한국산학기술학회논문지
Vol. 8, No. 2, pp. 245-249, 2007

Image Enhancement Techniques for UT - NDE for Sizing and Detection of Cracks in Narrow Target

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초음파 비파괴 평가를 위한 협소 타깃의 크랙 사이징 및 검출을 위한 영상 증진기술

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Abstract In this paper describes image enhancement technique using deconvolution processing for ultrasonic nondestructive testing. When flaws are detected for B-scan or C-scan, blurring effect which is caused by the moving intervals of transducer degrades the quality of images. In addition, acquisited images suffer form speckle noise which is caused by the ultrasonic components reflected from the grain boundary of material [1,2]. The deconvolution technique can restore sharp peak value or clean image from blurring signal or image. This processing is applied to C-scan image obtained from known specimen. Experimental results show that the deconvolution processing contributes to get improved the quality of C-scan images.

Key Words : Ultrasonic nondestructive testing, speckle noise, image, deconvolution

요 약 본 논문은 핵발전소의 초음파 비파괴 평가를 수행하기 위하여 핵발전소 설비의 초음파 비파괴 평가시 발생될 수 있는 스펙클 잡음을 억제하고 디컨벌루션 기법을 이용하여 결함의 정확한 위치 및 크기를 추정할 수 있는 영상 처리 기법을 제안하였다. 제안된 방법은 실제 핵발전소의 증기발생기 파이프라인으로 만들어진 시편을 이용하여 영상의 선명도를 확인 할 수 있었다.

1. Introduction

The classical method of nondestructive testing is the pulse-echo method [3]. An ultrasonic wave generated by a transducer is sent in the test material, and the reflected ultrasonic impulses are detected by the same transducer. The ultrasonic wave generated by a piezoelectric material at the surface of the material propagates through the test material and the intermediated material before it is detected by a transducer[4,5].

The propagation of the ultrasonic wave is influenced by reflections at all boundary surfaces in the media. These reflections contained in the ultrasonic wave leaving the material are suitable to obtain the necessary information about the properties of the material, i.e., thickness, flaws, layers of different materials. To discover the internal structure of the test sample as precisely as possible, the problem is to restore the signal leaving the material surface containing only the reflection information from the detected one using blind deconvolution techniques.

We have defined the convolution of two signals, *x(n)* and *h(n)* and for discrete case in figure 1. The effect of convolution is to smear the signal *u(n)* in time according to the recipe provided by response function *h(n)* in figure 1. A transducer provides the ultrasonic signal containing the reflection information to describe the material as wall as all influences of the propagation path and the transducer impulse response itself.

Conversely, deconvolution is the process of undoing

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the smearing in signals that occurred under the influence of known response function. The defining equation of deconvolution is the same as that for convolution, except left hand side is taken to be known, i.e. when *y(n)* is equal to *x(n),* transfer function *f(n)* is deconvolution function or inverse filter of *h(n).* But blind deconvolution defines unknown input signal and unknown transfer function, we only observe the output signal of known system and it is assumed the impulse response. In this paper, we apply deconvolution filter scheme to the enhancement of ultrasonic C-scan images[5].

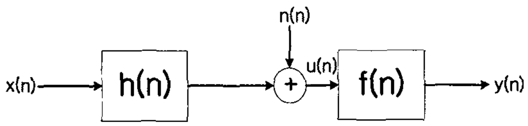
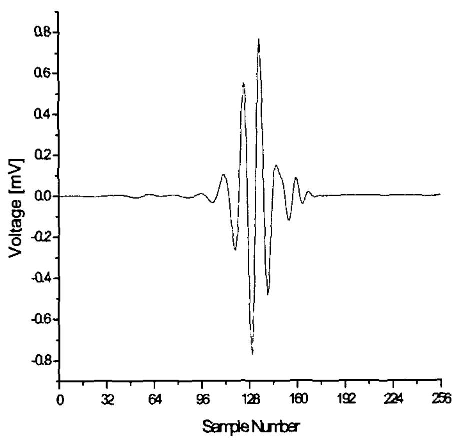


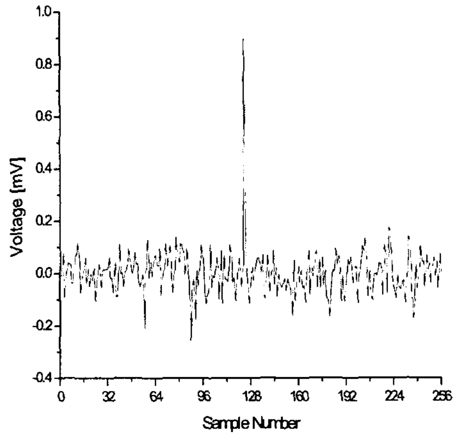
Fig 1. Schematics of convolution and deconvlloution

In [2] the 2-dimensional blind deconvolution frame work was proposed and applied to C-scan ultrasonic images. In this paper we used 1-dimensional blind deconvolution in order to enhance the improved C-scan images. The 1-D deconvolution is less complex calculation comparing with 2-D deconvolution and gets the same as image quality of 2-D deconvolution output.

In figure 2, it shows the examples of blind deconvolution. Figure 2(a) is observation signal which is similar with typical ultrasonic signal and it is spread on to time axis. Typical ultrasonic signal based on pulse-echo type is to be time-spread by characteristics of transducer system in itself.



(a) input signal, *x(n)*



(b) output signal $y(n)$

Fig 2. Example of deconvolution of 1-D ultrasonic signal, deconvolution is the process of undoing the smearing in signals that occurred under the influence of known response function. So result of deconvolution presents peak value like impulse function.

If the signal of figure 2(a) is assumed to be a signal reflected from flaw in internal of material, we can not know precise position of flaw. But the result of deconvolution in figure 2(b) is clear. The position of flaw is expressed as sharp peak value[6,7].

2. Experiment and Result

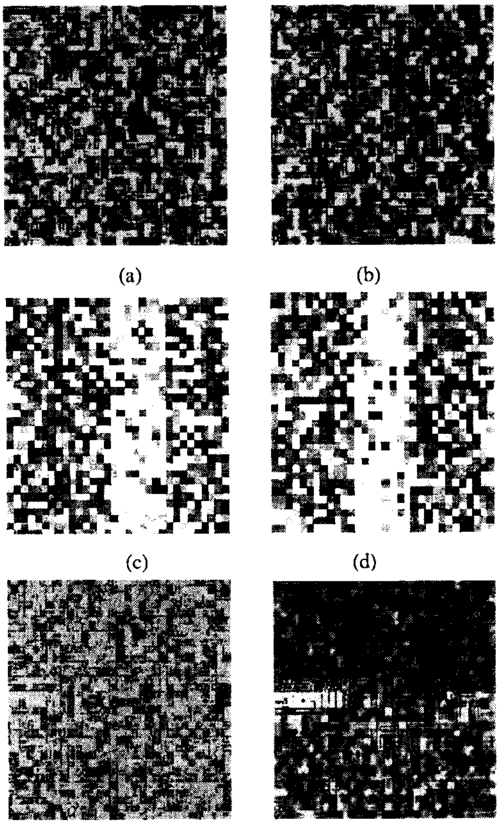
To experiment, we used the center frequency 2.25MHz dual rectangular transducer (PANAME TRICS, A109), pulser/receiver(PANAMETRICS, 500PR), oscilloscope and IBM-PC(PENTIUM-4). The received RF data in receiver are transmitted to digital oscilloscope by coxial cable and then sampled at 250MHz of sampling frequency. From [1]and [3], the AR model is used as observation model in formula (1)

$$h(z) = 1 - \frac{\sum_{i=1}^{M} b_i Z^{-i}}{\sum_{i=1}^{N} a_i Z^{-i}} \quad (1)$$

and its solution is

$$r = arg\ min\{|Z - Hr|^2\} \quad (2)$$

The sampled A-scan data are transmitted again to IBM-PC and processed by the deconvolution procedure. The inspected CCSS specimen was made the same material that of welding region of steam generator of power plants. Nine of hole and notches are manufactured in the specimen, the holes #1 to #3, notches #4 to #6 and holes #7 to #9. The holes #1 to #3 are flat bottom holes(FBH) which have the different depths, the notches #4 to #6 are notches which have same width and different depths and holes #7 to #9 are side-drilled holes(SDH) which have the same diameter and the different depths[2]. All data is distorted blurring images caused by contaminating ultrasonic speckle noise from random grain boundary of material[4].



(a) (b) (c) (d) (e) (f)

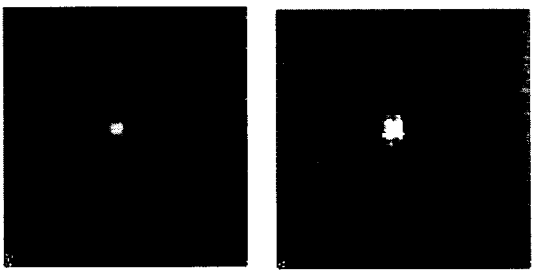
Fig 3. Ultrasonic C-scan raw data obtained from specimen. (a) and (b) are from #1 and #2, holes, (c) and (d) from #4 and #5, notches and (e) and (d) from #7 and #8, side drilled holes. All data is distorted blurring images caused by contaminated ultrasonic speckle noise resulted in random grain boundary of material.

Figure 3 shows speckle-contaminated ultrasonic raw data. From figure 3, the images of (a) and (b) are flat bottom holes, they are contaminated by ultrasonic speckle noise. The position of flat bottom holes is the center of images. But the manual inspector can not know existence of holes (assumed to be flaw). So in severe noise contaminated circumstance, it is difficult problem to judge the existence of flaw. The images of (c) and (d) are related to two notches. The main focus of notch inspection is width and depth of underlying notches. It is difficult for the manual inspector to estimate the depth and width of notches from images of (c) and (d).

The images of (e) and (f) show side drilled holes which have are different depths. From images of (e) and (f), the position of side drilled holes left-center of images. The image (e) can not know the existence of flaw, so the manual inspector is difficult to decide length of flaw and also the image (f) can observe an outline of side drilled hole. But the inspector is difficult to measure the length of flaw.

From observation of images in figure 3, The C-scan images which are non- processed data can not decide the existence of flaw and measure dimension sizing of flaw.

Speckle noise problem is solved by noise remover based on signal processing techniques [2] such as wavelet noise remover and adaptive noise canceller, etc. But the precise measurement of dimension of flaw makes demand clear images which is processed by signal processing techniques. In order to getting clear image which do not distorted the information of original image, 1-D deconvloution processing are applied to original C-scan images of figure 3 based on formula (1) and (2).



(a) (b)

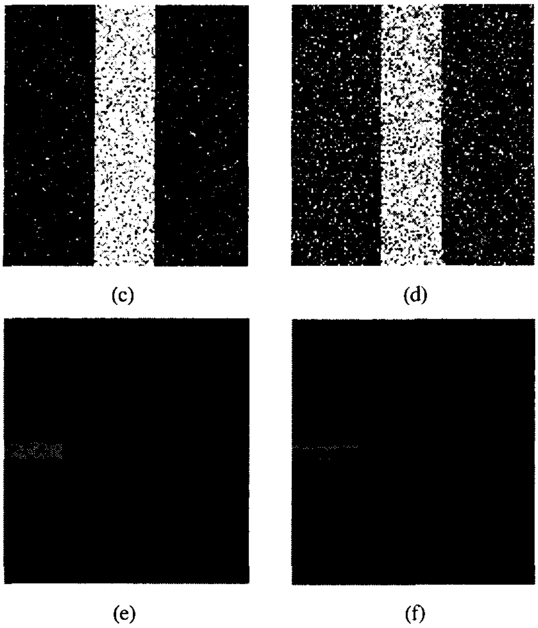


Fig 4. Results of deconvolution processing. The results of images about flat bottom holes, (a)and (b) show the enhancement of image quality. The inspector can observe white spots as representation of flat bottom holes, which do not represent from original images influenced by speckle noise. The inspector can observe clear notches and measure width of notches by results of images of notches, (c) and (d) show clear images about notches. And last two images are related to side drilled holes. From images, (e) and (f), the side drilled holes represent a board type in gray color which can be classified non-flaw region of images. The inspector is can measure size, depth and width of flaw by the deconvolution processed results.

Figure 4 shows that results of C-scan images of figure 3. The results of images about flat bottom holes, (a) and (b) show the enhancement of image quality. The inspector can observe white spots as representation of flat bottom holes, which do not represent from original images influenced by speckle noise. The clear images (a) and (b) is caused by characteristic of deconvolution processing itself, and they can be used as evidence of flaw-existence.

The inspector can also observe clear notches and measure width of notches by results of images of notches, (c) and (d) show clear images about notches. The resulting images (c) and (d) are still contaminated by speckle noise. But it is not difficulty in measurement of flaw. And last two images are related to side drilled holes. From images, (e) and (f), the side drilled holes represent a board type in gray color which can be classified non-flaw region of images.

In experiment we applied six images of ultrasonic C-scan to deconvolution processing and observed results of processing. The applied deconvolution process creates clear images as output which can decide the existence of flaw and measure size, width and depth of underlying flaw. Especially small flaw of figure 2(a) and (b) in severe speckle noise circumstance detected and also narrow target as figure 2(e) and (f) is clear by deconvolution processing. The application of deconvolution processing application to ultrasonic image makes good result in ultrasonic nondestructive evaluation fields, but mathematically or in software programming deconvolution process, the applied processing has many problems have such as inverse problem and high complexity on calculation. To calculate deconvolution algorithm, we have used personal computer including Pentium-4 processor and 512Mbyte RAM and have programmed the algorithm by Visual C++ complier which is possible to optimize itself. The implemented routine for deconvolution processing has have heavy time-consuming. On be half of experiment, we have experienced a few system shut-down by sensitivity of software algorithm. After investigation, it is verified to be caused non-robustness of algorithm itself by inverse problem. Therefore further study will be focused to solve robust inverse problem and low calculation complexity.

3. Conclusion

In this paper, the image enhancement method has been presented in order to detecting and measuring of narrow target as flaw from ultrasonic C-scan image. This has been processed the unknown priori information about distortion function and the statistics of noise in 1-D frame work.

In experiment we applied six images of ultrasonic C-scan to deconvolution processing and observed results of processing. The applied deconvolution process creates clear images as output which can decide the existence of flaw and measure size, width and depth of underlying flaw and especially, small flaw(assumed to be narrow target) in severe speckle noise circumstance detected but and also enhanced quality of images.

But the applied processing has many problems have such as inverse problem and high complexity on calculation. Therefore further study will be focused to solve robust inverse problem and low calculation complexity.

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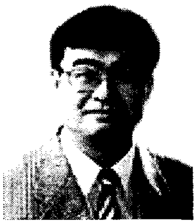

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