COMPARISON OF ELECTROMAGNETIC EMISSION FROM CRACKING OF PIEZOELECTRIC AND MAGNETITE PLATES

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Abstract

Electromagnetic emission (EME) caused by a fracturing of crystals in rocks has been studied theoretically [5-7]. In particular, in [2,3] we have considered a piezoelectric of a finite size with a uniformly moving crack whose linear front is parallel to the optical axis of the crystal. The tip of the crack has instantly begun the uniform movement at a moment \( t = T > 0 \). It has been revealed that time-dependent mechanical stresses which exist in the vicinity of the crack's apex are a source of the electromagnetic waves, see Fig. 1. The EME has been investigated for the piezoelectric crystals of point symmetry group 32 and for the piezoelectric crystals of D3d space group symmetry in the first approximation for piezoelectric coefficients and in zero approximation for the piezoelectric coefficients of the uncracked crystal. In the second variant, it is supposed that a piezocrystal with a power-like initial stress distribution is placed in an infinite elastic medium and the EME is considered under conditions for the symmetric field. It has been obtained that intensity of the emission has lots of maxima and zeroes as a function of its frequency, whose wavelengths are determined by the crystal size and the crack's velocity and are located in a long-wavelength region of spectrum. It has been found also that a source of the emission is equivalent to a time-dependent mechanical dipole for both piezoelectric and piezomagnetic crystals, and values of the magnetization vector and corresponding magnetization current have been estimated.

Basic Equations

It is supposed that a piezoelectric is surrounded by rocks having similar mechanical and dielectric properties. Therefore it is possible not to take into account boundary conditions for the electromagnetic field and mechanical strains, and to consider this medium as unbounded, but assume that some piezoelectric is of a size \( L \), placed inside of the rock [2, 3]. Then equations of the medium motion and equations of electromagnetic field written in the mechanical stresses tensor, respectively, \( \sigma \), and the constitutive equations for the piezoelectric crystal have the form:

\[
\begin{align*}
\rho \ddot{U} + \nabla \sigma &= 0, \\
\nabla \cdot \sigma &= 0,
\end{align*}
\]

where \( \rho \) is the crystal density, \( \sigma \) are components of displacement vector and mechanical stresses tensor, respectively. \( \ddot{U} \) denotes partial derivative with respect to \( t \), \( \nabla \) is the gradient operator, \( \nabla \cdot \sigma \) are vectors of electric and magnetic field and corresponding inductions, respectively; \( c \) is the velocity of light.

The constitutive equations for the piezoelectric crystal have the form:

\[
\begin{align*}
\sigma &= \epsilon_0 \varepsilon_0 E + \epsilon_0 \chi \varepsilon_i, \\
D &= \epsilon_0 \varepsilon_0 E + \epsilon_0 \chi \varepsilon_i + \rho_0 H.
\end{align*}
\]

for the piezoelectric crystal:

\[
\begin{align*}
\varepsilon_0 \varepsilon_0 \varepsilon_i E + \varepsilon_0 \chi \varepsilon_i &= \varepsilon_0 \varepsilon_0 \varepsilon_i E + \varepsilon_0 \chi \varepsilon_i + \rho_0 H, \\
\rho_0 H &= \mu_0 M.
\end{align*}
\]

References