A NEW APPROACH FOR PRACTICAL TWO DIMENSIONAL DATA FUSION UTILIZING A SINGLE EDDY CURRENT PROBE

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INTRODUCTION

Interest in data fusion techniques have been growing in recent years due to the belief that a single NDE measurement may often be inadequate for providing sufficient information about the state of a test specimen. A variety of data fusion approaches have been proposed for combining results obtained by different methods, as well as different sensors, to provide comprehensive information about the material under test [1-4]. Techniques proposed to date range from blind superposition to approaches that involve the use of statistical and AI methods [5-7].

Prior work carried out by the authors have shown that data fusion techniques can be employed to combine data obtained from multiple sensors and at multiple frequencies [2,4]. These techniques assume a linear degradation process with additive noise. A least mean square(LMMSE) approach is used to deconvolve each of the signals from the sensors. The signals are then combined, or fused, using a weighting scheme that takes the signal-to-noise ratio (SNR) of the image into account. Work reporting the use of these methods for fusing ultrasonic and eddy current images, as well as eddy current data obtained at multiple frequencies, have been presented in the past. This paper focuses on the use of the method to combine the real and imaginary components of a single eddy current image.

In generating 2D eddy current images, the operator typically tries to rotate the signal trajectories to align the liftoff and the flaw signals along orthogonal directions. In practical situations, this results in two separate images. The images represent variations of the real and imaginary parts of the probe impedance. While the operator attempts to have the liftoff and the flaw components in separate images, a variety of factors result in leakage of the liftoff component into the flaw image and vice-versa. In practice, the operator selects one of the two images that he/she deems best. Alternatively the two images are "combined" by computing the magnitude image, although such a strategy would defeat the original intent of suppressing unwanted artifacts such as liftoff effects.

We propose utilizing LMMSE method for fusing the two images and generating a single representative image that combines the flaw signal components of both images. The proposed method does not employ any a priori information relating to the transfer function. This paper presents results and examines the effectiveness of the method in preserving information in the images. Examples showing that the integrity of the images are preserved are given.

DATA FUSION

Data fusion approaches can be generally classified as either phenomenological or non-phenomenological. Phenomenological approaches use the material/energy interaction process to guide the development of the fusion procedure. Although the concept underlying phenomenological approaches is attractive, they are extremely cumbersome to derive and implement. Non-phenomenological approaches, on the other hand, ignore the material/energy interaction process and attempt fusion utilizing data statistics or some other appropriate approaches [1,2]. This study focuses on data fusion techniques at the pixel level, which fall into the non-phenomenological category.

The LMMSE techniques requires knowledge of the degradation mechanism and the SNR. In nearly every practical application the transfer function for the degradation is not known. The proposed fusion method circumvents the problem by using the ratio of the spectrum of sub-images in the transfer domain [2,4]. The ratio of the spectrum of each sub-image can be viewed as a measure of the signal to noise ratio, of the sub-image. Additional details of the strategy are described in [2]. In order to apply the method systematically to all images, the first step is to decompose the images, in the frequency domain, into narrow spatial frequency bands. Doing so effectively isolates fine and coarse structures in the image [2,4]. Figure 1 demonstrates the simplified algorithm.

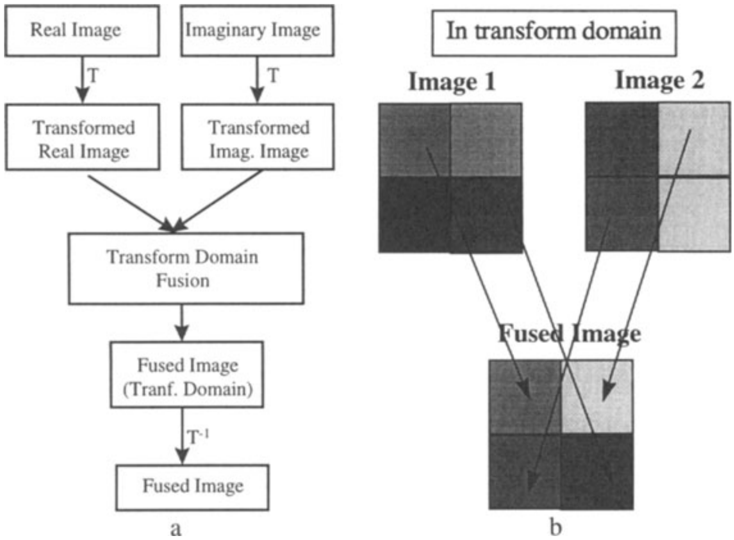


Figure 1. a) A simplified model for data fusion, b) Simplified depiction of the strategy for fusing data in the transfer domain. The images are shown with four segments.

The transformation can be performed utilizing a variety of methods including expansions using orthogonal as well as non-orthogonal basis functions. The orthogonal transformation methods include Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), and Wavelet based Transform. The results of this study are obtained implementing the discrete cosine transform, which only involves real variables and require modest computational effort.

RESULTS

Figure 2 depicts the instrumental setup that was used in this study for 2D eddy current imaging. All of the results are 256×256 C-scans. The fusion procedures are applied [2,4] utilizing Matlab™ on a Unix workstation platform.

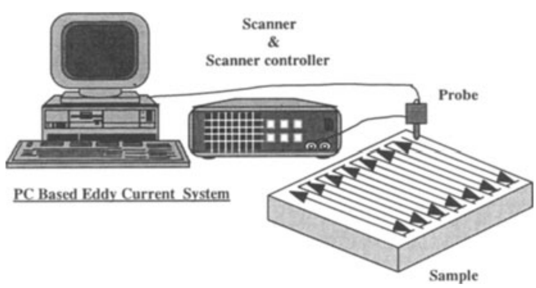
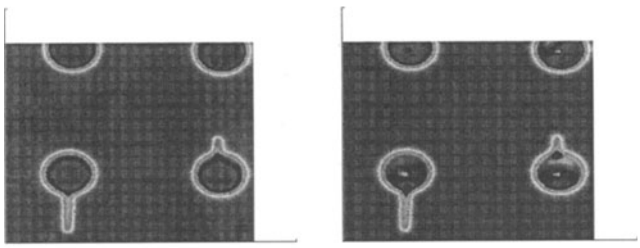


Figure 2. Experimental set up for data acquisition

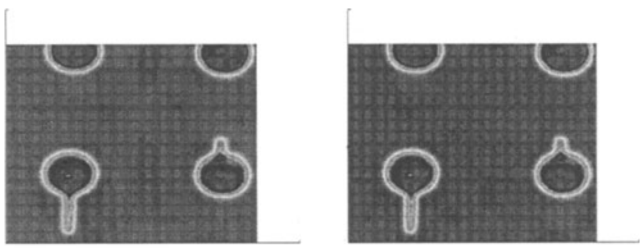
Utilizing the proposed fusion approach the two images can be fused into a single image containing "useful" information in both the real and imaginary parts of the impedance variation. Figure 3 shows the real and imaginary parts of a set of Al-rivets with EDM notch cracks. Figure 4 shows the fused results obtained using 6 and 12 segments. In this case, since the two real and imaginary images contain almost identical information, the fused image does not posses any additional or "novel" information.

Figure 5 shows a different scan result of a single Al-rivet with an EDM notch crack. Figure 6 shows the fused results obtained using 6 and 12 segments. In this case, the imaginary image contains more detailed information and is of better quality. In contrast the real image has very little to contribute. Consequently, the fusion algorithm does not produce an image superior to the original imaginary image.



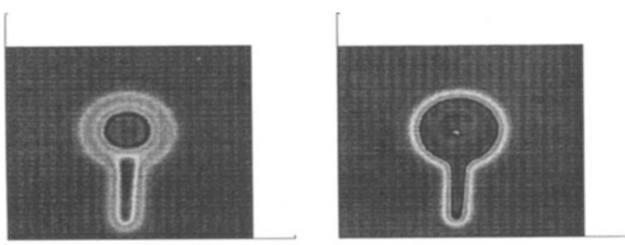
a b

Figure 3. Rivets with EDM notch cracks a) imaginary, b) real.



a b

Figure 4. Fusion results for a) 6 blocks, b) 12 blocks.



a b

Figure 5. Single rivet with EDM notch cracks a) imaginary, b) real.

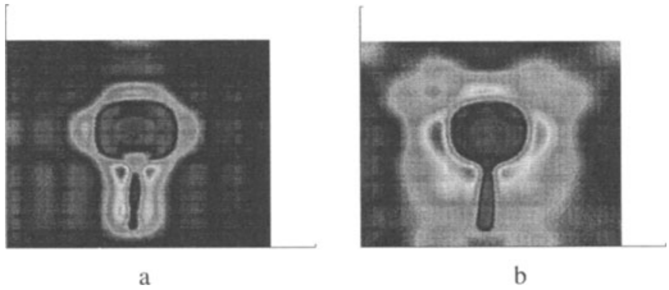


Figure 6. Fusion results for single rivet for a) 6 blocks, b) 12 blocks.

Figure 7 demonstrates the results for an EDM notch (Width 0.003, Length 0.02, Depth 0.010) on 7075-T6 Al sample. Figure 8 represents the fusion results for 6 and 12 segments. The original results indicate that the real image has better SNR and quality than the imaginary image. Consequently, the fused image does not enhance the quality of the real image.

Finally, Figure 9 demonstrates real and imaginary images of a coin. Figure 10 shows the fused images for 6 and 12 segments. The results clearly demonstrate that the fused image, in this case, contains more details that either of the real and imaginary images.

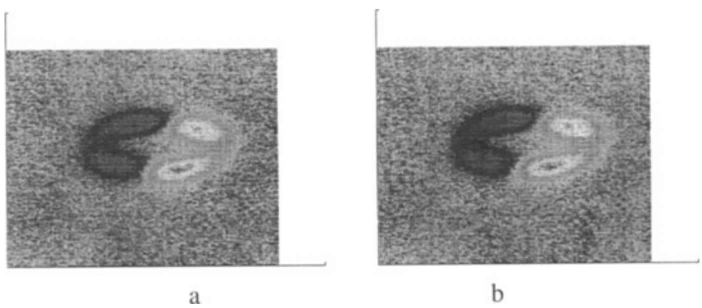


Figure 7. EDM notch (W:0.003, L:0.02, D:0.01) on 7076-T6 Al a) imaginary, b) real.

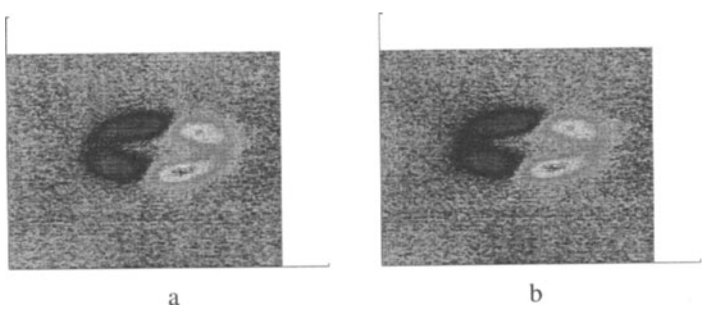
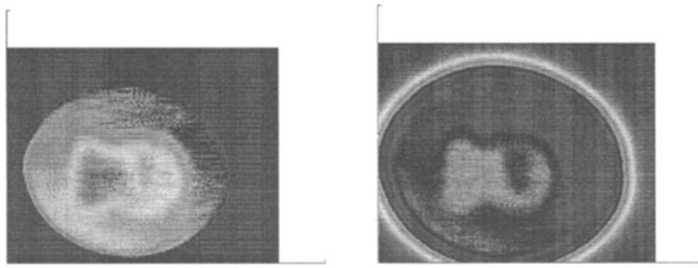
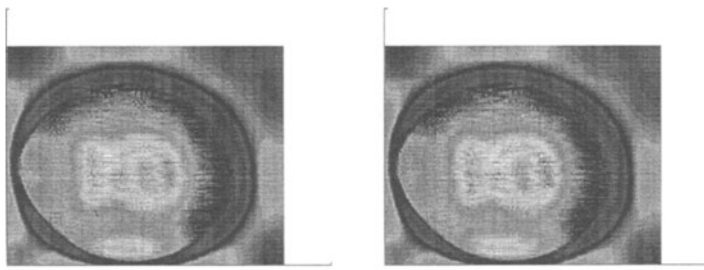


Figure 8. Fusion results for 7075-T6 Al sample a) 6 blocks, b) 12 blocks.



a b

Figure 9. 2-D Images of a coin a) imaginary b) real.



a b

Figure 10. Fused images of the coin a) 7 blocks, b) 12 blocks.

Based on many studied cases, we conclude the following:

a) The proposed method will always fuse the two images keeping the integrity the major features in each image.
b) When one of the images is significantly superior relative to the other, there is no need for fusion.
c) The proposed method is most effective when the two images are of similar qualities.
d) When the two images are equally good, there is no need for fusion
e) When the two images are relatively poor, the proposed method can most useful and effective.

CONCLUSIONS

In this paper we present a new scheme for applying data fusion methods for enhancing 2D eddy current images. The proposed method considers fusion of the real and imaginary images of the same scan to assist the operator in combining the information of both images. Qualitative results supporting the validity and limitations of the method as a practical approach for field application are presented.

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