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CONTRIBUTION TO THE LOCALIZATION ALGORITHM USING WAVELETS IN THE MULTIFREQUENCY DEFECTOSCOPY BY EDDY-CURRENTS

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Fast localization of defects and structure elements in the defectoscopy of steam generator tubes is the field where application of wavelet transformation is very perspective. Primary task is to find positions of potential indications within signal and secondary task is to calculate optimal boundaries of indications with respect to their future use in process of classification. Paper presents modifications to already presented localization algorithm based on method of wavelet transformation.

Keywords: defectoscopy, localization, eddy-currents, multifrequency

1 INTRODUCTION

Eddy current testing (ECT) is one of the methods that are useful in non-destructive defectoscopy. We are using output signal from testing heat-exchanger tubing by a differential probe. One of the methods to analyze signal data is application of wavelet transformation. Main task of presented new version of localization algorithm is to increase reliability of classification using all data from all frequency channels. Modification of localization algorithm (LA) is based on our previous research in this area.

2 THEORY

New algorithm uses basic steps of the first one [1] to calculate wavelet correlation coefficients from probe signal. For every position within signal we are able to calculate correlation between wavelet in different scales and signal (equation 1). Result matrix (equation 2) can be represented as greyscale image (picture 1).

$$C_{x(t)}(s,p) = \int_{-\infty}^{\infty} x(t).\psi'(s,p,t)dt \tag{1}$$

$$M(s,p) = \sqrt{C_x^2(s,p) + C_y^2(s,p)} \tag{2}$$

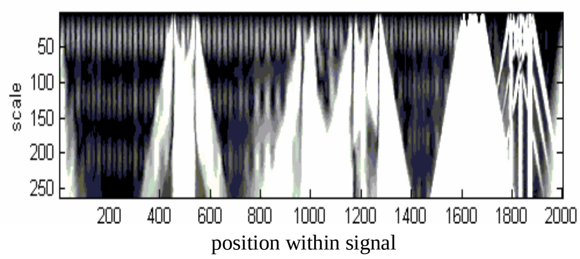

Fig. 1. Grayscale representation of correlation matrix calculated using wavelets

Local maximums of mentioned image calculated using morphological operators reflects all significant changes of signal. Then we are able to calculate global maximum for each region (peak). Result representation contains also original position within signal, scale coefficient of wavelet, correlation of wavelet and signal, correlations of wavelet and signal parts and relative angle of correlation components which corresponds to indication phase angle.

Table 1. Typical values for phase angle parameter for selected types of indications

type\frequency	25kHz	100kHz	200kHz	700kHz
defect 100%	40	40	40	40
defect 72%	51	60	81	120
defect 48%	57	69	117	230
support plate	106	131	40	---

We can easy interpret wavelet coefficients calculated using mentioned equations:

- position + scale = indication centre and effective range
- correlation M(s,p) = analogy to indication amplitude
- angle of correlation components = analogy to indication phase angle

Algorithm behavior we can demonstrate using pictures. Picture 2 shows output signal from measurement probe. From this input localization algorithm is able to calculate wavelet coefficients and wavelet surface (picture 3) and then local maximums, which correspond to the most significant changes of signal (picture 4). Pictures 5, 6 and 7 demonstrate calculated values of correlation, wavelet scale and indication phase angle.

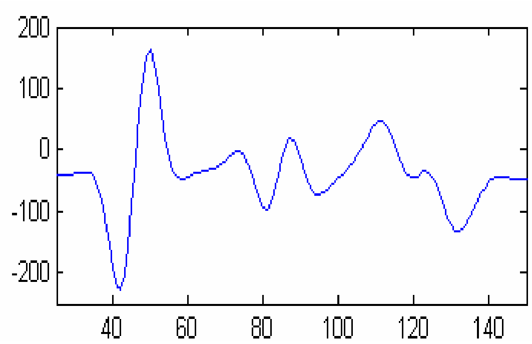

Fig. 2. Original probe signal (amplitude)

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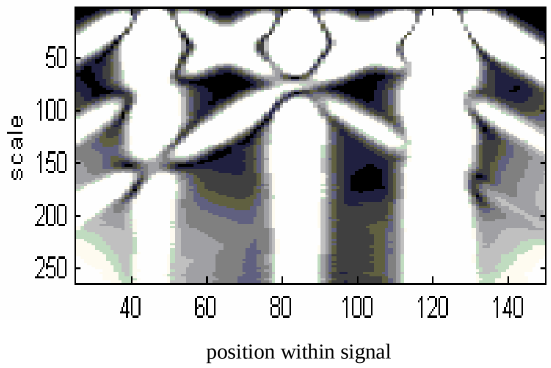

Fig. 3. Wavelet coefficients

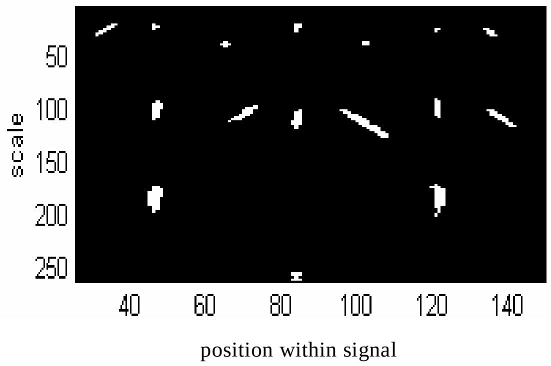

Fig. 4. Local maximums of coefficients surface calculated using morphological operators

Typical parameters for indication of 100% defect in 100 kHz signal are: correlation = 1320, scale = 20 a phase angle 40 degrees (after signal offset correction).

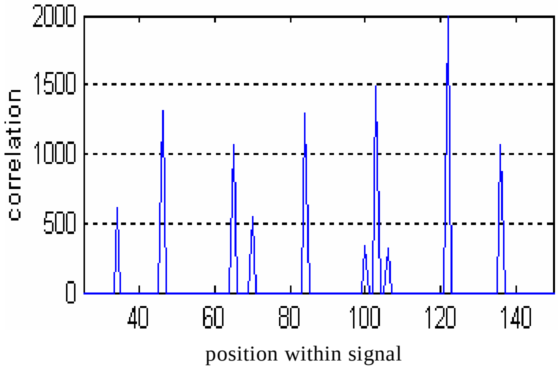

Fig. 5. Local maximums from view of correlation

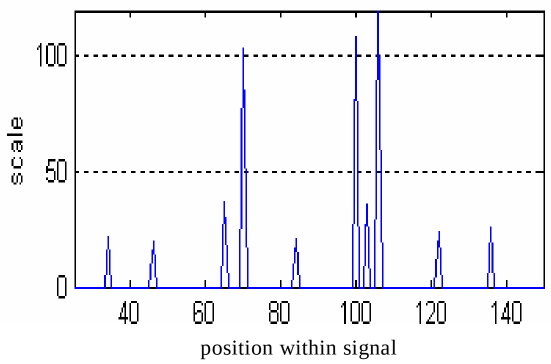

Fig. 6. Local maximums from view of scale parameter

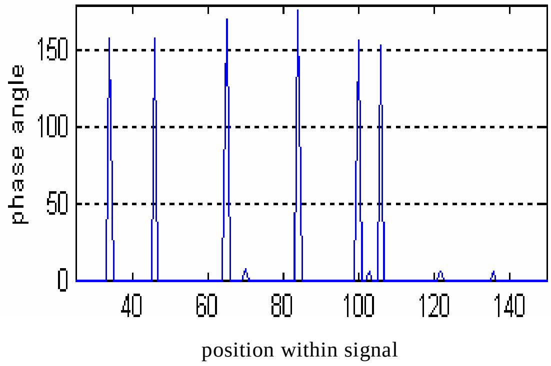

Fig. 7. Local maximums from view of calculated phase angle parameter

The same profile can be defined for this type of indication at frequencies 25, 200 and 700 kHz and also for all other types of indications.

Result lists of indication positions from all measurement frequencies are then filtered using know profiles of typical indications. Filtered lists are then connected. Some position is finally marked as indication only if it exists in 3 or more lists.

3 EXPERIMENTS

Analysis of mentioned representation shows that this method can detect potential indications of defects and structure elements with high reliability. It is sensitive to signal changes not recognized manually by operator. Not every marked location really corresponds to some defect or construct element. Typically indication edges cause significant change of signal marked by above algorithm as local maximum. This effect was expected and it's result of ECT method principle. These "false" indications can be eliminated using profiles.

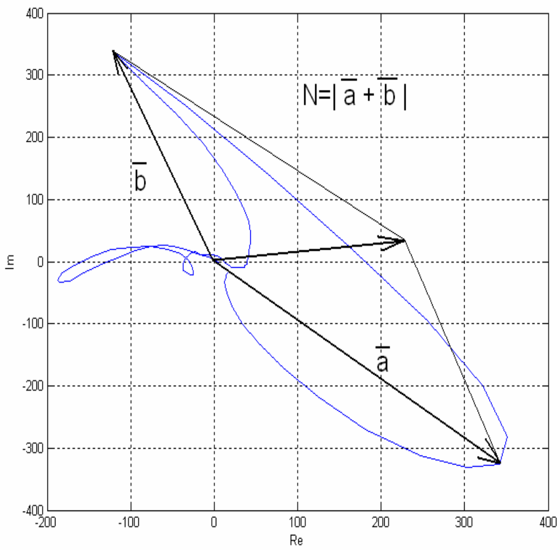

Fig. 8. Mixed indication and N-function, Re – X "real" part of signal, Im – Y "imaginary" part of signal

The second task to solve was to design representation (signature vector) of indication suitable for classification process. Analysis shows that representation "correlation-scale-angle" calculated and used in localization process can be used for classification. Only problem with mixed indication (defect under support plate, etc.) was notified. To separate mixed indications from clear we defined function called "N-function".

Shape of clear indication in complex surface is typically symmetrical. "N-function" calculates rate of this symmetry. Vectors „a" and „b" from indication centre to peaks with maximal distance are calculated. Result of "N-function" is absolute value of vector $a+b$. Low values of "N-function" indicate symmetrical indications (clear indications). Classification of mixed indications is based on using data from all frequencies. Low frequencies better indicate structure elements and high frequencies better describe defects. Mixed indication is indicated as dual (example: 25kHz – support plate with high probability, 200kHz – defect with high probability).

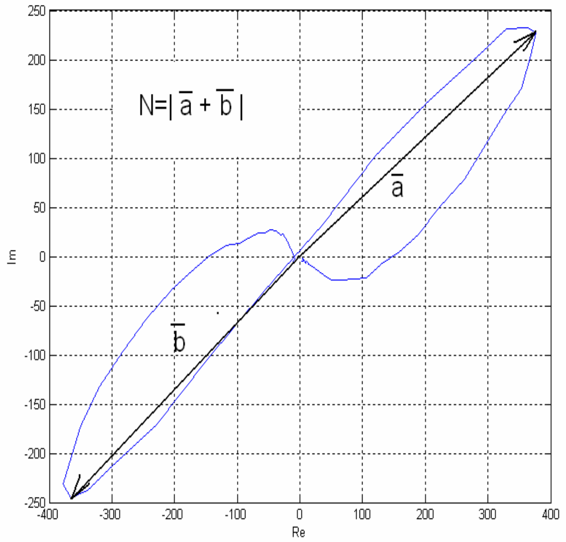

Fig. 9. Clear indication and Picture 8 and N-function, Re – X "real" part of signal, Im – Y "imaginary" part of signal

5 CONCLUSIONS

Above mentioned algorithm automate and formally copies behaviour of real testing procedure where operator finds an indication and studies shape of the same indication in different frequencies. Algorithm is very sensitive and result list of indications covers all relevant signal changes. Experiments show that real defects and structure elements are found with high reliability. Operator must evaluate indications, which couldn't match any of defined profiles manually. Number of mentioned unclassified indications is small, so detailed analysis of signal can be done more effective.

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