COMPUTERIZED ULTRASONIC TEST INSPECTION ENHANCEMENT SYSTEM FOR AIRCRAFT COMPONENTS

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INTRODUCTION

Current ultrasonic inspection of aircraft components often employs standard immersion test techniques and equipment. This includes the use of an immersion test tank, C-scan recorder, flaw detector and bridge system. As a direct result of the increasing needs on the system, a program was initiated to increase the inspection rates and the quality of the inspection.

The Computerized Ultrasonic Test Inspection Enhancement (CUTIE) System described in this paper consists of a TESTECH LS100 ultrasonic scanning device with an LS86 microprocessor based control, a KB-6000 ultrasonic flaw detector, an IBM PC, IBM XT, and a PrintaColor printer/plotter. The new system configuration allows the operator to define a scan plan, store it on disc, and recall the test scheme when necessary. This minimizes, to a great extent, the operator interface with the test bridge and expedites the test set-up.

The conventional technique of plotting the test results has been the C-scan using grey scaling. This technique is very subjective and requires proficient operators. In addition, data evaluation can be somewhat dissimilar from operator to operator. Therefore, the data is being enhanced by using a color scheme. Colors are assigned to various amplitude signals, which clearly display the severity of the discontinuities. This helps the inspector to make the proper decision about ambiguous areas.

Additional analytical procedures are available through computer software, which allow the inspector to further enhance the test results. The operator can zoom in on an area of concern, the X and/or Y axis can be expanded, and additional color versus amplitude assignments can be made.

The system is now in the process of being placed into service. However, development is continuing to employ an eight element array transducer, and perform flaw characterization via signature analysis using a two hundred megasample per second data acquisition system.

Each improvement described is pursuant to the task objective of increasing the inspection rate, advancing the quality of the inspection, and automating the evaluation of discontinuities which will ultimately reduce the inspection costs.

PROGRAM GOALS

The primary objective of our development program was to automate the inspection technique and evaluation of discontinuities for aircraft components, while maintaining reasonable implementation costs and reducing the overall inspection costs. A secondary objective was to design a system which would allow easy modification of the system for implementation of new innovative ideas. These objectives would permit us to benefit from the initial modifications within a reasonable time frame, and minimize the impact on the inspectors, while continuing to investigate new schemes to push the state-of-the-art.

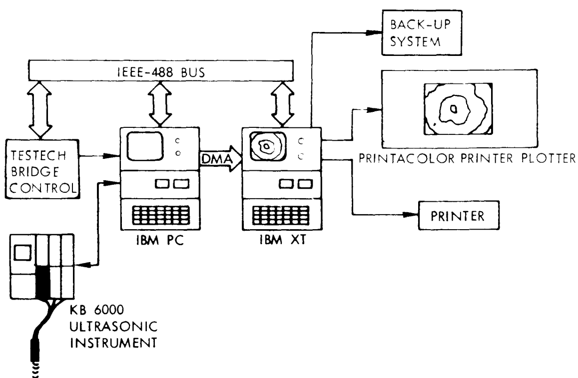

Figure 1. CUTIE SYSTEM CONFIGURATION

The ultrasonic immersion test system was the best candidate for automation. The existing system consisted of a 52 foot long, 6 foot wide and 3 foot deep immersion test tank, bridge control system, ultrasonic flaw detector and a C-scan recorder. This test scheme was redesigned and the resulting test configuration is depicted in Figure 1 and summarized below:

1. A TESTECH microprocessor based bridge system was installed on one end of the immersion test tank. Refer to Figure 2.

2. A PrintaColor ink jet plotter was chosen to display the C-scan results in lieu of the conventional grey scale C-scans.

3. An IBM PC and XT were installed in a control room to be used for system control, data acquisition and data evaluation.

4. A KB-6000 UT flaw detector was chosen to perform the ultrasonic inspection.

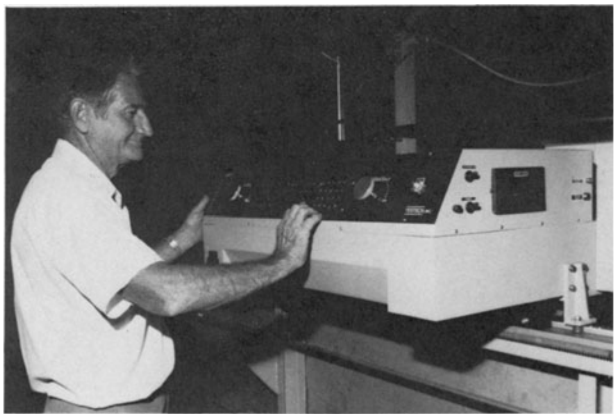

Figure 2. TESTECH MICROPROCESSOR UT IMMERSION SYSTEM

Figure 3. CUTIE SYSTEM EQUIPMENT AND CONTROL ROOM

These components make up Lockheed's CUTIE System. Items 2, 3 and 4 above are located in a control room adjacent to the UT immersion test system as depicted in Figure 3. Each component will subsequently be describe in detail.

ULTRASONIC TEST BRIDGE

The UT scanning device consists of an LS100 bridge with an LS86 microprocessor based motor control. This device is capable of providing a method for automatic scanning and also recording and recalling of a multitude of various scan programs for varying part geometries.

The system uses a combination of high speed DC servo and pulse stepping motor drives. The DC servo motor drives provide for the most accurate positioning and bridge movement with good acceleration and speed. The pulse stepping motors are used for manipulator movement in the vertical, swivel and gimbal directions. These motors also provide 0.001 inch movement per pulse. Rapid and precise positioning of the bridge can be accomplished with ease and excellent repeatability. The location of the bridge and manipulator can be determined at any time to the nearest 0.001 inch via the system keyboard.

Multidirectional scans can be accomplished. Rectilinear X scans with Y index, or Y scans with X index can be made. Rectilinear Y scans with a turntable or vertical (Z) index are also possible. These scans can be accomplished at speeds of 1 to 15 inches per second and are adjustable in 0.001 inch increments through the entire range.

The system has a diagnostic feature which allows the operator to check the electrical operation of the bridge. A total of nine operations can be checked.

The test bridge can be operated in a manual mode by using the system keyboard through an integral floppy disk drive, or externally via an IEEE General Purpose Interface Bus (GPIB). Motion commands, scan speeds, scan increments, scan index, index increments, total index, X/Y start position and Z start position can be made in any of the operational modes.

The instrument is menu driven for easy system operation. The display will ask the operator for the scan information; the program parameters are simply entered and edited as required. The instrument also has complete Teach and Learn capabilities. The operator can walk the system through a very complex program and the instrument will remember all of the test parameters. These parameters can be changed at any time and the new test program saved. When the scan plans have been developed, the operator can transfer them at any time from the LS86 floppy disc system or the host computer to inspect specific parts.

C-SCAN RECORDER

C-scan recordings are used to provide a permanent record of an ultrasonic test performed. Conventional recordings use grey scaling to display the severity of the discontinuities. Interpretation of the plots, however, is very subjective. Hence, a color plotter was chosen to improve the presentation of the test results, and to remove the ambiguity which is sometimes associated with interpreting data, especially when marginal situations present themselves.

The plotter chosen for this application is an ink jet printer/plotter which has both graphics and text printing capabilities. The plotter is ideal for our system. It can be connected to a host computer using either an RS-232 serial or a Centronics parallel interface. The graphics can be printed on a fan-fold or roll type paper. The UT results are normally recorded 1/4 scale. This allows the operator to record the results on a part measuring 5 feet wide by 50 feet long.

This system has exellent speed. It can print a twelve inch complex multicolor figure at a rate of three inches per minute. This is ideal for performing a screen dump of the desired image after the data has been manipulated and evaluated.

The recorder uses three basic ink colors, yellow, magenta, and cyan to produce a graphic image. A palette of 8 or 127 colors can be made, for printing and/or plotting, by selecting the desired colors from 4913 various shades.

The plotter is very versatile. The following parameters can be selected:

1. The horizontal dot density can be changed from 85 dots per inch (DPI) to 120 DPI. The operator, however, needs to be aware that when the dot density is changed, the aspect ratio is also changed.

2. The printer can be used in either a unidirectional or bidirectional mode.

3. The pixel size can be varied to match the computer monitor.

4. Background and foreground colors can be selected in the alphenumeric mode.

5. The raster protocol can be varied from an 8 to 127 color mode.

6. The character font can be selected.

The software package used with the plotter allows the inspector to zoom in on an area of concern and expand, in varying amounts, the X and/or Y axis. The operator can also change the color presentation of the image by choosing from three predefined color palettes to further enhance the image. This is a valuable technique to use when performing the final evaluation.

COMPUTER CONTROL

The system computer control consists of an IBM PC with two 360 KB floppy disc drives, and an IBM XT with one 360 KB floppy disc drive and one 10 MB hard disc. It has a color display which is used to monitor the ultrasonic test results in real-time.

The PC's have the same basic capabilities as the LS86 microprocessor. The test parameters can be downloaded from the PC to the LS86, or they can be uploaded to the PC. The test programs can be reviewed and changed from either location adding additional versatility to the system.

The major advantages associated with a computer controlled ultrasonic test system are outlined below:

1. A more complete and easy to use operating menu is achieveable using a computer.

2. The operator has the capabilities of programming and filing a multitude of UT scan plans.

3. The UT results can be stored and archived.

4. The data can be reviewed in 64K segments, any area of concern can be zoomed in on, the X and/or Y axis expanded, and color assignments can be made to enhance the test results.

5. An actual C-scan recording of the ultrasonic test does not have to be made of the whole part. The entire test can be reviewed and only those areas of concern plotted.

6. Because of the archival capabilities, many tests of similar parts can subsequently be reviewed and compared. This is a valuable tool which can be used to evaluate manufacturing processes.

7. A central control area can be established for the computers, plotter, ultrasonic flaw detector, and record keeping.

8. The use of computers offers opportunities for additional automation, innovation, and computer enhanced data evaluation.

ULTRASONIC FLAW DETECTOR

The KB-6000 flaw detector was chosen due to its computer compatibility and expansion potential. Its pulser/receiver is capable of reading commands, instructions or data from the computer. It has a special interface which is used to receive and transmit data between the flaw detector and the instrument. Some of the parameters which can be controlled by the computer are listed below:

1. Receiver gain can be selected from 0 to 49 db.

2. The ultrasonic test frequency can be chosen.

3. Receiver delay in inch or microsecond intervals can be selected.

4. The time corrected gain can be programmed.

5. Pulse repetition rate can be chosen.

6. The back echo attenuation can be selected.

7. Artificial sweep interface or interface window is selectable.

8. The amplitude threshold and logic for both gates can be set and the gates slaved.

9. Gate delay and range can be programmed.

10. The longitudinal or shear inspection mode can be chosen.

11. Ultrasonic wave form and video filters for the test can be selected.

The pulser/receiver parameters can be stored on disc and recalled for future scans. Once recalled, the scan program can be used as originally configured or segments changed as required.

ONGOING DEVELOPMENT PROGRAMS

The system modification being presently carried out have been very carefully thought through to allow for future implementation to innovative ideas. The development programs have been purposely segmented so that new concepts could be implemented and benefits received from them in a reasonable time frame. Concurrently being developed is a special eight element array transducer, to be used for increasing the inspection rate, and a high speed data acquisition syste, which will be used to evaluate the signatures of discontinuities. Both of these programs will be summarized in the following paragraphs.

EIGHT ELEMENT ELECTRONIC ARRAY TRANSDUCER

An obvious technique which will increase the inspection output is to use an array transducer. Commercially available transducers, however, are not suitable for our application. A special eight element array transducer, that is depicted in Figure 4, was developed which offers unique advantages over those commercially available. Some of the major benefits are listed below:

1. The transducer has eight individual elements held in a common fixture in lieu of all the elements potted in the same housing.

2. The effective scanning width is increased by 75% over commercially available array transducers.

3. The array can be configured by varying the transducer frequency, focal size and focal length as required for a particular scan plan.

4. Each element is individually selected and matched for a specific array. This optimizes the sensitivity and accuracy of the ultrasonic test. Hence, the array does not contain any hot spots and/or blind areas that are sometimes present in commercial transducers.

5. Individual elements in an array can be replaced at a much lower cost than replacing all eight elements.

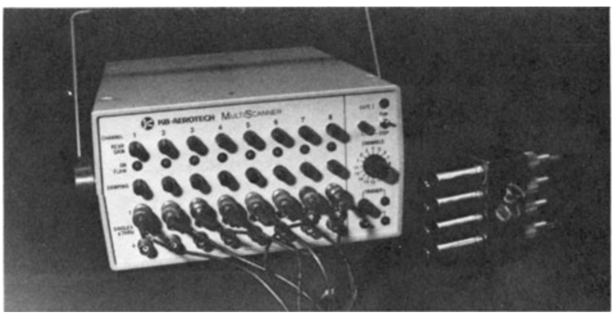

Figure 4. EIGHT ELEMENT ARRAY TRANSDUCER

SIGNAL ANALYSIS

Another area which can be improved upon is the interpretation of the data. The new ultrasonic test system advances this technology by employing color schemes, zooming and expansion techniques to enhance the test results. This is a beneficial evaluation method which reduces the ambiguity in judging the severity of discontinuities. Further improvements can be made, however, to classify discontinuities.

A high speed data acquisition system is now available which is capable of performing a detailed analysis of the ultrasonic waveform associated with the detection of discontinuities. The equipment chosen for this task is a Lecroy 200 megasample per second Data Acquisition System. This system is shown in Figure 5. Some of the distinctive features of the system are as follows:

1. This system is IBM compatible and blends extremely well into the present test scheme.

2. The instrument set-up is accomplished via simple keystroke operating commands.

3. System expansion is very easily done. Many signal processing, trigger controls and memory modules are available.

4. Total memory capacity can be expanded to two megabytes.

5. The display has very high resolution and supports up to four traces with independent time bases and grids. This can be real time or on previously stored data.

6. Traces are reviewed in 8K blocks and the active trace can be moved in any direction to align multiple traces.

7. Traces can be labeled using four characters, and up to two lines of text may be entered to annotate the display area.

8. Time and amplitude measurements can be made between the primary and secondary cursors. The amplitude resolution is 1 microvolt and the time resolution is 0.1 nanoseconds.

9. The data, set-up parameters, and user files can be stored and recalled when necessary.

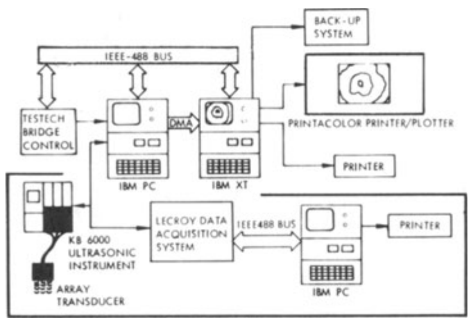

Figure 5. SIGNATURE ANALYSIS SYSTEM

This system will be used to perform a signature analysis of discontinuities. Selected features such as amplitude, rise time, pulse duration, and stress reversal ratio [1] will be used to classify defects and develop an algorithm for data evaluation.

CONCLUDING REMARKS

The Lockheed CUTIE System is the first step taken to automate the ultrasonic test system at the Lockheed-Georgia Company. Additional system sophistication is being developed to further enhance the UT capabilities, for increasing the data acquisition and processing rates, and reducing the cost ratio of performing product inspection versus manufacturing cost.

ACKNOWLEDGEMENTS

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