Contribution to localization algorithm in the defectoscopy of steam generator tubes by eddy-currents.

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Abstract. *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 modification to already presented localization algorithm based on method of wavelet transformation..*

Keywords: localization, wavelets, eddy-currents, steam generator

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. Tubes are made from nonmagnetic material. The shape of output signal from the probe reflects properties of tested material. More information was presented in [1]. One of the methods to analyse signal data is application of wavelet transformation [2] [3].

Modification of localization algorithm is based on our previous research in this area. More about the first version of LA can be found for example in [4]. Now only brief summarization:

1. output signal from probe has two parts s(x) := {x(t), y(t)} {for each frequency)
2. for each part, coefficients of continuous wavelet transformation were calculated:

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

3. result combination of matrixes was calculated using

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

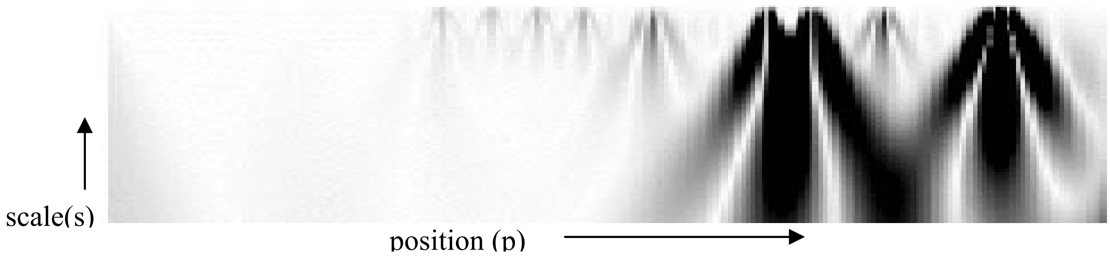

Fig. 1. Typical plot of M(s,p) contents – white colour = low correlation, black colour = high correlation

4. local maxima were found from equations (1) and (2)

$$A(p) = \max_{s \in <1,128>} (M(s,p)) \quad I(p) = \arg\max_{s \in <1,128>} (M(s,p)) \qquad (1)$$

$$IsMax\ (p) = \left[\max_{r \in < p - S(p), p + S(p) >} (A(r)) = A(p) \right] \quad S(p) = K * I(p) \tag{2}$$

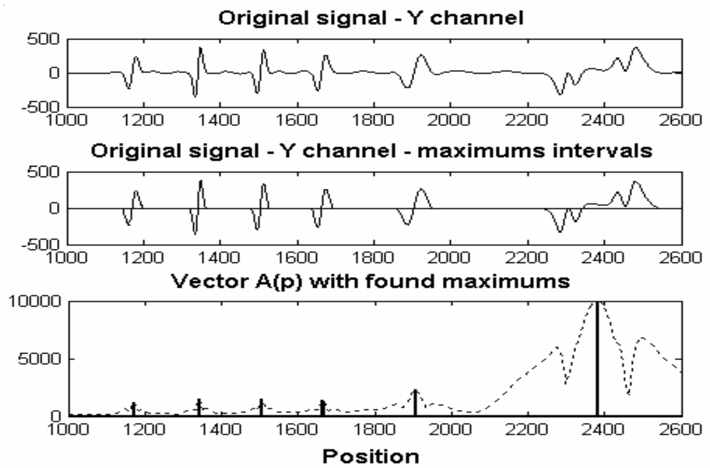

Fig. 2. Result of localization using original version of localization algorithm.

Figure 2 shows y-part of localization input signal, calculated intervals of indications in middle graph and calculated positions of indication centres.

This method couldn't find a small indication located near large one a was strongly influenced by noise. Main task of presented new version of localization algorithm is to eliminate mentioned problems.

2. Subject and Methods

New algorithm use steps 1 to 3 to calculate wavelet correlation coefficients M from probe signal. We changed only wavelet function from "Gaus1" to "Haar". Experiments show that Haar wavelet can better reflex real size of indication (constant K from equation. (2) is near 1) and because its effective support is on interval <0,1> we are able to use integer scale ratio.

We can interpret a matrix of wavelet coefficients as grey-scale image. So local maxima can be then calculated using methods of image processing.

We defined image local maximum as a connected region of pixels with the same grey level J if all neighbour pixels have grey level less than J. To eliminate local maxima of small size, we suppress small regions (number of pixels) and regions with small difference between their grey level and grey level of their neighbour pixels.

Figure 3 presents calculated regions. These regions are disjunct and each of them represents local maximum of surface of correlation coefficients. Let us assume set *RP*(region pixels) as:

$$RP = \{[s,p]; \mathit{if\ \ pixel}\ [s,p]\ \mathit{belongs\ \ to\ some\ \ region}\} \tag{3}$$

Finally we defined matrix E as:

$$E(s,p) = \begin{cases} M(s,p) & \mathit{if}\ [s,p] \in RP \\ 0 & \mathit{else} \end{cases} \tag{4}$$

Matrix E(s,p) contains only significant peaks from original surface defined by M(s,p). Now we can calculate global maximum for each region (peak). List of significant changes of correlation between wavelet and tested signal is a result of mentioned process. For each list item we can specify:

- original position within signal {position)
- scale coefficient of wavelet (scale)
- correlation of wavelet and signal $M(scale, position)$

- correlations of wavelet and signal parts $C_{x(t)}(scale, position)$, $C_{y(t)}(scale, position)$
- relative angle of correlation components $\alpha = \arctan(C_{y(t)}(s,p), C_{x(t)}(s,p))$ which corresponds to indication phase angle

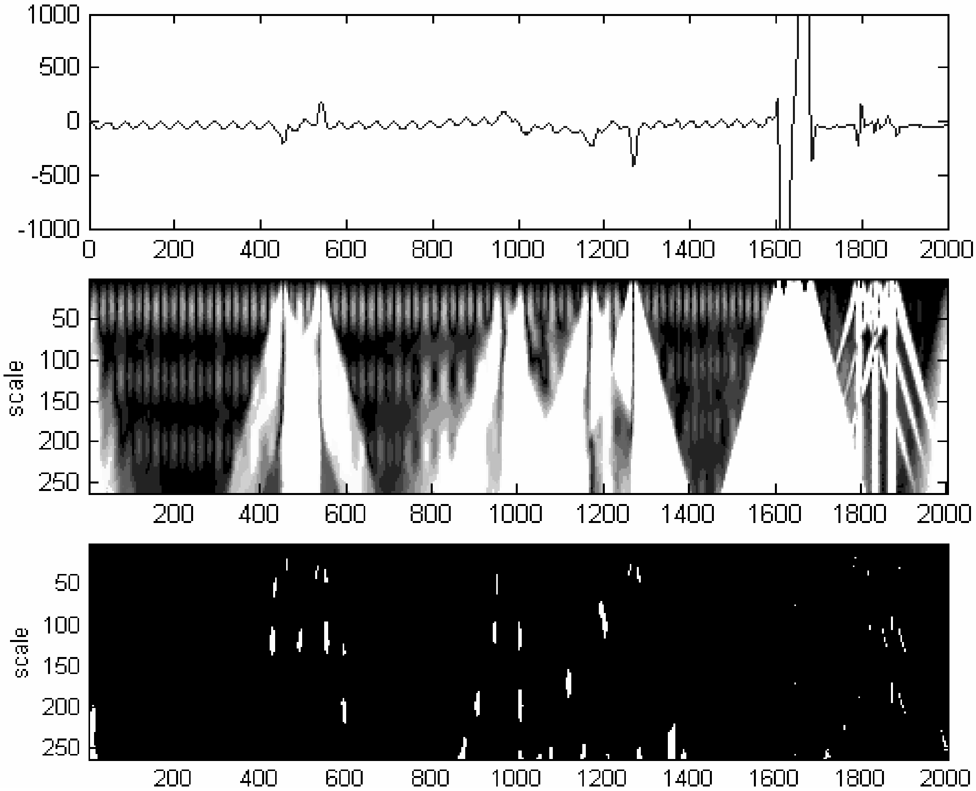

Fig. 3. Regions: original signal – wavelet transformation – regions for local maxima

3. Results

Analysis of above 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. Moreover we can easy interpret these parameters:

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

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. Figure 4 shows result for signal interval containing 3 defects.

4. Conclusions

Typical parameters for 100% defect indication in 100kHz signal are: correlation = 1320, scale = 20 a phase angle 40 degrees (after signal offset correction). The same profile can be defined for this type of indication on frequencies 25, 200 and 700kHz and also for all other types of indications. Result lists of indication positions from all measurement frequencies are filtered by the 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. Description of mentioned filtering and combination of lists is in excess of this paper.

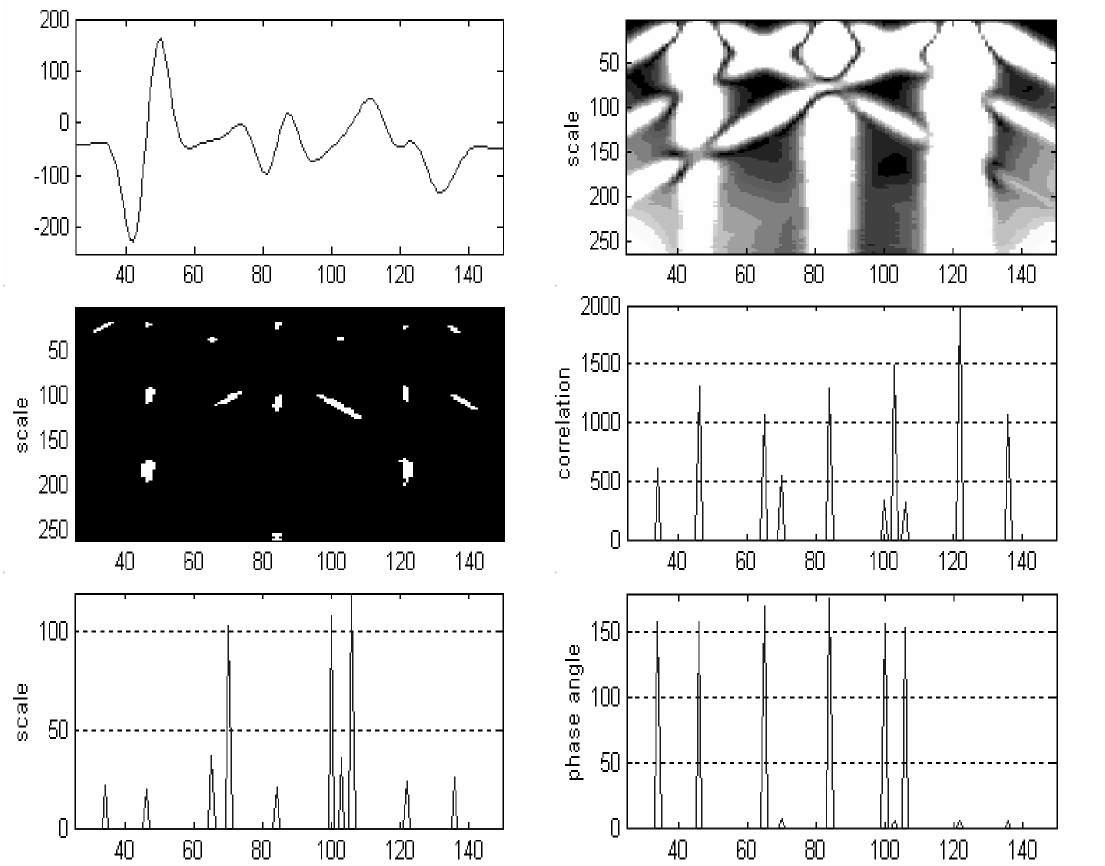

Fig. 4. original signal (indications of 3 defects – centres 46, 84 and 122) – wavelet transformation – regions – maxima correlation – maxima scale – maxima phase angle

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