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STRUCTURAL ANALYSIS OF THE TECHNOLOGICAL SYSTEMS UNDER ELECTROMAGNETIC FIELD ACTION

Electromagnetic field (EM-field) is an integral part of work for many elements of structures and machines. They include elements of power equipment, power conversion system (transformers, generators), devices designed to protect against lightning, etc. High-intensityEM-fields cause substantial energy levels in electro conductive bodies, which can lead to failures.

Therefore approaches to determine stress-strain states (SSS) of electro-conductive bodies are required to estimate the strength. Such methods should be based on suitable models of continuum thermo-mechanics. Historically, the formulation of such coupled models was motivated by the development of:

– the theory of piezoelectricity (piezomagnetism and piezosemiconductivity) bodies due to the wide usage of electromechanical energy converters;

– the theory of magnetoelasticity, which explores the mechanical behavior (in particular, strength) of conductive bodies in a strong magnetic field;

– the theory of propagation of waves in a deformable body taking into account the relationship between the mechanical and the electromagnetic fields (for problems of geophysics and seismology, and for the development of non-destructive testing methods in structural elements);

– the theoretical foundations of heat processing of bodies using external electromagneticradiation(highandultra-highfrequency)andvisual(thermalor laser).

Theoretical fundamentals describing models of continuum mechanics, which take into account the effect of the coupled fields of different physical nature (including electromagnetic) presents in classical works of Truesdell, Toupin, Pidstryhach (Podstrigach), Sedov, Eringen, Burak, Ambarcumyan, Maugin, Nowacki and other. Within these models, the external EM-field effects on the thermo-mechanical state of the body, the components that characterize the action of the field on the body, namely, the electromagnetic forces and electromagnetic moments are taken into account in the equilibrium equations. The presented model is based on Maxwell's equations, describing the nature of the electromagnetic field in vacuum and in moving deformed body, in accordance with its electromagnetic properties. Therefore, there is a practical need for the mathematical formulation of problems of non-isothermal elastoplastic deformation of bodies under the influence of external electromagnetic fields, taking into account the mutual influence of fields of different nature in a wide ranges of temperature, and taking into account the nonlinearity of electromagnetic, t hermal, and mechanical properties of materials.

The article [1] proposes an efficient method of analysis of inelastic deformation of a system of electrically conducting bodies in electromagnetic field. Numerical implementation of the method is based on finite element method in accordance of the variational principle of minimum of the total energy. The constitutive equations for the material behavior are assumed in the incremental form in accordance of the plastic flow theory.

The solution for several model problems was carried out with this method usage. A comparison of the numerical results with experimental results and analytical solutions showed good performance of this method.

Further, this method was applied to analysis of some technological systems designed for electromagnetic forming. Spatial-temporal distribution of the electromagnetic field vector component and tensor component of deformation process are obtained. The obtained results allowed to assess the strength of the compound technological systems of the electromagnetic forming. Also recommendations on improving the quality of technological operations were done.

References:

1. Altenbach H., Morachkovsky O., Naumenko K. and Lavinsky D. Inelastic deformation of conductive bodies in electromagnetic fields // Continuum Mech. Thermodyn. DOI 10.1007/s00161-015-0484-8