Ultrasonic Inspection — SAE J428b

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Purpose—The purpose of this report is to provide basic information on ultrasonics, as applied in the field of nondestructive inspection. References to detailed information are listed in the Bibliography.

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:

1. The sensitivity of the test equipment.
   (a) Physical characteristics of the transducer.
   (b) Gain/band width characteristics of the instrument.
2. The material inspected.
   (a) Physical properties (modulus, grain size).
   (b) Surface condition (rough, smooth, wavy, and so forth).
3. 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.
4. Orientation of discontinuity and its distance from the ultrasound entrant surface.
5. 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.

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 in extent 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 1–25 MHz, and the pulse repetition rates from a few Hz to thousands of Hz. 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.

Types of Tests—There are three basic types of ultrasonic test techniques. The Pulse Echo technique is by far the most commonly used.

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.

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.

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

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 indicate discontinuities in the part.

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.

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

3. **Resonance Testing**—A swept frequency beam of ultrasonic energy is coupled into the part from the transducer. When the resonant frequency of the material under test is reached, a thickness indication is obtained.

Advantages: Material down to a few thousandths of an inch can be measured or inspected from one side.

Disadvantages:
(a) Interpretation and calibration of instrument can be troublesome.
(b) For flaw detection, the sensitivity is generally less than in Pulse Echo testing.

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

1. **Contact Testing**—The transducer is placed directly against the material under test, with a film of liquid couplant (for example, water, oil, glycerine) between.

Advantages:
(a) Precision positioning apparatus requirements are reduced.
(b) 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.
(c) Good sound penetration
(d) Portable battery operated equipment available.
(e) Relatively low cost equipment.

Disadvantages:
(a) Good surface 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.

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 may also be used where immersion is undesirable.

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) Automatic inspection—uniform couplant.
(e) Transducer wear is minimized.

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.

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.