On wave propagation in linear piezoelectricity with full electromagnetic coupling

Adriano Montanaro*

* Dep. of Mathematics Tullio Levi Civita
University of Padua
via Trieste 63, 35121 Padova, Italy
e-mail: adriano.montanaro@unipd.it

ABSTRACT

As is well known, in the Voigt theory of linear piezoelectricity the electromagnetic equations are static and the electric and magnetic fields are not coupled. In this approximation, called quasi-static, no electromagnetic field evolves in time, and the wave behavior of electromagnetic fields cannot be described.

Couplings between electromagnetic waves and acoustic waves are used in certain ultrasonics applications involving piezoelectric or ferroelectric crystals and the conversion of electromagnetic energy into mechanical energy and vice versa can be realized by exploiting this coupling.

The interactions between the mechanical and electromagnetic fields in a piezoelectric material can be mathematically modeled by Voigt constitutive equations of linear piezoelectricity with full electromagnetic coupling, i.e. with a further linear coupling between the magnetic vector and the magnetic induction vector.

Many authors (e.g. [1]–[3]) have studied piezoelectric monoclinic crystals, because several monoclinic crystals show excellent piezoelectric properties and can be used for applications as electromechanic transducers.

In [4] we consider full coupling between electromagnetic fields and mechanical fields in the isothermal case. In a piezoelectromagnetic crystalline medium belonging to the class 2 of the monoclinic crystallographic system we find some classes of piezoelectricity-induced electromagnetic waves. These are time harmonic plane waves propagating along the symmetry axis and depending only on the axial coordinate. There are two independent modes of propagation, one longitudinal and one transverse, with mechanical and electromagnetical couplings. The transverse mode admits in a limit case an electromagnetic wave with no associated elastic deformation.

REFERENCES

[1] Mindlin, R.D. *Thickness-twist vibrations of an infinite, monoclinic, crystal plate*. *Int. J. Solids Struct.* (1965) **1**, 141–145.

[2] Mason, W.P. *Properties of Monoclinic Crystals Physical Review* (November 1946), **70**, n.9, 10.

[3] Zhu J. and Chen W., *Thickness-Twist and Face-Shear Waves in Piezoelectric Plates of Monoclinic Crystals IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control* (December 2011) **58**, no. 12,

[4] Montanaro A., *On the propagation of plane waves in piezoelectromagnetic monoclinic crystals Arch. Mech.*, (2015) **67**, 3, Warszawa, 197-212