TECHNICAL BACKGROUND ON MsS

Sensor Principle

- Guided wave generation—Based on the magnetostrictive (or Joule) effect
- Guided wave detection—Based on the inverse-magnetostrictive (or Villari) effect

The magnetostrictive effect refers to a small change in the physical dimensions of ferromagnetic materials—on the order of several parts per million in carbon steel—caused by externally applied magnetic field.

The inverse-magnetostrictive effect refers to a change in the magnetic induction of ferromagnetic material caused by mechanical stress (or strain).

The above effects exist only in ferromagnetic materials. The magnetostrictive effect was discovered by Joule in 1847 and the inverse effect by Villari in 1864.

Sensor Configurations, Instrumentation, and Technical Features

The sensor is configured to apply a time-varying magnetic field to the material under testing and to pick up magnetic induction changes in the material caused by the guided wave. For cylindrical objects (such as rod, tube, or pipe), the MsS is ring-shaped to encircle the object. For plate-like objects, the MsS is rectangular-shaped to be placed on the surface of the object.

A schematic diagram of the MsS and associated instruments for generation and detection of guided waves is shown in Figure 1. The MsS instrument is composed of a transmitter section and a receiver section. To allow the directionality control of the generated and detected guided wave signals, the MsS instrument contains two transmitters and two receivers. The output signals of the receiver section are displayed on a digital oscilloscope (with MsSR-2020) or on a laptop computer (with MsSR-2020D).

To operate the MsS, the material under testing needs to be in a magnetized state. This is achieved by applying a DC bias magnetic field to the material using either permanent magnet, electromagnet, or residual magnetization induced in the material. The DC bias magnetization is necessary to enhance the transduction efficiency of the sensor (from electrical to mechanical and vice versa) and to make the frequencies of the electrical signals and guided waves the same. The transduction efficiency of the MsS increases initially with increasing DC bias magnetic field level, reaches a maximum, and then decreases with further increase in the DC bias magnetic field level, as illustrated in Figure 2. The optimum DC bias magnetic field is typically the level just below the knee of the magnetization curve of the material under testing.

Technical features of the MsS include:

- Requires no couplant
- Can be operated with a gap to the material under testing
- Is broadband
- Has a good sensitivity in frequencies up to a few hundred kHz
Figure 1. Schematic diagram of the MsS and associated instruments

Figure 2. Transduction efficiency versus DC bias magnetic field level
Applicable guided wave modes are:

- Longitudinal, torsional, and flexural wave modes in cylindrical objects
- Symmetric and antisymmetric Lamb wave and shear horizontal wave modes in plates.

The operating wave mode of the MsS is controlled by the relative alignment between the DC bias magnetic field and the time-varying magnetic field produced by the MsS. For longitudinal wave modes in cylindrical objects and Lamb wave modes in plates, a parallel alignment is used. For torsional wave modes in cylindrical objects and shear horizontal wave modes in plates, a perpendicular alignment is used.

**Application to Nonferrous Materials—Thin-Ferromagnetic-Strip Approach**

Since the MsS relies on magnetostrictive effects, it is applicable only to ferrous materials such as carbon steel, alloy steel, and ferritic stainless steel (300 series). However, application of the MsS can be easily extended to nonferrous materials (such as aluminum) by bonding a thin strip of ferromagnetic material (such as nickel) to the nonferrous material and operating the MsS over that strip. In this case, the MsS generates the guided waves in the strip. The generated guided waves are then mechanically coupled to the nonferrous material and propagate. Detection of the guided waves is achieved in the reverse manner.

This thin-ferromagnetic-strip approach is also very useful for generating and detecting guided waves in ferrous materials. Advantages of this approach over direct generation and detection in ferrous materials are (1) higher MsS sensitivity and (2) no need to magnetize the ferrous material under testing. The thin-ferromagnetic-strip approach is particularly useful for long-range torsional wave inspection of piping and shear horizontal wave inspection of plate.
MsS INSTRUMENT (Model MsSR 2020) AND SPECIFICATIONS

Front View

Rear View

Specifications

Transmitter:
- Outputs: Two HV differentially driven synchronous burst type outputs. May be operated in-phase or with ±90-degree phase displacement (for directionality control)
- Waveforms: Sine or square
- No. of Cycles: 1–8 selectable
- Output Voltage: 300 Vpp max.
- Output Current: 40 App max.
- Output attenuation: 0 to 100% in 20% steps
- Frequency: 2 to 250 kHz with 500-Hz resolution
- PRF rate: 1 to 64 pps in binary increments
- Ext. Sync: TTL compatible, neg. edge justified
- Setup monitor: Switch settings readable by PC
**Receiver:**

**Inputs:** Two HV protected differential inputs summed together. Prior to summation, the signals may be electronically phase shifted ±90 degrees (unidirectional capability).

**Gain:**
- 110 dB max. overall
- 40 dB fixed gain standard (internally adjustable)
- 0–40 dB coarse gain (10-dB steps)
- 0–30 dB fine gain (2-dB steps)

**Filters:**
- 8 individual 4-pole active filter modules
- Standard designs span frequency range.
- (Other LP, HP, or BP designs can be provided for special applications.)

**Signal Output:** Analog waveform, ±3V max. into 50 ohms

**Output Impedance:** 50 ohms

**Setup monitor:** Switch settings readable by PC

**Optional Digital Signal Outputs:** 12 bits, parallel interface (for Model MsSR 2020D)

**Operating Modes:** Pulse-echo or pitch-catch

**Power:**

**MsS Unit:** 90–264V, 50/60 Hz

**Environmental Conditions:**

**Temperature:**
- +5 to +122 deg. F (operating)
- -15 to +50 deg. C
- -4 to +140 deg. F (storage)
- -20 to +60 deg. C

**Humidity:**
- 10 to 80 % rel. hum. (operating)
- 5 to 95 % rel. hum. (storage)
- Noncondensing

**Enclosure:**

**Dimensions:** 18.2" (46.3 cm) d x 18.5" (47.1 cm) w x 5.8" (14.7 cm) h without end covers
- Add 3.5" (8.9 cm) to depth with end covers installed.
- Tip-up handle also included.

**Weight:** 31.5 lbs (14.3 kg)
**PATENTS AND PUBLICATIONS**

*U.S. Patents on MsS (as of January 25, 2002)*


**Pending Patents**


Publications on MsS


