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ULTRASONICS IN INDUSTRY SESSION.

Electromagnetic Generation of Ultrasound in Hot Metals*

D.R. Peck† and E.R. Dobbs
Department of Physics, University of Lancaster

The direct generation of acoustic waves is achieved by applying pulses of r.f. to a flat coil placed near the metal surface in the presence of a static magnetic field. By this method, electromagnetic energy is converted into mechanical energy in the metal 'surface' without the use of a piezoelectric transducer; the metal surface acts as its own electromagnetic transducer.

Longitudinal and shear waves may be produced by the same coil, the mode generated depends only upon whether the static magnetic field is parallel or perpendicular to the plane of the coil.

Electromagnetic generation is the only known technique of directly coupling ultrasound into a metal without requiring an acoustic coupling medium between the ultrasonic generator and the metal under investigation. Unfortunately the conversion efficiency of an electromagnetic transducer is much less than that of conventional transducers[2,3], but in spite of this disadvantage the technique is likely to find application in industrial NDT where there is a need to overcome severe bonding problems. This obviously occurs in coupling ultrasound into hot metals from about 400°C to 1200°C.

We have used a conventional ultrasonic r.f. pulse system to drive an r.f. coil in contact with an insulating layer on the metal specimen, with a similar separate coil on the opposite face to detect the ultrasonic pulses. The component of the r.f. field produced by the transmitting coil, which is effective in generating longitudinal waves, is the fringing field at the metal surface parallel to the direction of the applied magnetic field. A study of various coil designs has shown that the flat spiral type of coil is the most efficient. The metal samples with their coils were heated in a vacuum furnace fixed between the poles of a large electromagnet.

The results obtained for generation of ultrasound in aluminium alloy HE30 and in mild steel at high temperatures are shown in Figures 1 and 2. The echo height observed in the receiving transducer depends on two factors: (a) the conversion efficiency of the generating and detecting processes and (b) the attenuation in the sample path length. Two successive echoes were monitored so that a separation of these two factors could be made.

For our system, using industrial metals and at radio frequencies, the power P of the received signal is[4]

$$P \propto \frac{B_O^4 \, I_T^2}{\rho^2 V^2 (1+\beta^2)^2}$$

where ρ is the density of the metal, V is the velocity of sound, $\beta = \frac{1}{2}(q\delta)^2$, q is the wave number, δ is the classical skin depth, B_O the static magnetic field and I_T the transmitter coil current. The generation in different metals depends on the factors ρ, V and β, and is more efficient in less dense materials. It is nearly independent of T above 0°C (Fig. 1) Generally our results in non-magnetic materials deviate at high temperatures (Figure 1)from the theoretical calculations using the above equation, which is based on a classical analysis of generation in a free electron metal.

Previous ultrasonic attenuation studies[5] in mild steel have been limited to 800°C, largely because a non-contact method was not available. They found no change in attenuation near the Curie point (770°C) and we have confirmed this result. In contrast, the generated signal exhibits a striking transition at the Curie point (Figure 2). We have verified that this enhancement of the generated signal is also obtained at the Curie point of Nickel. In addition to the dramatic amplitude change in the signal at the Curie point, other small, but definite, critical points are detected, which are not observable in the ultrasonic attenuation. These critical points occur at the temperatures of known phase changes in the alloys.

Our results show that electromagnetic generation may be useful in quality control by monitoring the temperature dependence of the phase transitions of hot metals, as well as providing a non-contact method of coupling ultrasound in both ferrous and non-ferrous metals at high temperatures.

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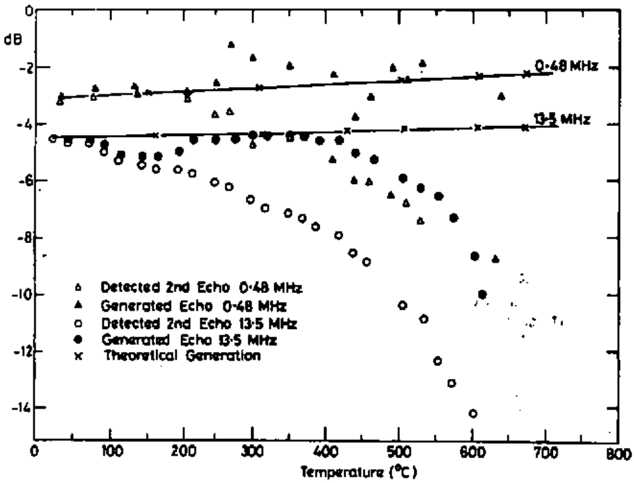

Fig.1 Temperature dependence of the electromagnetically generated and detected signals in aluminium alloy HE30.

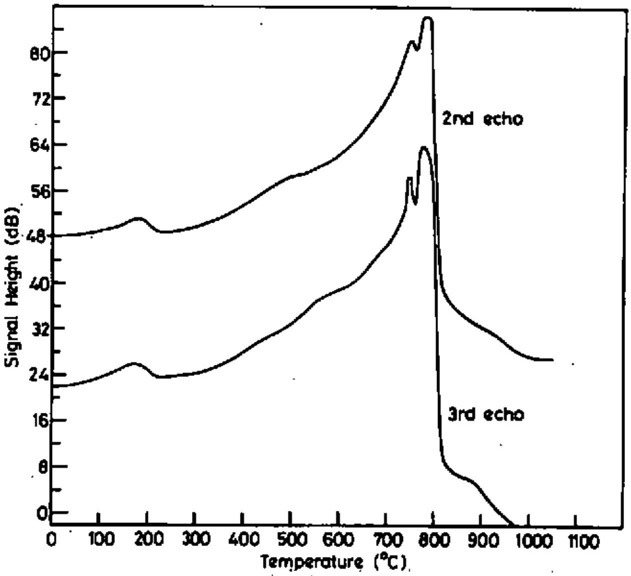

Fig.2 Plot of electromagnetically generated and detected signal heights vs temperature at 6.5 MHz in a 2.0 cm thick sample of mild steel. (The plot of the 3rd echo has been displaced 26 dB relative to the 2nd echo.)