MATHEMATICAL MODELING OF NONLINEAR DEFORMATION PROCESSES OF THIN MAGNETELASTIC PLATES OF COMPLEX CONSTRUCTIVE FORM

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Abstract
The article is devoted to the development of a mathematical model of the process of geometric nonlinear deformation of thin magnetoelastic plates of a complex structural shape based on the Hamilton-Ostrogradsky variational principle, and conducting computational experiments. In this case, the three-dimensional mathematical model was transferred to a two-dimensional view using the Kirchhoff-Liav hypothesis. The effects of the electromagnetic field on the deformation stress state of the magnetoelastic plate were observed using the Lorentz force and the Maxwell electromagnetic tensor representation, resulting in a mathematical model in the form of a system of differential differential equations with initial and boundary conditions for displacement. was created. To solve the equation, a calculation algorithm was developed using R-function, Bubnov-Galerkin, Newmark, Gaussian, Gaussian squares, and Iteration numerical methods, and numerical results were obtained. A comparative analysis of the results of the calculations was presented.

Keywords: Hamilton-Ostrogradsky principle, Bubnov Galerkin, Cauchy relation, Hooke's law, Maxwell's electromagnetic tensor, R-function, Gauss, Iteration.

Introduction

Based on the Hamilton-Ostrogradsky variational principle, a mathematical model of the process of geometric nonlinear deformation of a magnetoelastic plate was developed [1].

$$\begin{cases} -\rho h\dfrac{\partial^2 u}{\partial t^2}+\dfrac{\partial N_{xx}}{\partial x}+\dfrac{\partial N_{xy}}{\partial y}+F_x+R_x+q_x+T_{zx}=0, \\ -\rho h\dfrac{\partial^2 v}{\partial t^2}+\dfrac{\partial N_{yy}}{\partial y}+\dfrac{\partial N_{xy}}{\partial x}+F_y+R_y+q_y+T_{zy}=0, \\ -\rho h\dfrac{\partial^2 w}{\partial t^2}+\dfrac{\partial^2 M_{xx}}{\partial x^2}+2\dfrac{\partial^2 M_{xy}}{\partial x\partial y}+\dfrac{\partial^2 M_{yy}}{\partial y^2}+N_{xx}\dfrac{\partial^2 w}{\partial x^2}+N_{yy}\dfrac{\partial^2 w}{\partial y^2}+N_{xy}\dfrac{\partial^2 w}{\partial x\partial y}+ \\ +\left(\dfrac{\partial N_{xx}}{\partial x}+\dfrac{\partial N_{xy}}{\partial y}\right)\dfrac{\partial w}{\partial x}+\left(\dfrac{\partial N_{yy}}{\partial y}+\dfrac{\partial N_{xy}}{\partial x}\right)\dfrac{\partial w}{\partial y}+F_z+R_z+q_z+T_{zz}=0. \end{cases} \quad (1)$$

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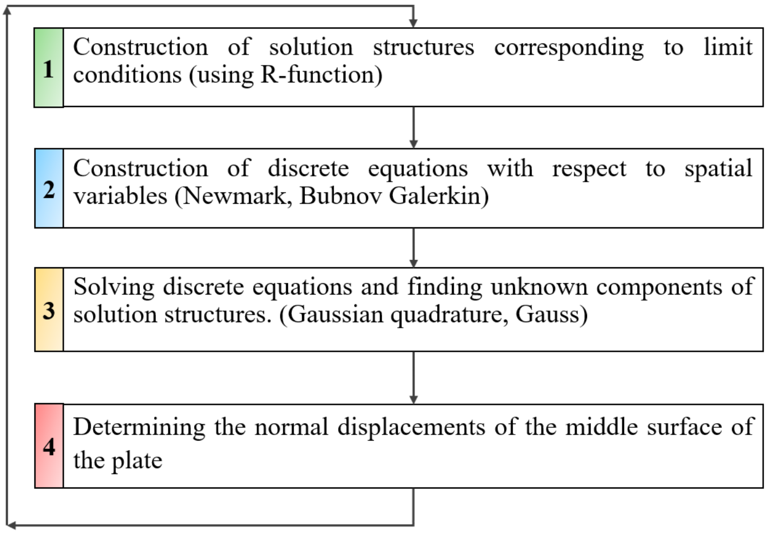
Initial conditions and boundary conditions:

$$\begin{cases} \rho h \dfrac{\partial u}{\partial t}\delta u\Big|_t = 0,\ \rho h \dfrac{\partial v}{\partial t}\delta v\Big|_t = 0,\ \rho h \dfrac{\partial w}{\partial t}\delta w\Big|_t = 0, \left(N_{xx} + N_{Px} + N_{Tx}\right)\delta u\Big|_x = 0, \\ \left(N_{xy} + N_{Py} + N_{Txy}\right)\delta v\Big|_x = 0,\ M_{xx}\delta \dfrac{\partial w}{\partial x}\Big|_x = 0,\ M_{xy}\delta \dfrac{\partial w}{\partial y}\Big|_x = 0, M_{yy}\delta \dfrac{\partial w}{\partial y}\Big|_y = 0,\ M_{xy}\delta \dfrac{\partial w}{\partial x}\Big|_y = 0, \\ \left(N_{yy} + N_{Fy} + N_{Tyy}\right)\delta v\Big|_y = 0,\ \left(N_{xy} + N_{Fx} + N_{Tyx}\right)\delta u\Big|_y = 0, \\ \left[N_{xx}\dfrac{\partial w}{\partial x} + N_{xy}\dfrac{\partial w}{\partial y} - \dfrac{\partial M_{xx}}{\partial x} - \dfrac{\partial M_{xy}}{\partial y} + N_{Pz} + N_{Txz}\right]\delta w\Big|_x = 0, \\ \left[N_{yy}\dfrac{\partial w}{\partial y} + N_{xy}\dfrac{\partial w}{\partial x} - \dfrac{\partial M_{yy}}{\partial y} - \dfrac{\partial M_{xy}}{\partial x} + N_{Fz} + N_{Tyz}\right]\delta w\Big|_y = 0. \end{cases}$$

where N_{xx}, N_{yy}, N_{xy} - normal and impact forces on the thickness of the plate. M_{xx}, M_{yy}, M_{xy} - bending and twisting moments of the plate, $\rho -$ body density, h-plate thickness, $q_x, q_y, q_z, T_{zx}, T_{zy}, T_{zz} -$ the surface forces, $R_x, R_y, R_z, T_{xx}, T_{xy}, T_{xz}, F_x, F_y, F_z, T_{yy}, T_{yz}, T_{zx}, -$ the generating contour forces.

Computational algorithm for numerical solution of the task.

Algorithm for calculating the geometric nonlinear deformation processes of electromagnetic thin plates [2]:



To calculate the unknowns in the equation of motion using the given algorithm, the unknown displacement coefficients are determined using a combination of the Bubnov-Galerkin method of variation, the Gaussian square method, the Gaussian method Nyumark and the iteration method [3].

Deformation calculations of a magneto elastic plate with a complex configuration were studied for the second symmetric field shown in Figure 1 below, and the following numerical results (Table 1) and graphs (Figure 2) were obtained [4].

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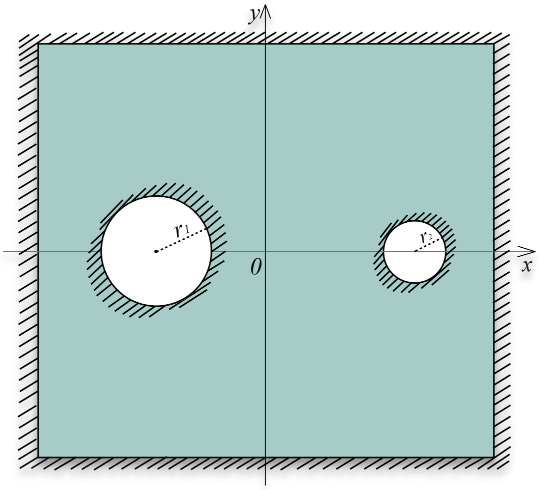

Figure 1. Magneto elastic plate with nonsymmetrical complex configuration.

An analytical equation was constructed for the applied asymmetric complex field of the *R*-function (Fig. 1) and was expressed by the following formula 2 [5]. This is a graph of the bending along the coordinate axis of a asymmetrical complex shaped magneto elastic plate shown in Figure 2.

$$\omega = \left(f_1 \wedge f_2 \right) \wedge f_3 \wedge f_4 \qquad (2)$$

here

$$f_1 = \frac{(a^2 - x^2)}{2a} \geq 0,\ \ f_2 = \frac{(b^2 - y^2)}{2b} \geq 0,\ \ f_3 = \frac{((x-a_1)^2 + y^2 - r^2)}{2r} \geq 0,\ \ f_4 = \frac{((x+a_2)^2 + y^2 - r^2)}{2r} \geq 0,$$

Geometric-mechanical parameters in computational experiments:

$a=1,\, b=1, a_1 = 0.5, a_6 = 0.55, h = 0.01,\, r_1 = 0.1, r_2 = 0.1\ \nu = 0.3,\ q=1,\ H_x = H_y = H_z = 10\,\kappa Э, E = 10^{11}\ H/м^2.$

Table.1

x	*y*	*w(x,y,t) function values when not affected by electromagnetic field forces*	*w(x,y,t) function values under the influence of electromagnetic field forces*
-1	0	0	0
-0.95	0	0,00009	0,00011
-0.9	0	0,00030	0,00038
-0.85	0	0,00027	0,00037
-0.8	0	0,00012	0,00019
-0.75	0	0,00003	0,00005
-0.7	0	0	0
-0.3	0	0	0
-0.25	0	0,00002	0,00002
-0.2	0	0,00007	0,00009
-0.15	0	0,00015	0,00019
-0.1	0	0,00025	0,00030
-0.5	0	0,00033	0,00040
0	0	0,00039	0,00047
0.5	0	0,00041	0,00050
0.1	0	0,00038	0,00047
0.15	0	0,00033	0,00040
0.2	0	0,00025	0,00030

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0.25	0	0,00016	0,00020
0.3	0	0,00009	0,00011
0.35	0	0,00003	0,00004
0.4	0	0,00001	0,00001
0.45	0	0	0
0.65	0	0	0
0.7	0	0,00001	0,00001
0.75	0	0,00005	0,00007
0.8	0	0,00011	0,00017
0.85	0	0,00018	0,00029
0.9	0	0,00020	0,00032
0.95	0	0,00010	0,00012
1	0	0	0

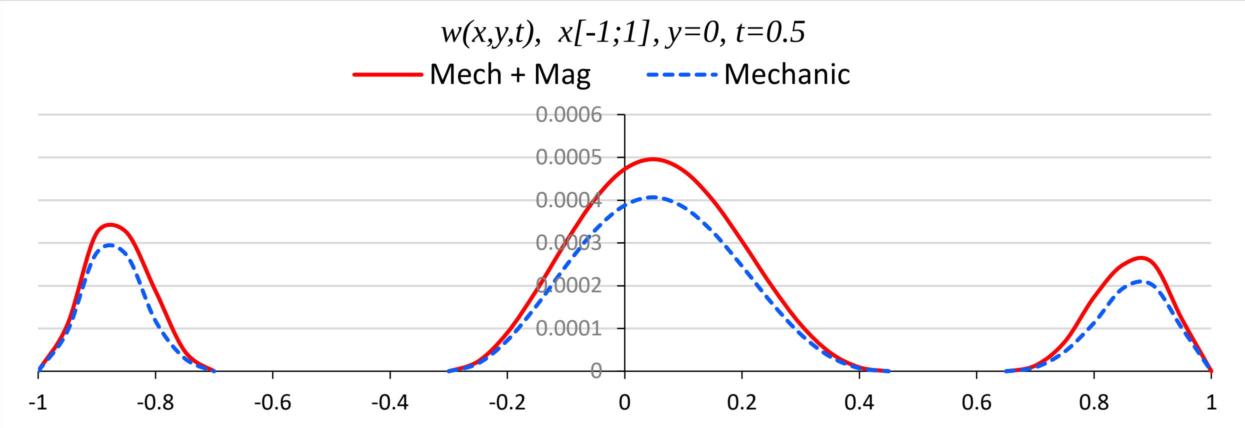

Figure 2. Bending of a magnetoelastic thin plate with a asymmetrical complex configuration.

In figure 3 the conical results of the bending along the axis of a complex shaped magnetoelastic plate (Table 2) and a graphical representation are showed (Figure 3) [6,7].

Table 2

y	*x*	*w(x,y,t) function values when not affected by electromagnetic field forces*	*w(x,y,t) function values under the influence of electromagnetic field forces*
-1	0	0	0
-0.9	0	0.0002	0.0002
-0.8	0	0.0010	0.0012
-0.7	0	0.0019	0.0023
-0.6	0	0.0022	0.0027
-0.5	0	0.0018	0.0022
-0.4	0	0.0013	0.0016
-0.3	0	0.0008	0.0010
-0.2	0	0.0005	0.0007
-0.1	0	0.0004	0.0005
0	0	0.0003	0.0004
0.1	0	0.0004	0.0005
0.2	0	0.0005	0.0007
0.3	0	0.0008	0.0010

0.4	0	0.0013	0.0016
0.5	0	0.0018	0.0022
0.6	0	0.0022	0.0027
0.7	0	0.0019	0.0023
0.8	0	0.0010	0.0012
0.9	0	0.0002	0.0002
1	0	0	0

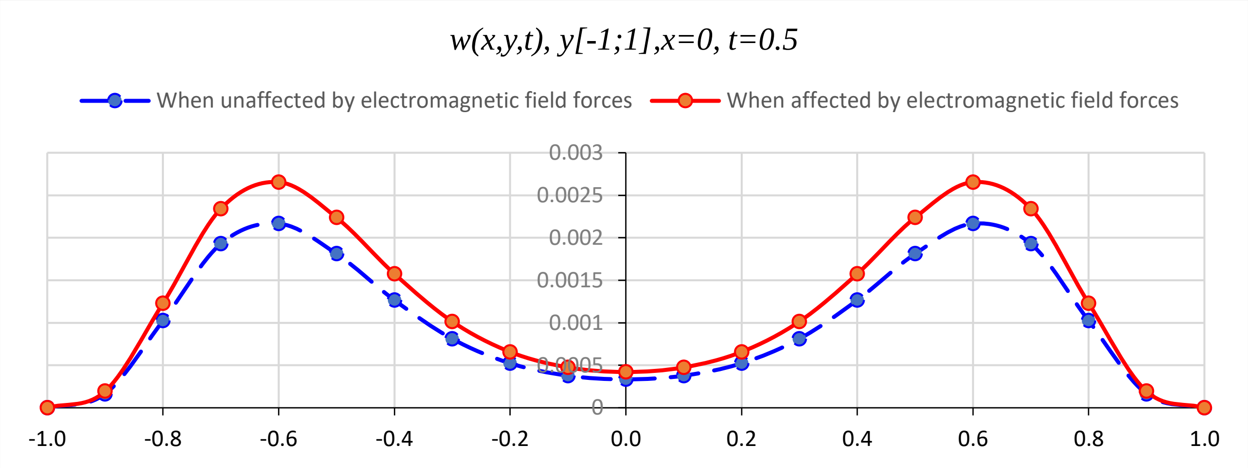

Figure 3. Bending of a magnetoelastic thin plate with a complex configuration along the Oy axis

Conclusion

A mathematical model in the form of a system of differential equations with differential equations representing the processes of geometric nonlinear deformation of a magnetoelastic thin plate with a complex structural shape was developed. A calculation algorithm was developed to find the unknown coefficients in the mathematical model. The unknown coefficients of the mathematical model were found on the basis of the conditions of rigidly fixed hinges in which the boundaries of the geometric nonlinear deformation processes of magnetoelastic thin plates of a complex structural shape under the influence of electromagnetic forces were fixed. The obtained numerical results were studied and their comparative analysis was presented. The results of the experiment show that the presence of magnetic field forces on thin magnetoelastic plates is small. This proves that the plate has a direct effect on the deformation process.

References

1. F. Nuraliev and Sh. Safarov, "Computational algorithm for calculating magnetoelastic flexible plates of complex configuration," 2019 International Conference on Information Science and Communications Technologies (ICISCT), Tashkent, Uzbekistan, 2019, pp. 1-4. DOI: 10.1109/ICISCT47635.2019.9011903.
2. F. Nuraliev, S. Safarov and M. Artikbayev, ”A computational algorithm for calculating the effect of the electromagnetic fields to thin complex configured plates,” 2020 International Conference on Information Science and Communications Technologies (ICISCT), 2020, pp. 1-4, DOI: 10.1109/ICISCT50599.2020.9351447.

3. F. Nuraliev, S. Safarov and M. Artikbayev, "Solving the problem of geometrical nonlinear deformation of electro-magnetic thin plate with complex configuration and analysis of results," 2021 International Conference on Information Science and Communications Technologies (ICISCT), 2021, pp. 01-05, DOI: 10.1109/ICISCT52966.2021.9670282.
4. Nuraliev F.M., Aytmuratov B.Sh., Safarov Sh.Sh., Artikbayev M.A. Mathematical modeling of geometric nonlinear processes of electromagnetic elastic thin plates of complex configuration // Scientific journal «Problems of Computational and Applied Mathematics» № 1(38), 2022. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=jalkwscAAAAJ&citation_for_view=jalkwscAAAAJ:9yKSN-GCB0IC.
5. F. Nuraliev, S. Safarov, M. Artikbayev and A. O.Sh, "Calculation Results of the Task of Geometric Nonlinear Deformation of Electro-magneto-elastic Thin Plates in a Complex Configuration," 2022 International Conference on Information Science and Communications Technologies (ICISCT), Tashkent, Uzbekistan, 2022, pp. 1-4,. DOI: 10.1109/ICISCT55600.2022.10146920.
6. Mahkamov, A. A., Jumayev, T. S., Tuhtanazarov, D. S., Dadamuxamedov, A. I. (2024). Using AdaBoost to improve the performance of simple classifiers. In Artificial Intelligence, Blockchain, Computing and Security Volume 2 (pp. 755-760). CRC Press.
7. Tuhtanazarov, D., Xodjayeva M., Jumayev T., Mahkamov, A. (2022, June). Computational algorithm and program for determining the indicators of wells based on processing of information of oil fields. In AIP Conference Proceedings (Vol. 2432, No. 1, p. 060021). AIP Publishing LLC.

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