NEW ELECTROMAGNETIC TRANSDUCER APPLICATIONS

R. B. Thompson
Science Center, Rockwell International
Thousand Oaks, California 91360

ABSTRACT

A number of recently identified applications of electromagnetic transducers (EMAT's) are identified. These have been made possible by the development of optimized electronics which allow one to obtain high signal-to-noise ratios in EMAT systems despite the fact that the transduction efficiencies are somewhat lower than those of piezoelectric transducers. It has been demonstrated that EMAT's can be used to excite horizontally polarized shear waves which have the property that the particle motion is always parallel to the surface of the part in which they are excited, independent of the direction of propagation. Such waves have a number of attractive features. They do not mode convert on reflection from obstructions parallel to the shearing motion, they are not accompanied by the excitation of surface waves, they can be scanned in angle with little change in amplitude by varying the drive frequency, and they can be excited and detected at surfaces that may be irregular, painted or at high temperatures. Application of these transducers to the inspection of welds in thick plates at welding temperatures is discussed. An ultrasonic ellipsometer, which excites a shear wave of controlled, elliptical polarization which can be used in a fashion analogous to optical ellipsometry to measure the properties of thin layers, such as adhesive bonds, is presented. The use of EMAT's to detect residual stress in ferromagnetic materials is also reviewed.

This poster summarizes a number of new ultrasonic inspection capabilities that have been made possible by electromagnetic-acoustic transducers (EMAT's) and that represent advances that contribute to the well-known advantages of non-contact operation.

Figure 1 shows that optimum transducer systems have been developed by combining the development of sensitive, dedicated electronics with analysis of radiation properties. This analysis is particularly appropriate for EMAT's since the coupling is very reproducible.

Figure 2 illustrates that horizontally polarized angle shear beams can be excited, as opposed to the vertically polarized beams produced by angled incidence of a compressional wave excited by a piezoelectric transducer. Several of the advantages of the horizontal shear waves are enumerated.

Figure 3 demonstrates one use of this new transducer in the high-temperature, electronically-scanned inspection of welds.

Figure 4 carries this idea one step further by indicating that shear waves of arbitrary elliptical polarization can be excited using the periodic permanent magnet EMAT. This makes possible the construction of an elastic wave ellipsometer having high sensitivity to surface conditions, analogous to an optical ellipsometer.

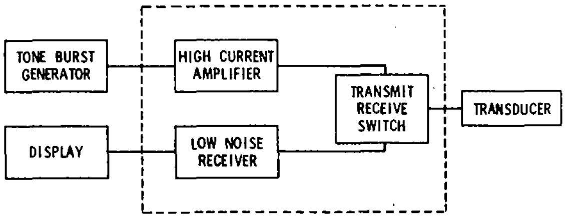
Figures 5 and 6 show that, on ferromagnetic materials, EMAT's can be used to measure residual stress. This occurs because magnetostriction is very stress sensitive. EMAT efficiency is determined by magnetostrictive properties, and specific parameters in the field variation of transducer efficiency can be selected as stress indicators. The properties of a device built on these principles are indicated.

In Fig. 7, a number of the many advantages of EMAT's are summarized.

Acknowledgement

This research was sponsored by the Center for Advanced NDE operated by the Science Center, Rockwell International, for the Advanced Research Projects Agency and the Air Force Materials Laboratory under contract F33615-74-C-5180, and the Rockwell International Independent Research and Development program.

ELECTRONIC DEVELOPMENT

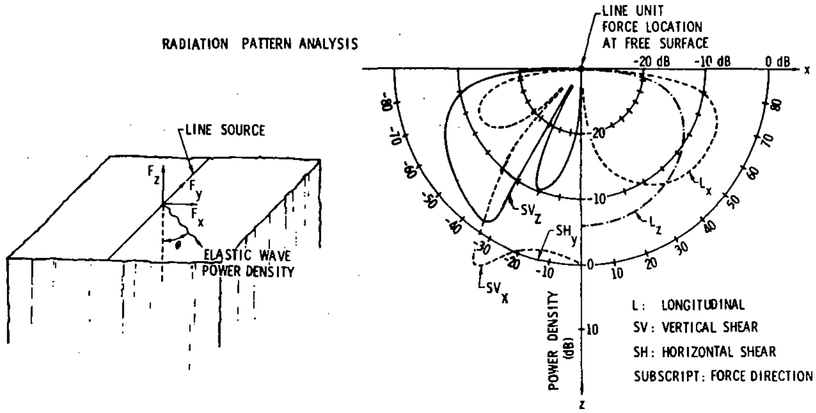


A. LIGHTWEIGHT DEDICATED ELECTRONICS

B. TRANSMIT PULSES OF 75 AMPS (p-p) INTO 1 OHM

C. RECEIVER NOISE FIGURE OF 1.5 dB

RADIATION PATTERN ANALYSIS



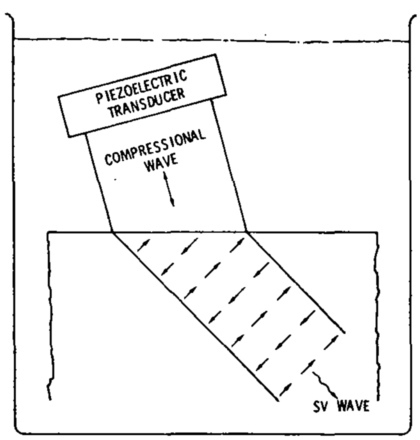
A. DETERMINE DIRECTIONS OF MOST EFFICIENT GENERATION

B. MINIMIZE UNWANTED MODES DUE TO STRAY FIELDS

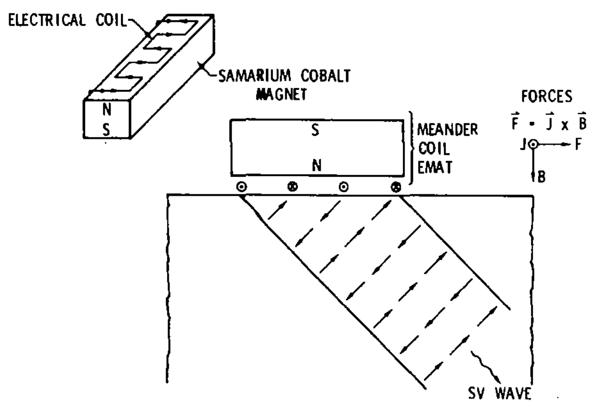
C. DEFINE DRIVE LEVEL NEEDED IN SCANNED BEAM APPLICATIONS

Figure 1. Optimized transducer systems.

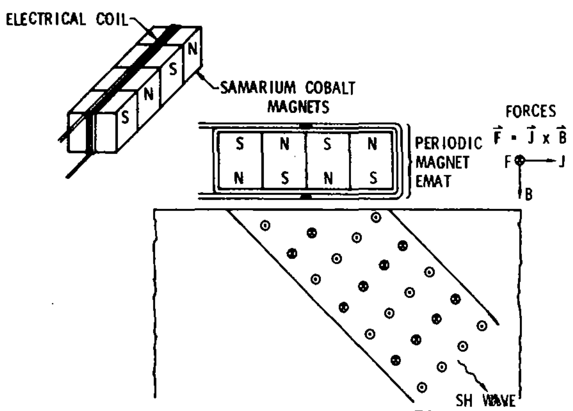
CONVENTIONAL TECHNIQUES EXCITE ANGLE SHEAR WAVE BY MODE CONVERSION



MEANDER COIL EMATs EXCITE VERTICALLY POLARIZED ANGLE SHEAR WAVES



PERIODIC MAGNET EMATs EXCITE HORIZONTALLY POLARIZED SHEAR WAVES



ADVANTAGES OF HORIZONTALLY POLARIZED SHEAR WAVES EXCITED BY EMATs

- CANNOT BE EXCITED BY CONVENTIONAL TECHNIQUES AND HENCE PROVIDE NEW INFORMATION
- DO NOT LEAK OFF OF IMMERSED PARTS BY MODE CONVERSION
- CAN BE GENERATED AT ANY ANGLE WITH RESPECT TO SURFACE WITHOUT LONGITUDINAL WAVES ALSO BEING GENERATED
- DO NOT MODE CONVERT TO LONGITUDINAL WAVES UPON REFLECTION FROM PARALLEL SURFACES SUCH AS WELD COUNTERBORES.
- CAN BE SCANNED IN ANGLE BY VARYING FREQUENCY
- CAN BE EXCITED ON PARTS AT ELEVATED TEMPERATURE

Figure 2. Horizontal shear waves.

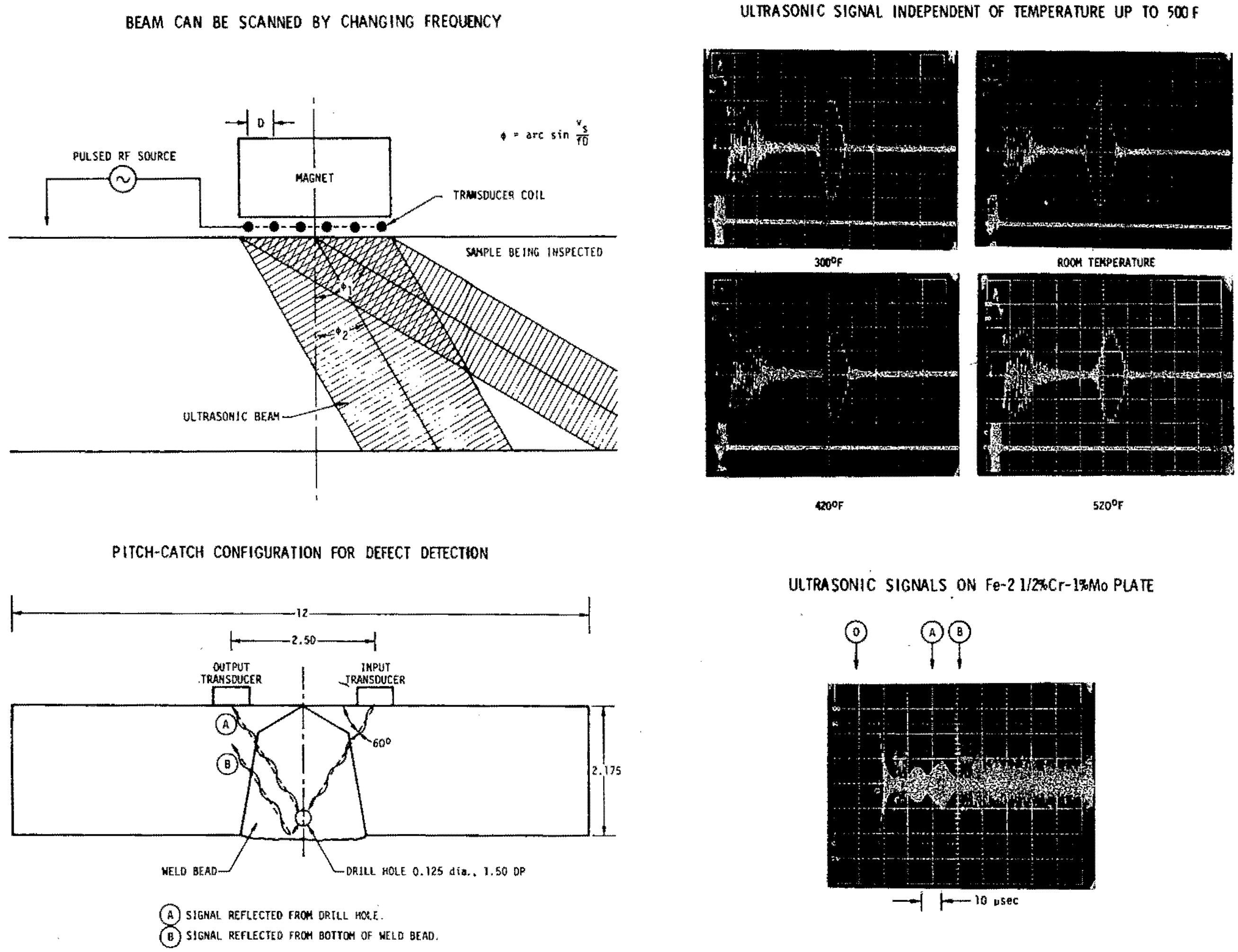


Figure 3. High temperature electronically scanned weld inspection.

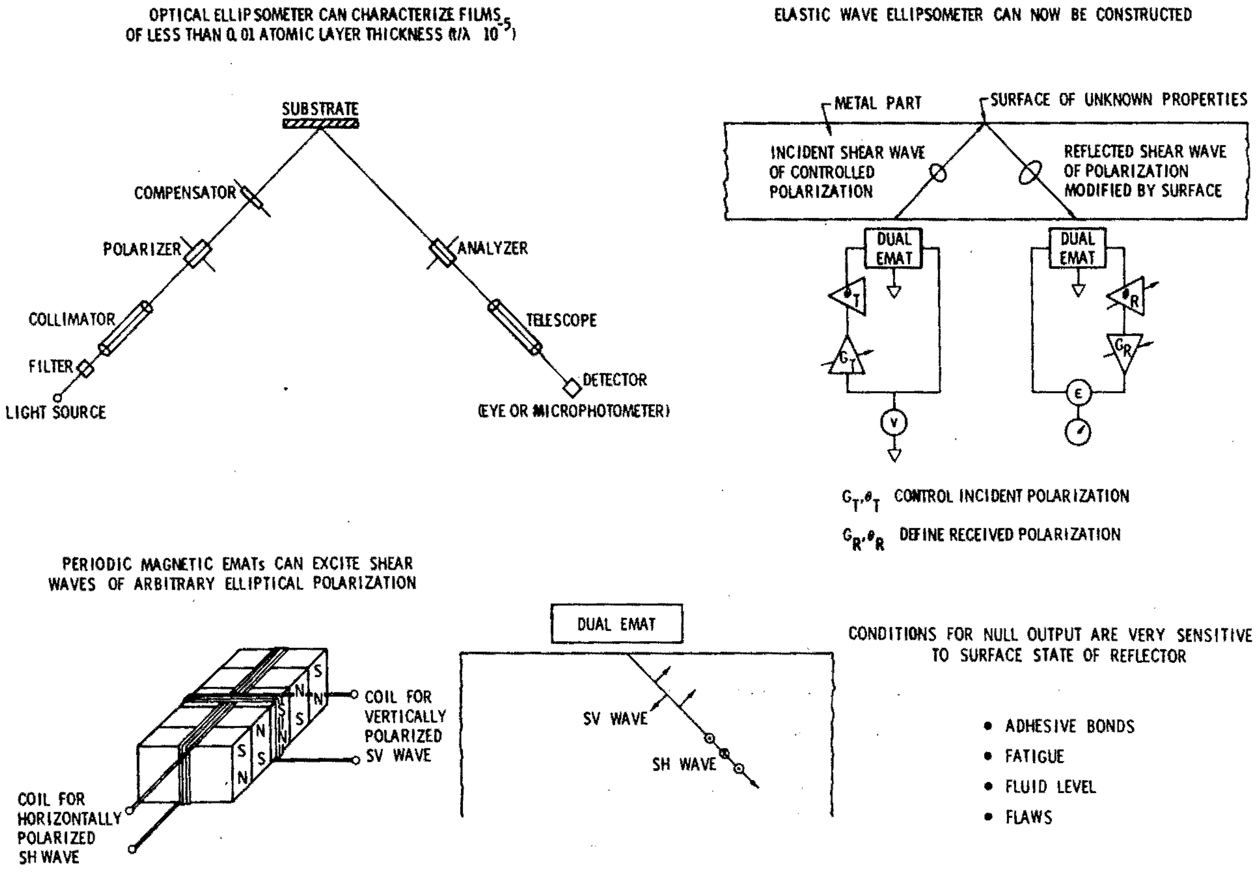


Figure 4. Elastic wave ellipsometer.

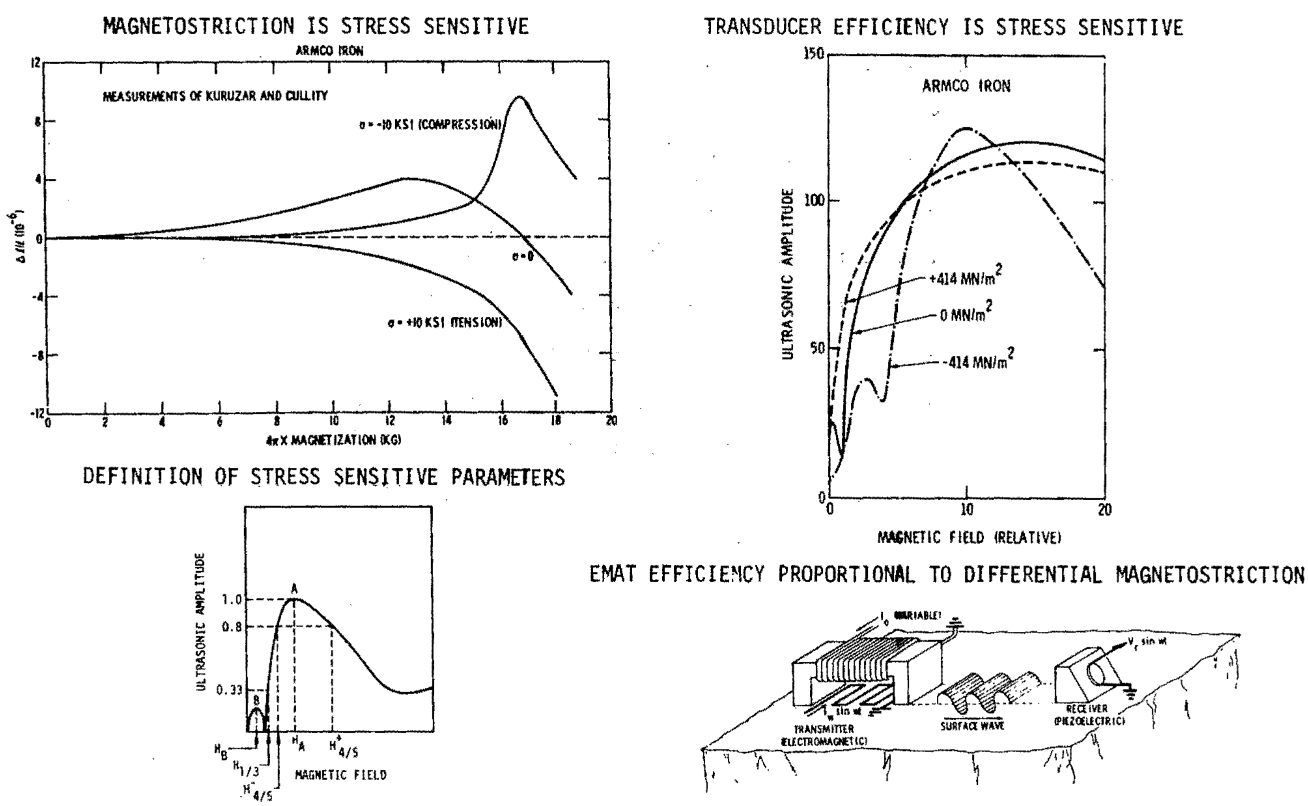
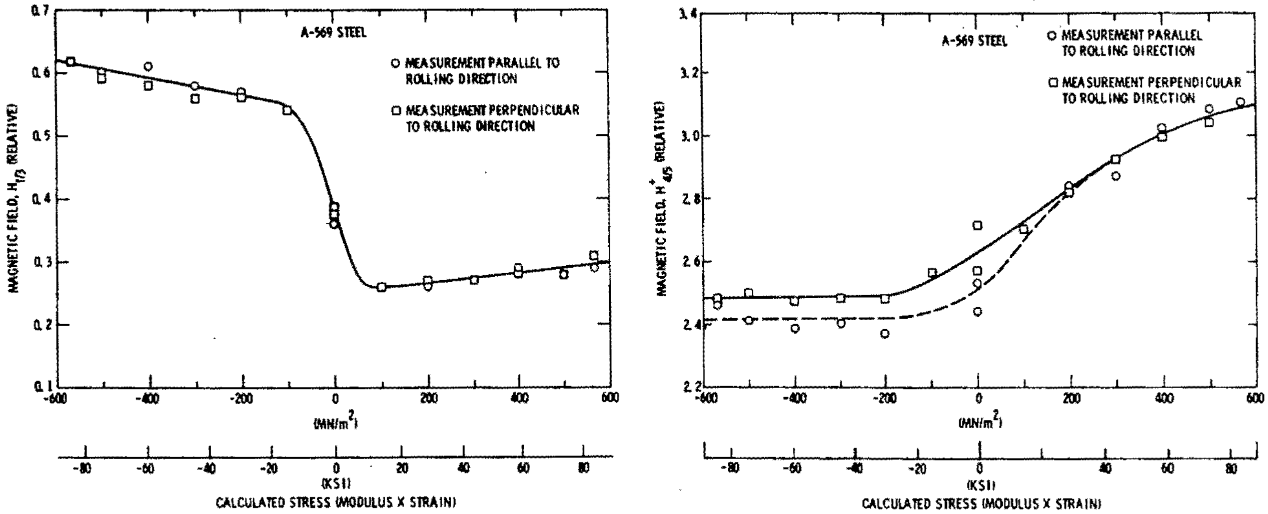


Figure 5. Stress detection in ferromagnets.



SUMMARY OF CHARACTERISTICS

- LIGHTWEIGHT, PORTABLE PROBE
- OPERATION ON PAINTED AND ROUGH SURFACES
- MEASUREMENT AVERAGES STRESSES OVER ELECTROMAGNETIC SKIN DEPTH
- PRELIMINARY EXPERIMENTS INDICATE FATIGUE DETECTION POSSIBLE
- MULTIPLE PARAMETERS USEFUL IN DISTINGUISHING STRESS EFFECTS FROM MATERIAL VARIABILITIES

Figure 6. Experimental data showing behavior of different parameters.

- ELECTROMAGNETIC TRANSDUCERS PARTICULARLY USEFUL
  - AT HIGH SPEED
  - AT HIGH TEMPERATURE
  - IN REMOTE LOCATIONS
  - FOR ELECTRONICALLY CONTROLLED BEAM SCANNING
- ELECTROMAGNETIC TRANSDUCERS CAN PRODUCE NEW WAVE TYPES
  - HORIZONTALLY POLARIZED SHEAR WAVES
  - SHEAR WAVES OF CONTROLLED ELLIPTICAL POLARIZATION
  - RADIALLY POLARIZED SHEAR WAVES
- ELECTROMAGNETIC TRANSDUCERS CAN BE USED TO DETECT STRESS IN FERROMAGNETIC MATERIALS

Figure 7. Conclusions.