection for two-dimensional structures.

By the language programming in Fortran, C++ and some application programs as Matlab, Surfer. We get the resolution of the method for tracking changes of all crack characteristics (location, length, depth) and its satisfactory lack of susceptibility to noise makes it favorable for use in experimental data analysis. It seems, however, that a key issue for an efficient application of the method is the spatial resolution and the accuracy of the response data.

REFERENCES

[1] S. Loutridis, ' A two-dimensional wavelet transform for detection of cracks in plates ' Engineering Structures, 2005.
[2] I. A. Ismail, El-Sayed M. El-Horbaty, M. A.Ashabrawy,"Autoregressive FilterAlgorithm for Sifting Digital Images" , I. J.Comput. Appl. 9(4): 200-204 (2002).
[3] Lee YY, Liew KM.' Detection of damage locations in beam using wavelet analysis' International Journal of Structural Stability and Dynamics, 2001.
[4] Chen HP, bicanic N. ' Assessment of damage in continuum structures based on incomplete model information ' Computers and Structures, 2000.
[5] Khadem SE, Rezaee M. Introduction of modified comparison functions for vibration, 2000.
[6] Wang Q, Deng X. ' Damage detection with spatial wavelets ' International Journal of Solids and Structures, 1999.
[7] Mallat S. ' A wavelet tour of signal processing ' 2nd ed. Academic Press, 1999.
[8] Deng X, Wang Q. ' Crack detection using spatial measurement and wavelets ' International Journal of Fracture 1998.
[9] Maclntyre, J., Smith, P. ' Neural networks for condition monitoring ', School of computing and Information, University of Sunderland, Profitable Condition Monitoring, 1996.
[10] Cawley P, Adams RD. ' The location of defects in structures from measurements of natural frequencies ' Journal of Strain Analysis ,1979.

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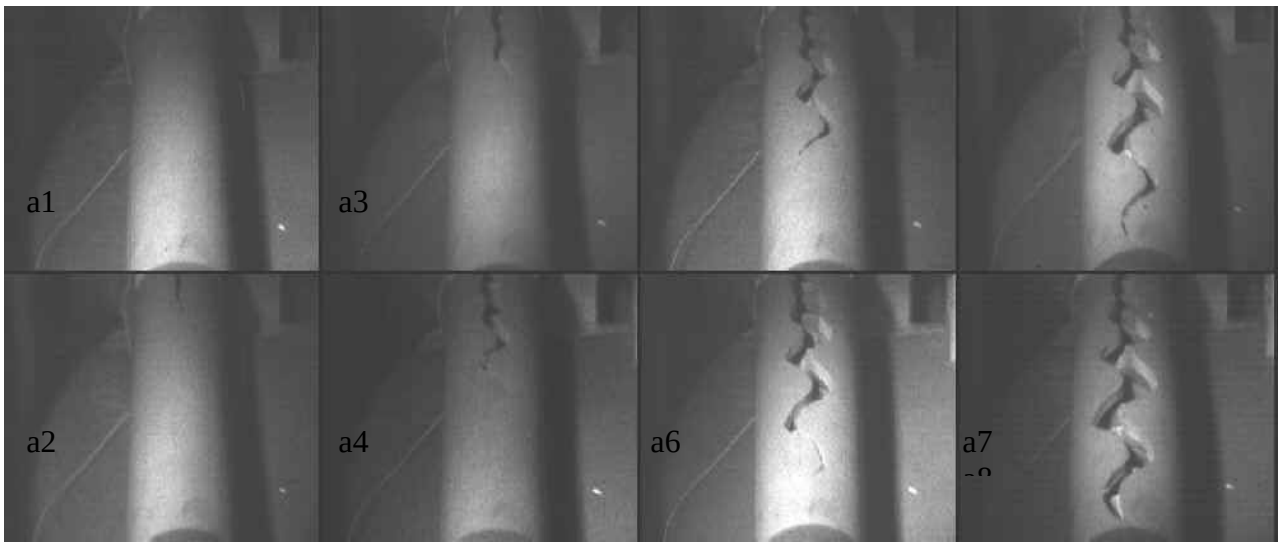
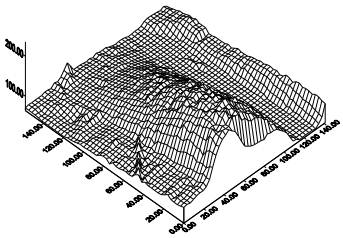
VI. LIST OF FIGURES

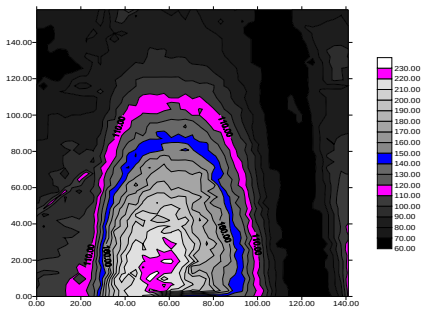


The original image (8 cases, starting the crack and the end all piping)

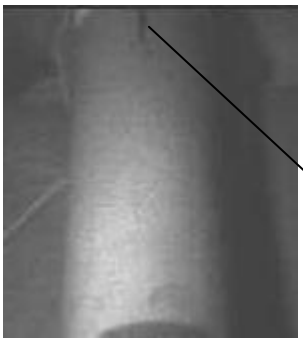
a1 (original image)



a1(surface, 2-D, Depth)



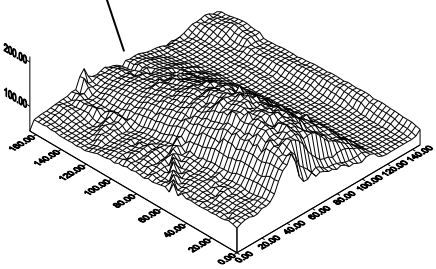
a1(Contour lines, no cracks)



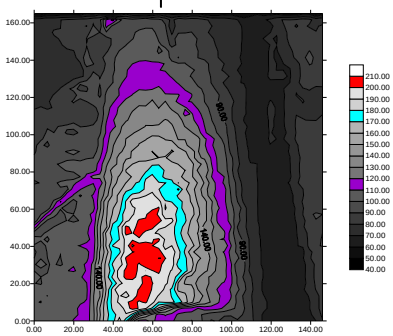
a2 (original image)

crack

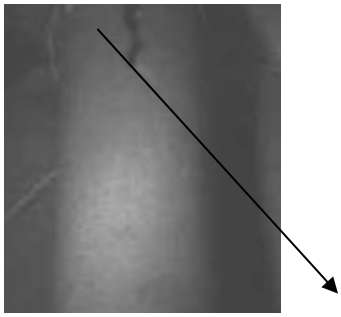
D_i



a2(surface, 2-D, depth)

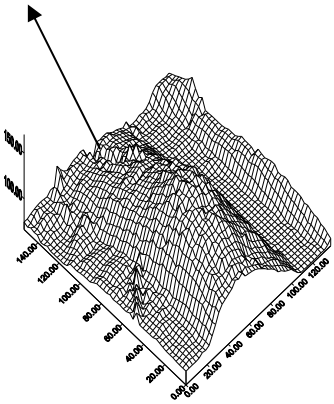


a2(Contour lines, cracks hear)

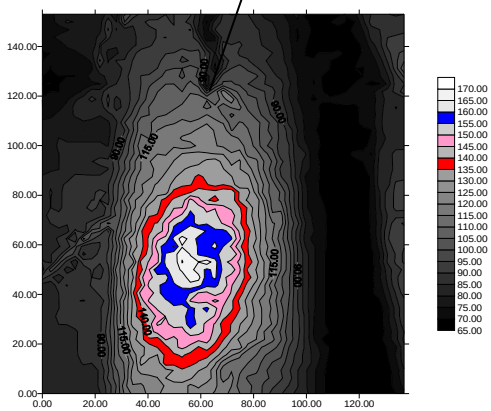


a3 (original image) Crack

D_i



a3(surface, 2-D, Depth)

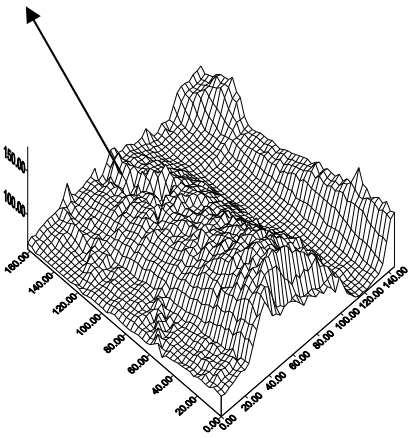


a3(Contour lines, cracks hear)

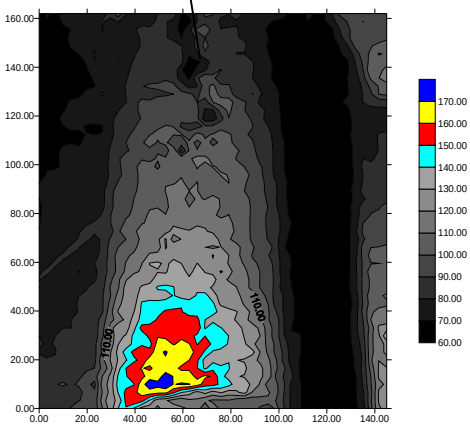
Crack

a4 (original image)

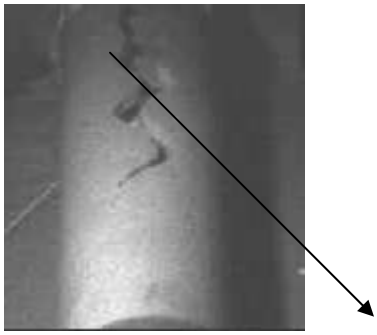
D_i



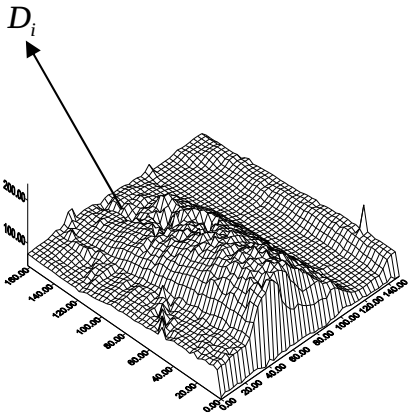
a4 (surface, 2-D, Depth)



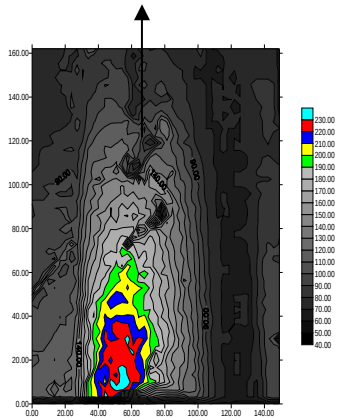
a4 (Contour lines, cracks hear)



a5 (original image) crack

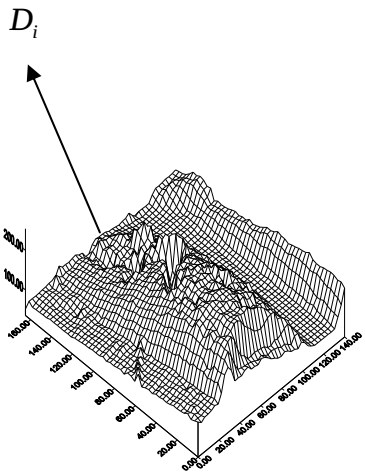


a5 (surface , 2-D, Depth)

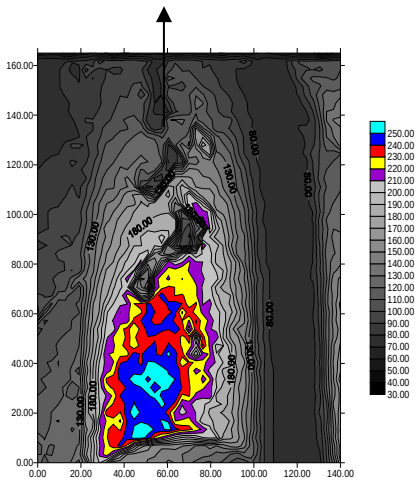


a5(Contour lines, cracks hear)

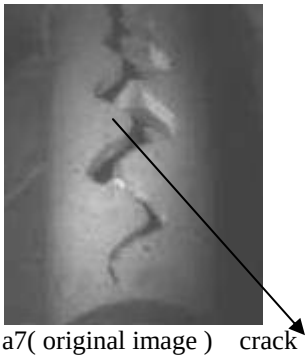
a6 (original image) crack



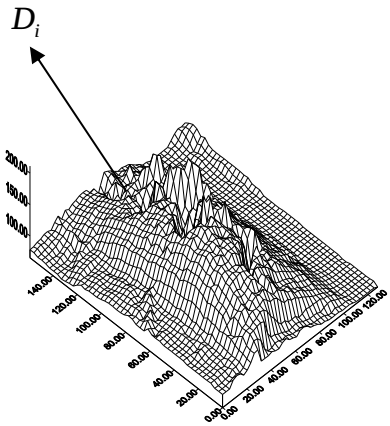
a6 (surface , 2-D, Depth)



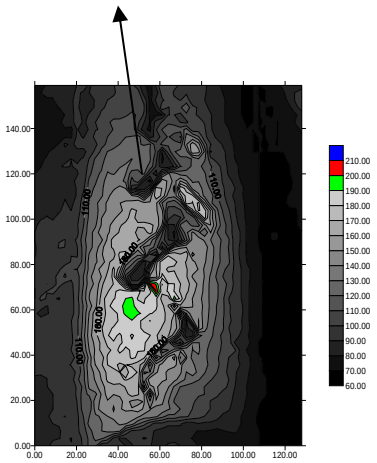
a6(Contour lines, cracks hear)



a7(original image) crack

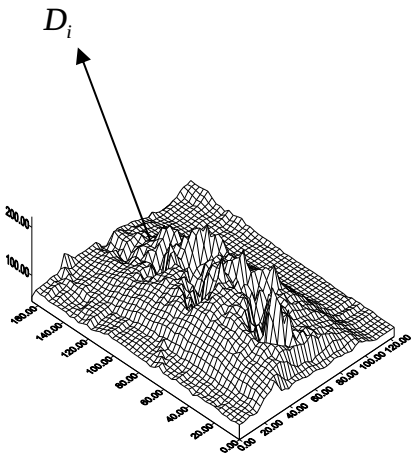


a7 (surface , 2-D, Depth)

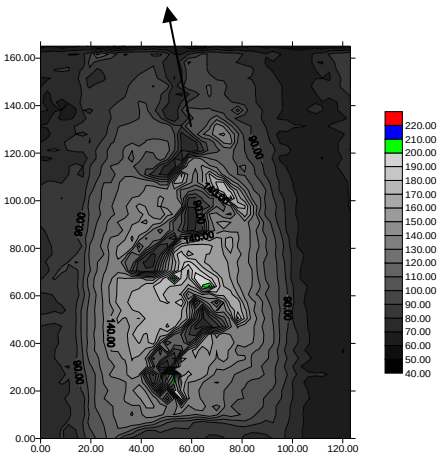


a7(Contour lines, cracks hear)

a8 (original image) crack



a8 (surface , 2-D, Depth)



a8(Contour lines, cracks hear)