PREFERRED
RELIABILITY
PRACTICES

ULTRASONIC TESTING OF AEROSPACE MATERIALS

Practice:

Three general methods of ultrasonic testing can be used singly or in combination with each other to identify cracks, debonds, voids, or inclusions in aerospace materials. Each has its own unique application and all require certain precautions or techniques to identify potentially flawed hardware. This practice describes selected principles that are essential in reliable ultrasonic testing.

Benefit:

Careful attention to detail in ultrasonic testing can result in the identification of very small cracks, debonds, voids or inclusions in aerospace hardware that could be detrimental to mission performance. New ultrasonic technologies are enhancing the accuracy, speed, and cost-effectiveness of this method of nondestructive testing.

Programs That Certified Usage:

Space Shuttle External Tank, Solid Rocket Booster, Space Shuttle Main Engine, and in-house manufacturing technology programs.

Center to Contact for More Information:

Marshall Space Flight Center (MSFC)

Implementation:

As schematically illustrated on Figures 1, 2, and 3 there are three principal methods of ultrasonic testing of aerospace materials: (1) the pulse-echo method; (2) the through-transmission method; and (3) the pitch-catch method. These three ultrasonic methods use pulses of energy during testing operations. These methods and their principal use in support of MSFC projects and technology programs are described below:

1. The pulse-echo method (Figure 1). In the pulse-echo method, a piezoelectric transducer with its longitudinal axis located perpendicular to and mounted on or near the surface of the test material is used to transmit and receive ultrasonic energy. The ultrasonic waves are reflected by the opposite face of the material or by discontinuities, layers, voids, or

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inclusions in the material, and received by the same transducer where the reflected energy is converted into an electrical signal. The electrical signal is computer processed for display on a video monitor or TV screen. The display can show the relative thickness of the material, depth into the material where flaws are located, and (with proper scanning hardware and software), where the flaws are located in the X-Y plane. In aerospace applications, the pulse-echo method is used primarily for the detection of flaws in metals, but has been used for first and second bondline interrogation in solid rocket motors (each transmitted/received wave in Figure 1 represents a pulse of energy).

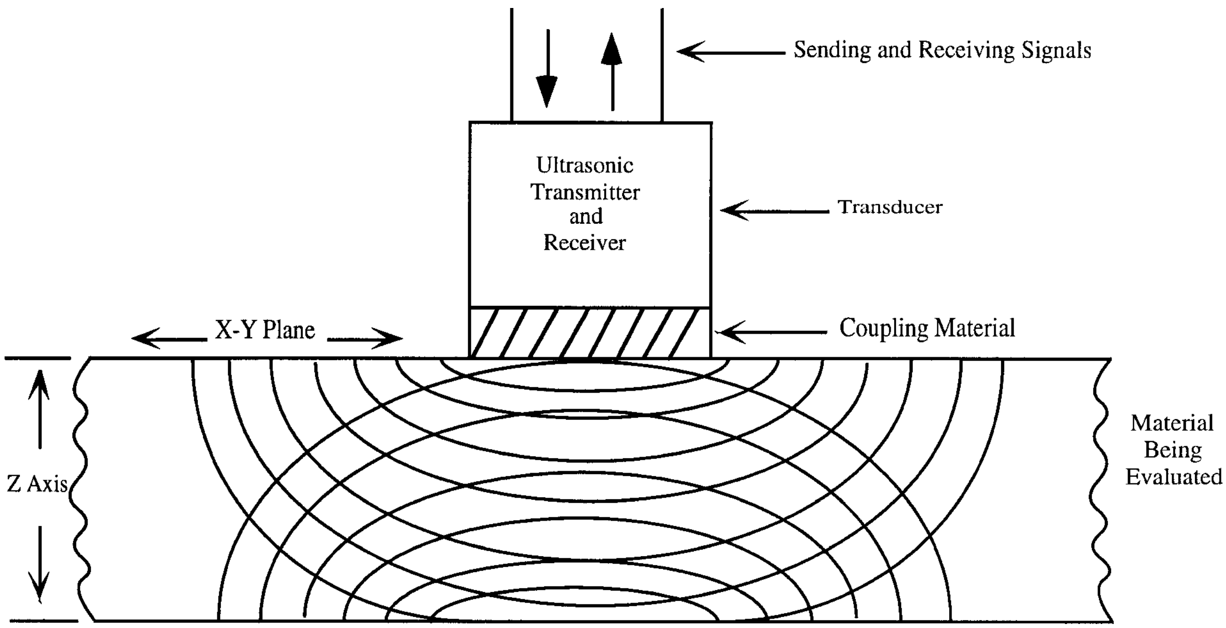

Figure 1. Pulse-Echo Method of Ultrasonic Testing

2. The through-transmission method (Figure 2). In the through-transmission method, an ultrasonic transmitter is used on one side of the material while a detector is placed on the opposite side. Scanning of the material using this method will result in the location of defects, flaws, and inclusions in the X-Y plane. This method is used for nondestructive testing of multi-layered and multicomponent materials as encountered in solid rocket motor case/insulation/liner /propellants, in composite materials, and on highly attenuative materials. (Each transmitted/ received wave in Figure 2 represents a pulse of energy.)

3. The pitch-catch method (Figure 3). The pitch-catch method, in which the ultrasonic energy is transmitted at any angle to the surface of the material and received as reflected energy returning at the reflected angle, is used primarily for cylindrical tubes and other nonlinear parallel sided surfaces. The pitch-catch method can determine depths of the flaw in the material

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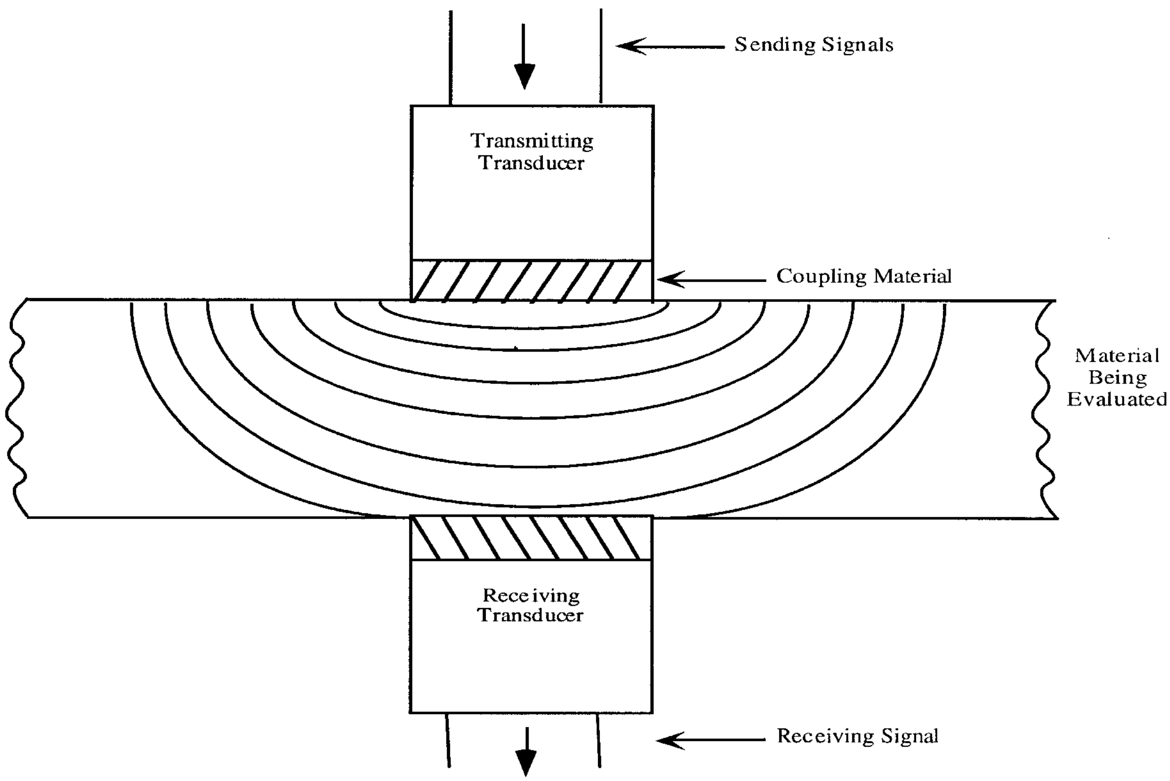

Figure 2. Through-Transmission Method of Ultrasonic Testing

as well as detect the location in the X-Y plane through scanning. (Each transmitted/received wave in Figure 3 represents a pulse of energy.)

All three methods are most effective on parallel sided surfaces, but techniques are being developed to inspect variable thickness materials or parts if and when the variation in thickness relative to the X-Y plane is known precisely.

Precautions to be observed in ultrasonic testing include: (1) acoustical impedance matching of the sensors with the subject test material through the use of the correct coupling media; (2) use of air-coupling for moisture-sensitive materials; (3) resolution requirements needed to discriminate between adjacent anomalies; and (4) the use of electronic methods wherever possible to make corrections in distance inaccuracies encountered due to ultrasonic beam spreading; (5) characteristics of the transducer(s); and (6) the dependence of resolution on index, scan speed, repetition frequency, computer speed, etc., when using automated scanning.

Water has been the best coupling media because of its ready availability, low viscosity, and its relatively safe use with most spacecraft construction materials. When immersion in water is not practical or desirable due to potential moisture absorption, material contamination, or part sizes

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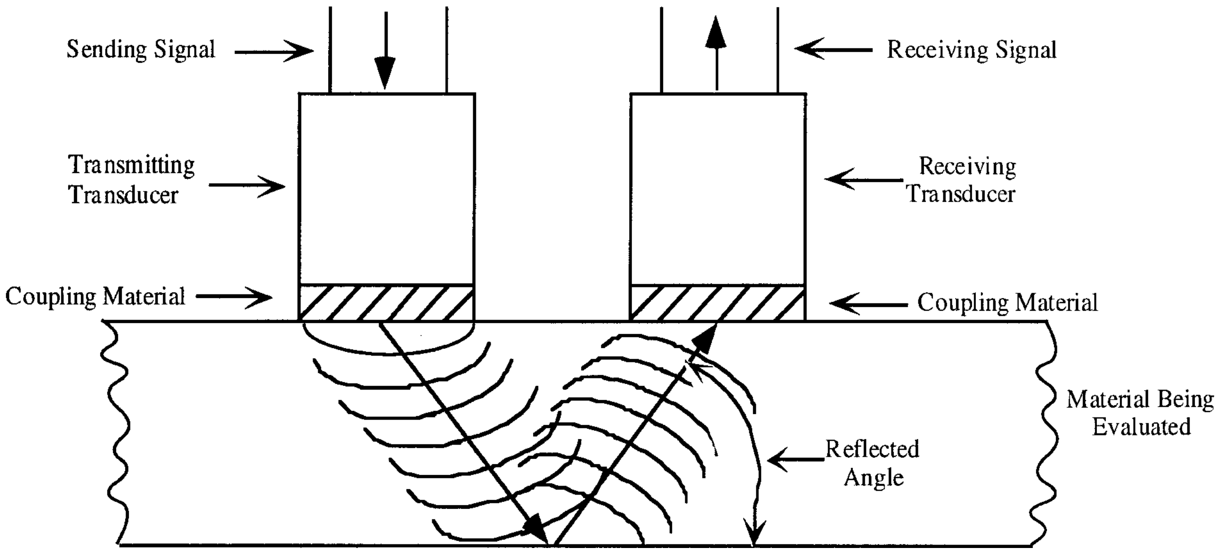

Figure 3. Pitch-Catch Method of Ultrasonic Testing

and configurations, various forms of “squirters” or “bubblers” have been devised to introduce a layer of water between the sensor and the material to serve as an acoustic coupler. In the pitch-catch method, a water-based gel has proven to be the most practical coupling agent. For solid propellant rocket motors, an elastomeric material similar to solid rocket propellant is used for acoustic coupling of sensors to the material during testing. Ultrasonic transmitters and receivers encased in a water jet nozzle have been used to provide continuous coupling during testing of large areas by continuously injecting a plane of water between the sensor and the material being tested.

The most thoroughly researched application of ultrasonic testing at MSFC has been the detection of bond line failures between the case and insulation, the insulation and liner, and the liner and propellant. Ultrasonic waves can be focused at an oblique angle to establish the integrity of adhesive bonding. These oblique ultrasonic excitations cause standing waves in any unbonded areas which can then be detected by conventional ultrasonic methods. In this manner, weak or “kissing” bonds can be detected. NASA has had considerable success in detecting imperfections and debonds between the case or insulation and the liner, but work is continuing to develop reliable methods of detecting debonds at the “second bondline” between the liner and the propellant. In materials that have high attenuation impedance such as solid rocket propellants, relatively low ultrasonic frequencies (50kHz in an available ultrasonic range of 3kHz to 50MHz) are more effective than the high ultrasonic frequencies used for metals. Rapid strides are being made in information processing and display techniques which filter out extraneous acoustic signals and provide improved visual images of ultrasonic testing results.

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The pulse-echo method regularly reveals defects down to .047 inch in diameter. Through-transmission methods have been able to detect anomalies of .050 inch in diameter, which are far smaller than those which could detrimentally affect a solid rocket motor's performance.

Ultrasonic capability to detect flaws depends on the wavelength (derived from the frequency and wave velocity). A general rule of thumb for the detection limit is: "the smallest detectable flaw size is half the wavelength." The use of higher frequencies improves the sensitivity to small flaws, however there is an increase in the wave attenuation and the noise due to scattering from the material microstructure. Also, in any ultrasonic test there is a "dead zone" caused by the finite pulse length. This "dead zone" leads to the inability to detect flaws near the surfaces of the test materials.

Ultrasonic testing personnel should be qualified and certified in accordance with MIL-STD-410E or SNT-TC-1A.

Technical Rationale:

Selection criteria for NDE techniques, specifically ultrasonic techniques, has been a subject of research by MSFC's Materials and Processes Laboratory for a number of years. These techniques have been verified by Thiokol Corporation, Martin Marietta, Aerojet, SAIC, The Naval Surface Warfare Center, and others.

Impact of Nonpractice:

Failure to detect cracks, flaws, and voids in aerospace materials through the proper use of ultrasonic testing and other approved nondestructive evaluation methods could result in the use of weakened structures, unbonded propellants and insulation layers, and potential pressure vessel failures or burnthroughs due to increased propellant surface area, resulting in potential mission failure.

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