INTRODUCTION

It was anticipated early on in the NIST program for Integrated Design, NDE and Manufacturing at Iowa State University that it would be desirable to have a scanning system that could accommodate the needs of scan plan research and development. To that end a Panametrics scanning system, a research version of the ARGUS (Advanced Robotic Gantry Ultrasonic Systems) class dual bridge, dual manipulator gantry systems for high speed contour scanning of large components up to 1.5 meters, was purchased. During 1996, advanced contour scanning software, designed for the ARGUS scanning system was purchased, providing a complete and practical approach to inspecting curved parts which cannot be inspected with rectilinear scanning methods. Parts with complex curvature may be scanned with a one or two probes in a pulse-echo scenario or by through transmission.

Points on the surface of a part are typically "taught" using a transducer manipulator to indicate a particular point. The system calculates the coordinates on the surface of the part by using the scanner coordinates and information about the scanner geometry. Ultrasonic "teaching", uses the time of flight of the signal in the current gate, and uses the current sound velocity to compute the water path. The "pivot distance" or "pivot offset" is the distance from the pivot axis of the transducer holder to the outer face of the transducer. This distance is added to the water path to get the total distance from the pivot axis to the surface of the part. The system uses the current scanner coordinates and the total pivot
distance to calculate the XYZ coordinates of the surface of the part. The normal vector, as defined by the scanner orientation during teaching, is also recorded for later use as required. Ultrasonic teaching is typically used for immersion systems and for cases when it is necessary to ultrasonically teach the normal vector (e.g. for pulse echo scanning). Part geometries may also be uploaded to the scanning system via CATIA files generated from CAD/CAM packages [1,2]. Moreover, scanning sequences, i.e., scan plans generated externally in software such as UTSIM may be uploaded, converted, and executed by the scanning software.

The typical ARGUS features two synchronized 5-axis bridges mounted on a gantry. The high speed contour scanning is coordinated with all digital acquisition and analysis of ultrasonic data from one or more channels up to eleven. The general layout of the ARGUS scanning system is shown in Figure 1.

ADDRESSING THE LEARNING CURVE

One important goal is that many investigators (and their students) should be able to efficiently use the advanced scanning capability. However, the learning curve on very capable large systems can be a real obstacle—the graduate student doesn’t want to spend half of his or her research time learning the tools as opposed to gathering the research data.

To address the "learning curve" problem, one principal investigator is designated to learn and maintain the scanning system who, in turn, trains other investigators as is necessary and appropriate. Internal web pages are being developed providing a set of
generic scanning scenario examples. Each operator has two primary things to consider... how to generate and receive the ultrasound, and how to scan the transducer(s) with respect to the part being inspected. The web pages serve to walk the operator through step by step examples of setup the ultrasonic equipment, teach part surfaces, generate the scan plan, and execute the scan.

Scan types range from simple line and rectilinear scans to through transmission scanning of parts with complex curvature involving ten degrees of freedom. Think in terms of surfaces—the software will figure out where to put the probes. All one needs to do is define the part surface. The operator uses the ultrasonic signal from the surface of the test material to interactively teach the geometry of the component to the system. The operator has great flexibility in the teach process because the software handles an unstructured set of teach points to define the part geometry. Thus, the teach process is very quick and efficient, particularly for parts which are gently curved.

Alternatively, if necessary, you can provide surface information (and probe orientation) from an ascii file with surface points defined by defining surface points and the direction of the UT probe pointing at those surface points. Software to convert CAD/CAM surface point data (such as CATIA data) to teach files is provided.

Consider a section of a composite leafspring as shown in figure 2. Once the surface(s) to be inspected have been determined, the next step is to set up the ultrasonic pulser system in preparation to ultrasonically "teach" the surface to be scanned [3]. The system’s ultrasonic set-up screen, shown in figure 3a, consists of a real time digital oscilloscope with software buttons and switches permitting the operator to set gates and control instrument parameters. The software permits the operator to easily define scan envelope and plot types. All mechanical and ultrasonic parameters may be stored and recalled from a file.

Teach points are acquired by positioning the probe at points along the "area" of the surface. Figure 3b shows the teach screen with a full compliment of teach points. The number of teach points is determined (by the operator) by the complexity of the surface to be scanned. One needs a sufficient number of teach points to sufficiently define the actual
surface curvature which, in many cases, is continually changing. The interactive screen allows for remote positioning of the "teach" probe, adjusting the time of flight (water path distance) and normalizing the probe to the surface at the teach point. The software records the position and orientation of the probe at each of the teach points. Teach points can be viewed in any of the three principal planes of the XYZ coordinate system.

Once a set of teach points are obtained, the points are processed to form a "grid" of points which can be thought of as "node" which the scanning probe will pass through during the actual scan. This new set of points, shown in figure 4a, may be viewed in any of the three principal planes as was done for the teach points. This allows the operator to visualize the smoothness of the resulting scan "surface". Often the teach points can be improved by editing the new scan points points to make a new teach point set set for re-processing. This is exactly what was done on this composite leafspring. There is a lot that can go wrong! This is where the "art" of teaching surfaces will come with experience. If your actual scan is rough or stalls, chances are the teach points and and resulting scan surface points are poorly defined.

Figure 4b shows the real-time oscilloscope screen now set up to acquire the full waveform beginning just after the front surface reflection and including the back surface.
Teach points can also be used to define a pseudo-surface for scanning. Figure 6 is a schematic drawing of a diffusion bond sample which must be inspected through a cylindrical interface. Initially the probe is positioned to maximize the front surface reflection from the cylindrical surface. By making virtual angular movement the the incident beam is normalized at the bond plane by maximizing its reflection. The virtual radial motion is used to equalize time of flight from the probe to bond plane. The resulting teach points (see Figure 7) and the subsequent scan points define a pseudo-surface through which the probe moves ensuring that the incident beam is normal to the bond plane and that time of flight is equal [4]. Figure 8 shows one of two screen used to control parameters in processing teach point. The user may set constraints on the type of polynomial fitting and provide upper and lower limits on radius of curvature that can result.

Figure 9 shows the resulting a-scan, b-scan, and c-scans for the diffusion bond sample. URLs for example web pages are listed as references at the end of this paper. The web pages include all relevant setup steps and computer screens for example scans involving the composite leafspring and diffusion bond samples. These examples and others serve as templates for setting up scans involving complex curved surfaces.
Lamb wave experiments were conducted with the geometry depicted in Figure 10. Transmitter and receiver transducers remain at constant incident angles as the receiving transducers is scanned though the angle $\theta$. Figure 11 shows a stack of time domain signals. X-axis is time. Y-axis is the scan angle. The gray scale is the amplitude of the signal as the receiver transducer scans. In the bond region, specular reflection and leaky wave are gradually separated due to different velocities. However, in the debond region (Figure 12), no leaky wave exists, so no such separation comes out. Only specular reflection is received by the receiver.

This Lamb wave research was done by generating all scan commands external to the ARGUS system software [5]. Results were recorded and processed externally, demonstrating the flexibility of the scanning capability.
reflection. Figure 5 shows the resulting a-scan, b-scan, and c-scans. The data, may be interactively viewed from the screen as well as post processed to extract signal information relevant to the inspection. It should be noted that once a set of teach points and three associated reference point have been determined, parts may be removed and brought back for scanning at a later date. By aligning the scanning system with respect to the reference points, previously determined teach and scan points may be recalled and transformed to the new orientation of the part within the scanning tank.

SUMMARY

As part of that validation process, complex contour following ultrasonic scanning capability was implemented on existing testbed hardware allowing backscatter and through transmission scanning of complex shaped parts. Many types of scanning have been accomplished with the system. In order to foster learning the system, example scans are being documented with internal web pages allowing investigators to focus on the essential task of setting up a part, teaching its surface, and optimizing the scanning process to provide complex contour ultrasonic scanning.

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REFERENCES


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