# SCIENCE AND EDUCATION IN KARAKALPAKSTAN

# ҚОРАҚАЛПОҒИСТОНДА ФАН ВА ТАЪЛИМ

# ҚАРАҚАЛПАҚСТАНДА ИЛИМ ҲӘМ ТӘЛИМ

# НАУКА И ОБРАЗОВАНИЕ В КАРАКАЛПАКСТАНЕ

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# COMPUTER MODELING OF PROCESSES OF VARIATION OF THIN PLATES LOCATED IN ELECTROMAGNETIC FIELD

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**Summary.** This article describes the development of an algorithm for calculating magnetoelastic thin plates with a complex shape based on a combination of the R-function methods of V. L. Rvachev and the Bubnov-Galerkin variation method that automates the process of oscillation of magnetoelastic thin plates with a complex shape. The problems of oscillations of magnetoelastic thin plates with a complex shape in the presence of an electromagnetic field are solved.

**Key words:** modeling equation, variation, magnitoelastic, plats, vibration, Hamilton-Ostrogradskiy, method Bubnov-Galerkin, V. L. Rvachev's R-function.

**Introduction.** This paper views the solution of problem about variation of thin plates located in electromagnetic field [1].

Isotropic elastic plate with permanent depth 2h, made from material with final electroconductivity and situated in external magnetic field with given vector of intensity is being viewed. External current and charges aren't present. Electromagnetic field in the plate doesn't change quickly [2-4].

The plate in the Decart $x_1, x_2, x_3$ coordinate system is situated so, that the middle plaine of middle plane coordinate plaine $x_1, x_2$. Hypothose for the internal task analytically will be [1,5-8]:

$$u_1 = -x_3 \frac{\partial w}{\partial x_1}, u_2 = -x_3 \frac{\partial w}{\partial x_2}, u_3 = w(x_1, x_2, x_3) \qquad (1)$$

where $w = w(x_1, x_2, t)$ - movement of middle plain of plate being searched, $\varphi = \varphi(x_1, x_2, x_3), \psi = \psi(x_1, x_2, x_3), f = f(x_1, x_2, x_3)$,- required function of the active electromagnetic field.

Then determinant equasions for thin plates in some particular cases of external magnetic field.

$$\Delta\varphi - \frac{\varepsilon\mu}{c^2}\frac{\partial^2\varphi}{\partial t^2} - \frac{4\pi\sigma\mu}{c^2}\frac{\partial\varphi}{\partial t} = -\frac{\mu}{c}\frac{\partial}{\partial t}\left[\frac{4\pi\sigma}{c^2}B_{02}\frac{\partial w}{\partial t} - \frac{\varepsilon\mu - 1}{\varepsilon\mu}\left(B_{02}\frac{\partial^2 w}{\partial x_1^2} - B_{01}\frac{\partial^2 w}{\partial x_1 x_2} - \frac{\varepsilon\mu}{c^2}B_{02}\frac{\partial^2 w}{\partial t^2}\right)\right],$$

$$\Delta\psi - \frac{\varepsilon\mu}{c^2}\frac{\partial^2\psi}{\partial t^2} - \frac{4\pi\sigma\mu}{c^2}\frac{\partial\psi}{\partial t} = \frac{\mu}{c}\frac{\partial}{\partial t}\left[\frac{4\pi\sigma}{c^2}B_{01}\frac{\partial w}{\partial t} + \frac{\epsilon\mu-1}{\epsilon\mu}\left(B_{02}\frac{\partial^2 w}{\partial x_1 x_2} - B_{01}\frac{\partial^2 w}{\partial x_2^2} + \frac{\epsilon\mu}{c^2}B_{01}\frac{\partial^2 w}{\partial t^2}\right)\right],$$

$$D\Delta^2 w + 2\rho h\frac{\partial^2 w}{\partial t^2} = P + \frac{2h^3\sigma}{3c}\left(B_{02}\frac{\partial^2\varphi}{\partial x_1^2} - B_{01}\frac{\partial^2\varphi}{\partial x_1\,\partial x_2} + B_{02}\frac{\partial^2\psi}{\partial x_1\,\partial x_2} - B_{01}\frac{\partial^2\psi}{\partial x_2^2}\right) + \frac{2h^3\sigma}{3c^2}\frac{\partial}{\partial t}\left[\left(\frac{1}{\epsilon\mu}B_{02}^2 + B_{03}^2\right)\frac{\partial^2 w}{\partial x_1^2} + \left(\frac{1}{\epsilon\mu}B_{01}^2 + B_{03}^2\right)\frac{\partial^2 w}{\partial x_2^2} - \frac{2}{\epsilon\mu}B_{01}B_{02}\frac{\partial^2 w}{\partial x_1\,\partial x_2}\right] + \frac{2\sigma h}{c}\left[B_{02}\left(\varphi - \frac{B_{02}}{c}\frac{\partial w}{\partial t}\right) - B_{01}\left(\psi + \frac{B_{01}}{c}\frac{\partial w}{\partial t}\right)\right] \quad (2)$$

Equations of magnetoelasticity (2) boundary will be solved in following conditions

Freely edge (territory):

$$w|\Gamma = 0, M|\Gamma = 0, \varphi|\Gamma = 0, \psi|\Gamma = 0 \quad (3)$$

and with basic condition

$$\dot{\varphi} = \dot{\varphi}_0, \dot{\psi} = \dot{\psi}_0, \dot{w} = \dot{w}_0,$$
$$\varphi = \varphi_0, \psi = \psi_0, w = w_0 \quad (4)$$

There are unidentified components of magnetic induction B0i, in equation (2) which are identified by Maxwell equation [9].

To solve the given problem (2-4), a=lm, b=0,5m, r=0,l, h=10 $^{-2}$m, E=11*10$^{10}$Н/м$^2$, p=8890 кг/м$^3$, nu=0,3, $j_{CI}$=-3,673205А/М$^2$, p=1,256* 10$^{-6}$ Гн/м; σ=3,6*10$^7$ (Ом м) $^{-1}$; ε=1; с=3*10$^8$м/с; P=5000 Н/м$^2$ sides are choosen like its geometric and physical parameters [9].

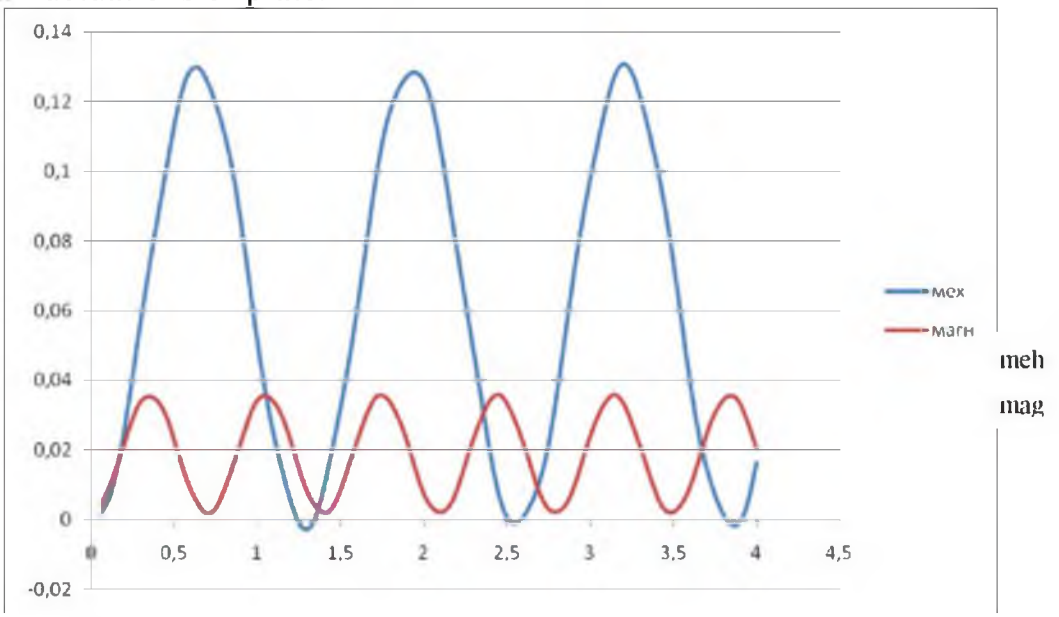
During the solving of this problem the following results were gotdeflection of plate under pressure of just mechanic forces and under joint pressure of mechanic and electromagnetic forces in appropriate places are shown also there are valves of components of electromagnetic field.

| t | w*(0;0;t)*10$^2$ | | w*(0,5;0,5;t)*10$^2$ | | φ*(0;0;t)*10$^2$ | ψ*(0; 0;t)*10$^2$ | φ*(0,5; 0,5;t)*10$^2$ | ψ*(0,5; 0,5;t)*10$^2$ |
|---|---|---|---|---|---|---|---|---|
| | мех | маг | мех | маг | | | | |
| 0,05 | 0,1664 | 0,4414 | 0,01807 | 0,018008 | -2,4760E-05 | 3,8143E-05 | -1,4987E-05 | 2,0801E-05 |
| 0,4 | 0,9349 | 0,34655 | 4,7396 | 1,486299 | -1,0894E-05 | 9,8571E-06 | -8,7076E-05 | 9,2244E-05 |
| 0,8 | 0,12791 | 0,9681 | 5,7854 | 0,379888 | -9,8869E-06 | 1,5324E-05 | -1,1995E-04 | 1,0862E-04 |
| 1,2 | 0,4895 | 0,22877 | 0,2987 | 0,862275 | -4,9540E-05 | -2,3372E-06 | 1,6930E-04 | -1,6538E-04 |
| 1,6 | 0,62658 | 0,23762 | 3,4517 | 0,930616 | -4,2947E-05 | 3,0127E-05 | -1,0992E-04 | 1,1116E-04 |
| 2 | 0,128467 | 0,7437 | 6,4484 | 0,262368 | -2,3014E-05 | 7,0804E-05 | -2,2045E-04 | 2,1919E-04 |
| 2,4 | 0,8736 | 0,35369 | 1,1212 | 1,349348 | -2,1577E-05 | -2,0541E-05 | 3,2249E-04 | -3,1446E-04 |
| 2,8 | 0,7288 | 0,2496 | 2,1168 | 0,075537 | 7,6155E-06 | 9,5468E-05 | -5,1003E-05 | 4,7379E-05 |
| 3,2 | 0,633473 | 0,34432 | 6,6656 | 1,387773 | 2,8345E-06 | 2,5868E-05 | -2,0787E-04 | 2,0719E-04 |
| 3,6 | 0,40209 | 0,9682 | 2,3075 | 0,434801 | -5,4298E-06 | 2,0429E-05 | 2,0654E-04 | -2,0659E-04 |
| 4 | 0,12669 | 0,20911 | 0,9565 | 0,874533 | -3,1672E-06 | -1,4756E-05 | -2,5491E-05 | 1,7106E-05 |

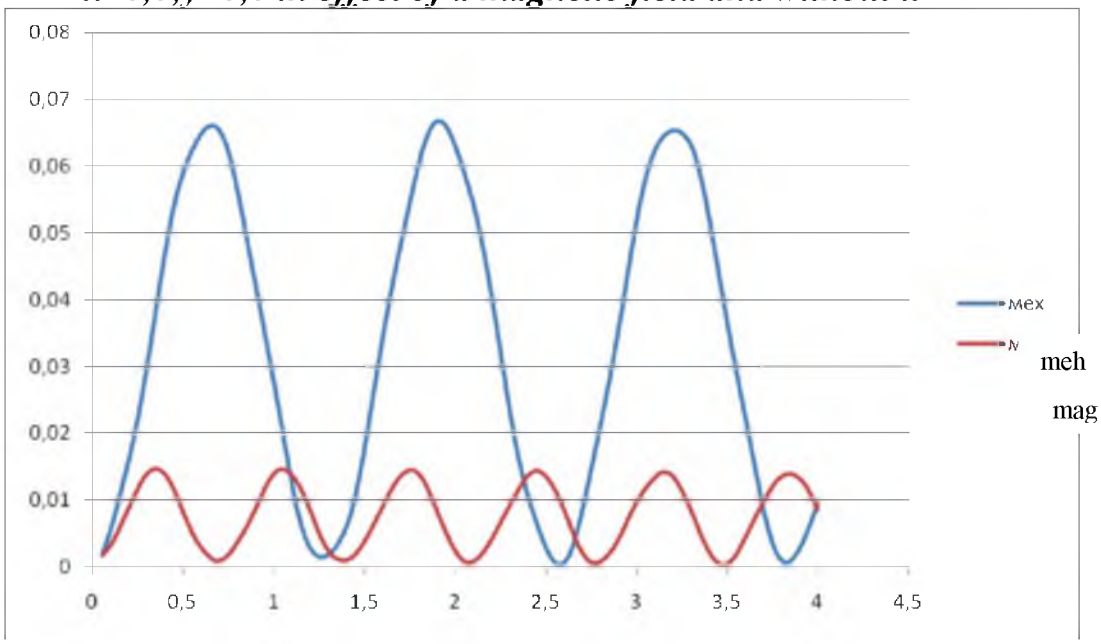
*Variations of plate and bahavior of components of electromagnetic field under simply supported boundary conditions*

Further there are graphics of variations under effect of mechanical force and magnetic field on different locations. Pic. 1-2 show fluctuations of a rectangular plate

with rounded corners under effect of magnetic field at simply supported boundary conditions. In the center of plate there are much more deffections, and also higher frequency of fluctuations of plate.




***Pic.l. Fluctuation of a rectangular plate with the rounded corners at point x=0,0;y=0,0 in effect of a magnetic field and without it***

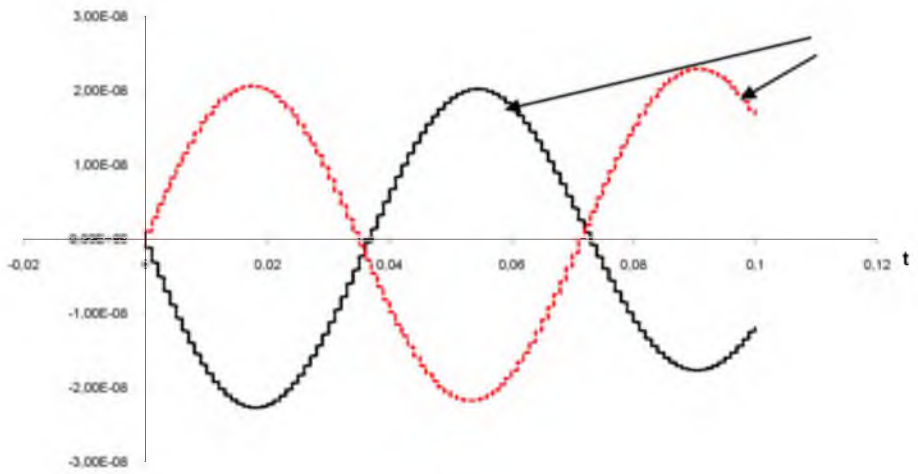



***Pic.2. Fluctuation of a rectangular plate with the rounded corners at point x=0,5;y=0,5 in effect of a magnetic field and without it***

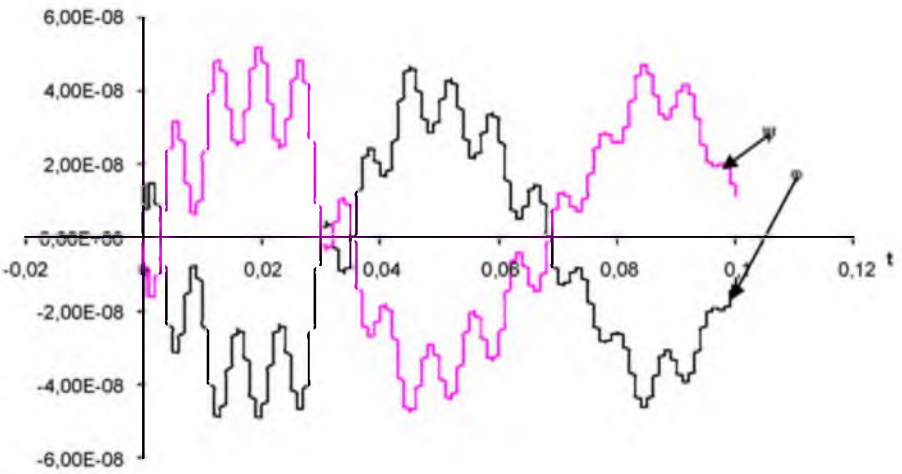
Pictures 3-4 shows research for components of the induced electromagnetic field φ,ψ at point x=0,0 y=0,0 (x=0,5 y=0,5) at a time interval t=[0;4]; Δt= 0,04 for area of a plate with rounded corners.

Here parameters of a magnetic field varies very quickly, has high frequencies and small amplitudes, a component of field φ opposite varies against a component of

field ψ.




***Pic.3. Behaviour electromagnetic component at φ(0,0;0,0;t) and ψ(0,0;0,0;t) at free a boundary condition***




***Pic.4. Behaviour electromagnetic component at φ(0,5;0,5;t) and ψ(0,5;0,5;t) at free a boundary condition.***

## Conclusions:

1. A unified effective computational algorithm was developed for calculating the oscillations of a magnetoelastic thin plate with a complex configuration based on the R-functions, Bubnov-Galerkin methods and numerical methods.

2. On the basis of the developed algorithm and software, a computational experiment was conducted to solve new problems of oscillation of magnetoelastic thin plates of complex configuration.

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***Rezyume.*** *Mazkur maqolada magnitoelastik masalasi qaralgan bo'lib, electromagnet maydonda joylashgan murakkab shalli yupqa plastinkalarning tebranish masalasi uchun hisoblash algoritmi ishlab chiqilgan va undan foydalangan holda plastinkaga elektromagnit maydonining ta'sir etish masalasi urganildi.*

***Резюме*** *В данной статье рассмотрена разработка алгоритма расчета магнитоупругих тонких пластин со сложной формой на основе комбинации методов R-функций В.Л. Рвачева и вариационного метода Бубнова-Галеркина, автоматизирующий процесс колебания магнитоупругих тонких пластин со сложной формой. Решены задачи колебания магнитоупругих тонких пластин со сложной формой при наличии электромагнитного поля.*

***Kalit so'zlar.*** *Matematik model, variattsiya, magnitelastik, plastinka, tebranish, Gamilton – Ostrogradskiy tamoili, Bubnov-Galerkin usuli, R-fuktsya.*

***Ключевые слова.*** *Математическая модель, вариация, магнитоупругость, пластинка, колебание, принцип Гамильтон – Остроградский, метод Бубнов-Галеркин, R-функция.*