핵발전소의 증기발생기 비파괴 평가를 위한 초음파 스펙클 감소 기술

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Ultrasonic Speckle Surpression Technique for Nondestructive Evaluation of Steam Generator in Nuclear Power plants

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SUMMARY

In this paper, we present a ultrasonic speckle suppression method for centrifugal-casted stainless steel sample by computer simulations of a flaw enhancement algorithm. Because of their practical importance in welds, the ultrasonic signal obtained from heat-affected zone or welds are investigated for computer simulation. The results for computer simulation present the more enhanced flaw-visibility and speckle suppression than the compared two techniques.

1. INTRODUCTION

It is often necessary to evaluate the properties of material without affecting the material's usefulness. This process is called nondestructive evaluation(NDE) of materials. NDE can be critically important in the safety evaluation of nuclear power plant. Various signal processing techniques have been utilized in the past for enhancement of detected echos from speckle noise environment, such as wavelet analysis[1], split spectrum analysis[2], deconvolution filter method[3], and adaptive filter technique[4] *et al.* In these techniques, time-frequency analysis techniques such as wavelet analysis and split spectrum analysis can be more appropriate since the ultrasonic signal for flaw detection is usually a broadband pulse modulated at center frequency of the transducer. The conventional method for the time-frequency analysis is the split spectrum analysis, which is based on short time Fourier transform(STFT).. In this paper, we show that it is possible to suppress the speckle noise in stationary wavelet domain while keeping time-invariant property of the underlying ultrasonic signal.

2. METHODS

The procedure of our method is following 3 steps. The first step is the stationary wavelet transform of the received ultrasonic signal to decomposition level L, where the ultrasonic signal is discretized to its sample number 2^N

and the decomposition level is $L<N$.

The second step is applying the threshold rule. As showing (5), the basic threshold rule is that the stationary wavelet coefficients at interval (a_1, a_2) are remained and other values are discarded.

$$w_d(j,\theta)=\begin{cases} 0 & \text{for } w_s(j,\theta)<a_1 \\ w_s(j,\theta) & \text{for } a_1< w_s(j,\theta)<a_2 \\ 0 & \text{for } w_s(j,\theta)>a_2 \end{cases} \tag{1}$$

where $w_s(j,\theta)$ and $w_d(j,\theta)$ are stationary wavelet coefficient and output value by threshold rule, respectively. And a_1 and a_2 are lower and upper threshold values. It has been shown that the threshold rule of (1) is near optimal for wide class of signals corrupted by additive white gaussian noise. Using this approach, all stationary wavelet coefficients whose modules is smaller than the threshold are discards and remainder values are used to reconstruct the signal as following

$$w_d(j,\theta)=\begin{cases} 0 & \text{for } |w_s(j,\theta)|<\lambda \\ sgn|w_s(j,\theta)| \cdot (|w_s(j,\theta)|-\lambda) & \text{for } |w_s(j,\theta)|\geq\lambda \end{cases} \tag{2}$$

where λ is the threshold.

Even though this procedure may seem similar to threshold the signal in time or frequency domain, stationary wavelet threshold results in minimal averaging or smoothing of the signal in time domain or frequency domain, because each time-scale domain of original signal is considered locally in the time-scale 2-dimensional domain. This approach is optimal for white noise, but it can fail if the noise is correlated as ultrasonic speckle. The choice of threshold λ is based on maintaining all $w_s(j,\theta)$ values higher than -3dB. Therefore if the noise has a higher correlation with any wavelets $2^{-j/2}\psi((t-\theta)/2^j)$ of the original signal, threshold rule can result in the complete elimination of the information of interest.

In order to avoid this drawback of threshold rule, the suggestion was made to utilize a level dependent soft threshold for a signal with stationary correlated noise. The threshold thus becomes a function of dilation j, i.e., $\lambda=\lambda(j)$, In [10], a functional relationship between j and λ is given for the case of stationary wavelet transform level based on knowledge of the noise characteristics. In [5], the only information available is the center frequency of the transducer used and its frequency bandwidth, while very little is known about noise. For this reason, it seems logical to define the threshold λ as frequency response of the transducer.

Finally the third step is the signal reconstruction by the remained coefficients through the inverse stationary wavelet transform.

3. EXPERIMENTAL RESULTS

The proposed method seems to be efficient in improving the signal strength and reducing the speckle noise. Hence SWT-based technique can be extremely useful for flaw detection. In order to simulate flaws in material and quantify the performance of the proposed method, an ultrasonic signal reflected from hole in SE part of test sample is obtained as fig. 1, then the white noise was added to flaw-reflected ultrasonic signal at levels of -12dB, -15dB as fig. 2(a)-(b).

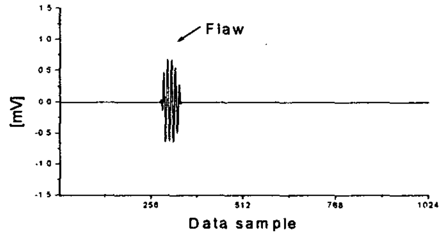
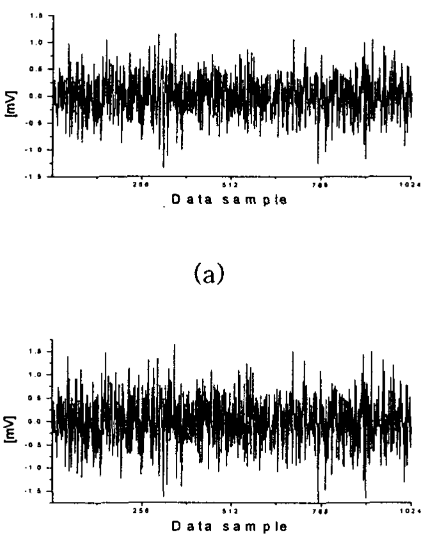


Fig. 1. Original ultrasonic signal obtained from SE part of test sample

The noise-contaminated ultrasonic signals are processed by two methods, SWT-based technique, and split spectrum processing(SSP), respectively. For comparison of visibility of methods, output signals of methods are expressed by their absolute values and rescaled by maximum peak value=1.

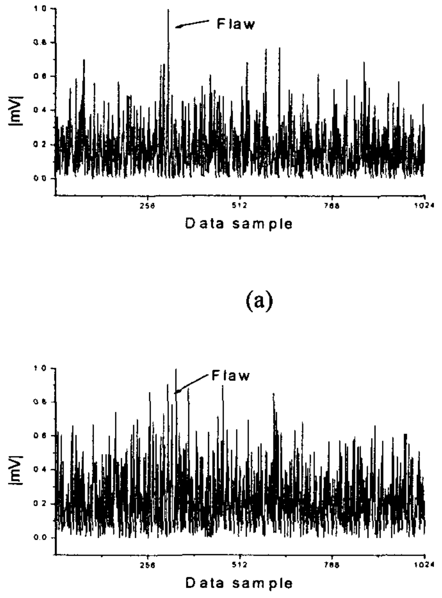


(a)

(b)

Fig. 2. Plots of ultrasonic signals added in white noise level (a)-12dB, (b) -15dB.

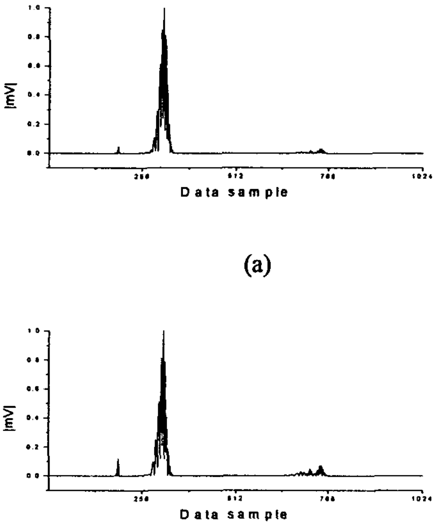
At the results of simulation case study, the SSP technique do not enhance the flaw visibility at -12dB and -15dB noise level. But the proposed method show that clean and sharp peak value at position of flaw is detected in all noise level.



(a)

(b)

Fig. 3. Results of SSP methd of fig. 2



(a)

(b)

Fig. 4. Results of the proposed methd of fig. 2

3. CONCLUSIONS

A method for suppressing speckle noise using the stationary wavelet transform was presented. The stationary wavelet transform was introduced and the proposed method was applied to ultrasonic signals, which were generated from noise-contaminated artificial signals.

The study of simulation case shows that the proposed method detects flaw and also does not generate false-flaw.

참고문헌

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