V. A. Komarov. *Electromagnetic-acoustic conversion—a method of nondestructive testing.* Ultrasound research methods are widely used in various branches of solid state physics.[1] In a number of cases, however (thin films, high and low temperatures, vacuum, samples with rough surfaces or with surfaces having complicated profiles, etc), their application is limited or extremely complicated because they require the formation of a reliable contact between the converter (usually, in the form of a piezoelectric element) and the sample.

Because of this, many other alternative methods of contactless excitation of sound in solid media are developed using, for example, a flux of charged particles, lasers, etc.

The so-called electromagnetic-acoustic (EMA) method, based on the phenomenon of mutual conversion of elastic and electromagnetic fields has undergone the greatest development.[2] As a result of the EMA conversion, it is possible not only to achieve a contactless excitation of sound in solid bodies[3], but also to obtain, without making any contacts, information about the sound velocity, amplitude, and attenuation with the help of an electromagnetic field caused by sound. This electromagnetic field and the radiation of a primary field are measured by an ordinary induction coil, the shape of which can be easily changed to fit the special features of the sample geometry.

Conversion of fields in solids can be performed using many physical phenomena which are responsible, for example, for magnetostriction, the Lorentz force, and the force caused by the gradient of a magnetic field.

Researchers in the area of methods of nondestructive testing have devoted a lot of attention to the EMA conversion phenomenon exactly because of the possibility of contactless excitation of sound.[2] Many of the devices developed by them were made only in a few isolated instances because of technological difficulties, but, still, with their help it became possible to demonstrate the significant potential usefulness of this phenomenon for technical applications: for the excitation of Lamb and Rayleigh waves, the measurement of crystallographic anisotropy and determination of elastic modulus, the measurement of internal friction, introduction of vibrations at an angle, and their focusing. For example, in the USA[4] the method has been used in the following areas: high-speed quality control of manufactured items (gas pipe-lines and railroads), hardness control of artillery shell warheads, detection of corrosion defects in pipes, breakdown of structural continuity in the areas of airplane wings difficult acces, testing of welding seams of aluminum pipes and pipelines, monitoring of contraction cavities in hot metal blanks, determination of the bending and the tension caused by it in pipelines, measurement of metal sheet thickness.

All the described applications of ultrasound methods using the EMA method exist primarily because of the absence of a contact; however, there is also a fundamentally new direction in the use of the phenomenon of mutual conversion of fields, related to the mechanisms of conversion.

During the rolling of hot metals, it is necessary to control the thickness of a metal in order to introduce timely corrective measures into the operation of a rolling mill. The metallurgical plant in Chelyabinsk is using an installation for thickness measurement of pipe walls during their manufacture. To a metal heated above the Curie point a converter is applied in the form of a coil, and an appropriate field is applied to the monitored area. The metal under the converter is cooled by an air flow. The temperature of the metal is reduced below the Curie point. At the moment of an order-disorder phase transition, intense longitudinal vibrations are excited in the metal (caused by volume magnetostriction[5]), the electric field of which is registered by the same converter. As in the usual thickness meter, the measured quantity is the time interval during which the sound pulse passes through the double thickness of the metal.

Analogous systems are used at metallurgical plants in Britain and Japan.

Other applications of the EMA conversion are also related to the manifestation of a magnetostriction mechanism accompanying the conversion of fields in ferromagnetic metals. In that case the excitation of elastic waves is caused by all the forces mentioned above, but their dependence on the polarizing field is determined by different phenomenological characteristics. The volume Lorentz force depends on induction, the surface force caused by the jump of magnetization at the boundary separating two media depends on the magnetic field and magnetostriction force, or on the differential magnetostriction, when the constant polarizing field and the high-frequency (HF) field of the converter are parallel, or on the ratio of the magnitude of magnetostriction to the amplitude of the polarizing field, if the HF field is perpendicular to it. The elastic vibrations determined by these forces depend on the polarizing fields in a complicated way. A detailed study of the EMA conversion[6] has shown that during the polarization of a ferromagnetic material by the tangential field (along the interface of two media), which is parallel to the vector of the HF field, it becomes possible to

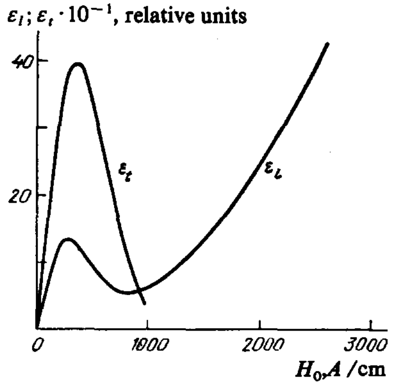

FIG. 1

create conditions, when the information about an electrodynamic mechanism and a mechanism caused by magnetostriction can be obtained separately. This is assisted by the fact that the elastic vibrations generated by the Lorentz force have phases opposite to the phases of vibrations generated by the surface force, which depends on magnetization. As a result, their total contribution becomes dependent on the magnitude of the internal polarizing field, and effects of the magnetostriction mechanism become noticeable in comparatively weak fields (300–500 Oe).

It was found that the efficiency of the magnetostriction mechanism depends to a large extent on the direction of elastic vibrations. In turn, the direction of propagation of these vibrations depends on the degree of the inhomogeneity of the HF field along the interface of two media, i.e. on the geometry of the source of radiation. In the process of producting an inhomogeneous field the manifestation of magnitostriction mechanism in weak fields increases sharply. Fig. 1 shows the efficiency of the double conversion (electromagnetic field—sound—electromagnetic field) as a function of the polarizing magnetic field. In the case of a relatively uniform HF field the efficiency of magnetostriction mechanism (ε_l) is small (longitudinal vibrations are excited). With an increase of the field, the contribution of the mechanism decreases sharply, and the contribution from the electrodynamic mechanism becomes dominant (section of the curve above $H_0 = 10^3$ A/cm).

For an inhomogeneous HF field the efficiency of excitaton of transverse vibrations (ε_t) in weak fields increase sharply due to magnetostriction. As a result, it becomes possible to use the EMA conversion of evaluation of internal stresses of the second kind and for quality control of thermal processing of steels[6], and for the measurement of internal friction. A device called EMAKS-1R has been developed, which allows (in the resonant regime) to use the phenomenon of field conversion for practical applications.

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