

Preface

Modern problems of science and technology stimulated the generation and development of the theory of conjugate fields of various physical characters. In recent years, with increasing intensity, a new area of this theory is developing—the theory of magnetoelasticity, which studies the interaction of mechanical and electromagnetic fields in deformable magnetoactive bodies. The issues of oscillations and wave propagation have own important role in the theory of magnetoelasticity. The results of theoretical and experimental studies of these issues allow deeper and more complete description of physical phenomena, to reveal new properties and patterns inherent to the investigating media and fields. Studies of oscillations and wave propagation processes in account of electromagnetic effects have acquired relevance in connection with the requirements of such fields of science and technology as mechanics of deformable solids, electrodynamics of continuous media, seismology, geophysics, defectoscopy, acoustics, engineering mechanics, optimal design, signal processing, design of mechanical resonators, filters, magnetomechanical energy converters, etc.

The purpose of this book is to acquaint the reader with the methods of mathematical modeling and solution of nonstationary dynamic problems in the theory of magnetoelasticity, and also to give an idea of richness of physical effects caused by the interaction of electromagnetic and mechanical phenomena in both conducting nonferromagnetic and dielectric magnetically active deformable bodies. The studies are limited with the model of elastic body under the assumption of small deformations.

The book consists of two sections. In the first section of the book (Chaps. 1–3), based on the main nonlinear equations and relations of mechanics and quasistatic electrodynamics of continuous media, the system of equations of magnetoelasticity, surface conditions, and determining equations describing perturbations behavior of nonferromagnetic conducting medium and interacting with an external magnetic fields is obtained using the linearization technique. On this basis, solving the certain problems of propagation of magnetoelastic waves, a number of qualitative and quantitative results, caused by the interaction of mechanical and magnetic phenomena in conducting nonferromagnetic deformable bodies, are revealed. Let us

present some of the most important results of magnetoelastic interactions, explored within the study of various problems of the theory of magnetoelastic waves in the following directions:

- 1) Propagation of bulk magnetoelastic waves in electrically conductive nonferromagnetic isotropic and anisotropic media:
 - Equations of magnetoelastic waves and corresponding characteristic equations in the above-mentioned media are derived. The classification of these waves into fast and slow waves as well as to quasi-longitudinal and quasi-transversal is done, depending on the physical–mechanical properties of the medium and on the magnitude and direction of external magnetic field. The character of connection between the group and phase velocities of these waves is found out;
 - The conditions are obtained under which the medium, depending on the orientation of the external magnetic field, is under the conditions of plane deformation. The conditions of full hyperbolicity of the equations of two-dimensional magnetoelastic waves are established, which ensure the possibility of propagation of magnetoelastic waves along any direction;
 - Due to the investigation of the roots of characteristic equation, it is shown that the presence of magnetic field can qualitatively change the propagation character of fast and slow waves, depending on the physical–mechanical properties of the medium and the strength magnitude of the external magnetic field;
 - The changes of phase velocities are studied depending on the noted parameters. In particular, the intervals of monotonicity of phase velocities, their extreme values, and extreme propagation directions are determined.
- 2) Reflection of magnetoelastic waves from the bound of electrically conductive half-space:
 - For any medium, in contrast to the purely elastic case, when longitudinal wave falls, the sliding angle necessarily exists for which the reflected longitudinal magnetoelastic wave does not arise.
- 3) Propagation of magnetoelastic waves in an anisotropic half-space in the presence of a dynamic pressure:
 - The case of an orthotropic half-space is considered, when the main directions of elasticity of the medium create a certain angle with the intensity vector of the external magnetic field. It is shown that having varied the location of principal directions of the material's elasticity, it is possible to change substantially the propagation velocities of magnetoelastic waves.
- 4) Existence and propagation character of magnetoelastic Rayleigh waves in the case of perfectly conductive half-space:
 - In the case of transversal magnetic field, only one velocity of propagation of magnetoelastic Rayleigh waves is possible for any elastic medium.

The critical value of magnetic field intensity, depending on the Poisson's ratio, is found, which exceeding leads to the disappearance of surface wave;

- In the case of longitudinal magnetic field, the media are possible for which there are three critical values of the external magnetic field, depending on Poisson's ratio, and the surface waves exist when the magnetic field is less than the first critical value or is between the second and the third critical values.

In the second section (Chaps. 4 and 5), magnetoelastic waves are considered in dielectric magnetostrictive and piezomagnetic media. Based on the main coupled nonlinear equations and relations of mechanics and quasistatic electrodynamics of continuum media, the system of equations, surface conditions, and state equations is obtained describing the perturbations behavior in magnetoactive ferromagnetic (magnetically soft, magnetostrictive, and piezomagnetic) dielectric media interacting with external magnetic fields. Solving the certain problems, the possibility of excitation and propagation of new types of surface waves and oscillations in these media, conditioned by the magnetostrictive (or piezomagnetic) properties of the medium and its interaction with an external magnetic field, is studied. In particular, it is established that three types of plane magnetoelastic waves can propagate in a magnetostrictive elastic medium: quasi-longitudinal and quasi-transversal magnetostrictively coupled and transverse unbound.

The influence of these factors (magnetostriction and interaction) on the behavior of classical surface waves (Rayleigh waves, Love waves, etc.) in the elastic media under consideration is investigated.

Here are some of the most significant new results, connected with the magnetoelastic interaction:

- It is shown that when a shear volume wave falls on the interface between the magnetically active half-space and the vacuum, the usual reflection is accompanied by qualitatively new oscillations localized at the surface of half-space and caused exclusively by the magnetostrictive (piezomagnetic) property of the medium. These oscillations are not natural oscillations of the system, but accompany the reflection process and arise solely due to the presence of magnetoelastic bulk wave incident on the interface, when the medium possesses magnetostrictive (piezomagnetic) properties. Since they are localized at the surface and accompany the reflection process, then, naturally, they are called concomitant surface magnetoelastic vibrations—CSMV. It is also shown that the reflection of magnetoelastic wave in magnetostrictive (piezomagnetic) media has the character of full internal reflection at any angle of incidence;
- When studying the percolation problems of bulk shear magnetoelastic wave through the gap between two magnetostrictive (piezomagnetic) half-spaces, the possibility of contactless transmission of magnetoelastic wave from one medium to another is established;
- When studying the existence and propagation of surface shear magnetoelastic Love waves in magnetostrictive media, it is established that (a) the possibility of

generation of Love waves with the phase velocity less than the velocity of bulk shear waves in the layer ($V < V_c$) is due solely to the magnetostriction effect; (b) the possibility of the existence of Love waves with the velocity greater than the velocity of bulk shear waves in the support ($V > V_n$) is conditioned by the same effect, also (let us remember that the velocity of purely elastic Love waves satisfies the condition $V_c < V < V_n$); and (c) the phase velocity of modified magnetoelastic Love wave depends on the frequency of oscillations and, therefore, for these waves, as for purely elastic Love waves, the dispersion takes place. In addition to these, it turns out that in the magnetostrictive half-space with the free boundary, the shear surface magnetoelastic wave (caused by the magnetostriction effect) can be excited. A formula is obtained to determine the penetration depth of surface wave into a half-space. It is established that the tangible localization of wave at the medium surface occurs in the case of short waves, and this phenomenon is enhanced with the increase of magnetic field intensity;

- The conditions for the existence of shear gapwaves due to the magnetostrictive (piezomagnetic) properties of the media under consideration are found. It is shown that for these media, two types of gapwaves propagate in a noncontact system: symmetric and antisymmetric. The formulas are obtained to determine the velocity and penetration depth of these waves;
- The possibility of generation of shear surface waves in magnetically soft ferromagnetic half-space is studied in detail and it is shown that in magnetically soft ferromagnetic half-space, when the Rayleigh wave propagates in it, as a result, the shear surface wave is excited if acting magnetic field inclined to the propagation plane;
- It is established that in the magnetostrictive half-space, Rayleigh and shear surface waves can propagate independently of each other if acting magnetic field is perpendicular to the plane of motion. Moreover, the existence of shear surface wave is due solely to the magnetostriction effect;
- The issues of existence and propagation character of bulk spin and surface waves in ferromagnetic media are investigated. The condition of existence of surface wave is obtained depending on the physical constants of the material of the medium and on the angle formed by the direction of wave vector and the direction of easy magnetization axis of the ferromagnetic. The segments of variation of wave numbers are determined, under which the propagation of surface wave becomes impossible (zones of silence). Formulas determining the phase velocity and penetration depth of surface wave are found. It is shown that via the appropriate choice of the direction of wave vector, it is possible to achieve the necessary localization of spin wave at the surface of the body;
- The process of reflection of bulk elastic–spin waves from the boundary of ferromagnetic half-space is investigated;
- The interaction of magnetic (spin) and shear elastic waves in a piecewise homogeneous space is studied. The propagation of waves along the interface of two ferroelastic half-spaces is considered. The influence of medium inhomogeneity on the existence and propagation character of surface magnetoelastic

interconnected waves is investigated. The existence of magnetoelastic waves localized near the interface between two media is shown, which behave differently, depending on the propagation direction, and damp with distance from the interface. The existence of zones of silence for the waves under consideration is also shown;

- It should be emphasized, at the end, that in the first part of this book the numerical calculations are done using Gaussian system of measurement, and in the second part of the book the SI international system was used.

The main part of the book comprises the results of the authors and their students (D.J. Hasanyan, M.A. Mikilyan, P.A. Mkrtchyan, S.L. Sahakyan, A.A. Sanoyan, I.A. Vardanyan). A great deal of work associated with the preparation of the manuscript was performed by the Editor of the book Marine A. Mikilyan. The authors express sincere gratitude to all of the listed persons. The authors are deeply thankful, also, to the scientists of the Institute of Mechanics of the National Academy of Sciences of Armenia for kind consideration of the results and scientific support.

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