NEW ULTRASONIC METHOD FOR EVALUATING WELD PENETRATION

IN STEP-TYPE WELD JOINTS

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INTRODUCTION

The welding process on step joint geometries in cylindrical parts produces compressive forces which can couple the interfaces at the weld joint. Traditionally, an ultrasonic window has been machined in the joint corner similar to a radiographic window as an indicator of weld penetration. The window serves as a reflector which ensures that the traditional ultrasonic angle beam shear method will detect the unpenetrated weld interface. Several window designs have been used successfully; however, there are problems associated with the use of ultrasonic windows. The welder's desire for a small window to minimize the manmade void near the root of the weld, makes it difficult to accurately machine and properly clean the window. It is also undesirable to have a hole at the root of the weld. These factors increase the cost of welding for the sake of the ultrasonic inspection.

The new ultrasonic inspection technique evaluates the effects of the weld penetration on the width of the step-joint landing rather than the unwelded interfaces at the root of the weld. A normal beam pulse-echo inspection technique is used to detect the presence of the unwelded interface. An LSI 11/73 computer system is used to acquire, analyze, and display the step-landing data, thus making it feasible to inspect the entire step-landing and collect the large amount of data required.

DATA ACQUISITION SYSTEM

A computer-controlled test facility [consisting of turntable, transducer holder assembly with water jacket, pulser/receiver, gated peak detector, analog-to-digital converter (ADC), scope, computer, and color monitor] was used for the acquisition and display of ultrasonic data.

Amplitude data were collected every tenth of a degree as the stepping motor-driven turntable rotated. The gated peak detector was used to determine the amplitude of the signal within a preset gate.

The amplitude was digitized with a 12-bit ADC and stored on a removable disk cartridge. Other equipment used in signal processing and display before storage included a Tektronix 7603 oscilloscope, Tektronix 4105 terminal, Tektronix 4696 color printer, Peritek color monitor, Panametric 5052 PRX pulser/receiver, and Panametric A311, 10 MHz transducer. The system is shown in Fig. 1a and 1b.

WELD PENETRATION USING ULTRASONIC TECHNIQUES

Traditional Ultrasonic Window Technique

Mechanically coupled interfaces at the root of a weld are often created by compressive forces resulting from weld shrinkage. Reflection of sound energy from mechanically-coupled interfaces is difficult which makes a traditional ultrasonic inspection nearly impossible. An ultrasonic shear wave pulse-echo inspection method uses the presence of reflected sound energy to determine incomplete weld penetration. The

![Diagram of weld system](a) Weld system

![Diagram of weld inspection equipment](b) Weld inspection equipment

Fig. 1. A computer-controlled test facility was used for the acquisition and display of ultrasonic data.
shear inspection schematic is shown in Fig. 2. If the two interfaces are at the root of the weld couple, the sound energy will be transmitted rather than reflected, giving a false indication of adequate weld penetration. An appropriately-designed ultrasonic window at the root of the weld area will prevent the coupling of the two interfaces. An ultrasonics shear inspection can then be used to detect the window. The depth of penetration can be determined from the amplitude of reflected sound. The cost of the welding process significantly increases with the use of windows because of machining and cleaning costs associated with the window. Consequently, alternate windowless inspections were investigated.

New Windowless, Step-Landing Ultrasonic Technique

A normal beam longitudinal pulse-echo technique can be used to detect the presence the step-landing. The sound beam is reflected from the step-landing as shown in Fig. 3. The ultrasonic amplitude data, as shown in Fig. 4a, can be used to indicate when the sound wave is obstructed by a discontinuity in the sound path (i.e., the step-landing depth). The amplitude data is used to map the step-landing around the part revealing the effects of the welding process on the landing. The width of the landing is measured by evaluating the amplitude responses from the landing interface above a set threshold, relative to position of the transducer as it is indexed around the part and across the landing. The ultrasonic step-landing inspection has reliably measured the landing width within ±3 mils of metallurgical section measurements of the landing. The normal beam inspection does not detect lack of penetration, but rather the presence of the unwelded step-landing interface which indicates whether or not the weld failed to penetrate into the step-landing. Fig. 4b shows the variation of amplitude responses from the step-landing in a gray scale indication around the part.

Fig. 2. Ultrasonic 45-degree angle beam shear inspection.
Fig. 3. Schematic of ultrasonic longitudinal step-landing inspection of a cylindrical step-joint weld sample.

Fig. 4. The width of the step-landing in the ultrasonic data can be correlated to acceptable weld penetration.
WELD EFFECTS ON THE STEP-LANDING

The step-landing may be affected by welding in several different ways that may influence the capability of the step-landing inspection to determine weld penetration -- shown and evaluated in Fig. 5. The welding specifications require the welder to penetrate into the step-landing; therefore, it is possible to utilize the ultrasonic step-landing inspection method to evaluate weld penetration. The fourth weld condition requires a minimum step-landing width for rejection of weld.

STEP-LANDING INSPECTION RESULTS

In verifying the step-landing inspection as a useful tool for evaluating weld penetration without the ultrasonic window, a weld ring sample was analyzed. Fig. 6 shows the inspection results from the ring. Fig. 6a shows the display of the normal step-landing data which indicate the varying penetration of the weld into the step-landing. The photomicrographs in Figs. 6b and 6c also serve to confirm the step-landing results concerning weld penetration. Fig. 7 compares the sectioned landing width measurements with ultrasonic measurements of landing width. The difference is consistently within ±3 mils which is as good as can be expected considerably that the index increment of the Z-axis across the step-landing is 3 mils.

![Fig. 5. Possible weld conditions that may be encountered.](image1)

![Fig. 6. Scaled step-landing width determined from signal amplitude data. Photomicrographs verification of weld penetration.](image2)
CONCLUSIONS

The ultrasonic inspection of the step-landing width for determination of weld penetration proved to be a useful tool in evaluating welds. The inspection can be used on any weld having the step-joint geometry, provided the material attenuation will permit ultrasound penetration to the step-landing surface and the weld bead has been machined flat. The inspection will definitely reduce the cost of the total welding process because the expense of machining, certifying, and cleaning an ultrasonic window is eliminated.