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The Combined Models of Electromagnetic Fields of Microelectromechanical Systems

SYSTEMS ENGINEERING FOR MEMS AND MOEMS

In recent years mathematical modeling finds application both at designing of microelectromechanical systems, and in a full-scale-model testing of such systems. Advanced field simulations are proved to be useful not only at the stage of treatment and analysis of the gained measurement data, but also in the course of measurements itself. The success of modeling depends to a large extent on the applied mathematical models of magnetic fields. The batch software which have gained wide application in modeling of fields, for example, ANSYS, MAXWELL, FEMLAB, and others, based on the mathematical models in the form of partial differential equations and the finite element method, allow to ensure great accuracy of computations of the electromagnetic field parameters, but do not ensure the short calculation time necessary for solving measuring problems on a real-time scale. The development of computer models of electromagnetic fields being able to meet the requirements of the fast response and a high calculation accuracy is therefore necessary. To develop the effective models of electromagnetic fields of microelectromechanical systems of new generation it is offered:

- to apply the combined mathematical models: for the description of fields in the linear medium – integral equations, in the nonlinear medium – partial differential equations;
- to use the combined numerical methods: to solve the boundary value problems for the partial differential equations – a finite difference method or a finite element method, for the solution of integral equations - a boundary element method;
- to apply vector magnetic potential $\vec{A}$ and scalar electrical potential u_e while calculating electromagnetic quasi-stationary fields in conducting mediums, and a single and double layer scalar magnetic potential u_M in non-conducting mediums and in a space V_0 surrounding the bodies.

The mathematical model in this case has the following form:

– in conducting bodies

$$\mathrm{rot}\left(\mathrm{rot}\,\vec{A}/\mu\right)+\gamma\left(\partial\,\vec{A}/\partial t+\mathrm{grad}\,u_{\mathrm{e}}\right)=0,\ \mathrm{div\,grad}\,u_{\mathrm{e}}=0\,;$$

– in non-conducting ferromagnetic bodies

$$\mathrm{div}\,\mu\ \mathrm{grad}\,u_{\text{м}}=0\,;$$

– in the environmental space

$$\Omega u_{\text{м}}=\iint\limits_{S}\left[u_{\text{м}}\,\partial(1/r)/\partial n-(1/r)\partial u_{\text{м}}/\partial n\right]dS\,;$$

– on the surface of the conducting bodies

$$H_{0\tau}-\partial u_{\text{м}}/\partial\tau=\mathrm{rot}_{\tau}\vec{A}/\mu;\quad \mu_0\left(H_{0n}-\partial u_{\text{м}}/\partial n\right)=\mathrm{rot}_{n}\vec{A}\,;$$

– on the surface of the non-conducting ferromagnetic bodies

$$H_{0\tau}-\partial u_{\text{м}}^{(0)}/\partial\tau=-\partial u_{\text{м}}/\partial\tau;\quad \mu_0\left(H_{0n}-\partial u_{\text{м}}^{(0)}/\partial n\right)=-\mu\,\partial u_{\text{м}}/\partial n\,,$$

where $u_{\text{м}}^{(0)}$ – a scalar magnetic potential in V_0;

– the initial conditions for $\vec{A}$.

The numerical analysis of a field of microelectromechanical systems by means of the suggested model is to be implemented within the following scheme: to solve boundary value problems for differential equations by means of a finite element method, integral equations – by a method of boundary elements, grids being constructed for ferromagnetic (conducting and non-conducting) and conducting nonmagnetic bodies only. When changing the reciprocal position of the bodies the grids are not reconstructed. It is expedient to construct the same grid for the analysis of the both electromagnetic and mechanical stress fields.

The application of this model has proved that for systems with an open magnetic circuit the dimensionality of the problem reduced approximately by a factor of 10^2 in comparison to the known models. The efficiency of the suggested combined models proves to be true for the solution to applied problems.

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