ULTRASONIC INSPECTION OF BERYLLIUM WELD SAMPLES

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INTRODUCTION

Three beryllium cylinders containing a step weld were received for ultrasonic inspection. Radiographic inspection of the welds indicated the presence of a crack in one of the welds.

The samples were received as fabricated. They had rough surfaces which were machined prior to inspection. This report describes the testing techniques and the results.

INSPECTION OF SAMPLES

Beryllium presents unique problems for ultrasonic inspection because it has a very high acoustic velocity causing sound to be refracted at large angles with small angles of incidence. This causes problems particularly when using focused transducers since the half angle of the beam from the transducer is large enough to flood the part with sound over a wide range of angles. For instance, a 30 MHz, 6.35 mm. diameter 50 mm focal length transducer has a half angle of 3.6 degrees and produces longitudinal energy at angles up to 33 degrees in beryllium. In addition, it is difficult to resolve flaws near the surface since the transit time to the flaw is extremely short. Thus, inspection of beryllium requires high frequency inspection techniques and precision manipulators.

The weld samples were open-ended cylindrical beryllium specimens joined at the equator with an electron beam weld which uses a 0.46 mm thick aluminum shim to aid in making the weld (see Figure 1) since high stresses cause a weld in pure beryllium to crack. The weld nugget produced is an aluminum-beryllium alloy. Consequently the velocity of sound in the weld metal is lower (intermediate between the velocity of aluminum and beryllium) than the velocity in the base metal. Although there was the potential for reflection and refraction at the weld metal - base metal interface, this did not appear to be a significant

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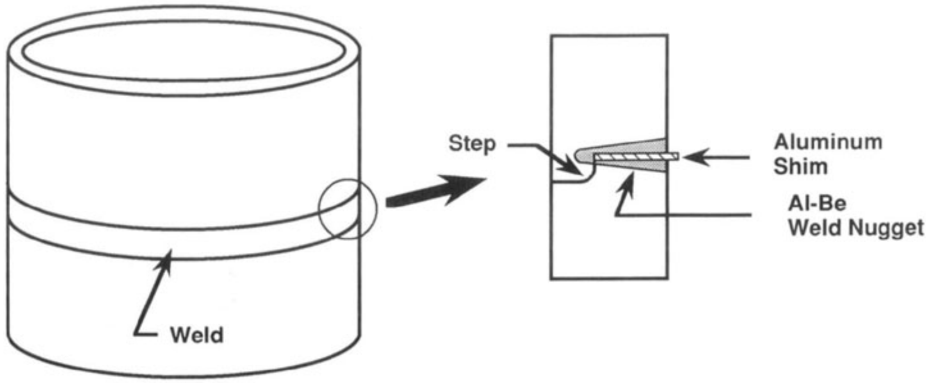

Figure 1. Beryllium Test Sample Geometry.

problem. Before ultrasonic inspection, a centerline crack around a small portion of the circumference was detected in one of the welds using radiography. This weld had been fabricated using 2 passes. The other two welds had been fabricated using a single pass.

Data were taken using three different acquisition systems using both normal and shear inspection techniques. All inspections were made with the parts immersed in water using 20 and 30 MHz transducers. The welds were first inspected using a MIDUS scanning system with instrumentation which enables the amplitude in each of two gates and time of a signal in the first gate to be recorded. The gates have to be preset before scanning begins. The MIDUS scanning system consists of a 6 axis system that can be programmed to scan parts in a 0.8 x 1.5 x 0.6 m volume. The system is interfaced to an LSI 11/73 computer for data acquisition and analysis.

The second acquisition system is referred to as the Weld Gage and incorporates a B-Scan module [1] which enables more accurate time information to be recorded. This system is designed for cylindrical inspection and is also interfaced to an LSI 11/73 computer for data acquisition and analysis. The weld gage system gives better resolution of the flaw indications than the MIDUS system. This is due to both the higher precision scanner and the better ultrasonic instrumentation.

The third system, the Waveform Data Acquisition System (WADAS) [2], is designed to acquire full digitized waveforms at up to a 100 MHz sampling rate. This system can inspect parts of revolution and can store up to 4 MBytes of data in a single scan. The acquisition of full digitized waveforms enables flexible setting of the gates during post acquisition analysis. Because of the large amount of data acquired, the volume of the weld inspected was reduced to a minimum. With this system, full RF waveforms are taken and the analytic signal of each waveform is calculated. The analytic signal effectively rectifies the RF waveform independent of the frequency of the signal. An imaging program developed at Y-12 is then used for analysis and display.

Using a normal longitudinal WADAS inspection, porosity was detected in all three welds. Figure 2 is a composite of the analysis of the analytic signal of the waveform data taken from the weld with the crack.

Although the analysis and display program normally produces color displays, the figures in this report have been produced in shades of gray with some loss of display sensitivity. The top scan of the figure shows the amplitude of flaws in the weld between the front surface and the step. The crack is located near 110 degrees and four other defects, which are probably porosity, can be easily seen. The second scan shows the amplitude of signals gated between the step and including the back surface of the weld. The weld area is seen in the center of the scan. The brighter spots in the center of the weld area are probably the reflection of the signal from the root of the weld at the weld nugget-base metal interface. These signals occur later in time than the back surface of the weld since the velocity of sound in the weld nugget is lower than the velocity in the base metal. The third scan is a circumferential B-Scan through the center of the weld. The four porosity type defects and the crack can be seen near the front surface of the weld. The brighter signals seen near the bottom of the scan are from the weld root. The scan is taken near the center of the weld so that the back surface is not shown. The signal from the crack is not very large and is difficult to see in this scan. The bottom scan is a depth scan which color or shade codes the signals according to their depth. Larger signals which produce brighter colors represent deeper reflections. The histogram at the top shows the distribution of depths in this weld. Note the bright indications in the center of the weld indicating that the weld root signal occurs later in time than the back surface of the part shown as a darker shade at the top and bottom of the scan. The even darker band below the weld is the step. While the porosity type indications are only one shade, the crack shows several

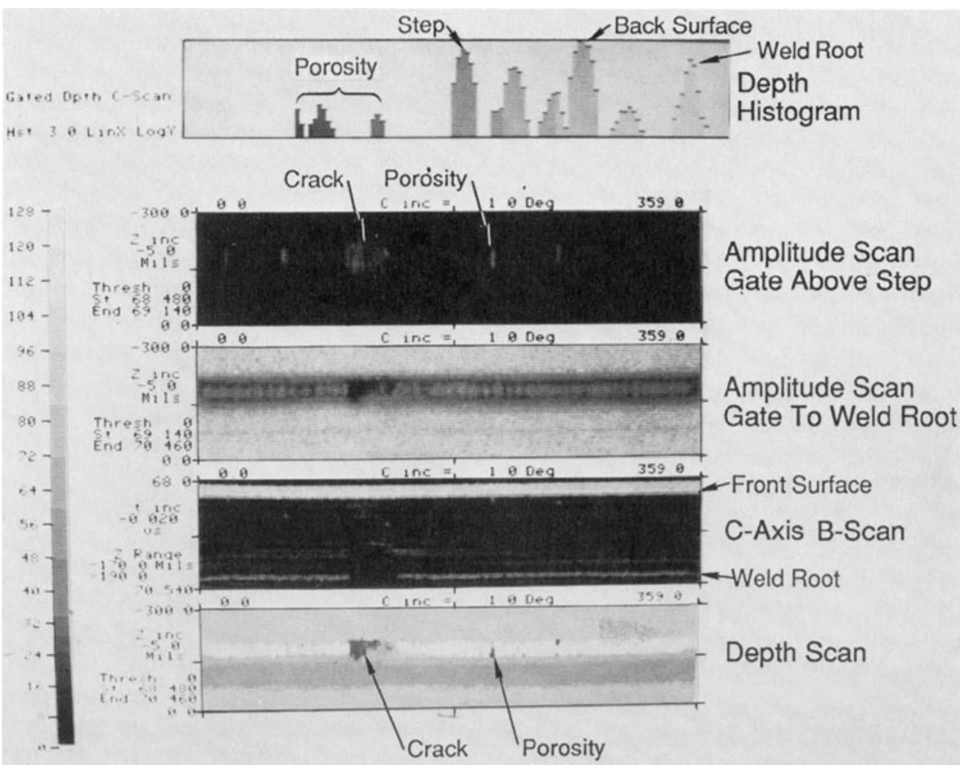

Figure 2. Composite of Longitudinal WADAS Data.

shades indicating that reflections occur at several depths. Figure 3 shows three axial B-scans of this data. The top and bottom B-scans were taken through the porosity located at 61 and 206 degrees. While the porosity at 206 degrees is near the front surface, the porosity at 61 degrees is considerably deeper. The center B-Scan was taken through the cracked area. The step, back surface and the weld root can also be seen in these scans. Note that the weld root appears to be deeper than the back surface due to the lower velocity in the weld nugget.

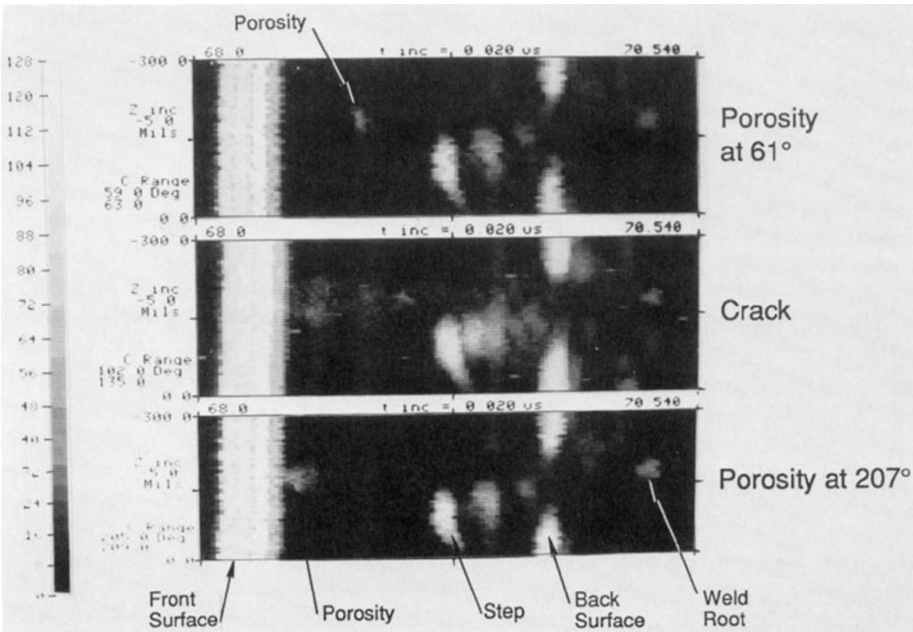

Figure 3. Longitudinal Axial B-Scans of Cracked Weld.

At the frequencies (20 and 30 MHz) used for inspection the weld is quite attenuative. The data in Figure 2 were taken with maximum instrumentation gain. An additional set of RF data was taken using a supplemental amplifier in series with the system to obtain additional gain. This scan was also taken over a shorter scan range so that a longer RF waveform could be taken (256 points instead of 128). This caused the weld to appear wider and the defects to be elongated in the axial direction. Figure 4 shows the data taken from the third weld using the higher gain. This data is presented in a circular format which is closer to the weld geometry. The outer scan is the amplitude of the data in a gate above the step. Even the smaller porosity is easily seen in this weld since the higher gain produced larger signals. This weld had a larger number of smaller porosity indications than either of the other welds. The noise level was also increased producing a brighter background color. The inner scan is the data from the step to the root of the weld and shows several indications from the root of the weld.

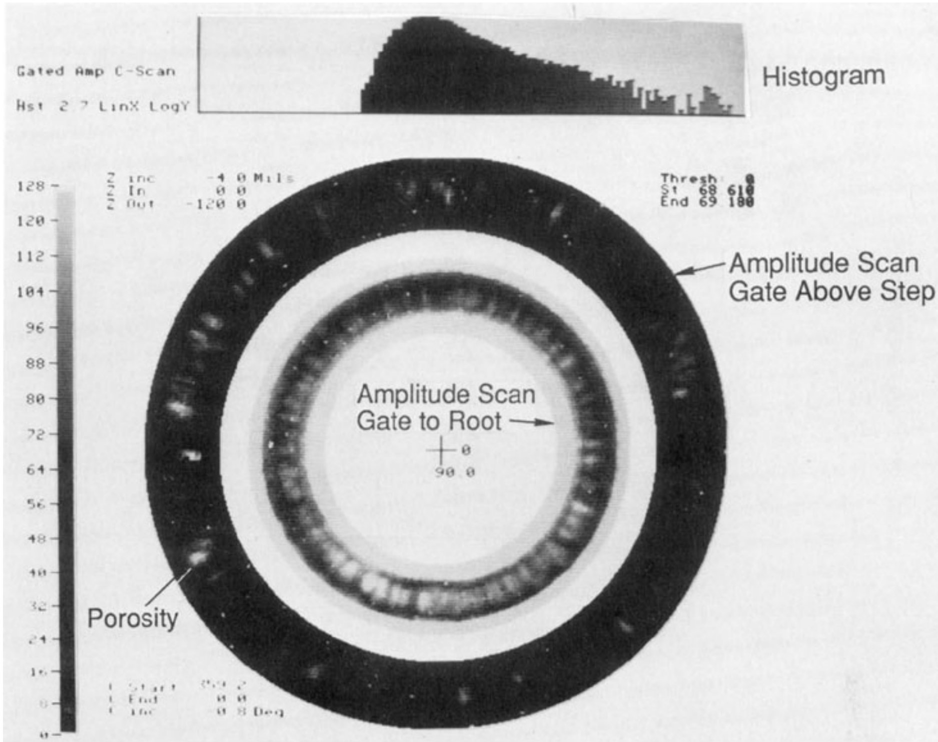

Figure 4. High Gain WADAS Longitudinal Data.

Shear inspection of the welds clearly detected the weld start defect in the cracked weld. As with the longitudinal inspection, data were taken using several different acquisition systems. The major problem with the shear inspection is high beryllium velocity which causes the weld to be flooded with sound from a large range of angles. The best results were obtained using the WADAS data acquisition system since complete ultrasonic waveforms were taken and the gate could be precisely located to detect the defect indications. Figure 5 is a composite of several scans made on the weld sample with the crack. The top scan is an amplitude scan with the gate set between the front surface and the step. Several porosity indications can be seen along with the crack indication. The second scan is an amplitude scan with the gate set to include the step and the back surface. Not only can indications be seen from the crack, but also note that the indication from the weld root (at the bottom of the scan) is shielded by the crack. The third scan is a circumferential B-Scan which shows clearly the front surface, the crack and internal porosity and the weld step. The scan is an accumulation of the B-scans across the center of the weld. The bottom scan is a depth scan with the gate set in the same location as the top scan. In this scan the brightness of the indication represents the depth of the indication. Figure 6 shows four axial B-Scans of the data from the cracked part. The top scan shows the signals in the region of the crack. The middle two scans image areas of porosity while the bottom scan is taken in an area with no flaws.

Although they are rather attenuative the beryllium welds are inspectable. Ultrasonic inspections of these welds detected the known crack as well as other internal defects. However, the size of these

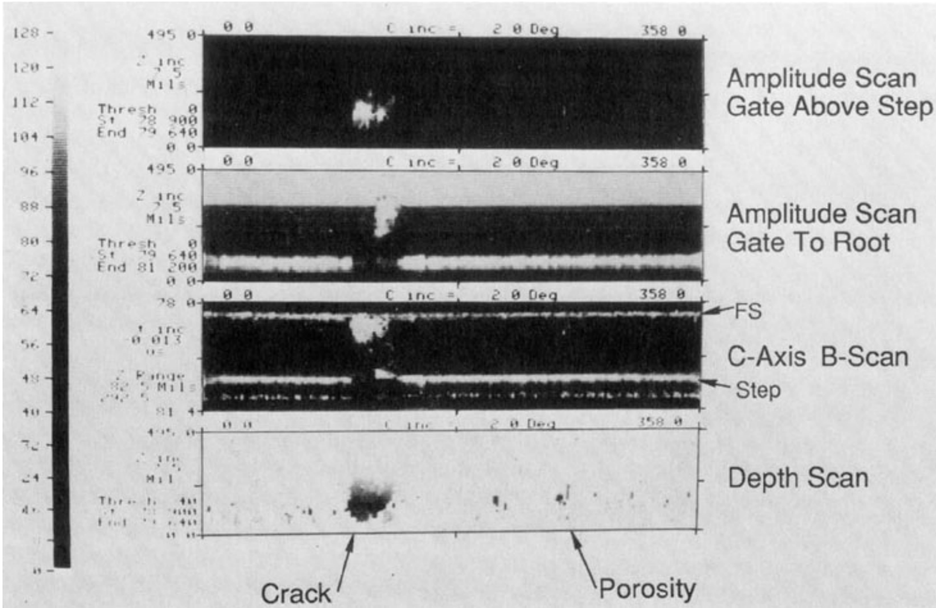

Figure 5. Shear WADAS Data Taken From Cracked Part.

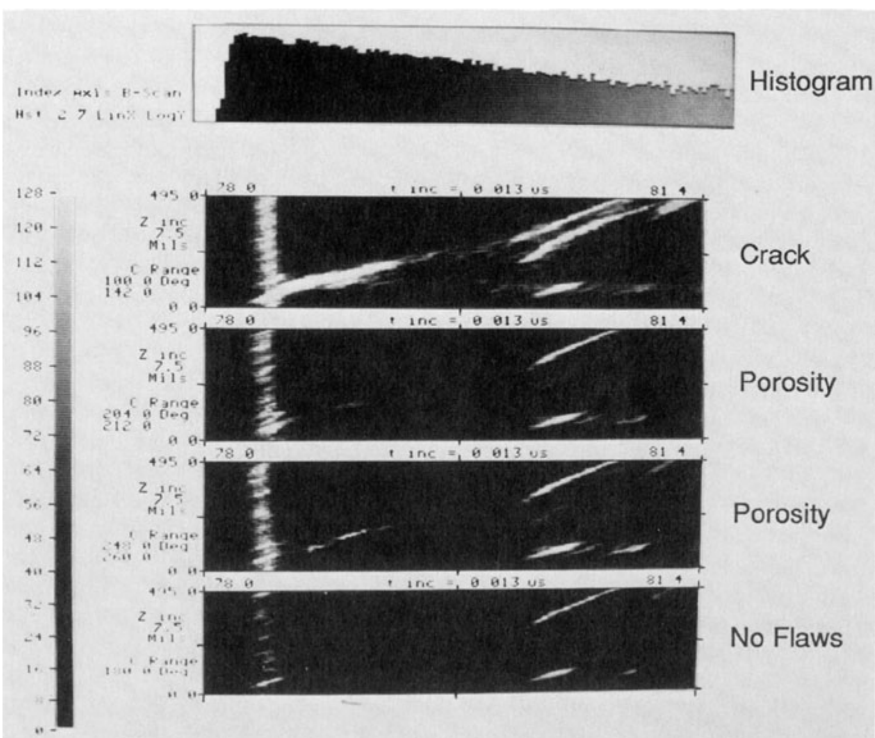

Figure 6. Shear Axial B-Scans Showing Crack and Porosity.

defects are unknown because there is no reference standard to compare the signals with. Longitudinal inspection seems more sensitive to porosity while shear inspection is more sensitive to cracking. No indications of lack-of-penetration were noted although the indications from lack-of-penetration would probably be similar to those from the crack. Great care was necessary for these inspections because precise angles are critical. Ultrasonic techniques should be quite adequate to inspect welds of this type.

REFERENCES

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