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Algorithmization in Magneto-elasticity of Thin Plates and Shells of the Complex Configurations

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Abstract The work is devoted to algorithmization with regard to solution of tasks classes in magneto-elasticity of thin plates and shells of complex form in plan, thus, adhering to the general theory of algorithmization offered by the academician V.K.Kabulov, formation, composition and structure of the basic (data, laws, principles, models, algorithms, applied programs) and auxiliary algorithmic (statement and operational) banks are described in brief.

Keywords Algorithmization, Magneto-Elasticity, Mathematical Model, Calculating Algorithm, Shells, Plates

1. Introduction

Now, one of modern methodologies of automation of scientific researches is the algorithmization methodology offered by the academician V.K.Kabulov [1-3]. The point of algorithmization methodology consists of formalization and working out of automating system in which process of research of various objects is divided into seven consecutive stages, representing a cybernetic chain with feedback: experience – laws – problems – mathematical models – algorithms –software – computing experiment.

As it is marked in works [1-3], at practical realization algorithmization stages are made out in the form of six basic and two auxiliary algorithmic banks (AB). The basic banks are bank of data (B1), laws (B2), features (B3), models (B4), algorithms (B5) and applied programs (B6), and auxiliary ones – bank of statement (B0) and operational bank (B7). And each bank consists of two parts: information and operational. The numerical or symbolical data in fixed languages which are brought in advance (the constant information) are stored in information part. Operational part of AB contains software packages processing information collections of this bank.

Recently, the algorithmization theory is applied in various areas of science and technology, such as: mechanical engineering, medical, biological and technical cybernetics, social and economic sphere and others.

2. Algorithmization in Magneto-elasticity of Thin Plates and Shells

Algorithmization with regard to the solution of problem classes in magneto-elasticity of thin bodies (plates and shells) of complex form in plan is resulted in the given work. We will briefly describe formation, composition and structure of the basic and auxiliary AB in magneto-elasticity of thin plates and shells on the basis of the general theory of algorithmization. Thus, are referred to certain obtained results in the given direction of researches [3-7].

Firstly, bank of data is described. Values from laws and also the factors characterizing movement of system, particularly from the elasticity and electrodynamics theory are stored in bank of data:

Parameters (constants):

1) E – modules of elasticity of Yung.
2) G – rigidity module.
3) ν – Poisson's ratio.
4) h – thickness of plate.
5) $D=Eh^3/12(1-\nu^2)$ – cylindrical rigidity.
6) ε – dielectric constant.
7) μ – factor of magnetic conductivity.
8) $\sigma=1/R$ – factor of electro conductivity mediums.
9) R – specific electric resistance.
10) c – velocity of light.
11) π – constant Pi. Etc.

Functions:

1) ρ – density of material of shell (plate).
2) k_1, k_2 – principal curvature.
3) A_1, A_2 – factors of first quadratic form, etc.

Vectors:

1) $\vec{X}$ – coordinates.
2) $\vec{U}$ – displacement vector.
3) $\vec{E}$ – vector of electric field intensity.
4) $\vec{H}$ – vector of magnetic field intensity.
5) $\vec{D}$ – vector of electric induction.
6) $\vec{B}$ – vector of magnetic induction, etc.

Tensors:

1) $\hat{\delta}$ – pressure (stress) tensor.

2) $\hat{\varepsilon}$ – deformation tensor.

3) $\hat{T}$ – tensor of stress of Maxwell.

4) δ_{ij} – Kronecker symbol, etc.

Operators:

1) $\frac{\partial}{\partial t}, \frac{\partial^2}{\partial t^2}, \frac{\partial}{\partial x_i}, \frac{\partial^2}{\partial x_i^2}, \ldots$ – derivatives.

2) grad $= \left\{ \frac{\partial}{\partial x_1}, \frac{\partial}{\partial x_2}, \frac{\partial}{\partial x_3} \right\}$ – gradient.

3) div = $\left(\frac{\partial}{\partial x_1} + \frac{\partial}{\partial x_2} + \frac{\partial}{\partial x_3} \right)$ – divergence.

4) rot = $\left(\frac{\partial}{\partial x_2} - \frac{\partial}{\partial x_3}, \frac{\partial}{\partial x_3} - \frac{\partial}{\partial x_1}, \frac{\partial}{\partial x_1} - \frac{\partial}{\partial x_2} \right)$ – curl.

5) $\Delta = \frac{\partial^2}{\partial x_1^2} + \frac{\partial^2}{\partial x_2^2} + \frac{\partial^2}{\partial x_3^2}$ – Laplace operator, etc.

The bank of laws in algorithmization represents basic axioms of the theory, i.e. formed on the basis of laws (variation principles, laws of conservation, relations of the theory of elasticity and electrodynamics laws) from which mathematical models magneto-elasticity thin plates and shells are deduced in consequence.

Here are fundamental laws concerning magneto-elasticity:

1) $\delta \int_t (K - \Pi + A) dt = 0$ – variation principle of Hamilton-Ostrogradskiy.

2) $\int_t \delta K dt = \int_t \int_v \rho \left(\frac{\partial u_1}{\partial t} \delta \frac{\partial u_1}{\partial t} + \frac{\partial u_2}{\partial t} \delta \frac{\partial u_2}{\partial t} + \frac{\partial u_3}{\partial t} \delta \frac{\partial u_3}{\partial t} \right) dv dt$ – variation of kinetic energy.

3) $\int_t \delta \Pi dt = \int_t \int_v \rho (\sigma_{11} \delta \varepsilon_{11} + \sigma_{12} \delta \varepsilon_{12} + \sigma_{22} \delta \varepsilon_{22}) dv dt$ – variation of potential energy.

4) $\int_t \delta A dt = \int_t \int_v (X_i + \rho K_i) \delta u_j + \int_t \int_{s_i} (P_{ij} + T_{ij}) \delta u_j$ – variation of external forces work.

5) $div\, \vec{\sigma} + \rho K = \rho \frac{\partial^2 U}{\partial t^2}$ – movement equation.

6) $\frac{\partial \rho_y}{\partial e} + div\, j = 0$ – the law of conservation of electric charge.

7) $\begin{cases} rot\ E = -\frac{1}{c} \frac{\partial B}{\partial t} \\ rot\ H = \frac{4\pi}{c} j + \frac{1}{c} \frac{\partial D}{\partial t} \\ div\ D = 4\pi \rho_e \\ div\ B = 0 \end{cases}$ – electrodynamics laws (equations of Maxwell).

8) $\begin{cases} j = \delta \left(E + \frac{1}{c} v \times B \right) + \rho_e v \\ D = \varepsilon E + \frac{\varepsilon\mu - 1}{\mu c} v \times B \\ B = \varepsilon H - \frac{\varepsilon\mu - 1}{c} v \times E \end{cases}$ – the Ohm's law.

9) $T_{ij} = \frac{1}{4\pi} (E_i D_k + H_i B_k) - \frac{\delta_{ik}}{8\pi} (ED + HB)$ – efforts of electromagnetic field (tensor of stress of Maxwell).

10) $\rho K = \frac{1}{4\pi} rot(rot(u \times H)) \times H$ – volume forces of electromagnetic origin (for ideal conducting material).

11) $\varepsilon_{ij} = \frac{1}{2} \left(\frac{\partial u_i}{\partial x_i} + \frac{\partial u_j}{\partial x_i} \right)$ – Cauchy relations (tensor of deformations).

12) $\sigma_{ij} = C_{ij,mn} \varepsilon_{mn}$ – Hooke's law, etc.

The bank of statement provides problem statement of magneto-elasticity thin bodies (shells and plates) and consists of atomic words – making terminological basis of theory, based on which, statement and problem solving are carried out. It consists of the name of problem, boundary conditions and factors. The set of atomic words provides choice of the equations from bank of laws, conditions imposed on parameters from bank of features and on their basis, the conclusion of mathematical models and choice of algorithms of solving is carried out.

As example of such atomic words in magneto-elasticity can serve

1) problems: plate, shell, bend, state, vibration, stability, flat, spherical, cylindrical, linear, nonlinear, statics, dynamics and etc.

2) principles: Kirchhoff, Kirchhoff-Love, magneto-elasticity thin bodies (at conclusion of models).

3) field: cross-section, longitudinal, another.

4) area: square, circle, difficult area, area with cuts and etc.

5) boundary conditions: of rigid-clamped, hinged-simply supported, mixed and etc.

6) and etc.

In methodology of algorithmization, the conclusion of mathematical models is carried out by means of the computer. And classes of problems, in particular, magneto-elasticity are formed by means of principles space (certain restrictions). Set of problems principles is entered in the bank of principles. As principles of create of models of magneto-elasticity thin plates and shells are restrictions on movings, i.e. hypotheses of the theory of elasticity and magneto-elasticity can serve:

1) $$\begin{cases} u_1 = (1+k_1\alpha_3)u - \dfrac{\alpha_3}{A_1}\dfrac{\partial w}{\partial \alpha_1}, \\ u_2 = (1+k_2\alpha_3)v - \dfrac{\alpha_3}{A_2}\dfrac{\partial w}{\partial \alpha_2}, \\ u_3 = w(t,\alpha_1,\alpha_2) \end{cases}$$

– hypothesis of Kirchhoff-Love for shells.

2) $$u_1 = u - z\frac{\partial w}{\partial x_1}, \quad u_2 = v - z\frac{\partial w}{\partial x_2}, \quad u_3 = w(t,x,y)$$

– hypothesis of Kirchhoff-Love for plates.

3) $$u_1 = -\frac{\alpha_3}{A_1}\frac{\partial w}{\partial \alpha_1}, \quad u_2 = -\frac{\alpha_3}{A_2}\frac{\partial w}{\partial \alpha_2}, \quad u_3 = w(t,\alpha_1,\alpha_2)$$

– hypothesis of Kirchhoff for shells.

4) $$u_1 = -z\frac{\partial w}{\partial x_1}, \quad u_2 = -z\frac{\partial w}{\partial x_2}, \quad u_3 = w(t,x,y)$$

– hypothesis of Kirchhoff for plates and etc.

Let's notice that the conclusion of mathematical models is carried out in operational bank.

3. Mathematical Model of Magneto-Elasticity of Thin Plate

At construction of mathematical models of magneto-elasticity of thin plates and shells are used systems of mathematical algebra, particularly, mathematical system Maple which has large opportunities for carrying out of analytical calculations can be used. We will give some equations of plates movement deduced on the basis of the above-mentioned principles in Maple system [6, 7]:

$$\rho h\frac{\partial^2 U}{\partial t^2} - \left(\frac{Eh}{1-\nu^2} - \frac{h}{4\pi}(H_y^2 + H_z^2)\right)\frac{\partial^2 U}{\partial x^2} - \left(\frac{Eh}{2(1+\nu)} - \frac{h}{4\pi}H_y^2\right)\frac{\partial^2 U}{\partial y^2} - \frac{h}{4\pi}H_xH_y\frac{\partial^2 V}{\partial x^2} -$$
$$-\left(\frac{Eh\nu}{1-\nu^2} + \frac{Eh}{2(1+\nu)} - \frac{h}{4\pi}H_y^2\right)\frac{\partial^2 V}{\partial x\partial y} - \frac{h}{4\pi}H_xH_y\frac{\partial^2 V}{\partial y^2} - \frac{h}{4\pi}H_xH_z\frac{\partial^2 W}{\partial x^2} - \frac{h}{4\pi}H_yH_z\frac{\partial^2 W}{\partial x\partial y} -$$
$$-\frac{h}{4\pi}H_xH_z\frac{\partial^2 W}{\partial y^2} = Q_1;$$

$$\rho h\frac{\partial^2 V}{\partial t^2} - \frac{h}{4\pi}H_xH_y\frac{\partial^2 U}{\partial x^2} - \left(\frac{Eh\nu}{1-\nu^2} + \frac{Eh}{2(1+\nu)} - \frac{h}{4\pi}H_x^2\right)\frac{\partial^2 U}{\partial x\partial y} - \frac{h}{4\pi}H_xH_y\frac{\partial^2 U}{\partial y^2} -$$
$$-\left(\frac{Eh}{2(1+\nu)} - \frac{h}{4\pi}H_x^2\right)\frac{\partial^2 V}{\partial x^2} - \left(\frac{Eh}{1-\nu^2} - \frac{h}{4\pi}(H_x^2 + H_z^2)\right)\frac{\partial^2 V}{\partial y^2} - \frac{h}{4\pi}H_yH_z\frac{\partial^2 W}{\partial x^2} -$$
$$-\frac{h}{4\pi}2H_xH_z\frac{\partial^2 W}{\partial x\Im y} - \frac{h}{4\pi}H_yH_z\frac{\partial^2 W}{\partial y^2} = Q_2;$$

$$\rho h\frac{\partial^2 W}{\partial t^2} - \rho\frac{h^3}{12}\frac{\partial^4 W}{\partial x^2\partial t^2} - \rho\frac{h^3}{12}\frac{\partial^4 W}{\partial y^2\partial t^2} - \frac{h}{4\pi}H_xH_z\frac{\partial^2 U}{\partial x^2} - \frac{h}{4\pi}H_yH_z\frac{\partial^2 U}{\partial x\partial y} -$$
$$-\frac{h}{4\pi}H_xH_z\frac{\partial^2 V}{\partial x\partial y} - \frac{h}{4\pi}H_yH_z\frac{\partial^2 V}{\partial y^2} + \left(D + \frac{I}{4\pi}(H_y^2 + H_z^2)\right)\frac{\partial^4 W}{\partial x^4} +$$
$$+\frac{I}{4\pi}2H_xH_y\frac{\partial^4 W}{\partial x^3\partial y} + \left(2D + \frac{I}{4\pi}(H_x^2 + H_y^2 + H_z^2)\right)\frac{\partial^4 W}{\partial x^2\partial y^2} - \frac{I}{4\pi}2H_xH_y\frac{\partial^4 W}{\partial x\partial y^3} +$$
$$+\left(D + \frac{I}{4\pi}(H_x^2 + H_z^2)\right)\frac{\partial^4 W}{\partial y^4} + \frac{h}{4\pi}(H_y^2 - H_x^2)\frac{\partial^2 W}{\partial x^2} - \frac{h}{4\pi}4H_xH_y\frac{\partial^2 W}{\partial x\partial y} -$$
$$-\frac{h}{4\pi}(H_y^2 - H_x^2)\frac{\partial^2 W}{\partial y^2} = Q_3,$$

Here is $I = \dfrac{h^3}{12}$.

The corresponding initial and boundary conditions depending on the way of fastening of edges of plate (shell) are added to these equations.

Next, the mathematical models deduced from general laws on magneto-elasticity according to the bank of principles are analyzed by means of procedures of bank of models, i.e. methods of mathematical and functional analyses [1-2].

Then, the computing scheme is chosen from the bank of algorithms, resolving equations are constructed, numerical data from bank of data and program for calculation from bank of applied programs are selected. In particular, at solving problems of magneto-elasticity of thin plates and shells of complex form in the plan, joint application of variation methods of Bubnov-Galerkin and structural method of R-functions are used [8]. Thus, resolving equations have view of the system of ordinary differential equations – in case of dynamics, the system of linear algebraic equations – in case of statics or problem of own values and vectors – in case of consideration of stability problem of thin plates and shells in electromagnetic field.

The bank of applied programs consists of library of subprograms and library of modules. Programs consist of software of computer (ready predetermined procedures and functions), as well as software for solution of resolving equations, in particular, solution – systems of ordinary differential equations, systems of linear algebraic equations, problems of own values and vectors and others can be part of this [9]. Programs on results registration, i.e. their visualization by means of representation in form of tables, schedules, etc.

4. Conclusions

In conclusion, we will notice that the algorithmic system is created for realization of all blocks of algorithmization in magneto-elasticity of thin plates and shells of the complex form in the plan for computers. Some calculating results of electro-magnetic fields' affection of thin conducting plates by complex form are given in paper [10].

REFERENCES

[1] Kabulov V. K. Algorithmization in the mechanic of continuous environments. Tashkent: Fan, 1979. 304 p

[2] Kabulov V. K, Fajzullaev O.F., Nazirov SH.A. Al-Horezmi – algorithm – algorithmization. Tashkent: Fan, 2006. 665 p.

[3] Kabulov V. K, Nuraliev F.M.algorithmization in magneto-elasticity thin plates and shells of the difficult form in the plan. Reports of AS RU. 2008, № 4. p. 43-48.

[4] Ambartsumjan S.A., Bagdasarjan G. E, Belubekjan M.V.Magnitouprugost of thin shells and plates. M: Nauka, 1977. 272 p.

[5] Rvachev V. L. The theory of R-functions and its some appendices. Kiev: Naukova Dumka, 1982. 552 p.

[6] Nuraliev F.M. Conclusion of the movement equations magneto-elastic plates in system Maple. // Vopr. Vichisl. i Prikl. Matematiki. 2007. № 118. p. 110-115.

[7] Nuraliev F.M. Mathematical models of magneto-elasticity of thin plates and shells. // Vopr. Vichisl. i Prikl. Matematiki. 2012. № 128. p. 53-63.

[8] Nuraliev F.M. Algorithm of calculation magneto-elastic thin shells by method of R-functions. // Problemi Informatiki I Energetiki. 2007. № 5-6. p. 89-93.

[9] Nuraliev F.M. The description of software for automation of the solution of classes of problems of magnetoelasticity of thin plates and shells. Vestnik TUIT. 2011, №3. p. 55-58.

[10] Nazirov Sh.A., Nuraliev F.M. Mathematical modeling of processes of electro-magnetic fields' affection thin conducting plates by complex form. American Journal of Computational and Applied Mathematics. 2012, 2 (1): 30-33 pp.