COMPUTER EVALUATION OF REAL-TIME X-RAY AND ACOUSTIC IMAGES

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ABSTRACT

The weakest link in the inspection process is the subjective interpretation of data by inspectors. To overcome this troublesome fact computer based analysis systems have been developed. In the field of nondestructive evaluation (NDE) there is a large class of inspections that can benefit from computer analysis. X-ray images (both film and fluoroscopic) and acoustic images lend themselves to automatic analysis as do the one-dimensional signals associated with ultrasonic, eddy current and acoustic emission testing.

Computer analysis can enhance and evaluate subtle details. Flaws can be located and measured, and acceptance decisions made by computer in a consistent and objective manner.

This paper describes the interactive, computer-based analysis of real-time x-ray images and acoustic images of graphite/epoxy adhesively bonded structures.

INTRODUCTION

In general, there are three classes of inspection that lend themselves to automatic, computer-based analysis; those tasks that are too dangerous, those that are too difficult, and those that aren't worth peoples' time. The chief example of the dangerous class is inspections around nuclear reactors. There is a big effort under way to automate these tasks. Jobs in the not-worth-it catagory have been automated for years. These are usually single-purpose system-checking the presence of labels on bottles, for example. In NDE there exists a class of inspections much too difficult for inspectors to perform with an acceptable degree of consistency. These involve assessing complex visual data. It is this type of inspection that will be discussed in this report.

Although systems for the computer-based processing of visual data have been in use for years, these methods have not found wide acceptance on the factory floor. They have for the most part been used in laboratory. Over twenty years ago Moore[1] worked in metallography. Janney[2,3] and his associates at Los Alamos have described many applications of computer-based image analysis. Nevatia[4] surveyed the industrial field in 1978. Pearson[5,6], Firschein[7,8], and Eppler[9] have described techniques for the fully automated inspection of defects imaged on x-ray film. Many more examples could be cited.

The purpose of our work is to develop, by building on these previous efforts, an interactive system that will analyze x-ray and acoustic images. This paper presents examples of computer evaluations of real-time x-ray and acoustic images that are too complicated for inspectors to evaluate accurately.

METHODS

The steps listed below are used to acquire and evaluate images.

X-ray

Images on film or formed on a fluoroscopic conversion screen are scanned with a TV camera. To obtain accurate measurements of defect size the parameters listed below are rigidly controlled.

- o Stability, sweep linearity, geometrical distortion
- o Block level and shading
- o Output signal voltage, synchronization, S/N ratio, resolution
- o Blemishes, persistence, microphonics

Acoustics

Acoustic images are acquired by a through-transmission, water coupled, scanning system which moves the sending/receiving transducers horizontally across a fixed test piece. At the end of one horizontal scan line the transducers move vertically to the next station and scan back again horizontally. This pattern is repeated for 512 vertical steps. Each horizontal line contains 512 pulses, with each pulse digitized to eight bits. The acoustic image is stored in memory under computer control where it can be evaluated automatically.

Video

Images on video tape collected at remote inspection sites can also be processed. The taped video signal is sampled, digitized, and stored in image memory. The video recorder should have 525 line interlaced format, the ETA RS-170 standard. Tape motion needs to be controlled by an external sync signal through a capstan servo on the video recorder.

Image Evaluation

Evaluation methods have been described previously[10]. To review briefly; processing is divided into three parts:

- Noise Reduction
- Thresholding
- Measurement

These techniques are familiar. The important consideration for inspection is how these techniques are applied. Inspectors have always used reference images to evaluate complicated x-rays. The American Society for Testing and Materials (ASTM), publishes x-ray pictures showing flaws in castings. Each condition depicted is given a grade. The inspector compares the test image with the reference images and assigns a grade to the test image. With computer evaluation, this subjective method is replaced by a repeatable, quantitative evaluation of the test image, an evaluation that doesn't merely grade the image but actually counts and dimensions each defect. This improved evaluation is absolutely necessary to establish accurate correlations between inspection data and performance data.

EXAMPLES

These examples are taken from the real-time x-ray and acoustic imaging of graphite/epoxy composite structures. Unlike homogeneous metallic structures, composites as the name implies are a conglomeration of flaw-like indications. Often as many as 40 or 50 per square inch. It is difficult for an inspector to count and measure these indications accurately.

1. Real-time x-ray evaluation of destructive test specimens.

   Over 1000 tensile and compression test specimens were inspected by real-time x-ray and the resulting images evaluated by computer. Figure 1 is the digitized x-ray image of a group of tensile specimens. The operator evaluates each separately. Figure 2 is the binary image of one particular specimen. Figure 3 shows the printout listing the voids in the specimen. All 1000 specimens were evaluated in this manner. Based on this data, realistic acceptance standards were established for graphite/epoxy structures, standards less rigid than those based on theoretical considerations.

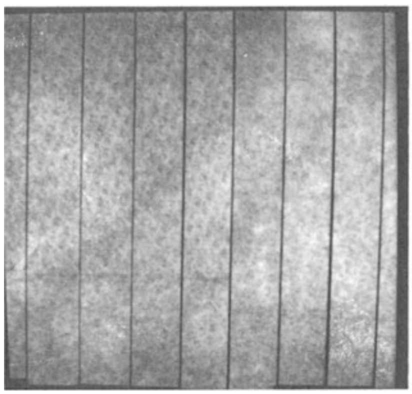

Figure 1. Tensile Specimens

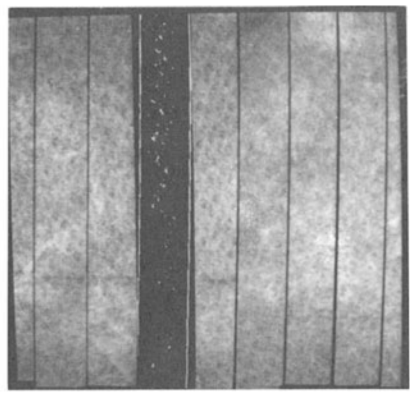

Figure 2. Binary Image

NUMBER OF DEFECTS GROUPED BY SIZE BINS:

SIZE BIN				NUMBER
	<	.050	INCHES	45
.050	-	.080	INCHES	12
.080	-	.120	INCHES	8
.120	-	.180	INCHES	3
.180	-	.250	INCHES	0
	>	.250	INCHES	1

Figure 3. Defect List

2. Adhesive bond evaluation by acoustic imaging

Graphite/epoxy composites cannot be joined by welding as can metals and thermoplastics. The choice is between adhesive bonding and mechanical fasteners, with bonding the preferred method mainly due to lower weight and better strength. All-bonded graphite/epoxy composite structures have not as yet been built primarily because it is extremely difficult to inspect for bond integrity. Accoustics is the preferred modality for inspecting adhesive bonds. Chaskelis[11] has approached the problem from the fundamentals of ultrasonic wave propagation in solids. Williams[12] has expanded on this work using pattern recognition to assess adhesive properties. Our approach is strictly deterministic, no bond properties are measured as such. Test specimens are fabricated in a way to produce a wide variety of adhesive bond strengths. The bonded region is then probed with acoustic energy in the 10 to 50 MHz range. The methods discussed above are used to count and measure pixels below a threshold. These numbers are then correlated with adhesive bond performance during pull tests.

Figure 4 is an acoustic image of the bonded region of a test specimen. Figure 5 superimposes the histogram of the intensity values over the image. Figure 6 is the binary image and Figure 7 the list of indications below the threshold. The total area of the indications is then correlated with bond strength.

SUMMARY

Accurate and consistent evaluations of real-time x-ray and acoustic images of graphite/epoxy structures often exceed the capabilities of inspectors. Computer evaluation is required.

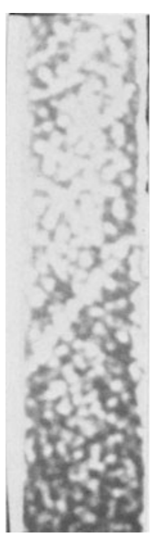

Figure 4. Acoustic Image of Bond Region

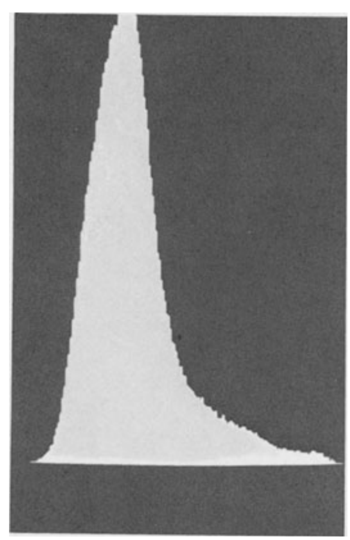

Figure 5. Histogram

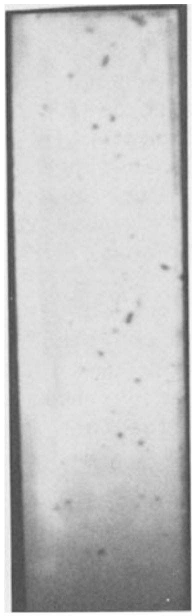

Figure 6. Binary Image

DEFECT OUTPUT LIST

GRP.NO.	CNTR X	CNTR Y	QUMCAV
1	186	26	2
3	187	30	12
4	194	30	20
5	209	32	21
2	202	31	78
6	193	44	90
7	205	55	92
8	186	59	99
9	182	79	114
10	168	83	121
11	142	171	127
12	145	173	129
13	129	329	130
14	127	443	131
15	146	460	132
16	127	464	133
17	198	467	134
18	129	478	136
19	133	478	137

Figure 7. Defect List

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