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Segmentation of Thermogram Based on Region Based Technique using Split and Merge Method

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Abstract: ***The main aim of segmentation is to identify the Region of Interest for image analysis. The segregation of an image into meaningful structures is often an important phase in image analysis, object representation, visualization and also in various other image processing tasks. Image segmentation is mostly useful in applications like detection where it is difficult to process whole image at a time. In this paper Region based image segmentation is used to identify the delaminations in Thermographic image of Infrared Non-Destructive Testing. There are two basic techniques in Region based segmentation viz. Region growing method, splitting and merging method. New method based Split and Merge segmentation technique is employed to identify the defective regions in thermogram. Results obtained after segmentation as compared with state of art segmentation methods.***

Keywords: - Non Destructive Testing & Evaluation, Pulse Compression, Segmentation, Split and Merge Technique,.

I. INTRODUCTION

Glass Fiber reinforced Polymers (GFRP)**[10]** are more suitable materials for electronics, infrastructure and aircraft applications. Due to its high mechanical strength, light weight, corrosion and temperature resistant properties, thermal insulation, smooth internal surface and cost effectiveness GFRPs have become good alternatives for CFRPs which are brittle in nature **[1,17]**. The Basic principle of Nondestructive Evaluation (NDE) is the process of evaluating materials for discontinuities without destroying the serviceability of the part or system. The most commonly used Non Destructive Evaluation techniques are Liquid Penetrant, Electromagnetic Testing, Magnetic Particle ***Testing***, Ultrasonic Testing &Thermal Infrared Testing etc.**[1,10]** Out of these techniques Infrared thermography became most popular method to detect sub-surface anomalies in various composite materials. The reason is that it is a non-contact type technique which provides a fast, reliable and accurate temperature profile of any composite material surface.

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In order to identify the delamination defects in composite materials there exist many infrared thermographic techniques but a few of the techniques are frequently used. They are
Pulse Thermography (PT), Lock in Thermography (LT) [2] and Pulse Phase Thermography [3,16] etc. But these methods do suffer from certain limitations. Pulse Thermography technique is sensitive to the local variation of emissivity coefficient. This technique can mask the visibility of defect because of Non-Uniform heating. The setbacks of Lock in Thermography are penetration depth i.e. the depth range of thermal waves is limited and depends on thermal diffusion length and even though a steady state technique e it is slow. In order to overcome some of these limitations an alternative method viz. Frequency Modulated Thermal Wave Imaging (FMTWI) **[2]** has been suggested to identify defects in solid composite materials. To visualize the subsurface defects and to determine the size and shape of delamination in the thermographic sample, processing of image data is an important phase. In this paper a GFRP sample is used in which 25 square shaped Teflon inserts of various dimensions are placed at various depths. These inserts are checked by means of FMTWI. The proposed segmentation algorithm is implemented over GFRP sample and results are compared with existing segmentation methods.

II. FREQUENCY MODULATED THERMAL WAVE IMAGING

To minimize the setbacks of PT & LT, Frequency Modulated Thermal Wave Imaging **[4]** is introduced. In this technique the incident heat flux is changed by driving the heat sources by Linear FM signal. Linear frequency modulated heat flux is exposed on the surface of test object. The absorbed heat energy propagates through the object by conduction and produces a time varying thermal response over the surface of the object. Thermal response of heated object is monitored by Infrared camera controlled by the computer. Expression for the resulting temperature i.e. incident on the object is given by,

$$T(x,t) = T_0 e^{-x\sqrt{\pi/\alpha(f+Bt/\tau)}} e^{j(2\pi(ft+Bt^2/2\tau)-x\sqrt{\pi/\alpha(f+Bt/\tau)}}$$

$$= T_0 e^{-x\sqrt{\pi/\alpha(f+Bt/\tau)}}[\cos(k)+j\sin(k)] \quad (1)$$

From equation (1) the diffusion length (μ_{fm}) can be calculated as,

$$\mu_{fm} = \sqrt{\alpha/\pi(f+Bt/\tau)} \quad (2)$$

The thermal diffusion length (μ f_m) helps to scan entire depth of the sample in one cycle (f_m). The Thermal wavelength (λ) in case of FMTWI is given by

$$\lambda = 2\pi\mu = 2\pi\sqrt{\alpha/\pi(f + Bt/\tau)} \qquad (3)$$

From equation (3), it is clear that λ in FMTWI varies as a function of frequency. This indicates that the depth resolution for the detection of detects varies with depth.

III. EXPERIMENTAL SETUP

An experiment is conducted on Glass Fiber Reinforced Polymer sample with 25 square shaped Teflon inserts incorporated in it. The Teflon inserts with different dimensions are placed at different depths as shown in fig.1. An Infrared camera [15] with a frame rate of 450 Hz and 0.001 K temperature resolution with 320 x 256 pixel resolution is used to capture image sequences. A frequency modulated thermal wave stimulation of frequency ranging from 0.01Hz to 0.1 Hz in 100 sec is applied to the sample using two halogen lamps of power 1 Kw each. Thermal response is captured at a frame rate of 20Hz. The experimental set up is shown in fig.2.

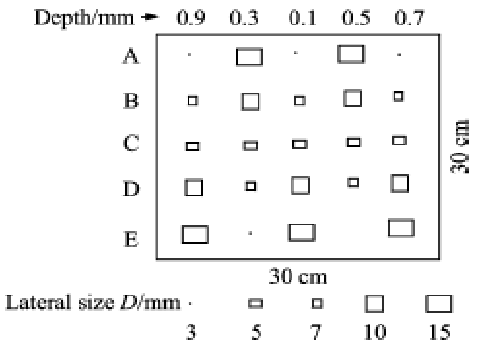

Fig.1 Layout of GFRP sample

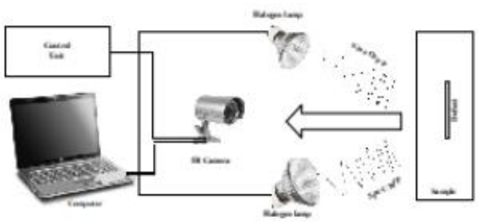

Fig.2 Experimental setup

IV. PRINCIPLE OF PULSE COMPRESSION

Pulse compression is a signal processing technique commonly used by radar and sonar to increase the range resolution as well as the signal to noise ratio. This is achieved by modulating the transmitted pulse and then correlating the received signal with the transmitted pulse. This provides better defect detection capability and depth resolution equal to that of short duration high peak power pulse techniques even in the presence of noise.

The fig.3 shows the principle of pulse compression. Let $s(t)$ represents reflected signal i.e. reflected from a target. This signal is similar to the transmitted wave signal but its amplitude has been reduced. Let us consider a matched filter whose time response is matched to the transmitted wave, i.e., its impulse response $h1(t)$ is the time inverse of $s(t)$. The same concept is applied thermogram by taking cross correlation between signal from defective area and non-defective.

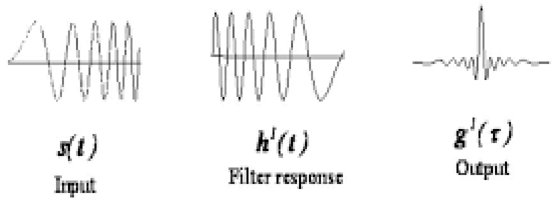

Fig.3.Illustration of principle of pulse compression g1(v), for a linear frequency modulated (chirp) input waveform s(t), and its matched filter h1(t).

V. SEGMENTATION OF THERMAL IMAGES

Thermal Imaging [6] is used for fault diagnosis in materials and it uses thermal camera for images. Identification of defective areas is a major task in thermographic images. Image segmentation is an effective method that helps to analyze thermographic images both quantitatively and qualitatively. In this paper segmentation is used to find the size and depth of defects in thermographic images taken for a GFRP material. In general, Segmentation is done through two steps such that in the first step the image will be decomposed into regions for analysis. The second step is used to perform a change of representation of image. An exhaustive survey was carried out on segmentation techniques and their performance metrics, in the past. Basically there are three types of segmentation techniques viz. Thresholding, Edge detection and Region based segmentations. Thresholding [7] is one of the popularly used segmentation methods for discriminating foreground from background by choosing a threshold value T. This makes it suitable for NDT & Evaluation. But the performance of Thresholding techniques has the following limitations: small size of the object large variances of the object and background intensities and large amount of noise etc. There are several segmentation based algorithms have been proposed viz. Otsu's method [9], Histogram based thresholding [11], Clustering based thresholding [12], Entropic thresholding and Fuzzy Thresholding[13].

VI. PROPOSED SEGMENTATION METHOD

In the present work Region based segmentation approach is implemented on thermogram. Before implementing segmentation the best thermogram has been chosen from Frequency Modulated Thermal Wave Imaging technique. The best thermogram was then Pulse Compressed to obtain good PSNR with reduced Noise in the image. Split and merge segmentation [8] is a region based image segmentation technique used to segment an image.

The main goal of splitting and merging is to differentiate the homogeneity of image. It depends on the concept of quad tree. This means that every node in the tree contains four descendents and root of the tree represents entire image.

This means the proposed algorithm attempts to divide an image into uniform regions and begins with a whole image and divides it up such that the segmented pixels are more homogeneous than the whole. However, Level of subdivision depends on the problem being solved. The main idea in this segmentation technique is to identify different regions in an image that have similar features (gray level, colour, texture, etc.). The input image is divided into sub regions until the sub regions become small enough for segmentation. Then final segmentation results are obtained by using appropriate merging rule.

1. Identify criteria for splitting like mean, variance and texture etc.
2. Start with the full image and split it into sub-images.
3. Check each sub-image. If it is not uniform, split it again into sub-images.

After each split, a test is required to determine whether each new region needs subsequent splitting. The criterion for the test is the homogeneity of the region. There are several ways to define homogeneity, some of them are:

Uniformity- the region is homogeneous if its gray scale levels are within a given threshold.

Local mean vs global mean - if the mean of a region is greater than the mean of the global image, then the region is homogeneous

Variance - the gray level variance is defined as

$$\sigma^2 = \left(\frac{1}{N-1}\right)\sum_{(r,c)\in R}[I(r,c)-I]^2$$

Where r is row and c is column, N is the number of pixels in the region.

4. Repeat step-3 until no more splitting is possible.
5. Compare sub-images with the neighboring regions and merge if they are uniform.
6. Repeat step-5 until no more merging is possible.
7. After completion of division, each region subjected to different threshold value by Adaptive thresholding approach.

8 Finally, the images are merged to obtain whole image.

The splitting results in a partitioned image into 2 levels are as shown below:

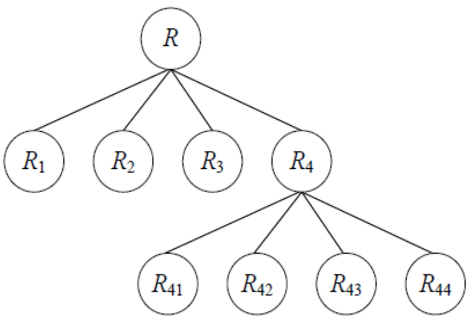

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Fig.5. Structure of Quad Tree

Each level of partitioning can be represented as a tree -like structure.

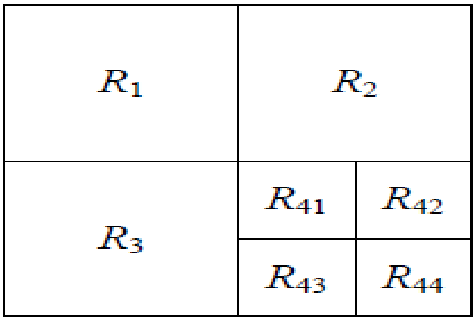
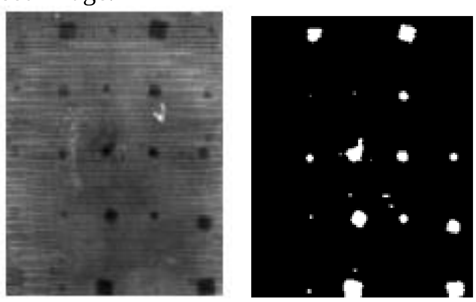


Fig.6. Partitioned Image

VII. RESULTS AND DISCUSSION

The proposed Split and Merge segmentation algorithm is applied over pulse compressed image. This is the image of a Glass Fiber Reinforced Polymer specimen, taken using FMTWI [14] technique, in which 25 Teflon inserts of various dimensions are incorporated at various depths. The results shown indicate that the proposed segmentation method shows good performance in qualitative measures. When compared with thermogram, the segmented image illustrates more information about the defects. The Proposed segmentation is based on the assumption that neighboring pixels in one region have similar value. The process is to compare one pixel with its neighbours. If the comparison process is successful then the pixel can be considered belonging to the cluster as one or more of its neighbours. This process became successful in determining subsurface defects in GFRP specimen image. The results are compared with various segmentation techniques Viz. Otsu's method, Adaptive Thresholding, K-means clustering and FCM as shown in fig. The tabulated results emphasize that the proposed method is able to identify all the defects in the specimen object when compared with other segmentation methods. The proposed algorithm is able to identify all the 25 defects in the image with 100% accuracy. The accuracy rate of other segmentation methods is 60%, 88%, 64% and 56% with Otsu's, Adaptive Thresholding, K-means and FCM methods respectively.

The following fig. illustrates the subsurface defects identified by various segmentation techniques from a pulse compressed image.



(a) (b)

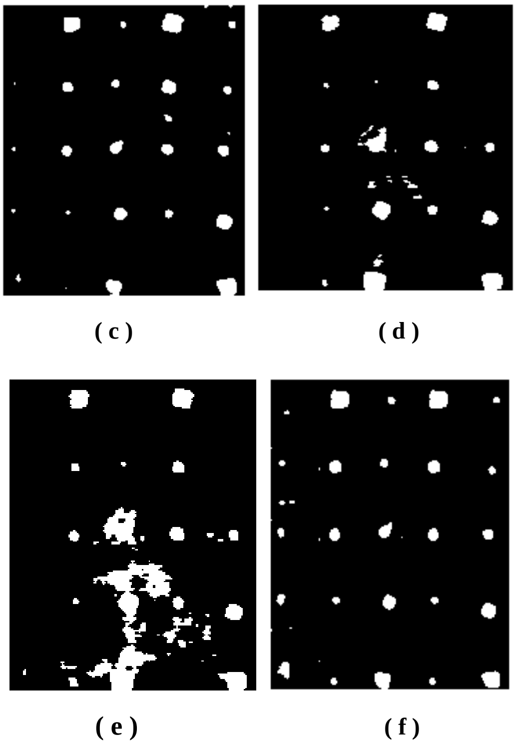
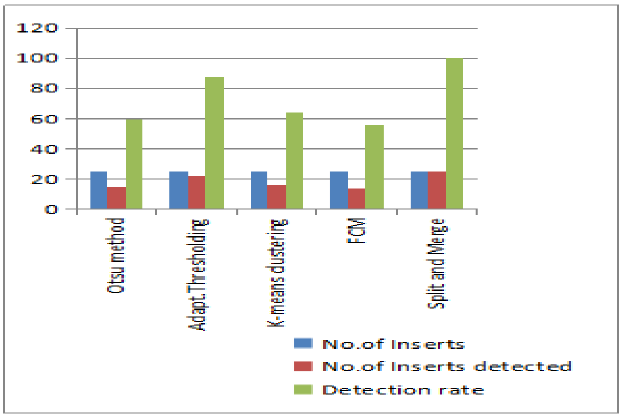


Fig. 7. Comparison of outputs of various segmentation methods applied on pulse compressed image. (a) Pulse compressed image (b) Otsu's Method (c) Adaptive Thresholding (d) K-Means Method (e) F C M (f) Proposed Method

Table 1 Segmentation method vs. no. of inserts detected

Segmentation method	Number of Inserts	Number of inserts detected	Detection rate (%)
Otsu	25	15	60
Adpt. thresh	25	22	88
K means	25	16	64
FCM	25	14	56
Split and Merge	25	25	100

Table 2 Comparison of segmentation methods vs. Detection rate



VIII. CONCLUSION

Segmentation is one of the most prominent techniques to identify and illustrate subsurface defects in a thermogram. Conventional algorithms couldn't be able to identify the defects properly with respect to number and size. In this paper Split and Merge technique is implemented for the segmentation of NDT images. This method mainly depends on the assumption that neighboring pixels within a region have same value. If similarity criteria is success the pixel can be considered belongs to the cluster as one or more of its neighbours. This concept helped in improving the defect detection capability of system for NDT images. The no. of defects in the GFRP specimen was calculated and their shape was observed by applying various segmentation techniques viz. Otsu's method, Adaptive Thresholding and FCM. It is concluded that an appreciable performance was observed using proposed method in qualitative measure such as size and number of defects.

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