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Computational Algorithms For Solving Boundary Value Problems Of Magnetoelastic Plates With Complex Form

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Abstract: This article presents a method of constructing a sequence of coordinate functions (solution structures) using the R-function method of V.L. Rvachev (Rvachev Function Method, RFM) to solve numerically the problem of the boundary of magnetoelastic plates of complex structural form in the process of thermoelectromagnetic-elastic deformation according to the given boundary conditions and constructing an algorithm with the joint use of the Newmark method, Bubnov-Galerkin variational and variational forms, Gaussian numerical methods.

Keywords: Rvachev's Function Method, thermo-electro-mangnite-elasticity, Newmark, Bubnov-Galerkin, Gauss, algoritm.

I. INTRODUCTION

The widespread use of plates as structural elements in various fields of modern technology, the complexity of their shape and working conditions, in particular the problem of calculating the stress-strain state under the influence of electromagnetic forces, remains relevant [1]. In order to study areas of complex shape, the problem of building (developing) a structure of solutions of their boundary equations arises. Modern technology presents researchers with the problem of automation of all classes of problems, requiring durability of these elements and their reliability during operation for a long time, and these problems differ only in their physical parameters. not only, but also related to the constructive form of the studied field. [2].

II. RELATED WORKS

The paper [3] considers the free vibrations of microplates of non-classical shape. The fundamental equations are studied on the basis of modified coupled stress theory and Kirchkov-Lev plate theory. The plate is assumed to be isotropic or orthotropic and to satisfy various boundary conditions. The analysis was carried out using the variational structural method based on the R-function theory and the Ritz method. In the paper [4], the authors studied the free bending vibrations of homogeneous thin orthotropic plates of

arbitrary shape with mixed boundary conditions using the R-function method. The proposed method is based on the use of R-function theory and variational methods.

The classical two-dimensional elasticity problem of a rectangular plate $(2a*2b)$ under the action of parabolically distributed boundary loads applied on both sides of $x=\pm a$ is solved in [6] using the Bubnov-Galerkin variational method. It was developed for a rectangular freely supported small plate and uses the Bubnov-Galerkin method with a two-mode model, which reduces the problem to the study of a system of second-order ordinary differential equations (ODEs) [7].

The general mathematical model developed considering the initial and boundary conditions of the thermo-electromagnetic-elastic deformation of thin plates is represented by the following equation of motion [8].

$$
\begin{cases}
\rho h\frac{\partial^2 u}{\partial t^2}+\frac{Eh}{1-\mu^2}\frac{\partial^2 u}{\partial x^2}+\frac{Eh}{1-\mu^2}\frac{\mu\partial^2 v}{\partial x\partial y}+\frac{Eh}{1-\mu^2}\frac{\partial T}{\partial x}\frac{a_T}{1-\mu}+\\
+\frac{Eh}{2(1+\mu)}\frac{\partial u^2}{\partial y^2}-\frac{Eh}{2(1+\mu)}\frac{\partial u^2}{\partial x\partial y}+\frac{h}{4\pi}H_y^2\frac{\partial^2 u}{\partial x^2}+\frac{h}{4\pi}H_y^2\frac{\partial^2 u}{\partial y^2}+\\
+\frac{h}{4\pi}H_z^2\frac{\partial^2 u}{\partial x^2}+\frac{h}{4\pi}H_z^2\frac{\partial^2 v}{\partial x\partial y}-\frac{h}{4\pi}H_xH_y\frac{\partial^2 v}{\partial x^2}-\\
-\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_xH_z\frac{\partial^2 w}{\partial y^2}-\frac{h}{2\pi}H_yH_z\frac{\partial^2 w}{\partial x\partial y}+N_x+q_x+T_{zx}=0 \qquad (1)\\
\rho h\frac{\partial^2 v}{\partial t^2}+\frac{Eh}{1-\mu^2}\frac{\partial^2 v}{\partial y^2}-\frac{Eh}{1-\mu^2}\frac{\mu\partial^2 u}{\partial x\partial y}+\frac{Eh}{1-\mu^2}\frac{\partial T}{\partial y}\frac{a_T}{1-\mu}+\\
+\frac{Eh}{2(1+\mu)}\frac{\partial^2 u}{\partial x\partial y}+\frac{Eh}{2(1+\mu)}\frac{\partial^2 v}{\partial x^2}+\frac{h}{4\pi}H_x^2\frac{\partial^2 v}{\partial x^2}+\frac{h}{4\pi}H_x^2\frac{\partial^2 v}{\partial y^2}+\\
+\frac{h}{4\pi}H_z^2\frac{\partial^2 v}{\partial x^2}+\frac{h}{4\pi}H_z^2\frac{\partial^2 v}{\partial x\partial y}-\frac{h}{4\pi}H_xH_y\frac{\partial^2 u}{\partial x^2}-\\
-\frac{h}{4\pi}H_xH_y\frac{\partial^2 u}{\partial y^2}+\frac{h}{4\pi}H_yH_z\frac{\partial^2 w}{\partial x^2}-\frac{h}{4\pi}H_yH_z\frac{\partial^2 w}{\partial y^2}-\frac{h}{2\pi}H_xH_z\frac{\partial^2 w}{\partial x\partial y}+N_y+q_y+T_{zy}=0\\
\rho h\frac{\partial^2 w}{\partial t^2}-\frac{E}{1-\mu^2}\frac{h^3}{12}\frac{\partial^4 w}{\partial y^4}-2\frac{E}{1-\mu^2}\frac{h^3}{12}\frac{\partial^4 w}{\partial x^2\partial y^2}-\frac{E}{1-\mu^2}\frac{h^3}{12}\frac{\partial^4 w}{\partial x^2}-\\
-\frac{h}{4\pi}H_xH_z\frac{\partial^2 u}{\partial x^2}-\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 x^2}-\frac{h}{4\pi}H_yH_z\frac{\partial^2 v}{\partial x\partial y}-\\
-\frac{h}{4\pi}H_y^2H_z\frac{\partial^2 w}{\partial x^2}+\frac{h}{4\pi}H_y^2H_z\frac{\partial^2 w}{\partial y^2}+\frac{h}{4\pi}H_x^2H_z\frac{\partial^2 w}{\partial x^2}-\frac{h}{4\pi}H_x^2H_z\frac{\partial^2 w}{\partial y^2}+\frac{h}{\pi}H_xH_yH_z\frac{\partial^2 w}{\partial x\partial y}+N_z+q_z+T_{zz}=0,\\
\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=\frac{1}{a_T}\frac{\partial T}{\partial t}
\end{cases}
$$

The Hamilton-Ostrogradsky variational principle, a system of high order linear partial differential equations with initial and boundary conditions of displacement [12, 13, 14], was used to develop the above mathematical model. In the construction of the mathematical model, the initial representation of the migration was

obtained using the Kirchhoff-Liave hypothesis. The changes in potential energy, kinetic energy and work of external forces were determined. The state of thermo-electromagnetoelastic deformation of thin magnetoelastic plates under the action of an electromagnetic field was investigated using the Cauchy relation, the Dumel-Neumann relation, Hooke's law, the Lawrence force and the electromagnetic Maxwell tensor.

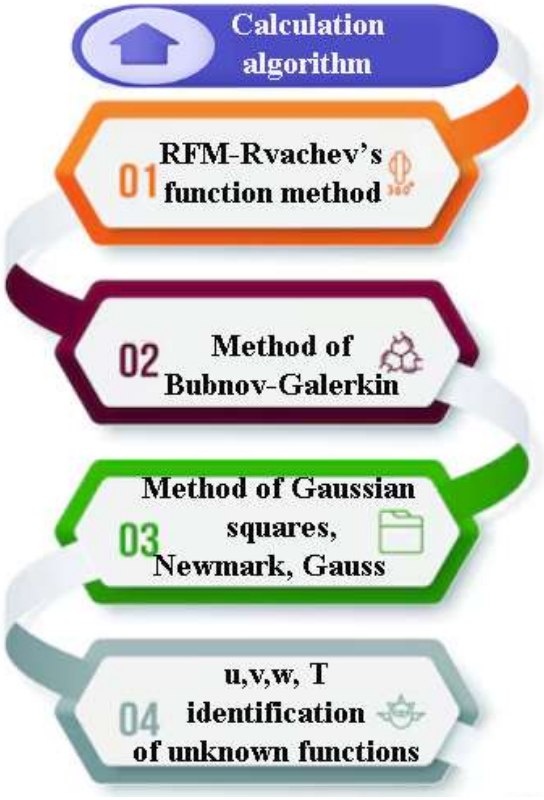


Figure-1. Calculation algorithm for a magnetoelastic plate of complex form.

The process of solving boundary value problems for magnetoelastic plates consists of the following steps:

1. Sequence of coordinate functions (solution structures) corresponding to the given boundary conditions using the R-function method of V.L. Rvachev (Rvachev Function Method, RFM).

2. The Bubnov-Galerkin method for spatial variables is a discretisation of discrete equations, i.e. the construction of discrete equations using the Bubnov-Galerkin variational method.

3. Solve discrete equations (Newmark method (dynamics) or Gauss method (statics) and calculate integrals using the Gauss quadrature method) and find (determine) the unknown components of the solution structures.

4. Finding (determination) of unknown functions (u, v, w, T) on the basis of solution structures constructed according to the method of R-functions (RFM) of V.L.Rvachev.

III.METODS

Consider the steps to build the structure of solutions based on the complex boundary field equation using RFM.

Aytaylik, $S_2(x) \equiv (x \geq 0), x \in R^1, \quad x \geq 0$ bo‘lganda 1 qiymatga ega, aks holda $x \geq 0$ bo‘lganda 0 qiymatga ega predikat (mulohaza) bo‘lsin[9].

Suppose there is a predicate (sentence) that has value 1 when $S_2(x) \equiv (x \geq 0), x \in R^1, \quad x \geq 0$, otherwise has value 0 when $x \geq 0$ [9].

In this: $x = (x_1, x_2, ..., x_n)$; $S_2(x) = \{S_2(x_1), S_2(x_2), ..., S_2(x_n)\}$. Then the function $y = f(x)$ is called an R-function if there exists such a logical function $Y = F(X), \ X = (X_1, X_2, ..., X_n)$ and the following condition is satisfied:

$$S_2[f(x)] = F[S_2(x)]. \tag{2}$$

The function $Y = F(X)$ is a logical function if the elements of the set X_i and $B_2 = \{0;1\}$ consist of only two elements, namely 0 and 1.

In formula (2) above, each R-function corresponds to a Boolean function. The reverse is not true: a single Boolean function can correspond to an infinitely large set of R functions.

Using the R-function for thin plates with complex forms, the following solution structures are constructed taking into account different natural spheres.

1. Boundary conditions in the case where the boundaries of the plates are fixed in a rigid manner

$$u\big|_\Gamma = 0, \quad v\big|_\Gamma = 0, \quad w\Big|_\Gamma = 0, \quad \frac{\partial w}{\partial n}\Big|_\Gamma = 0, \quad T\big|_\Gamma = T_0 \tag{3}$$

where n is the external normal to the surface of the plate, the Γ limit.

At the top is the solution structure that is constructed by the given boundary condition:

$$u = \omega\phi_1, \tag{4}$$

$$v = \omega\phi_2, \tag{5}$$

$$w = \omega^2\phi_3, \tag{6}$$

$$T = \omega\phi_4 \tag{7}$$

where ω is a normalised function representing a field of complex

configuration. $\phi_1, \phi_2, \phi_3, \phi_4$ are uncertain components of the decision structure.

$$\phi_1 = \sum_{i=1}^{n_1} C_i(t)\gamma_i(x,y), \quad \phi_2 = \sum_{j=1}^{n_2} C_j(t)\tau_j(x,y),$$
$$\phi_3 = \sum_{k=1}^{n_3} C_k(t)\psi_k(x,y), \quad \phi_4 = \sum_{l=1}^{n_4} C_l(t)\lambda_l(x,y) \tag{8}$$

C_i, C_j, C_k, C_l - unknown coefficients requiring determination, $\gamma_i, \tau_j, \psi_k, \lambda_l$ - complete systems of basic polynomials (e.g. degrees, Chebyshev, trigonometric, splines, etc.).

The value of formula (8) is added to formulas (3-5), resulting in the structure of solutions to the condition.

$$u_i = \omega\gamma_i,\ v_j = \omega\tau_j,\ w_k = \omega\psi_k,\ T_l = \omega\lambda_i \tag{9}$$

2. Boundary conditions in the case of an articulated boundary between plates:

$$u\big|_\Gamma = 0,\ v\big|_\Gamma = 0,\ w\big|_\Gamma = 0,\ M_n\big|_\Gamma = 0,\ T\big|_\Gamma = T_0 \tag{10}$$

The structure of the solutions, which satisfy the basic boundary conditions, will have the following form

$$u = \omega\phi_1, \tag{11}$$

$$v = \omega\phi_2, \tag{12}$$

$$w = \omega\phi_3 - \omega^2(\phi_3(P_2\omega + vP_1\omega) + 2P_1\Phi_3)/2, \tag{13}$$

$$T = \omega\phi_4 \tag{14}$$

P_1, P_2, P_3 differential operators

Designing the panels when the edges need to be hinged:

$$u_i = \omega\gamma_i,\ v_j = \omega\tau_j,$$
$$w_k = \omega\psi_k - \omega^2(\psi_k(D_2\omega + vD_1\omega) + 2D_1\psi_k)/2,\ T_l = \omega\lambda_i \tag{15}$$

3. Boundary conditions and solution structure for partially rigidly clamped and partially elastically clamped plate boundaries. The boundary conditions for the plate in the case where the boundaries of the first region are rigidly clamped and the boundary of the second region is hinged are as follows [11]:

$$u\big|_{\Gamma_1} = 0, \quad v\big|_{\Gamma_1} = 0, \quad w\Big|_{\Gamma_1} = 0, \quad \frac{\partial w}{\partial n}\Big|_{\Gamma_1} = 0, \quad T\big|_{\Gamma_1} = T_0$$
$$u\big|_{\Gamma_2} = 0, \quad v\big|_{\Gamma_2} = 0, \ M_n\big|_{\Gamma_2} = 0, \quad (N_n - M_{n,\varphi})\big|_{\Gamma_2} = 0, T \tag{16}$$

In view of the boundary conditions, we construct the following solution structure:

$$u = \omega\phi_1,\ v = \omega\phi_2,\ \ w = \frac{\omega_2\omega_1^2}{\omega_2 + \omega_1^2}\Phi_3,\ T = \omega\phi_4, \tag{17}$$

$\omega_1 - \Gamma_1$ - the normal equation of the sphere; $\omega_2 - \Gamma_2$ – the normal field equation; ω – the generalised normal field equation of complex form, ω = 0 - equation at all field boundaries;

The Bubnov-Galerkin variational method is used to find the desired $u(x,y),\ v(x,y),\ w(x,y),\ T(x,y)$ functions from the structure of solutions constructed by given boundary conditions, and its overview is given in the following expressions [10; p. 68-87].

$$\phi_1 = \sum_{i=1}^{n_1} C_i(t)\gamma_i(x,y), \quad \phi_2 = \sum_{j=1}^{n_2} C_j(t)\tau_j(x,y),$$
$$\phi_3 = \sum_{k=1}^{n_3} C_k(t)\psi_k(x,y), \quad \phi_4 = \sum_{l=1}^{n_4} C_l(t)\lambda_l(x,y) \tag{18}$$

$$u = \sum_{i=1}^{n_1} C_i(t)u_i(\omega,x,y), \quad v = \sum_{j=1}^{n_2} C_j(t)v_j(\omega,x,y),$$
$$w = \sum_{k=1}^{n_3} C_k(t)w_k(\omega,x,y), \quad T = \sum_{l=1}^{n_4} C_l(t)T_l(\omega,x,y) \tag{19}$$

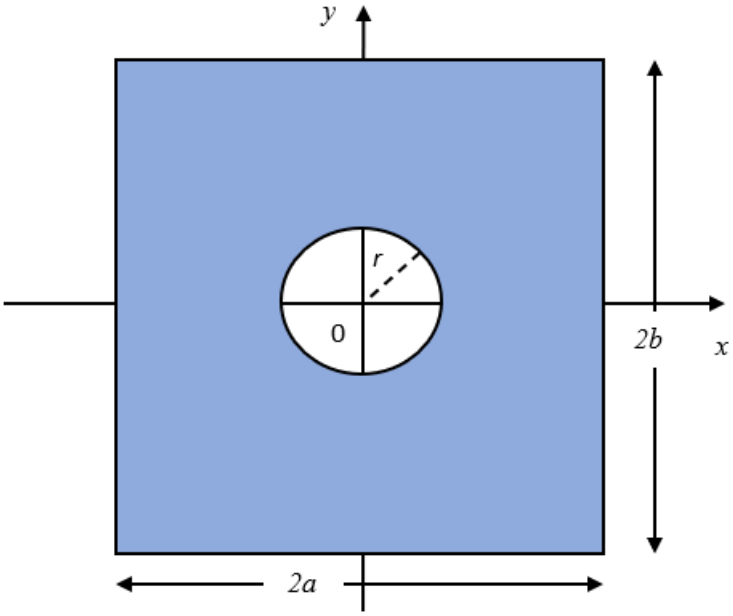


Figure 1: A thin sheet of magnetoelastic material with a complex form.

Consider the construction of the above complex field (Fig. 1) using the R-function and creating an algebraic equation:

$$f_1 = \frac{(a^2 - x^2)}{2a}, \quad f_2 = \frac{(b^2 - y^2)}{2b}, f_3 = \frac{(x^2 - y^2 - r^2)}{2r} \tag{20}$$

$$\omega = (f_1 \wedge f_2) \wedge f_3$$

It is discretised in terms of spatial variables (discrete equations, i.e. discrete modelling);

The constructed equation consists of static or dynamic equations, depending on the problem. If the problem is considered in a static state, the equation will look like this:

$$NC = F$$

Here $M=\{a_{ij}\}$ are matrix elements and $C=c_1,c_2,c_3,...,c_n, J=\{f_i\}$ are vector elements.

For the dynamic case it looks as follows:

$$M\ddot{C}+NC=J$$

Where:

$$M=\begin{pmatrix} M_{11} & 0 & 0 & 0 \\ 0 & M_{22} & 0 & 0 \\ 0 & 0 & M_{33} & 0 \\ 0 & 0 & 0 & M_{nm} \end{pmatrix};\quad B=\begin{pmatrix} N_{11} & N_{12} & N_{13} & N_{nm} \\ N_{21} & N_{22} & N_{23} & N_{nm} \\ N_{31} & N_{32} & N_{33} & N_{nm} \\ N_{41} & N_{42} & N_{43} & N_{nm} \end{pmatrix};\quad C=\begin{pmatrix} C_1 \\ C_2 \\ C_3 \\ C_n \end{pmatrix};\quad F=\begin{pmatrix} f_1 \\ f_2 \\ f_3 \\ f_n \end{pmatrix}$$

n=1,2,3…. m=1,2,3….

The Bubnov-Galerkin variational method is used to find each term of the vector and matrix. We do this as follows:

$$M_1=\iint_\Omega L_1u_i d\Omega,\qquad i=\overline{1,n_1};$$

$$M_2=\iint_\Omega L_2v_j d\Omega,\qquad j=\overline{1,n_2};$$

$$M_3=\iint_\Omega L_3w_k d\Omega,\qquad k=\overline{1,n_3};$$

$$M_4=\iint_\Omega L_4T_l d\Omega,\qquad l=\overline{1,n_4};$$

$$N_{11}=\iint_\Omega L_{11}u_iu_j d\Omega,\qquad i=\overline{1,n_1},\ j=\overline{1,n_2};$$

$$N_{12}=\iint_\Omega L_{12}u_iv_j d\Omega,\qquad i=\overline{1,n_1},\ j=\overline{1,n_2};$$

$$N_{13}=\iint_\Omega L_{13}w_ku_i d\Omega,\qquad i=\overline{1,n_1},\ k=\overline{1,n_3};$$

$$N_{14}=\iint_\Omega L_{14}u_iT_l d\Omega,\qquad i=\overline{1,n_1},\ l=\overline{1,n_4};$$

$$N_{21}=\iint_\Omega L_{21}u_iv_j d\Omega,\qquad i=\overline{1,n_1},\ j=\overline{1,n_2};$$

$$N_{22}=\iint_\Omega L_{22}v_iv_j d\Omega,\qquad i=\overline{1,n_1},\ j=\overline{1,n_2};$$

$$N_{23}=\iint_\Omega L_{23}v_jw_k d\Omega,\qquad j=\overline{1,n_2},\ k=\overline{1,n_3};$$

$$N_{24}=\iint_\Omega L_{24}v_jT_l d\Omega,\qquad j=\overline{1,n_2},\ l=\overline{1,n_4};$$

$$N_{31}=\iint_\Omega L_{31}u_iw_k d\Omega,\qquad i=\overline{1,n_1},\ k=\overline{1,n_3};$$

$$N_{32}=\iint_\Omega L_{32}w_kv_j d\Omega,\qquad k=\overline{1,n_1},\ j=\overline{1,n_2};$$

$$N_{33}=\iint_\Omega L_{33}w_k d\Omega,\qquad k=\overline{1,n_3};$$

$$N_{34}=\iint_\Omega L_{34}w_kT_l d\Omega,\qquad j=\overline{1,n_2},\ l=\overline{1,n_4};$$

$$J_1=\iint_\Omega q_1w_k d\Omega,\qquad k=\overline{1,n_3};$$

$$J_2=\iint_\Omega q_2w_k d\Omega,\qquad k=\overline{1,n_3};$$

$$J_3=\iint_\Omega q_3w_k d\Omega,\qquad k=\overline{1,n_3};$$

$$J_4=\iint_\Omega q_4w_k d\Omega,\qquad k=\overline{1,n_3};$$

L_i, L_{ij} - differential operators

Practical results of solving thin magnetoelastic plate boundary problems

Numerical results and graphical representation of a thin plate with a rigidly fixed centreless condition on the plate.

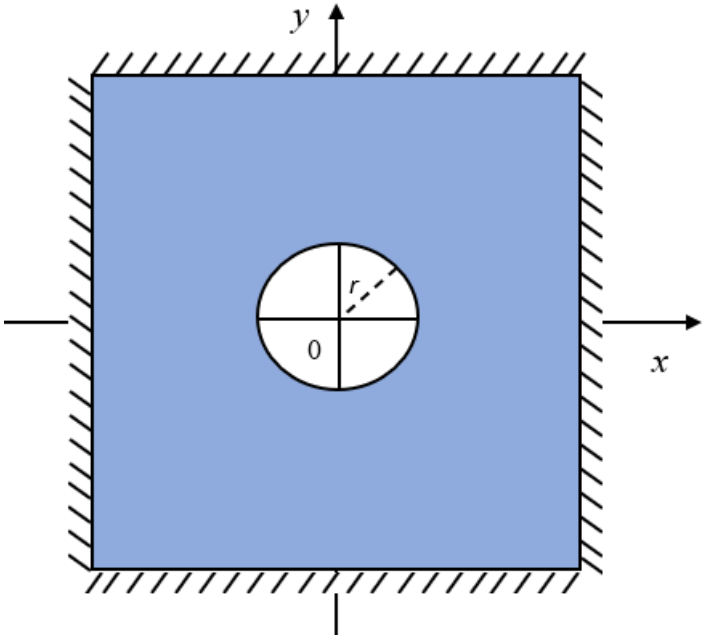


Figure 2. Illustration of plate boundaries in mixed conditions

The analytical equation for the reference symmetric complex field R-function (Fig. 1) is constructed, which is expressed by formula (20).

The geometrical and mechanical parameters in the design experiment are as follows.

$$a = 1м, b = 1м,\ h = 0.01м,\ r = 0.2м,\ \nu = 0.3, t_0 = 0, E = 10^{11}\ H/м^2$$

Numerical results obtained under mixed conditions at the plate boundary

Table 1.

№	x	Taking into account the mechanical forces w(x,y,t) y=0 t=0.5	Taking into account the mechanical and magnetic field forces w(x,y,t) y=0 t =0.5
1.	-1	0	0
2.	-0.9	0.0005	0.0006
3.	-0.8	0.0015	0.0018
4.	-0.7	0.0028	0.0033
5.	-0.6	0.0039	0.0047
6.	-0.5	0.0049	0.0058
7.	-0.4	0.0057	0.0067
8.	-0.3	0.0062	0.0073
9.	-0.2	0.0066	0.0077
10.	0.2	0.0066	0.0077
11.	0.3	0.0062	0.0073
12.	0.4	0.0057	0.0067
13.	0.5	0.0049	0.0058
14.	0.6	0.0039	0.0047

15.	0.7	0.0028	0.0033
16.	0.8	0.0015	0.0018
17.	0.9	0.0005	0.0006
18.	1	0	0

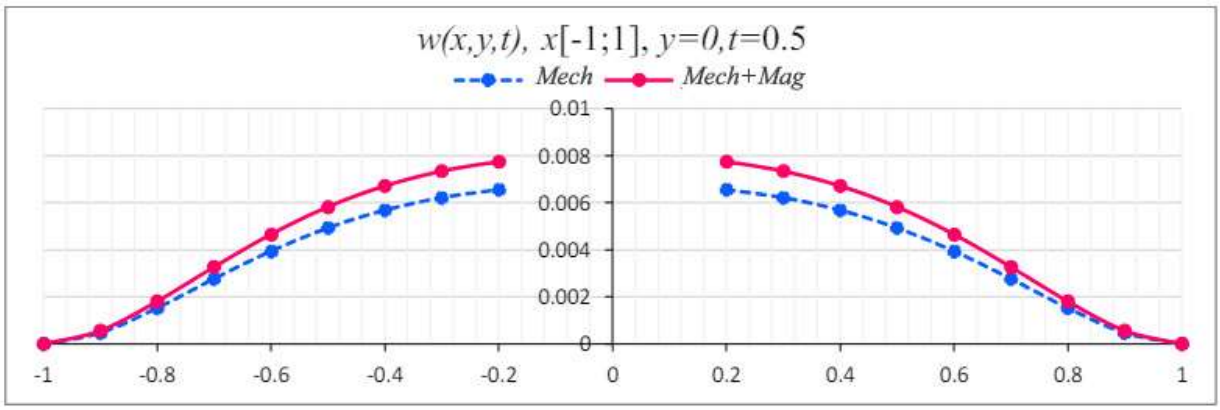


Figure 3. Graphical representation of the numerical results obtained under the mixed conditions.

Experiments were carried out to calculate the effect of mechanical forces on an electrically conducting thin plate of complex form, and the effect of magnetic field forces on mechanical forces. As a result, the sum of the values expressed in (Table 1, Figure 3) shows that their mutual difference was 18%.

CONCLUSION

According to the results of the analysis of the calculation results, it can be concluded that the influence of electromagnetic fields on the deformation state of thin electrically conductive plates can be reliably confirmed. In particular, the influence of electromagnetic forces is more significant in the centre of the plate. As can be seen from the figures, the influence of the magnetic field on the deformed state of the plate is not very large compared to the mechanical forces when the plate is rigidly fixed along the entire contour, when it is hinged and in different positions. mixed conditions. mixed conditions. mixed conditions. The numerical results of the calculation have been presented in tabular form and graphically for analysis. The numerical results of the calculation of the degree of magnetoelasticity of complex structured thin magnetoelastic plates with electrically conducting symmetry have been analysed.

REFERENCES

[1] Safarov Sh.Sh. Algorithm of calculation of flexible magnetoelastic plate. Republican scientific-practical conference on the topic "Actual problems of using information and communication technologies in the educational process" May 17-18, 2019 Gulistan pp:166-169

[2] F.M. Nuraliyev, Sh.Sh Safarov, M.A. Artikbayev. Computational algorithm for solving the problem of flexible magnetoelastic plate. The importance of information and communication technologies in the innovative development of economic sectors Republican scientific and technical conference. Tashkent March 5-6, 2020. S 73-76.

[3] Antonio Z., Giovanni I., Francesco P., Tetyana Sh. Novel Semi-Analytical

Solutions: Experimental Modal Analysis, Finite Element Method, and R-Functions Method. Hindawi, Volume 2020, Article ID 8882867, 23 pages

[4] Lidiya Kurpa., Vladimir Rvachev., Eduard Ventse l. The R-function method for the free vibration analysis of thin orthotropic plates of arbitrary shape. Journal of Sound and Vibration, Volume 261, Issue 1, 13 March 2003, Pages 109-122

[5] Jan A., Grzegorz K., Olga M. Double mode model of size-dependent chaotic vibrations of nanoplates based on the nonlocal elasticity theory. (2021) Pp: 3425-3444

[6] Mama B.O, Nwoji C.U, Onah H.N, Ike C.C.Bubnov-Galerkin method for the Elastic Stress Analysis of Rectangular Plates under Uniaxial Parabolic Distributed Edge Loads. International Journal of Engineering and Technology (IJET). Vol 9 No 6, Jan 2018, pp:4323-4332

[7] Jan Awrejcewicz, Grzegorz Kudra, Olga Mazur. Parametric vibrations of graphene sheets based on the double mode model and the nonlocal elasticity theory. Nonlinear Dyn (2021) Pages: 2173–2193

[8] Nuraliyev F.M., Mirzaakhmedov M, K., Abdulayev O.K., Tahirov B. Mathematical model of thermo-electro-mangnite-elasticity of thin plate. Scientific Journal "Tatu News". No. 1, 15 p.

[9] Rvachev V. L. The theory of R-function and some of its applications/Kiyev : Nauk, Dumka, 1982.— 552 p. (in russian)

[10] Nuraliyev F.M. Mathematical models of magnetoelasticity of thin shells and plates. Questions of computational and applied mathematics. Mir № 128. Tashkent 2012. pp: 53-63.(in russian)

[11] Nuraliev F. M., Safarov Sh. Sh. Mathematical modeling of processes of the electromagnetic fields' effecs on thin conductive bodies by the method of R-function. Proceedings of the International Scientific and Practical Conference. Dubai April 20-21, 2015, pp 24-29 .

[12] Artikbayev M.A. Development of a mathematical model of the problem of vibration of electromagnetic elastic thin anisotropic plates. Journal "Fan and society", Nukus-2021, № 4/1. – pp: 3-7.

[13] Kabulov V.K. Algorithmization in the theory of elasticity and deformation theory of plasticity. Tashkent: Fan, -1966. 395 p. (in russian)

[14] Nuraliev F., Mirzaakhmedov M., Tojiyev N. Mathematical Model of a Thin Plate's Thermo-Electro-Magnetic-Elasticity International Conference "Modern Problems of Applied Science and Engineering". Samarkand, 2.-3. May. 2024