

## How to Detect Laser-Weld Defects in Pacemaker Casings

Posted in [Testing Equipment](#) by [bmichaels](#) on January 14, 2015

**Acoustic imaging is a nondestructive technique for detecting voids in titanium pacemaker casings.**



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Heart pacemakers and other implantable medical devices must be free of even minor defects, particularly in the titanium casing that holds and protects the electronics. Ranging in thickness from 0.15 to 0.30 mm, this casing typically has the form of a rounded rectangle and is manufactured by welding together two clamshell-like halves.

Appearing around the circumference of the casing, the weld can often contain defects that can be difficult to inspect directly. This article discusses methods for detecting defects in pacemaker casings, focusing on nondestructive acoustic imaging. Elk Grove Village, IL-based Sonoscan Inc. will be exhibiting its acoustic imaging microscope systems at [MD&M West](#), Booth 1573, February 10–12, in Anaheim, CA.

### Methods for Detecting Defects in Pacemaker Casings

The most frequent defects in pacemaker casings are voids—bubbles that form where the weld temperature is too high. Two types of voids exist: keyhole and trapped voids. Appearing as holes or channels in the casing weld, keyhole voids reach the surface and may extend all the way through the weld, destroying its hermeticity. Trapped voids, on the other hand, do not reach the surface and do not immediately destroy hermeticity, but they indicate a weak weld. Voids of both types consist of an interface between the air or another gas and the surrounding titanium.

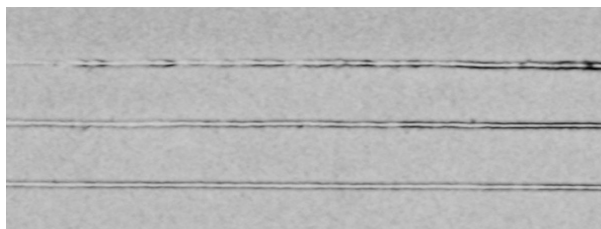
Because trapped voids do not contain cracks that reach the surface, weld penetrants generally do not locate them. X-ray also has difficulty in imaging such tiny bubbles because the amount of titanium that has been replaced by the bubble is too small. The other inspection methods currently available for finding defects in pacemaker casings include the use of die penetrants, which are suitable only for cracks that reach the surface, or involve such destructive methods as cutting and grinding to produce a visible cross-section of the material. While the latter method reveals whether a pacemaker weld has defects, the resulting data may apply only to the pacemaker casing that has been destroyed during the defect-detection process.

In contrast, acoustic microimaging tools working in the reflection mode pulse ultrasound into the sample, reflecting the ultrasound from material interfaces. Acoustic images depend on the amplitude of the return signal. Because weld zones containing only homogeneous materials do not reflect ultrasound, they produce black grayscale images. Solid-to-solid interfaces range from dark gray for low-amplitude images to light gray for those with higher amplitudes. Producing the highest signal amplitude, such solid-to-gas interfaces as those between titanium and air appear bright white in acoustic images of welds. Thus, while most solid-to-solid interfaces reflect only 20 to 60% of the ultrasound, solid-to-gas interfaces reflect nearly 100%.

The interface between titanium and a gas, or any other gap-type defect, is thus relatively easy to image acoustically. Because the defects present in pacemaker casings are primarily voids, acoustic imaging can detect them. In addition, this imaging process is nondestructive.

### Using Acoustic Imaging Tools to Detect Voids

To determine the ability of acoustic imaging techniques to detect voids in pacemaker casings, experiments were conducted using a C-SAM microimaging tool from Sonoscan Inc. In order to raster-scan the surface of a sample, this system uses a transducer that is coupled to the surface using water or another fluid. As it scans back and forth at a speed that can exceed 1 meter per second, the transducer sends an ultrasound pulse into the sample at a rate of thousands of times per second.



**Figure 1: Surface and near-surface acoustic image of three continuous test welds.**

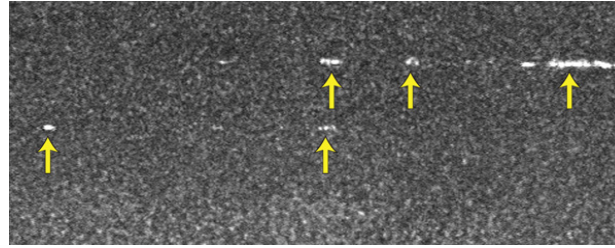
The casing samples used in this study were made from stainless steel rather than titanium because titanium samples are difficult to obtain. However, the type of stainless steel selected for this study can undergo a similar welding process as that used to weld titanium, while its physical properties and defects closely match those of

titanium. Thus, the use of an acoustic microscope to image the samples produced results similar to those obtained when imaging titanium samples.

The echoes returned from the interior of a sample are typically gated at a depth of interest. In other words, only those echoes returned from features within a desired depth range are used to produce the acoustic image, while echoes from other depths are discarded. The width of a particular gate can be as small as several microns. In imaging the pacemaker casing discussed here, up to three nonoverlapping gates were made on a sample with a thickness of 0.30 mm or less.

A reference image whose purpose is to locate interior features, Figure 1 presents the acoustic image of the top surface and near-surface of the stainless-steel plate featuring three continuous test welds. Because the ultrasound in this image was primarily reflected from the interface between the water couplant and the plate, no internal features are visible. The acoustic appearance of the weld surface does not reliably correlate with internal features or defects.

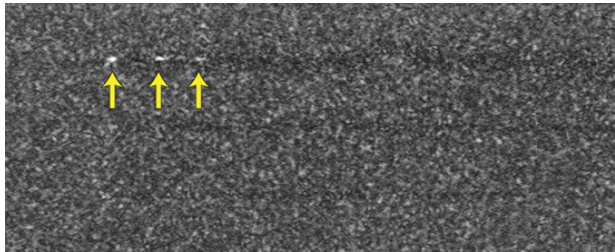
Figure 2 presents a subsurface acoustic image of the same region of the stainless-steel plate as that shown in Figure 1. This image was produced using data from echoes at a depth extending through the weld but not extending to either the top or bottom surface of the material. Most of the image shows a mottled pattern caused by the grain structure of the metal. Indicated by arrows, the bright white features present in two of the three welds are voids. The third weld is not visible when imaged at this depth because it has no voids. By showing the location and size of the voids in the first two welds, this acoustic image could tell engineers that the welding process must be modified.



**Figure 2: Subsurface acoustic image of the same three welds as in the first figure. The bright areas marked by arrows are voids in the welds.**

Figure 3 presents a subsurface acoustic image of three continuous welds at a different area of the sample. Probably because of small differences in gating or other parameters, the three welds are faintly visible in this image as slightly darker regions. It is likely that welding in these regions altered the grain structure of the material, reducing its ability to reflect ultrasound.

While welds 2 and 3 in Figure 3 did not return echoes, indicating that anomalies were not present, weld 1 contained three small defects. The middle and right defects were voids similar to those that formed as a result of excessive heat in the welds in Figure 2. But the defect at the left was a keyhole void—a void that is at least partly open to the surface. Keyhole voids form when the laser begins to perform the welding operation. A near-surface acoustic view of the end of this weld, including the roughly oval-shaped keyhole defects, is shown in Figure 4.

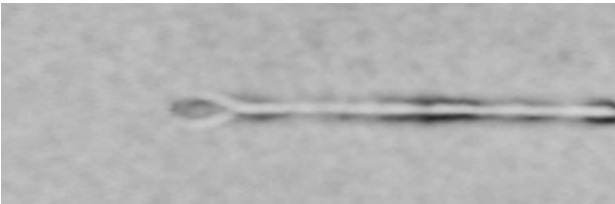


**Figure 3: On a different area of the test sample, weld 1 has three defects. The one at the left is a keyhole defect.**

#### Advantages of Acoustic Imaging

Used in the lab and on the production floor, the acoustic microimaging methods described in this article have the advantage of locating and imaging weld defects without destroying the pacemaker case. After acoustic imaging has been performed, manufacturers can decide to conduct physical analysis to learn more about the defects that have been detected. Destructive physical analysis is performed more quickly and accurately when an acoustic image shows the locations of internal features.

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**Figure 4: Near-surface image of the end of weld 1 shows the structure of the keyhole defect.**