MURAKKAB SHAKLGA EGA BO'LGAN ANIZOTROP TERMO-ELEKTRO-MAGNIT PLASTINALARNING NOCHIZIQLI KUCHLANLANGANLIK-DEFORMASIYALANGANLIK JARAYONLARINI MATEMATIK MODELI VA HISOBLASH TAJRIBALAR TAHLILI

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Anotatsiya: Matematik modelni qurishimizda biz Gamilton-Ostrogradskiy variatsion tamoyili va Kirxgof-Lyav gepotizasidan foydalanib uch o'lchovli koordinatani ikki o'lchovli koordinataga o'tkazamiz bunda ko'chishlarning dastlabki ko'rinishiga ega bo'lamiz. Kinetik energiya, Potensial energiya va Tashqi kuchlar bajargan ishlarni variatsion ko'rinishi hisoblab chiqildi. Furening issiqlik o'tkazuvchanlik qonuni, Dyugamelya-Neymananing tenglamasi,Koshi munosabati,Guk qonuni,Lorens kuchi va Maksvell elektromagnit tenzor ko'rinishidan foydalanib, termo-elektro-magnit maydon ta'siri ostidagi, murakkab shaklga ega bo'lgan anizotrop termo-elektro-magnitelastik plastinalarning nochiziqli kuchlanlanganlik va deformasiyalanganlik holati o'rganildi.

Kalit so'zlar: Model,Matemetik model, Modellashtirish,Gamilton-Ostrogradskiy tamoyili,Kirgof-Lyav gipotezasi, Furening issiqlik o'tkazuvchanlik qonuni, Dyugamelya-Neymananing tenglamasi,Koshi munosabatlari,Guk qonuni,Maksvell elektromagnit tenzori,anizotrop,plastina.

Annotation: In constructing the mathematical model, we transform the three-dimensional coordinate into a two-dimensional coordinate using the Hamilton-Ostrogradsky variational principle and the Kirchhoff-Lyaw hypothesis, in which the initial form of displacements We will be. The variational form of the work done by the kinetic energy, potential energy and external forces was calculated. Using the Fourier law of thermal conductivity, the Dugamel-Neumann equation, the Cauchy relation, Hooke's law, the Lorentz force and the Maxwell electromagnetic tensor form, the nonlinear stress and deformation state of anisotropic thermo-electro-magneto-elastic plates with a complex shape under the influence of a thermo-electro-magnetic field was studied.

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Keywords: Model, Mathematical model, Modeling, Hamilton-Ostrogradsky principle, Kirchhoff-Lyew hypothesis, Fourier's law of thermal conductivity, the Dugamel-Neumann equation, Cauchy relations, Hooke's law, Maxwell electromagnetic tensor, anisotropic, plate.

Аннотация: При построении математической модели мы используем вариационный принцип Гамильтона-Остроградского и гипотезу Кирхгофа-Лью для преобразования трехмерной координаты в двумерную, тем самым получая начальное представление перемещений. Рассчитана вариационная форма кинетической энергии, потенциальной энергии и работы внешних сил. С использованием закона теплопроводности Фурье, уравнения Дюгамеля-Неймана, соотношения Коши, закона Гука, силы Лоренца и представления электромагнитного тензора Максвелла исследовано нелинейное поведение напряжений и деформаций анизотропных термоэлектромагнитоупругих пластин сложной формы под воздействием термоэлектромагнитного поля.

Ключевые слова: Модель, Математическая модель, Моделирование, принцип Гамильтона-Остроградского, гипотеза Кирхгофа-Лью, закон теплопроводности Фурье, уравнение Дюгамеля-Неймана, соотношения Коши, закон Гука, электромагнитный тензор Максвелла, анизотропный, пластина.

Kirish

Aviatsiya va kosmik texnologiyalarda tuzilmaviy boshqaruv,energiya boshqaruvi,harorat va elektr maydon ta'sirida energiyani samarali taqsimlash va boshqarish imkonini beradi.Energetikada termoelektrik generatorlar,elektr energiyasini o'zgartirishva elektromagnit maydon ta'sirida energiya oqimini boshqarish uchun ishlatiladi.[2] Sensorlar va aktuatorlarda harorat, bosim va elektromagnit maydon o'zgarishlarini sezuvchi yuqori sezgir qurilmalarda qo'llaniladi,Elektromagnit maydon ta'sirida harakatni yaratish uchun ishlatiladi. Tibbiyot texnologiyalarida tibbiyotda elektromagnit maydon asosida ishlaydigan qurilmalarda qo'llaniladi,reabilitatsiya texnologiyalarida elektromagnit maydon orqali davolash usullari uchun ishlatiladi. [5].

Matematik modellashtirish

. Gamilton-Ostrogradskiy variatsion tamoyilining umumiy ko’rinishi:

$$\int_t (\delta W_K - \delta W_\Pi + \delta W_A)dt = 0; \tag{1}$$

Bunda : $\delta -$ variatsiya amali; W_K – kinetik energiya; $W_\Pi -$ potensial energiya; W_A – tashqi hajm va sirt kuchlari bajargan ish.

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Murakkab shaklga ega plastinaning harakat tenglamalarini keltirib chiqarishda ko’chishning o’zgarish qonunlari sifatida Kirxgofa-Lyav gepotezasidan foydalanamiz [2].

Anizotrop moddalar uchun temperaturaning xarakat tenglamalari

Furye issiqlik o'tkazuvchanlik qonuni asosan anizotrop nochiziqli deffirensial tenglamani olamiz.

$$\lambda_{ij} T,_{ij} - C_\varepsilon \dot{T} - T \beta_{ij} \dot{\varepsilon}_{ij} = 0 \qquad (2)$$

Bu yerda yuqoridagi formuladagi tenzor ifodani yoyib quysak tenglamamiz quyidagi (3) ko’rinishga keladi.[14]

Natija

Termo-elektro-magnitelastik anizotrop murakkab shaklga ega plastinalarning matematik modeli

Yuqoridagi (1) Gamilton-Ostrogradskiy variasion tamoyiliga asosan aniqlanilgan, kinetik va potensial energiyaning o‘zgarishi va termo-elektro-magnit maydon kuchlarni hisobga olgan holda tashqi kuchlar bajargan ishning variasiyalarini keltirib o‘rniga qo‘yamiz. Natijada termo-elektro-magnitelastik anizotrop murakkab shaklga ega plastinalar uchun quyidagi boshlang‘ich va chegara shartlarga ega bo‘lgan harakat tenglamalari tizimi hosil bo’ladi Ushbu tenglamalar tadqiq qilinayotgan murakkab shaklga ega bo’lgan plastina chegaralarini mahkamlanish usullariga qarab tegishli chegaraviy shartlarga
muvofiq yechiladi. [8]

$$\begin{cases}
-\rho h\frac{\partial^2 u}{\partial t^2} - hC_{1111}\frac{\partial^2 u}{\partial x^2} - \frac{h}{2}C_{1212}\frac{\partial^2 u}{\partial y^2} - \frac{h}{2}C_{1111}\frac{\partial^3 w}{\partial x^3} - \frac{h}{2}C_{1222}\frac{\partial^3 w}{\partial y^3} - \frac{h}{2}C_{1112}\frac{\partial^2 v}{\partial x^2} - \frac{h}{2}C_{1222}\frac{\partial^2 v}{\partial y^2} - \\
-(hC_{1122} + \frac{h}{2}C_{1212})\frac{\partial^2 v}{\partial x \partial y} - (\frac{h}{2}C_{1122} + \frac{h}{2}C_{1212})\frac{\partial^3 w}{\partial x \partial y^2} - (hC_{1211} + \frac{h}{2}C_{1112})\frac{\partial^2 u}{\partial x \partial y} - (\frac{h}{2}C_{1112} + \frac{h}{2}C_{1211})\frac{\partial^3 w}{\partial x^2 \partial y} + \\
+h\frac{\partial}{\partial x}(\alpha_{11}(T - T_0)) + h\frac{\partial}{\partial y}(\alpha_{12}(T - T_0)) + N_x + R_x + q_x + T_{zx} + \theta_{Tzx} + \theta_{\mathrm{T}} = 0, \\
-\rho h\frac{\partial^2 v}{\partial t^2} - hC_{2222}\frac{\partial^2 v}{\partial y^2} - \frac{h}{4}C_{1212}\frac{\partial^2 v}{\partial x^2} - \frac{h}{2}C_{2212}\frac{\partial^2 u}{\partial y^2} - \frac{h}{2}C_{1211}\frac{\partial^2 u}{\partial x^2} - \frac{h}{2}C_{2222}\frac{\partial^3 w}{\partial y^3} - \frac{h}{4}C_{1211}\frac{\partial^3 w}{\partial x^3} - \\
-(hC_{2211} + \frac{h}{4}C_{1212})\frac{\partial^2 u}{\partial x \partial y} - (\frac{h}{2}C_{2212} + \frac{h}{2}C_{1222})\frac{\partial^2 v}{\partial x \partial y} - (\frac{h}{2}C_{2211} + \frac{h}{4}C_{1212})\frac{\partial^3 w}{\partial x^2 \partial y} - (\frac{h}{2}C_{2212} + \frac{h}{4}C_{1222})\frac{\partial^3 w}{\partial x \partial y^2} + \\
+h\frac{\partial}{\partial y}(\alpha_{22}(T - T_0)) + \frac{h}{2}\frac{\partial}{\partial x}(\alpha_{12}(T - T_0)) + N_y + R_y + q_y + T_{zy} + \theta_{Tzy} + \theta_{\mathrm{T}} = 0, \qquad (3) \\
-\rho h\frac{\partial^2 w}{\partial t^2} - \frac{h}{2}C_{1111}(\frac{\partial u}{\partial x}\frac{\partial^2 w}{\partial x^2} + \frac{1}{2}\frac{\partial^4 w}{\partial x^4}) - \frac{h}{2}C_{1122}\frac{\partial v}{\partial y}\frac{\partial^2 w}{\partial x^2} - \frac{h}{2}\frac{\partial^4 w}{\partial x^2 \partial y^2}(\frac{1}{2}C_{1122} + \frac{1}{2}C_{2211} + C_{1212}) - \frac{h}{4}C_{1112}\frac{\partial u}{\partial y}\frac{\partial^2 w}{\partial x^2} - \\
-\frac{h}{2}\frac{\partial^4 w}{\partial x^3 \partial y}(\frac{1}{2}C_{1112} + C_{1211}) - \frac{h}{2}C_{2211}\frac{\partial u}{\partial x}\frac{\partial^2 w}{\partial y^2} - \frac{h}{2}C_{2222}(\frac{\partial v}{\partial y}\frac{\partial^2 w}{\partial y^2} + \frac{1}{2}\frac{\partial^4 w}{\partial y^4}) - \frac{h}{4}C_{2212}(\frac{\partial u}{\partial y}\frac{\partial^2 w}{\partial y^2} + \frac{\partial v}{\partial x}\frac{\partial^2 w}{\partial y^2}) - \\
-\frac{h}{2}\frac{\partial^4 w}{\partial x \partial y^3}(\frac{1}{2}C_{2212} + C_{1222}) - hC_{1211}\frac{\partial u}{\partial x}\frac{\partial^2 w}{\partial x \partial y} - hC_{1222}\frac{\partial v}{\partial y}\frac{\partial^2 w}{\partial x \partial y} - \frac{h}{2}C_{1212}(\frac{\partial u}{\partial y}\frac{\partial^2 w}{\partial x \partial y} + \frac{\partial v}{\partial x}\frac{\partial^2 w}{\partial x \partial y}) + \\
+\frac{h}{2}\frac{\partial^2 w}{\partial x^2}\alpha_{11}(T - T_0) + \frac{h}{2}\frac{\partial^2 w}{\partial y^2}\alpha_{22}(T - T_0) + h\frac{\partial^2 w}{\partial x \partial y}\alpha_{12}(T - T_0) + \frac{h}{12}C_{1111}\frac{\partial^4 w}{\partial x^4} + \frac{h}{12}\frac{\partial^4 w}{\partial x^2 \partial y^2}(C_{1122} + C_{2212} + C_{1211}) + \\
+\frac{h}{12}\frac{\partial^4 w}{\partial x^3 \partial y}(C_{1112} + C_{2211}) + \frac{h}{12}\frac{\partial^4 w}{\partial x \partial y^3}(C_{2222} + C_{1212}) + \frac{h}{12}C_{1222}\frac{\partial^4 w}{\partial y^4} + N_z + R_z + q_z + T_{zz} + \theta_{Tzz} + \theta_{\mathrm{T}} = 0, \\
\lambda_{11}\frac{\partial^2 \theta_{\mathrm{T}}}{\partial x^2} + \lambda_{12}\frac{\partial^2 \theta_{\mathrm{T}}}{\partial x \partial y} + \lambda_{21}\frac{\partial^2 \theta_{\mathrm{T}}}{\partial y \partial x} + \lambda_{22}\frac{\partial^2 \theta_{\mathrm{T}}}{\partial y^2} - C_\varepsilon\frac{\partial^2 \theta_{\mathrm{T}}}{\partial t} - \theta_{\mathrm{T}_0}\beta_{11}(\frac{\partial^2 u}{\partial x \partial t} - z\frac{\partial^3 w}{\partial x^2 \partial t} + \frac{1}{2}\frac{\partial^3 w}{\partial x^2 \partial t}) - \\
-\theta_{\mathrm{T}_0}\beta_{22}(\frac{\partial^2 v}{\partial y \partial t} - z\frac{\partial^3 w}{\partial y^2 \partial t} + \frac{1}{2}\frac{\partial^3 w}{\partial y^2 \partial t}) - \theta_{\mathrm{T}_0}\beta_{12}(\frac{\partial^2 u}{\partial y \partial t} + \frac{\partial^2 v}{\partial x \partial t} - z\frac{\partial^3 w}{\partial x \partial y \partial t} + \frac{1}{2}\frac{\partial^3 w}{\partial x \partial y \partial t}) = 0.
\end{cases}$$

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Boshlang’ich shartlar:

$$\rho h\frac{\partial u}{\partial t}\delta u\Big|_t=0,\rho h\frac{\partial v}{\partial t}\delta v\Big|_t=0,\rho h\frac{\partial w}{\partial t}\delta w\Big|_t=0,\ \theta_T\Big|_{t=0}=T_0 \qquad (4)$$
$$\rho\frac{h^3}{12}\frac{\partial^2 w}{\partial t\partial x}\delta w\Big|_x\Big|_t=0,\ \rho\frac{h^3}{12}\frac{\partial^2 w}{\partial t\partial y}\delta w\Big|_y\Big|_t=0;$$

Chegaraviy shartlar:

$$\begin{aligned}
&h\left[C_{1111}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{1122}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{1112}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{11}(T-T_0)\right]\delta u\Big|_x=0,\\
&\frac{1}{2}h\left[C_{1211}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{1222}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{1212}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{12}(T-T_0)\right]\delta v\Big|_x=0,\\
&h\left[C_{2211}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{2222}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{2212}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{22}(T-T_0)\right]\delta v\Big|_y=0,\\
&\frac{1}{2}h\left[C_{1211}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{1222}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{1212}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{12}(T-T_0)\right]\delta u\Big|_y=0,\\
&\frac{h^3}{12}\left(C_{1111}\frac{\partial^2 w}{\partial x^2}+C_{1122}\frac{\partial^2 w}{\partial y^2}+C_{1112}\frac{\partial^2 w}{\partial x\partial y}\right)\delta\frac{\partial w}{\partial x}\Big|_x=0,\\
&\frac{1}{2}h\left[C_{1111}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{1122}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{1112}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{11}(T-T_0)\right]\frac{\partial w}{\partial x}\delta w\Big|_x=0,\\
&-\frac{h^3}{12}\left(C_{1211}\frac{\partial^3 w}{\partial x^2\partial y}+C_{1222}\frac{\partial^3 w}{\partial y^3}+C_{1212}\frac{\partial^3 w}{\partial x\partial y^2}\right)\delta w\Big|_x=0,\\
&\frac{1}{2}h\left[C_{1211}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{1222}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{1212}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{12}(T-T_0)\right]\frac{\partial w}{\partial y}\delta w\Big|_x=0,\\
&\frac{h^3}{12}\left(C_{2211}\frac{\partial^2 w}{\partial x^2}+C_{2222}\frac{\partial^2 w}{\partial y^2}+C_{2212}\frac{\partial^2 w}{\partial x\partial y}\right)\delta\frac{\partial w}{\partial y}\delta w\Big|_y=0 \qquad (5)\\
&\frac{1}{2}h\left[C_{2211}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{2222}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{2212}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{22}(T-T_0)\right]\frac{\partial w}{\partial y}\delta w\Big|_y=0,\\
&\frac{h^3}{12}\left(C_{1211}\frac{\partial^2 w}{\partial x^2}+C_{1222}\frac{\partial^2 w}{\partial y^2}+C_{1212}\frac{\partial^2 w}{\partial x\partial y}\right)\delta\frac{\partial w}{\partial x}\Big|_y=0,\\
&\frac{1}{2}h\left[C_{1211}\left(\frac{\partial u}{\partial x}+\frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right)+C_{1222}\left(\frac{\partial v}{\partial y}+\frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right)+C_{1212}\left(\frac{1}{2}\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial v}{\partial x}+\frac{1}{2}\frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)-\alpha_{12}(T-T_0)\right]\frac{\partial w}{\partial x}\delta w\Big|_y=0,\\
&h\left[\left(\Phi_{Px}+\Phi_{Txx}+\Phi_{\theta_{Txx}}\right)\delta u+\left(\Phi_{Py}+\Phi_{Txy}+\Phi_{\theta_{Txy}}\right)\delta v+\left(\Phi_{Pz}+\Phi_{Txz}+\Phi_{\theta_{Txz}}\right)\delta w\right]\Big|_x=0,\\
&h\left[\left(\Phi_{Fx}+\Phi_{Tyx}+\Phi_{\theta_{Tyx}}\right)\delta u+\left(\Phi_{Fy}+\Phi_{Tyy}+\Phi_{\theta_{Tyy}}\right)\delta v+\left(\Phi_{Fz}+\Phi_{Tyz}+\Phi_{\theta_{Tyz}}\right)\delta w\right]\Big|_y=0.\\
&\frac{\partial\theta_T}{\partial n}+\alpha_{\theta_T}(\theta_T-T_0)=0 \quad \textit{chegarada};
\end{aligned}$$

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Endi, elektro‘tkazuvchan murakkab shaklga ega anizotrop plastinaga termo-elektro-magnit maydon ta'siri natijasida kelib chiqadigan hajmiy kuchlar, sirt va kontur kuchlarni mos ravishda (4) tenglamalar tizimidagi o‘rnilariga keltirib qo‘yiladi. Natijada quyidagicha tenglamalar tizimi ko‘rinishida yozishimiz mumkin bo‘ladi.

Ushbu tenglamalar tadqiq qilinayotgan murakkab shaklga ega bo’lgan plastina chegaralarini mahkamlanish usullariga qarab tegishli chegaraviy shartlarga muvofiq yechiladi.

Endi, madel uchun eng keng tarqalgan chegara shartlarini keltiramiz

1. Mahkamlangan, tebranish vaqtida plastina chegaralari joyidan qo’zg’almaydi (qattiq mahkamlanish):

$$w\Big|_{\Gamma}=0, \quad \frac{\partial w}{\partial n}\Big|_{\Gamma}=0, \tag{6}$$

$$u\big|_{\Gamma}=0, \quad v\big|_{\Gamma}=0, \tag{7}$$

Bu yerda $n-\ \Gamma$ plastina konturidagi tashqi normali, $u,v-$ plastinaning tegishli x va y o’qlari bo’yicha ko’chishi.[7]

2. Sirpanuvchi mahkamlanish:

$$w\Big|_{\Gamma}=0, \frac{\partial w}{\partial n}\Big|_{\Gamma}=0, \tag{8}$$

$$\sigma_n\big|_{\Gamma}=0, \quad \tau_n\big|_{\Gamma}=0. \tag{9}$$

bunda:

$$\sigma_n=\sigma_{11}l_1^2+\sigma_{22}l_2^2+2\sigma_{12}l_1 l_2, \tag{10}$$

$$\tau_n=\sigma_{12}\left(l_1^2-l_2^2\right)+\left(\sigma_{22}-\sigma_{11}\right)l_1 l_2, \tag{11}$$

Bu yerda σ_n - normal kuchlanish; τ_n - tangensial kuchlanish; $l_1=\cos\alpha,\ l_2=\sin\alpha$;

Hisoblash algoritmi asosida murakkab murakkab shaklga ega nochiziqli anizotrop egiluvchan plastinalar masalalarini yechishni avtomatlashtirish uchun dasturiy majmuasini yaratish; algoritmik - dasturiy vositalar asosida yangi masalalari uchun hisoblash tajribalarini o‘tkazish.[9]

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Murakkab simmetrik shakldagi yupqa anizotrop plastinalarning termo-elektro-magnit-elastiklik masalasini yechishni hisoblash tajribalar tahlili

Anizotrop plastinaning *Ox* koordinata o‘qi bo‘ylab egilishiga elektromagnit maydon kuchlarini va harorat ta’sirini baholash uchun olingan sonli natijalari ushbu (($x\epsilon[-1;1]$, $y=0$, $t=1$) $W(x,y,t)$) qiymatlarni hisobga olgan holda.

1-jadval

Yupqa anizotrop plastinaning turli radiuslarda X o‘qi bo‘yicha olingan sonli natijalari

x	*Электромагнит майдон кучлар таъсири қаралмаган* **W(x,y,t)**	*Электромагнит майдон кучлар таъсир қилганда* **W(x,y,t)**	*Термо-электро-магнит майдон кучлар таъсир қилганда* **W(x,y,t)**	**x**	*Электромагнит майдон кучлар таъсири қаралмаган* **W(x,y,t)**	*Электромагнит майдон кучлар таъсир қилганда* **W(x,y,t)**	*Термо-электро-магнит майдон кучлар таъсир қилганда* **W(x,y,t)**
-2	0,002577	0,002677	0,0029447	2	0,002577	0,002677	0,0029447
-1,9	0,001756	0,001856	0,0020416	1,9	0,001756	0,001856	0,0020416
-1,8	0,00098	0,00108	0,001188	1,8	0,00098	0,00108	0,001188
-1,7	0,000402	0,000502	0,0005522	1,7	0,000402	0,000502	0,0005522
-1,6	0,000091	0,000191	0,0002101	1,6	0,000091	0,000191	0,0002101
-1,5	0	0	0	1,5	0	0	0
-0,5	0	0	0	0,5	0	0	0
-0,4	0,00041	0,000502	0,0005522	0,4	0,00041	0,000502	0,0005522
-0,3	0,001367	0,001675	0,0018425	0,3	0,001367	0,001675	0,0018425
-0,2	0,002441	0,002991	0,0032901	0,2	0,002441	0,002991	0,0032901
-0,1	0,003254	0,003987	0,0043857	0,1	0,003254	0,003987	0,0043857
0	0,003555	0,004354	0,0047894	0	0,003555	0,004354	0,0047894

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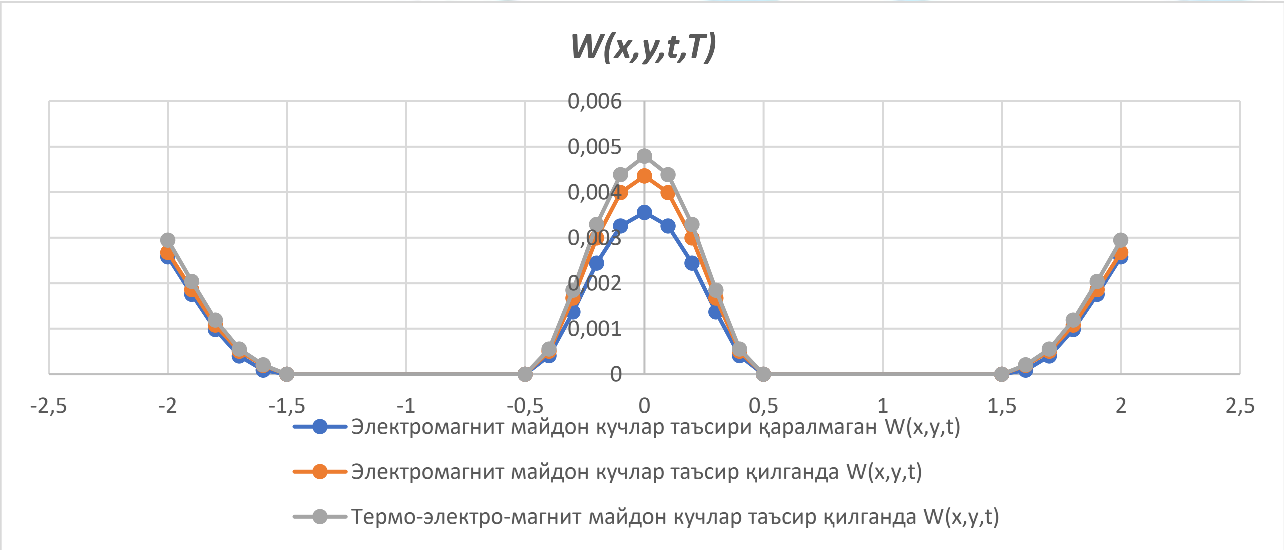
Hisoblash tajribasi natijasida olingan natijalar (1-jadval) va (1-rasm) shuni ko‘rsatadiki mexanik va elektromagnit maydon kuchlar ta’siri qaralganda 11%, harorat ta’sirlarini qo‘shib hisoblaganda 16% yupqa plastinaning *OX* koordinata o‘qi bo‘ylab ***W(x,y,t,T)*** ning ko‘chishi ekanligini ko‘rsatadi.



1-rasm. Yupqa plastinaning u - bo‘yicha egilishida mexanik va magnit maydon kuchlarining, haroratini o‘zaro ta’sirini taqqoslash grafigi.

Anizotrop plastinaning *OZ* koordinata o‘qi bo‘ylab egilishiga elektromagnit maydon kuchlarini va harorat ta’sirini baholash uchun olingan sonli natijalari ushbu (($x\epsilon[-1;1], y=0, t=1$) $W(x,y,t,T)$) qiymatlarni hisobga olgan holda.

2-jadval

Anizotrop plastinaning OZ koordinata o‘qi bo‘ylab egilishining sonli natijalari

x	*Mexanik kuchlar ta’siri qaralganda* ***W(x,y,t) t=0.1***	*Mexanik kuchlar va Elektromagnit maydon kuchlar ta’siri qaralganda* ***W(x,y,t) t=0.1***	*Mexanik kuchlar va Elektromagnit maydon kuchlari, harorat ta’siri qaralganda* ***W(x,y,t) t=0.1***
-1	0	0	0

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-0,9	0,000025	0,000029	0,000036
-0,8	0,000091	0,000107	0,000132
-0,7	0,000184	0,000215	0,000265
-0,6	0,000289	0,00034	0,000418
-0,5	0,000398	0,000466	0,000574
-0,4	0,000499	0,000585	0,000721
-0,3	0,000586	0,000687	0,000846
-0,2	0,000652	0,000765	0,000942
-0,1	0,000693	0,000813	0,001001
0	0,000707	0,00083	0,001022
0,1	0,000693	0,000813	0,001001
0,2	0,000652	0,000765	0,000942
0,3	0,000586	0,000687	0,000846
0,4	0,000499	0,000585	0,000721
0,5	0,000398	0,000466	0,000574
0,6	0,000289	0,00034	0,000418
0,7	0,000184	0,000215	0,000265
0,8	0,000091	0,000107	0,000132
0,9	0,000025	0,000029	0,000036
1	0	0	0

Hisoblash tajribasi natijasida olingan natijalar (2-jadval) va (2-rasm) shuni ko‘rsatadiki mexanik va elektromagnit maydon kuchlar ta’siri qaralganda 13%, harorat ta’sirlarini qo‘shib hisoblaganda 17% yupqa plastinaning *OZ* koordinata o‘qi bo‘ylab ***W(x,y,t,T)*** ning ko‘chishi ekanligini ko‘rsatadi.

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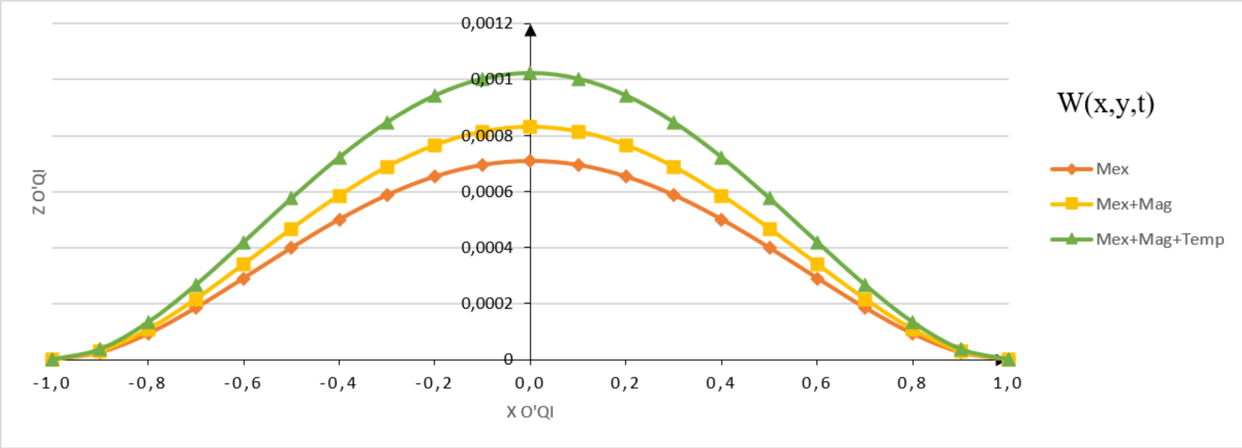

2-rasm. Yupqa plastinaning w - bo‘yicha egilishida mexanik va magnit maydon kuchlarining, haroratini o‘zaro ta’sirini taqqoslash grafigi.

Xulosa

Gamilton-Ostrogradskiy variasion tamoyili asosida Kirxgof-Lyav gipotezasi, Koshi munosabatlari, Guk qonuni,Fure issiqlik o’tkazuvchanlik qonuni hamda Maksvell elektromagnit tenzor ko‘rinishlaridan foydalanib, potensial energiya, kinetik energiya va tashqi kuchlar bajargan ishning variasion ko‘rinishlari aniqlanildi. Natijada ko‘chishga nibatan boshlang‘ich va chegaraviy shartlarga ega, xususiy hosilali nochiziqli differensial tenglamalar tizimi ko‘rinishidagi matematik modeli olindi.

Ishlab chiqilgan matematik modeldan termo-elektro-magnit maydonda joylashgan yupqa murakkab shaklga ega anizotrop plastinalarning termo-elektro-magnitelastiklik masalalarini tadqiq qilishda foydalanish mumkin.

Foydalanilgan adabiyotlar ro’yxati

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