COMMISSARIAT A L'ENERGIE ATOMIQUE
CENTRE D'ETUDES DE SACLAY
M I S T
Service des Bases de Données Spécialisées
F91191 GIF SUR YVETTE CEDEX

FR9200171
CEA-CONF--10689

CRACKLIKE DEFECTS DETECTION AND SIZING FROM CO-OCCURENCE MATRICES

MOYSAN J.- BENOIST P.
CEA Centre d'Etudes de Saclay, 91 - Gif-sur-Yvette (FR). Dept. de Technologie des Materiaux

CORNELOUP G.
Institut Universitaire de Technologie, 13 - Aix-en-Provence (FR)

MAGNIN I.
Institut National des Sciences Appliquees, 69 - Villeurbanne (FR)

Communication présentée à : 5. European Conference on Nondestructive Testing

Sarajevo (YU)
22-27 Sep 1991

CEREM
Centre d'Etudes et de Recherches
sur les Materiaux

Commissariat à l'Energie Atomique
Direction des Technologies Avancees

SERVICE DES TECHNIQUES AVANCEES

5TH ENDT SARAJEVO'91
September 22-27

CRACKLIKE DEFECTS DETECTION AND SIZING FROM CO-OCCURRENCE MATRICES

J.Moysan[1],G.Corneloup[2],I.Magnin[3],P.Benoist[1]
[1].Lab. de Contrôle par Ultrasons (STA/LCUS)- CEN Saclay FRANCE
[2].Lab. de Contrôle Non Destructif - IUT Aix en Provence FRANCE
[3].Lab. de Traitement du Signal et Ultrasons - INSA Lyon FRANCE

ABSTRACT

The inspection of austenitic welds used in nuclear field with ultrasounds poses problems in interpretation : strong grain noise makes difficult the detection of the crack top and the crack bottom. Since corresponding echoes enable the defect sizing, defect sizing also becomes difficult. The formation of 2D images(BSCAN), and their processing enable an increase in the effectiveness of testing. We present a segmentation method, based on co-occurrence matrix, which separates defects zones and noise zones. Examples of segmentation improvement applied to artificial defects are presented .

I.INTRODUCTION

A powerful data acquisition and imaging system is developed by the CEA's Advanced Technology Departement. This system called SPARTACUS enables us to elaborate specific image processings . The system creates ultrasonic images where grain noise is the background and defects echoes are the picture's objects. Our work is research on a detection algorithm based on image segmentation. The segmentation method uses a thresholding technique based on the co-occurrence matrix [1]. A threshold can be defined from co-occurrence matrix [2],[3], and thus the analysis of the co-occurence matrix enables us to separate defects from grain noise. In a second time, defect sizing could be achieved through the analysis of the processed image.

II. DATA ACQUISITION

The segmentation method is tested on images of defects fabricated by electroerosion in stainless steel plates which comprise an austenitic weld. Immersion technique is employed. We use 45° longitudinal waves. The central frequency of the focused probe, fc, is 2 Mhz and the sampling frequency, fe, is 20 Mhz. The total waveform is recorded. On Fig.1 a BSCAN of a crack in a weld is represented. On this image several echoes are noticeable (1)(2)(3)(4), plus a large amount of grain noise. With no weld, only echoes (1)(2) would be noticed.

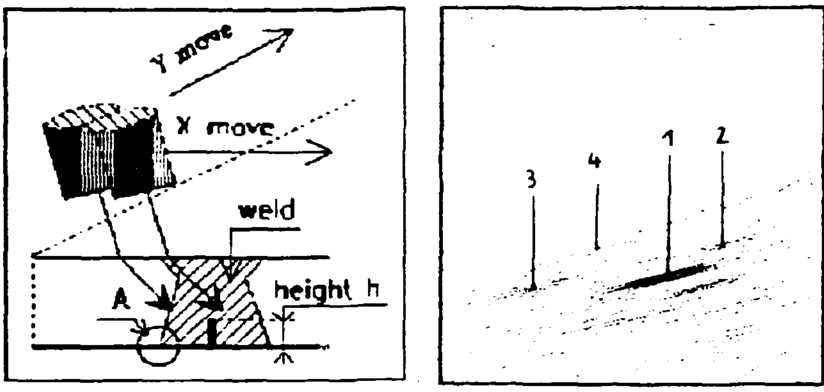


Fig.1. Ultrasonic testing system and BSCAN image.

III. CO-OCCURRENCE MATRIX.

A pre-processing step is set down, the analytic signal [4] is employed in order to construct a simpler image.

III.1. Definition.

BSCAN image is described as a two dimensional function f defined over a discrete and finite domain D. D=XxY,a cartesian product of X which is the set of coordinates on the x axis and of Y which is the set of coordinates on the y axis, $X=\{0,1,\ldots,M-1\}$, $Y=\{0,1,\ldots,N-1\}$. The function f takes its values in a discrete set e of L elements, f is then defined:

$$f: D \rightarrow e \ , \ f(x,y) \in e \qquad (1)$$

f(x,y) are pixel intensities, often described in gray levels. The co-occurrence matrix is a parametric function from e x e to N. We note i and j the two variables of the co-occurrence matrix. The two parameters are the image f and a displacement vector d=[dx,dy].

$$c: e \times e \rightarrow N \quad c(i,j,f,d) = |Aij| \qquad (2)$$

|Aij| is the cardinality of the set Aij which is defined as:

$$Aij=\{((x,y),(x',y')) \mid (x,y)\in D,(x',y')\in D \text{ and } (x',y')=t_d(x,y) \text{ and } f(x,y)=i \text{ and } f(x',y')=j\} \qquad (3)$$

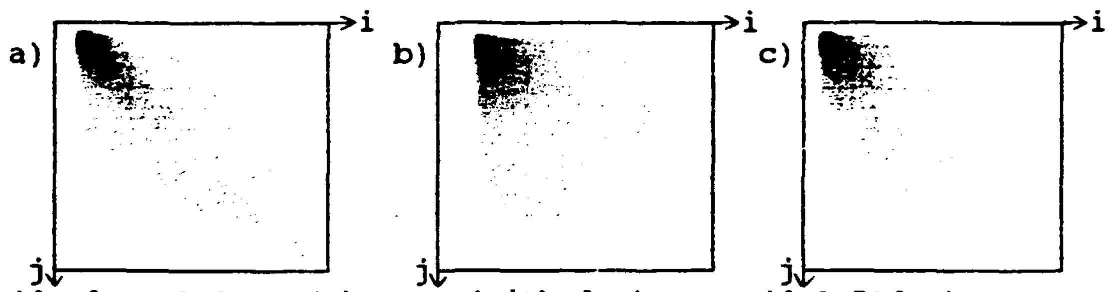
In this definition (3) t_d represents the translation of vector d. As indicated in (3) |Aij| gives the number of co-occurrences in the image f of pairs of pixels, separated by a displacement d, which have respectively pixel intensity i and pixel intensity j. Symmetric co-occurrences matrices are obtained with the calculation of the coefficients c(i,j,f,-d), we consider the coefficient Cij defined the sum of c(i,j,f,d) and c(i,j,f,-d). Cij coefficients are normalized by dividing each coefficient by the total sum of Cij coefficients.

III.2. Calculation of matrices: the choice of vector d.

Numerous co-occurrence matrices can be calculated from the image f depending on the value of d. Two ultrasonic parameters help us to choose d. First, as explained in part II, a focused beam is used, so ultrasound path has an angle of 45° with the vertical in the plate reference system. This creates a optimal orientation in BSCAN image, we note θ_{op} the corresponding angle in the image reference system. Second, the conversion of the central period of the transducer fc in number of pixels on axis Y (temporal axis) gives a value called dy_{op}. With the previous notations (Cf.II.) we can write:

$$dy_{op} = fe/fc \quad (4) \qquad \text{and } dx_{op} = dy_{op} * \tan(\theta_{op}) \quad (5)$$

The Fig.2 represents three normalized co-occurrence matrices displayed with 32 gray levels in logarithmic scale. Since the edges between grain noise and defects create off-diagonal elements in the co-occurrence matrix, the best discriminating matrix is the one for which off-diagonal entries are important. In Fig.2 the matrix which best fulfills this criterion is the one calculated with $d_{op}=[dx_{op}, dy_{op}]$.

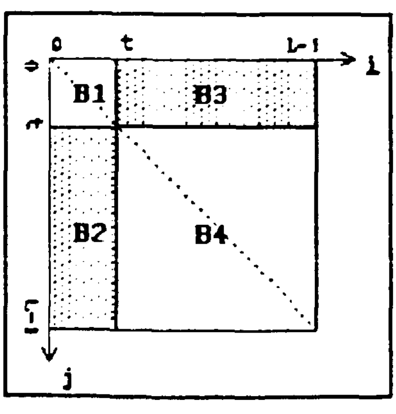


$(dy=dy_{op}, \theta=\theta_{op}+\pi/2)$ (with d_{op}) $(d=0.5*d_{op})$

Fig.2 Examples of co-ocurrence matrix.

III.3. Threshold value selection.

Let t be a value for the searched threshold. The tested threshold t divides the co-occurrence matrix into four blocks of variable sizes B1(t),B2(t),B3(t),B4(t) as shown in Fig.3.



In the first block, i and j values are less than t, so the Cij coefficients in this block represent all pairs of pixels whose pixel intensities are both less than t. In the samme manner, the fourth block B4(t) represents all pairs of pixels whose pixel intensities are both greater than t. At last, in the second and in the third block, one of the two pixels has a pixel intensity less than t and the other one has a pixel intensity greater than t. The block B3(t) contains the information of the edges between noise and defect.

Fig.3.Matrix division.

The automatic threshold selection is based on this distribution of Cij coefficients in co-occurrence matrix. A function M(t) is calculated over a sub-division of the matrix. We have defined a function called Average Graylevel Variance Measure (AVGM) [5]. This function calculates the variance of the position of the Cij coefficients in the third block. Thus the function is created to detect border region. With the Busyness [2] definition on block B3(t) we have :

$$Busy(t) = \sum_{i=t}^{L-1} \sum_{j=0}^{t} C_{ij} \tag{6}$$

$$AGVM(t) = \sum_{i=0}^{t} \sum_{j=t+1}^{L-1} \frac{(i-\mu_i)^2 * (j-\mu_j)^2 * C_{ij}}{Busy(t)} \tag{7}$$

where μ_i and μ_j are means of i and j in block B3(t):

IV. CONCLUSION.

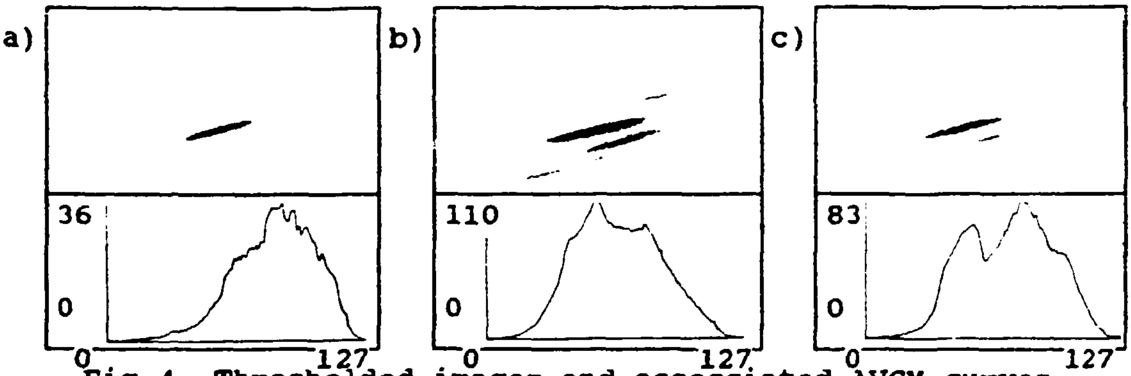


Fig.4. Thresholded images and assocciated AVGM curves.

Fig.4 shows three thresholded BSCAN with the algorithm applied on the image of Fig.1 for the same displacement vectors used in Fig.2. The second one, with d_{op}, enables us to succesfully separate noise from the two defects echoes. In the firts one, AVGM(t) is less dicriminative and only the major echo is correctly obtained. A correct threshold is obtained from co-occurrence matrices analysis. This supposes a BSCAN image with at least a defect echo. Others applications can be developed for the analysis of BSCAN images in ultrasonic testing. These developments are currently studied in LCUS laboratory.

References

[1] R.M. HARALICK,K.SHANMUGAN,I. DEINSTEIN,"Textural features for image classification",IEEE Transaction on Systems, Man, and Cybernetics, vol SMC-3 n°6,Nov. 1973, pp610-621.

[2]J.S.WESKA, A.ROSENFELD, "Threshold evaluation techniques", IEEE Transactions on Systems, Man and Cybernetics, vol SMC-8 n°8, August 1978, pp622-629.

[3] B. CHANDRA, D.D. MAJUMBER,"A note on the use of the graylevel co-occurrence matrix in threshold selection",Signal Processing, N°15 , 1988, pp149-167.

[4] P.M. GAMMEL , "Improved ultrasonic detection using the analytic signal " , Ultrasonics , mars 81 , pp 73-76

[5] J.MOYSAN, G.CORNELOUP,I.MAGNIN, P.BENOIST, O.BASSET, "Cracklike defects sizing from co-occurrence matrix",Proc.of the 1990 IEEE Ultrasonics Symposium.