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(R) ULTRASONIC INSPECTION

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. **Scope**—The scope of this SAE Information report is to provide basic information on ultrasonics, as applied in the field of nondestructive inspection. References to detailed information are listed in Section 2.

2. **References**

2.1 **Related Publications**—The following publications are printed for information purposes only and are not a required part of this document.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2631, Ultrasonic Inspection of Titanium Alloys, November, 1972..

2.1.2 ASM PUBLICATION—ATTN: MSC/Book Order, ASM International, PO Box 473, Novelt, OH 44072-9901.

Metals Handbook, Ninth Ed., Vol. 17, Nondestructive Evaluation and Quality Control, 1989.

2.1.3 OTHER PUBLICATIONS

Nondestructive Testing Handbook, Vol. 7, Ultrasonic Testing, 1990, American Society for Nondestructive Testing, Columbus, OH 43228

Tool and Manufacturing Engineers' Handbook, Vol. 4, Quality Control and Assembly, 1987, Society of Manufacturing Engineers, Dearborn, MI 48121

J. & H. Krautkramer, "Ultrasonic Testing of Materials." New York: Springer-Verlag, Third Edition, 1983

T. F. Hueter and R. H. Bolt, "Sonics" (Fifth Edition). New York: John Wiley & Sons, Inc., 1966.

R. Goldman, "Ultrasonic Technology." New York: Reinhold Publishing Corp., 1962.

J. Frederick, "Ultrasonic Engineering." New York: John Wiley & Sons, Inc., 1965.

R. C. McMaster, ed., "Nondestructive Testing Handbook," Vol. II, Section 43–50, 1959. American Society for Nondestructive Testing, Columbus, OH 43328

A. L. Phillips, ed., "Welding Handbook" (Sixth Edition), pp. 6.54-60. New York: American Welding Society, 1968.

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3. **General**—Ultrasonic testing is a versatile nondestructive inspection method which is applicable to most solid materials, metallic or nonmetallic. Materials inspected include steel, aluminum, cast iron, concrete, rubber, glass, and plastics. Through these tests, surface and internal discontinuities such as laps, seams, voids, cracks, blow holes, inclusions, lack of bond, and porosity can be detected. Material thickness can be accurately measured from one side. Under certain conditions, materials at elevated temperatures can be inspected.

Totally automatic systems are in use in heavy industry. Location of defects can be marked on parts, or graphic recordings made of parts. Parts can be automatically removed from a processing line when defect severity exceeds established limits.

In many cases, the extent of discontinuities can be determined. The minimum size discontinuity which can be located by ultrasonics in a given application is determined by:

- a. The sensitivity of the test equipment
 1. Physical characteristics of the transducer
 2. Gain/band width characteristics of the instrument
- b. The material inspected
 1. Physical properties (modulus, grain size)
 2. Surface condition (i.e., rough, smooth, wavy, scaly, painted)
- c. The test frequency used; in general, higher test frequencies permit detection of smaller discontinuities. Lower frequencies permit penetration of greater thickness of material, or of coarse grained material that cannot be inspected with the higher frequencies.
- d. Orientation of discontinuity and its distance from the ultrasound entrant surface
- e. Type of defect and acoustic impedance mismatch

In addition to discontinuity detection, ultrasonic energy is also used to gage the thickness of materials from one side. Yield or tensile strength of nodular cast irons can be estimated through its relationship to the velocity of ultrasonic energy in the metal.

4. **Principles**—Ultrasonic inspection is made possible by the ability of most solid materials to support the transmission of high frequency sound waves. This ability to support these mechanical vibrations varies for different materials, and depends upon certain physical properties of each material, such as density, modulus, grain structure, etc.

All ultrasonic tests involve introducing controlled ultrasonic energy into the object under test, and observing how the passage of sound is affected in transit. Any discontinuity in the material can reflect, disperse, or attenuate the energy. The ultrasonic energy used for testing is usually generated in short bursts or pulses by piezoelectric transducers driven by appropriate electronic circuitry. Test frequencies used are usually between 1 to 25 MHz, and the pulse repetition rates from a few hertz to thousands of hertz. Since air will not support these ultrasonic signals, a liquid such as water or oil is used to couple the energy from the transducer into the material under test. Ultrasonic transducers, often called search units, are typically less than 25 mm (1 in) in diameter. Thus, when inspecting large objects, it is necessary to scan the object with the transducer.

5. Types Of Tests

5.1 Pulse Echo—A pulse of ultrasonic energy is transmitted into the part. The time required for the reflected energy to return to the transducer is observed. A discontinuity is usually indicated by:

- a. Reflections received from locations where no physical discontinuities (such as end faces, grooves, or holes) are known to exist
- b. Loss of the reflection from the known physical discontinuity

5.1.1 ADVANTAGES

- a. Single transducer operation permits inspection with access to only one side of the material
- b. The resolution and sensitivity of this method, in most applications, is superior to other ultrasonic methods

5.1.2 DISADVANTAGES—The minimum thickness of material which can be inspected is about 0.254 mm (0.01 in) with present-day equipment.

5.2 Through Testing—Either a pulsed or continuous beam of energy is coupled into the material from one transducer. A second transducer, placed in a position to receive the transmitted energy, receives the energy leaving the material. Changes in the amplitude of the received energy indicates discontinuities in the part.

5.2.1 ADVANTAGES

- a. The energy passes through the part only one time, permitting this test to be used on materials difficult to penetrate
- b. Very thin materials can be tested

5.2.2 DISADVANTAGES

- a. Precision fixturing for two transducers and preparation of two test surfaces are required
- b. The accuracy is usually less than in Pulse Echo testing
- c. Depth of discontinuity cannot be determined

6. Procedure—Two techniques, contact testing and immersion testing, are used in ultrasonic inspection. In any application, the material under test should be cleaned to remove any loose particles or scale prior to inspection.

6.1 Contact Testing—The transducer is placed directly against the material under test. A film of liquid couplant (i.e., water, oil, glycerine) is required between them.

6.1.1 ADVANTAGES

- a. Relatively low cost equipment
- b. Portable battery operated equipment available
- c. Good sound penetration
- d. Surface defects can be detected by transmitting a surface wave along the outside contour of most parts. Results are a direct function of surface smoothness, improving with better surface.

6.1.2 DISADVANTAGES

- a. A reasonably smooth surface finish is required
- b. The energy cannot be readily focused to obtain increased resolution and sensitivity in a given area
- c. Difficult to control shape and direction of beam
- d. The transducer is subject to wear thus requiring replacement or wear/shoes in some applications
- e. Sensitivity is variable, depending upon the efficiency of the coupling

6.2 Immersion Testing—The material to be inspected is placed in a reservoir of couplant liquid. The transducer is immersed in the reservoir and accurately positioned relative to the material under test. Water columns between the transducers and the test surface may also be used where immersion is undesirable.

6.2.1 ADVANTAGES

- a. The energy can be focused or shaped for the part, permitting increased resolution and sensitivity
- b. Immersion coupling facilitates the inspection of nonuniformly contoured parts
- c. Better close-to-surface resolution than other ultrasonic techniques
- d. Lends to automatic inspection and recording of results
- e. Transducer wear is minimized
- f. Test results are more repeatable

6.2.2 DISADVANTAGES

- a. The requirement of immersing the sample
- b. The necessity of accurate positioning of the material and transducer(s)
- c. The sample (or object) size is limited by the size of the immersion reservoir
- d. Equipment is expensive when compared to contact techniques

7. Notes

7.1 Marginal Indicia—The change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE IRON AND STEEL TECHNICAL COMMITTEE DIVISION 25—
NONDESTRUCTIVE TEST METHODS