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Advanced Image Enhancement of Ultrasonic Scan Images For Intelligent Quality Inspection of Adhesively Bonded Joints in Ceramics

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Abstract— **Quality assurance is the systematic monitoring and evaluation of the various aspects of a product to maximize the probability that minimum standards of. To achieve zero defects ("Zero PPM") output cost-effectively, manufacturers are making the commitment to move to online, automated Non Destructive Testing (NDT) methods. One of the major difficulties with real-time image acquisition is Errors due to diffraction /refraction of scanning wave due to continuous scanning of scenes. The proposed NDT method is a interface predictive coding, is one of the most powerful image coding techniques that can control the blur due to diffraction /refraction which may be even internal fault in nature and measure them by intelligent object detection and feature extraction tools. The paper introduces the Neighbourhood Expectation Maximum based automated visual quality inspection and NDT employed using intelligent image enhancement in ultrasonic pulsed scan images**

Keywords— **Adhesive Bonds, Ceramics, Intelligent quality inspection, Image Enhancement, Neighbourhood Expectation Maximum algorithm**

I. INTRODUCTION

For over sixty years, the nondestructive testing (NDT) or nondestructive evaluation (NDE) of materials has been an area of continued growth. The need for NDT has increased dramatically in recent years for various reasons such as product safety, in-line diagnostics, quality control, health monitoring, and security testing, etc. Besides the practical demands the progress in NDT has a lot to do with its interdisciplinary nature [2]. Non-Destructive Testing and Evaluation (NDT & E) plays a crucial role in ensuring the reliability and performance of jointed components. The NDT methods are able to verify the structural integrity and compliance to the standards by examining the surface and subsurface of the joints parts as well as the surrounding test object.

Manufacturing of ceramic parts in the requisite precision and durability as the imperfection in the ceramic leads to cracks, which can lead to potentially dangerous equipment failure. In order to encourage the expanded application of engineering ceramics, the use of appropriate nondestructive evaluation (NDE) approaches is critical to effective process control and the assurance of high-quality products and reliable performance in service [3].

Adhesive components and structures are widely used in almost all industries, especially in ceramics. With the awareness of the fact that Adhesive bond is the weakest link in a component, and most failures of components are related to joint and element performance, fabricating jointed components with high quality and ensuring their performance and reliability in service is critical [4]. In this regard, various nondestructive testing (NDT) techniques have been developed to assess the joint quality without destroying the jointed components. Ultrasonic methods are still most popular because of its capability, flexibility, and relative cost effectiveness. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more [6][7].

II. ULTRASONIC TESTING PE TESTING

A typical UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices [8][9]. A pulser/receiver is an electronic device that can produce high voltage electrical pulses. Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen.

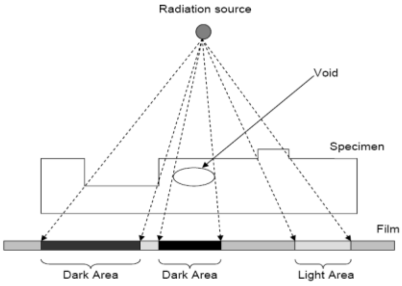

Fig 1: Basic design of AE scanner

In the applet below, the reflected signal strength is displayed versus the time from signal generation to when a echo was received. Signal travel time can be directly related to the distance that the signal traveled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

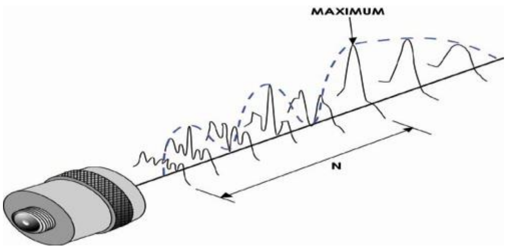

Fig 2: Wave distribution to through axis of propagation

These test systems use one or more ultrasonic transducers, which are moved over the surface of the unit under test (UUT). As the transducer is moved over the surface, it is pulsed and receives echoes from various surfaces. This process is repeated many times a second - sometimes more than 50,000 times per second (>50 kHz). There are several pieces of the test system that must work together to get expected results. The following list includes the steps, and the accompanying hardware and software pieces, required to get one pulse and the subsequent echoes:

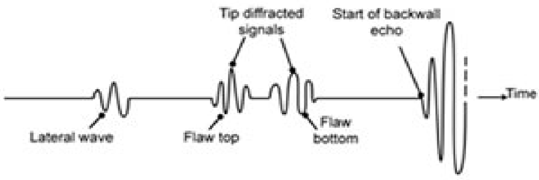

Fig 3: Wave distribution to scanner

III. RELATED WORKS AND STRATEGIES

As same source produces all scanning wave they are more coherent and identical in nature. Ultrasounds have more reflective properties than restrictedness [10][11]. Due to multiple reflections, when waves interact, they superimpose on each other, and the amplitude of the sound pressure or particle displacement at any point of interaction is the sum of the amplitudes of the two individual waves. Thus it creates an interference pattern which should be eliminated. Consider two identical waves that originate from the same point and when they are in phase (so that the peaks and valleys of one are exactly aligned with those of the other), they combine to double the displacement of either wave acting alone. When they are completely out of phase (so that the peaks of one wave are exactly aligned with the valleys of the other wave), they combine to cancel each other out. When the two waves are not completely in phase or out of phase, the resulting wave is the sum of the wave amplitudes for all points along the wave. Since it is important to know the part of the measured attenuation contributed by diffraction in the ultrasonic field. In certain cases, particularly at the lower megacycle frequencies, the diffraction loss can be much greater than the attenuation intrinsic to the specimen. The diffraction loss in decibels has been computed elsewhere as a function of the distance the ultrasonic pulse travels back and forth in the sample.

The sound travels faster in some materials than others. Sound waves travel outward in straight lines from their source until something interferes with their path. When sound changes mediums, or enters a different material, it is bent from its original direction. This change in angle of direction is called refraction. Refraction is caused by sound entering the new medium at an angle. Because of the angle, part of the wave enters the new medium first and changes speed. The difference in speeds causes the wave to bend. In adhesive bonds where there is a variation of materials to a small extend make a different image as that of original one due to successive refraction [12].

Both of the above modes of errors are characterized by a sudden variation in amplitude or pixel values in a definite region of image or range of image which could be identified and smooth and continuously distributed image pixel levels are made using intelligent image processing methods [13].

Schuöcker attributed the periodic striation formation to a pulsation of the light layer on cutting front where fluctuations in the laser beam energy absorption causes reactive thickness and temperature oscillations of the layer (Schuöcker 1987) [14]. Bar-Wave calibration of practical AE sensors which showed a advanced mode of error correction and calibration for bar waves, (Ono K., ChoH. and Matsuo,“2010) [15]. A comparison of Acoustic Emission Signal, its properties and precisions has ben studied and proposed where a mathematical approach has been implemented (F. Vlašic, P. Mazal, F. Hort ,2010) [16]. But most of the baouve method needs higher precision and any variations from preset level make system less accurate. K. Ono, H. Cho and T. Matsuo proposed a modified method of calibration in 2011 which is more advanced [17].

Most of the above methods are based on sensor array correction, mechanical modeling and control circuit implemented. But these methods lack of system environmental friendly and need redesign if working characteristics are altered.

The proposed method uses Neighbourhood Expectation - Maximization Algorithm on the enhanced image which is pre-processed so that it fist sort the pixel levels to find largest consecutive variation among regions and apply mean threshold level to compare each pixel with the same and diffracted or refracted patterns are eliminated [18].

IV. MODELING OF PROPOSED SYSTEM

The testing principle is based on the influence of adhesion quality on the amplitude of ultrasonic signal, reflected from the interface between layer and main ceramic [6][7][19].

Within the pulse-echo method, a piezoelectric transducer using its longitudinal axis situated perpendicular to and installed on or near the top of test material can be used to transmit as well as receive ultrasonic power. The ultrasonic surf are reflected through the opposite face from the material or through discontinuities, layers, voids, or inclusions within the material, and received through the same transducer in which the reflected energy is changed into an electrical transmission.

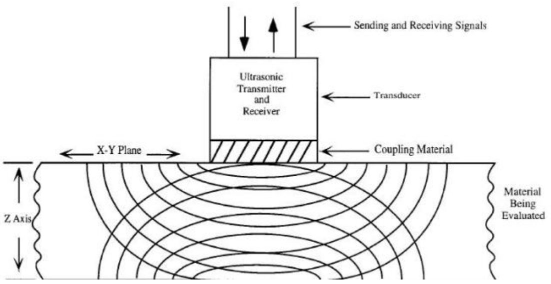

Fig 3: Ultrasonic Transreceiver Scanning System

The electrical transmission is computer prepared for display on the monitor which shows the relative thickness from the material, depth to the material where flaws can be found, and, in which the flaws are positioned in the X-Y airplane.

The development of Computed Ultrasonic Spectrography has improved the conventional UST to a filmless testing method. Computer aided inspection uses very similar equipment as those of conventional UST. An imaging plate is used in place of a film to create the image matrix. The imaging plate contains acoustic stimulable materials, which store the radiation level received at each point in local energies When the plate is put through the scanner, a scanning laser beam causes the electrons to relax to lower energy levels, emitting light that is measured to compute the digital image.

Once the image is acquired it then preprocessed, analyzed and implemented intelligent object detection algorithms. The image is enhanced for diffraction and refraction error correction by advanced image restoration methods.

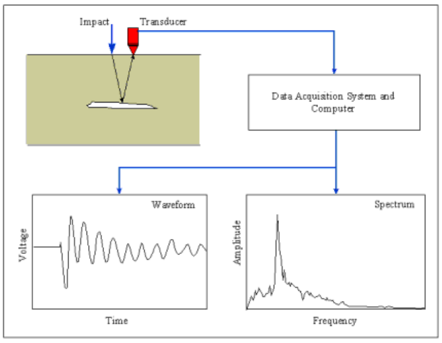

Fig 4: US Intensity Image matrix Formation

In order to achieve higher prediction model, a frequency distribution image is also taken correspondingly to compare detect the fringe pattern or adhesive bond position characterized by rate of frequency about position. From the enhanced image obtained, the Neighborhood Expectation - Maximization process is executed to eliminate diffraction or refraction error in image.

V. IMAGE PRE-PROCESSING

Image preprocessing method is based on a series of steps that are designed to counter the effects of illumination variations, local shadowing and highlights, while still preserving the essential elements of visual appearance for use in recognition of flaws or cracks. There are executed some basic operations to enhance the image as follows

A. Gamma Correction

Gamma Correction is a nonlinear gray-level transformation that replaces gray-level I with I (for > 0) or log(I) (for = 0), where 2 [0,1] is a user-defined parameter. It has the effect of enhancing the local dynamic range of the image in dark or shadowed regions, while compressing it in bright regions and at highlights.

B. Noise removal

Max-median/Max-mean filters effectively remove noise and preserve geometrical features of the signals.

$$y(m,n)=max[z,z ,z ,z]$$

C. Fixed Pattern Noise

Fixed pattern noise (FPN) is the result of differences in responsively of the detectors to incoming irradiance. It is a common problem when working with focal plane arrays (FPA). FPN for a particular configuration can be recovered from a blackbody image for later subtraction from the image sequence.

D. Badpixels

A *bad pixel* can be defined as an anomalous pixel behaving differently from the rest of the array. For instance, a *dead* pixel remains unlit (black) while a *hot* pixel is permanently lit (white). In any case, bad pixels do not provide any useful information and only contribute to deteriorate the image contrast. A map of bad pixels is generally known from the FPA manufacturer or they can be detected manually or automatically, the value at badpixel locations is then replaced by the average value of neighbouring pixels.

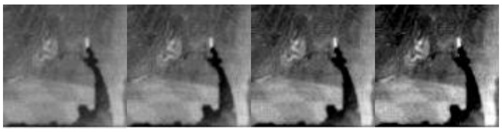

Fig 5: Image Enhancement

VI. NEIGHBOURHOOD EXPECTATION - MAXIMIZATION METHOD

In the Expectation Maximization (EM) approach chose to apply the transformation process at the structural level rather than simply at the image level [18]. This not only provides the means for building robustness against variability but also provides a mechanism to segregate the pattern from other disturbances and interferences. Furthermore, to achieve these objectives, the approach emphasizes on the flexible identification of diffraction or refraction patterns (or primitives) of a ceramic in the recognition process of the entire object. Moreover, high performance and a robust but efficient recognition process should be based on hierarchical threshold analysis as against to many one-stage recognition algorithms. In such a hierarchical process, the focus should shift in subsequent stages from the initial objective of segmentation and approximate recognition of a large variation in pixel levels of consecutive regions of the pattern to finally improving the recognition accuracy. Such a strategy is also essential for maintaining generality in the recognition process for which Neighborhood Expectation - Maximization Algorithm is a essential one [20][21].

Thus the basic idea behind this method is to determine a group of consecutive pixels that differs from the neighboring values greater than a definite threshold level and to find mean of them and perform the same for adjacent levels till it reaches mean error value.

The algorithm design is as follows

1. Simulate the patience sorting game to get all the longest increasing subsequence of pixels within O(*n* log *n*) which is taken as sorting pixel.
2. Moore Neighborhood is found for a selected sorting pixel
3. Given an image with gray-level range, compute the gray-level frequency distribution and histogram.
4. Initial Gaussian components are found.
5. Find mean threshold level T_{opt}

$$T_{opt} = \frac{1}{m}\sum_{i=1}^{m}\mu$$

6. The EM is used to determine the Gaussian parameters(ω_j, π_j μ_j, σ_j)
7. If the estimation error for step (3) is less than a predefined threshold or the number of iteration is greater than T, stop and output results.
8. Otherwise, go to step (3).
9. Add a new Gaussian component and perform step (2) again.
10. In the end, we choose the optimal threshold among a definite which is the average of these means m = μ,

VII. RESULTS AND DISCUSSIONS

The measurements are performed using pulse response technique with 5 MHz impersion transducers. The designed ultrasonic system consists of the electronic unit, scanner, testing tank and IBM PC type computer with specialized software. The test results can be presented in the usual A, B, C scan modes including options of signal processing, which allow determine the zones of delamination. The results and discussions show that method is able to determine diffractive and refractive errors using the proposed method.

The figure show below describes the blur caused to diffraction and effect of waves during medium change.

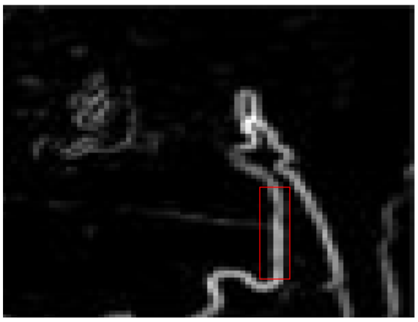

Fig 5: Effect of Diffraction/ Refraction Blur

Fig 6: Extracted from Diffracted/ Refracted

It was also observed that lower that AE frequency, higher the errors and less detraction. The most of the previous methods uses random selection of pixels initially which is less accurate and is eliminated in this method. The conventional Neighborhood algorithms take mostly 8*8 mode or diagonal mode which takes more iteration time. Since there implemented Moors criteria which are more advanced in selection of neighbor a less time for execution. The proposed obtains near-to-optimal data models, requiring far less computational time than other proposals this makes it appealing to be used in practical problems. The proposed algorithm refines iteratively an initial selection constituted by only one pixel level and then Neighborhood of the one, augmenting its order incrementally until a good model is obtained.

Fig 7: Enhance image using Maximum Expectation ($To_{pt1} < To_{pt1}$)

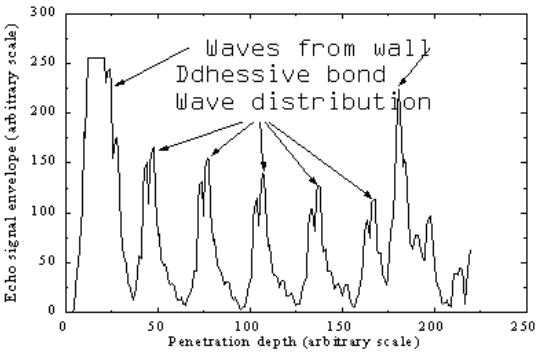

Fig 8: Wave distribution obtained during simulation

VIII. CONCLUSION

As has just been discussed, a number of advanced can be implemented for image quality and accuracy of detection of image based acoustic emission methods. With the use of image enhancement techniques, the errors due to diffraction of waves and affects due to medium change in acquired, image is decreased. Advanced image processing and enhancement techniques, is applied to improve the data usefulness. The Neighborhood maximum expectation algorithm showed many advantages like less time consuming, less iterative and avoids defects of random selective iteration. The proposed system shows many advantages over conventional system in the effective and accurate detection of defects during bonding in ceramics.

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