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MAGNIT MAYDONIDA TOK O'TKAZUVCHI MIKROELEMENTNING MAGNITOELASTIK TEBRANISHINI MODELLASHTIRISH

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Annotatsiya. Magnitoelastik materiallar kelajakda yangi qurilmalar va tizimlarning rivojlanishiga olib kelishi mumkin bo'lgan aqlli materiallar va nanotexnologiya kabi yangi texnologiyalardan foydalanish uchun olib borilayotgan izlanishlar muhim ahamiyat kasb etmoqda. O'zgaruvchan magnit maydon o'tkazuvchan materialda qo'shimcha mexanik kuchlanish va deformatsiyaga olib kelishi mumkin bo'lgan induksiyali oqimlarning paydo bo'lishiga olib keladi. Magnit maydon ta'sirida magnitoelastik materialning o'lchami va shaklining o'zgarishi mumkin. Magnitostriksiyaning teskari ta'sirida materialdagi mexanik kuchlanish uning magnit xususiyatlarining o'zgarishiga olib keladi. Mexanik tebranishlar va elektromagnit maydonlar o'rtasidagi o'zaro ta'sir rezonans hodisalariga olib kelishi mumkin. Ishda magnit-elektro-termo-elastik bog'lanishlarni hisobga olgan holda qobiq shaklidagi mikroelementning magnitoelastik tebranishi matematik modellashtirilgan. Sonli natijalar taxlil qilingan.

Kalit so'zlar: deformatsiya, qobiq, kuchlanish, elektromagnit maydon, magnito-elastiklik.

I. KIRISH

Nanotexnologiyadan foydalanish yangi va takomillashtirilgan xususiyatlarga ega magnitoelastik materiallarni ishlab chiqishda asosiy rol o'ynaydi. Jumladan, magnit elastik materiallarning nanozarralari yuqori sezgir sensorlar va aktuatorlarni yaratish uchun ishlatilishi mumkin. Ularning kattaligi tufayli ular magnit maydonlarni mikro va nano o'lchovlarda aniqroq boshqarishni ta'minlaydi.

Magnit elastik materiallarda nanostrukturali tuzilmalarni yaratish orqali ularning magnit va mexanik xususiyatlarini yaxshilash mumkin. Bu yuqori magnitostriksiyaga ega yoki turli haroratlarda yaxshiroq ishlashga ega bo'lgan materiallarni yaratishga olib kelishi mumkin.

Magnit elastiklik muammolarini matematik modellashtirish sohasidagi tadqiqotlar materiallardagi magnit va mexanik maydonlarning o'zaro ta'siri mexanizmlarini tushunishni yaxshilashga yordam beradi.

So'nggi yillarda ilmiy adabiyotlarda statsionar bo'lmagan mexanik, issiqlik va elektromagnit yuklar ta'sirida tashqi o'zgaruvchan magnit maydonga joylashtirilgan elektr o'tkazuvchan jismlarning deformatsiyalanish jarayonini o'rganishga katta e'tibor berilmoqda. Mexanik tebranishlar va elektromagnit maydonlar o'rtasidagi o'zaro ta'sir rezonans hodisalariga olib kelishi mumkin, bu juda sezgir sensorlar va rezonatorlarni ishlab chiqish uchun muhimdir.

Bu sohadagi tadqiqotlarga qiziqish statsionar bo'lmagan mexanik, issiqlik va elektromagnit

jarayonlar o'rtasidagi bog'liqlik murakkab o'zaro ta'sirini miqdoriy o'rganish va baholash va ularni zamonaviy texnologiyaning turli sohalarida yangi texnologiyalarni ishlab chiqishda, nanotexnologiya va mikroelektronika sohasida, shuningdek, zamonaviy o'lchash tizimlari va boshqalarda amaliy qo'llash muhimligi bilan bog'liq [1-10].

II. MASALANING QO'YILISHI

2.1 Elastik jism magnitelastik modeli.

Mexanik yuklar ta'sirida va o'zgaruvchan magnit maydonda bo'lgan izotropik elastik jism uchun magnit elastiklik masalalarini yechishda quyidagi Maksvell tenglamalaridan foydalanamiz [1,2]:

$$\text{rot } \vec{E} + \frac{\partial \vec{B}}{\partial t} = 0, \quad \text{div } \vec{D} = 0, \quad (1)$$

$$\text{rot } \vec{H} - \frac{\partial \vec{D}}{\partial t} = \vec{J}, \quad \text{div } \vec{B} = 0.$$

Harorat hisobga olinganda harakatlanuvchi jism uchun Om qonuni ifodasini quyidagicha yozamiz:

$$\vec{J} = \sigma (\vec{E} + \vec{V} \times \vec{B} - \eta \text{grad } T), \quad (2)$$

(2) ning har ikkala tomonini \vec{J} ga ko'paytirib va undan $\vec{J}\vec{E}$ ni topamiz:

$$\vec{J}\vec{E} = \frac{1}{\sigma} \vec{J}\vec{J} + (\vec{J} \times \vec{B})\vec{V} + \eta \vec{J} \text{grad } T, \quad (3)$$

bu yerda $\frac{1}{\sigma} \vec{J}\vec{J}$ - had Joule issiqligini ifodalaydi.

Yuqoridagilarni hisobga olgan holda Lorens kuchi va elektr maydonida elastik elektr o'tkazuvchan muhitning harakatning quyidagi

tenglamalari qo'llaniladi harakat tenglamasini quyidagi ko'rinishda hosil qilamiz:

$$\sigma_{ij,j} + \rho F_i + (\vec{J} \times \vec{B})_i = \rho \frac{\partial^2 U_i}{\partial t^2}, \quad (4)$$

$(\vec{J} \times \vec{B})_i$ - ifoda bu Lorens kuchi, \vec{E} va \vec{H} elektr va magnit maydon kuchlanganlik vektorlari, \vec{D} , \vec{B} - elektr va magnit induksiya vektorlari, \vec{J} - tok o'tkazuvchanlik zichligi, σ_{ij} - kuchlanishlar tenzori, U_i - elastik siljish vektori, ρ - material zichligi.

Agarda issiqlik effektlari hisobga olinsa, u holda chiziqli deformatsiya tenzori komponentalarini quyidagi yig'indi ko'rinishida ifodalashimiz mumkin:

$$\varepsilon_{ij} = \varepsilon_{ij}^{(S)} + \varepsilon_{ij}^{(T)}, \quad (5)$$

bu yerda $\varepsilon_{ij}^{(S)}$ - kuchlanish maydoni ta'sirida hosil bo'lgan deformatsiya; $\varepsilon_{ij}^{(T)}$ - esa temperatura maydoni ta'sirida hosil bo'lgan deformatsiya.

Temperaturaning qandaydir T_0 - boshlang'ich qiymatidan, biror T - qiymatigacha o'zgarishi natijasida hosil bo'lgan izotrop jismning elementar hajmi deformatsiyasi komponentalari, tashqi kuchlar mavjud bo'lmaganda quyidagi formula yordamida aniqlanadi.

$$\varepsilon_{ij}^{(T)} = \alpha(T - T_0)\delta_{ij}, \quad (6)$$

bu yerda α - chiziqli issiqlik kengayish koeffitsiyenti,

$$\delta_{ij} = \begin{cases} 1 & \text{teng } i = j \text{ bo'lsa,} \\ 0 & \text{teng } i \neq j \text{ bo'lsa,} \end{cases}$$

Kroneker simvoli.

(6) - tenglamani va

$$\varepsilon_{ij} = -\frac{\lambda}{2\mu(3\lambda + 2\mu)}\delta_{ij}\sigma_{kk} + \frac{1}{2\mu}\sigma_{ij}$$

tenglamani (5) - ga qo'yib, quyidagi ifodani topamiz:

$$\varepsilon_{ij} = \frac{1}{2\mu} \left(\sigma_{ij} - \frac{\lambda}{3\lambda + 2\mu} \delta_{ij} \sigma_{kk} \right) + \alpha(T - T_0)\delta_{ij}. \quad (7)$$

(7) - munosabatga Dyugamel - Neyman munosabati deyiladi. (7) - munosabatdan σ_{ij} - ni topishimiz va termoelastiklikni aniqlovchi tenglamani quyidagi ko'rinishda yozishimiz mumkin:

$$\sigma_{ij} = \lambda\delta_{ij}\varepsilon_{kk} + 2\mu\varepsilon_{ij} - (3\lambda + 2\mu)\alpha\delta_{ij}(T - T_0), \quad (8)$$

(7) - dan (8) - ni quyidagicha hosil qilish mumkin, ya'ni $i = j$ - bo'lganda

$$\sigma_{ii} = (3\lambda + 2\mu)(\varepsilon_{ii} - 3\alpha(T - T_0))$$

bo'ladi. (7) - ni σ_{ij} - ga nisbatan yechib quyidagini hosil qilamiz:

$$\begin{aligned} \sigma_{ij} &= 2\mu\varepsilon_{ij} + \lambda\delta_{ij}\sigma_{kk} / (3\lambda + 2\mu) - 2\mu\alpha\delta_{ij}(T - T_0) = \\ &= 2\mu\varepsilon_{ij} + \lambda\delta_{ij}(\varepsilon_{kk} - 3\alpha(T - T_0)) - 2\mu\alpha\delta_{ij}(T - T_0) = \\ &= 2\mu\varepsilon_{ij} + \lambda\delta_{ij}\varepsilon_{kk} - (3\lambda + 2\mu)\alpha\delta_{ij}(T - T_0). \end{aligned}$$

Agarda issiqlik effektlari hisobga olinsa, u holda (1), (4) tenglamalarga chiziqli elastik jism uchun Guk qonunini

a) Termoelastiklikni aniqlovchi tenglama:

$$\begin{aligned} \sigma_{ij} &= \lambda\delta_{ij}\varepsilon_{kk} + 2\mu\varepsilon_{ij} - \\ &- (3\lambda + 2\mu)\alpha\delta_{ij}(T - T_0); \end{aligned} \quad (9)$$

b) Deformasiyaning ko'chish orqali ifodasi:

$$\varepsilon_{ij} = \frac{1}{2}(U_{i,j} + U_{j,i}). \quad (10)$$

Qutblanish va magnitlanish xossalari ega bo'lmagan harakatlanuvchi izotrop muhit uchun quyidagi holat tenglamalarini qo'shish mumkin:

$$\begin{aligned} \vec{D} &= \varepsilon\vec{E} + \alpha(\vec{V} \times \vec{H}), \\ \vec{B} &= \mu'\vec{H} - \alpha(\vec{V} \times \vec{E}), \end{aligned} \quad (11)$$

bu yerda μ, λ - elastik o'zgarishlar, ε, μ' - elektr va magnit o'tkazuvchanliklar, $\vec{V} = \partial U / \partial t$ - tezlik vektori, $\alpha = \varepsilon\mu' - \varepsilon_0\mu_0$, bu yerda ε_0, μ_0 - vakuumning elektr va magnit o'tkazuvchanliklari.

(1) - (4) tenglamalar bir jinsli, izotrop muhit uchun chiziqli bo'lmagan magnit elastiklik tenglamalarining yopiq tizimini tashkil etadi.

Bu tenglamalar berilgan boshlang'ich shartlar va ikki muhitning ajralish yuzasida chegaraviy shartlarni hisobga olgan holda yechilishi zarur.

Magnitoelastiklikda masalaning mexanik qismini xarakterlovchi funksiyalar uchun chegaraviy shartlar, agarda ular ko'chishlarda formulirovka qilingan bo'lsa odatdagi elastiklik nazariyasidagi kabi bo'ladi [1,2]:

$$\vec{u}|_S = \vec{u}_*, \quad (12)$$

bu yerda \vec{u}_* jism sirtidagi nuqtalarning berilgan ko'chish vektoridir.

Agarda, jism sirtida, \vec{F} - sirt kuchlari berilgan bo'lsa, u holda chegaraviy shartlar quyidagicha yozilishi mumkin:

$$\vec{n} \cdot (\hat{\sigma} + \hat{\tau})|_S = \vec{F} + \vec{n} \cdot \hat{\tau}|_S. \quad (13)$$

Mexanik kuchlanishlar uchun chegaraviy shartlarni shakllantirishda elektromagnit maydon ta'sirida muhitda Maksvell kuchlanishlar elektrodinamik tenzorlari bilan aniqlanuvchi cho'zuvchi va qisuvchi harakatlar paydo bo'lishini hisobga olish zarur.

$$\begin{aligned} \tau_{ij} &= E_i D_j + H_i B_j - \\ & - \frac{1}{2} \delta_{ij} (E_k D_k + H_k B_k). \end{aligned} \quad (14)$$

Jismdagi to'la kuchlanishlar elastik va Maksvell kuchlanishlar yig'indisiga teng bo'lganligi sababli S da chegaraviy shartlarni quyidagicha yozish mumkin:

$$[\sigma_{ij} + \tau_{ij}] n_j = 0. \quad (15)$$

2.2 Qobiq shaklidagi mikroelement magnitoelastik modeli. Issiqlik maydonini hisobga olgan holda ferromagnit bo'lmagan tok

o'tkazuvchi izotrop aylanma egiluvchan qobiq magnitoelastikligi ikki o'lchamli modelini qurishda Kirxgof-Lyav va quyidagi elektromagnit gipotezalaridan foydalanib [1,2], qobiq magnitoelastikligi umumiy tenglamalaridan [2-6] va Lorens kuchi tashkil etuvchilaridan foydalanib, ba'zi bir almashtirishlardan keyin magnit maydonida issiqlik maydonini hisobga olgan holda ferromagnit bo'lmagan tok o'tkazuvchi izotrop aylanma egiluvchan qobiq magnitoelastik ikki o'lchamli modelini ifodalaydigan tenglamalarni hosil qilamiz, magnitoelastiklik tenglamalari:

$$\begin{aligned} \frac{\partial}{\partial s} (r N_s) - \cos \phi N_\theta + \frac{\partial}{\partial \theta} + \frac{1}{R_s} \frac{\partial H}{\partial \theta} + \frac{r}{R_s} Q_s + r (P_s + \rho F_s^\wedge) &= r \rho h \frac{\partial^2 u}{\partial t^2}; \\ \frac{\partial N_\theta}{\partial \theta} + \frac{1}{r} \frac{\partial}{\partial s} (r^2 S) + \frac{\partial}{\partial s} (\sin \phi H) + \frac{\cos \phi}{R_s} H + \sin \phi Q_\theta + r (P_\theta + \rho F_\theta^\wedge) &= r \rho h \frac{\partial^2 v}{\partial t^2}; \\ \frac{\partial}{\partial s} (r Q_s) + \frac{\partial Q_\theta}{\partial \theta} - \frac{r}{R_s} N_s - \sin \phi N_\theta + r (P_\gamma + \rho F_\gamma^\wedge) &= r \rho h \frac{\partial^2 w}{\partial t^2}; \end{aligned} \quad (16)$$

$$\frac{\partial H}{\partial \theta} + \frac{\partial}{\partial s} (r M_s) - \cos \phi M_\theta - r Q_s - r (N_s - \frac{\sin \phi}{r} M_\theta) v_s - r S v_\theta = 0;$$

$$\frac{1}{r} \frac{\partial}{\partial s} (r^2 H) + \frac{\partial M_\theta}{\partial \theta} - r Q_\theta - r (N_\theta - \frac{1}{R_s} M_s) v_\theta - r S v_s = 0;$$

$$-\frac{\partial B_\gamma}{\partial t} = \frac{1}{r} \left(\frac{\partial (r E_\theta)}{\partial s} - \frac{1}{r} \frac{\partial E_s}{\partial \theta} \right);$$

$$\sigma_1 [E_s - \frac{\partial v}{\partial t} B_\gamma - 0,5 \frac{\partial w}{\partial t} (B_\theta^+ + B_\theta^-)] = \frac{1}{r} \frac{\partial H_\gamma}{\partial \theta} + \frac{H_\theta^+ - H_\theta^-}{h}; \quad (17)$$

$$\sigma_2 [E_\theta - \frac{\partial u}{\partial t} B_\gamma + 0,5 \frac{\partial w}{\partial t} (B_\theta^+ + B_\theta^-)] = -\frac{\partial H_\gamma}{\partial s} + \frac{H_\theta^+ - H_\theta^-}{h};$$

Deformasiyaning ko'chish orqali ifodasi:

$$\begin{aligned} \varepsilon_{ss} &= \frac{\partial u}{\partial s} + \frac{w}{R_s} + \frac{1}{2} v_s^2; \quad \varepsilon_{\theta\theta} = \frac{1}{r} \frac{\partial v}{\partial \theta} + \frac{\cos \phi}{r} u + \frac{\sin \phi}{r} w + \frac{1}{2} v_\theta^2; \\ \varepsilon_{s\theta} &= \frac{1}{r} \frac{\partial u}{\partial \theta} + r \frac{\partial}{\partial s} \left(\frac{v}{r} \right) + v_s v_\theta; \quad \chi_{ss} = \frac{\partial v_s}{\partial s}, \quad \chi_{\theta\theta} = \frac{1}{r} \frac{\partial v_\theta}{\partial \theta} + \frac{\cos \phi}{r} v_s; \\ \chi_{s\theta} &= \frac{\partial v_\theta}{\partial s} + \frac{1}{r} \frac{\partial v_s}{\partial \theta} - \frac{\cos \phi}{r} v_\theta + \frac{1}{R_s} \left(\frac{1}{r} \frac{\partial u}{\partial \theta} - \frac{\cos \phi}{r} v \right) + \frac{\sin \phi}{r} \frac{\partial v}{\partial s}, \end{aligned} \quad (18)$$

bu yerda $v_s = -\frac{\partial w}{\partial s} + \frac{u}{R_s};$

$v_\theta = -\frac{1}{r} \frac{\partial w}{\partial \theta} + \frac{\sin \phi}{r} v$ - normalning burilish

burchaklari, elastiklik munosabatlari:

$$N_s = \frac{e_s h}{1 - \nu_s \nu_\theta} [\varepsilon_{ss} + \nu_\theta \varepsilon_{\theta\theta} - (1 + \nu_s) \varepsilon_T];$$

$$N_\theta = \frac{e_\theta h}{1 - e_s e_\theta} [\varepsilon_{\theta\theta} + \nu_s \varepsilon_{ss} - (1 + \nu_\theta) \varepsilon_T];$$

$$S = \frac{e_s h}{2(1 + \nu_\theta)} \varepsilon_{s\theta}; \quad H = \frac{e_\theta h^3}{12(1 + \nu_s)} \chi_{s\theta};$$

$$M_s = \frac{e_s h^3}{12(1 - \nu_s \nu_\theta)} [\chi_{ss} + \nu_\theta \chi_{\theta\theta} - (1 + \nu_s) \chi_T]; \quad (19)$$

$$M_\theta = \frac{e_\theta h^3}{12(1 - \nu_s \nu_\theta)} [\chi_{\theta\theta} + \nu_s \chi_{ss} - (1 + \nu_\theta) \chi_T];$$

Shuningdek,

$$\varepsilon_T = \frac{1}{h} \int_{-h/2}^{h/2} \alpha T(s, \theta, \gamma, t) d\gamma;$$

$$\chi_T = \frac{12}{h^3} \int_{-h/2}^{h/2} \alpha T(s, \theta, \gamma, t),$$

bu yerda: ε_T, χ_T - temperatura maydoni integral xarakteristikalari, R_s - egrilik bosh radiusi; α - chiziqli temperatura kengayishi ko'effitsiyenti, $T(s, \theta, \gamma, t)$ - qobiq joul issiqligi.

Lorens kuchi tashkil etuvchilari quyidagi ko'rinishga ega:

$$\begin{aligned} \rho F_s^{\wedge} &= hJ_{\theta st} B_{\gamma} + \sigma_1 h E_{\theta} B_{\gamma} + \sigma_1 h \left\{ 0,5 \frac{\partial w}{\partial t} (B_s^+ + B_s^-) B_{\gamma} - \right. \\ &\quad \left. - \frac{\partial u}{\partial t} B_{\gamma}^2 - \frac{\partial u}{\partial t} \left[0,25 (B_{\theta}^+ + B_{\theta}^-)^2 + \frac{1}{12} (B_{\theta}^+ + B_{\theta}^-)^2 \right] + \right. \\ &\quad \left. + \frac{\partial v}{\partial t} \left[0,25 (B_s^+ + B_s^-) (B_{\theta}^+ + B_{\theta}^-) + \frac{1}{12} (B_s^+ - B_s^-) (B_{\theta}^+ - B_{\theta}^-) \right] \right\}; \\ \rho F_{\theta}^{\wedge} &= -hJ_{sst} B_{\gamma} - \frac{h}{r\mu} \frac{\partial B_{\gamma}}{\partial \theta} B_{\gamma} + \\ &\quad + \sigma_2 h \left\{ \frac{\partial u}{\partial t} \left[0,25 (B_s^+ + B_s^-) (B_{\theta}^+ + B_{\theta}^-) + \frac{1}{12} (B_s^+ - B_s^-) (B_{\theta}^+ - B_{\theta}^-) \right] - \right. \\ &\quad \left. - \frac{\partial v}{\partial t} \left[0,25 (B_{\theta}^+ + B_{\theta}^-)^2 + \frac{1}{12} (B_{\theta}^+ - B_{\theta}^-)^2 \right] - \frac{B_{\theta}^+ - B_{\theta}^-}{\mu} B_{\gamma}; \right. \\ \rho F_{\gamma}^{\wedge} &= 0,5h \left[J_{sst} (B_{\theta}^+ + B_{\theta}^-) - J_{\theta st} (B_s^+ + B_s^-) \right] + \frac{h}{2r\mu} \frac{\partial B_{\gamma}}{\partial \theta} (B_{\theta}^+ + B_{\theta}^-) - \\ &\quad - 0,5\sigma_2 h E_{\theta} (B_s^+ + B_s^-) + \sigma_2 h \left\{ 0,5 \frac{\partial u}{\partial t} (B_s^+ + B_s^-) B_{\gamma} - \frac{\partial w}{\partial t} \left[0,25 (B_s^+ + B_s^-)^2 + \right. \right. \\ &\quad \left. \left. + \frac{1}{12} (B_{\theta}^+ - B_{\theta}^-)^2 + \frac{1}{12} (B_s^+ - B_s^-)^2 \right] \right\} + \frac{(B_{\theta}^+)^2 - (B_{\theta}^-)^2}{\mu}. \end{aligned} \quad (20)$$

Hosil qilingan tenglamalarga boshlang'ich va chegaraviy shartlarni qo'shish zarur bo'ladi. Bu yerda: N_s, N_{θ} - normal va tangensial kuchlar, S - siljitivchi kuch, M_s, M_{θ} - eguvchi momentlar; H - burovchi moment, Q_s, Q_{θ} - ko'ndalang kuchlar, u, v, w - ko'chish vektori komponentalari, $\varepsilon_{ss}, \varepsilon_{\theta\theta}, \varepsilon_{s\theta}, \chi_{ss}, \chi_{\theta\theta}, \chi_{s\theta}$ - deformatsiya tenzori komponentalari, $P_s, P_{\theta}, P_{\gamma}$ - mexanik kuch tashkil etuvchilari, E - Yung moduli, ν - Puasson ko'effitsiyenti, μ - magnit singdiruvchanlik.

Olingan (16) - (20) tenglamalar sistemasi, ferromagnit bshlmagan tokli o'tkazgich qobiq sirtida elektr-magnit maydoni kuchlanganligi taqsimlanishi ma'lum deb olingan shartda, ferromagnit bo'lmagan tok o'tkazuvchi aylanma egiluvchan qobiq elektr-magnit-elastik bog'langan nohiziqli differensial tenglamalari to'liq yopiq sistemasini tashkil etishini ta'kidlab o'tamiz.

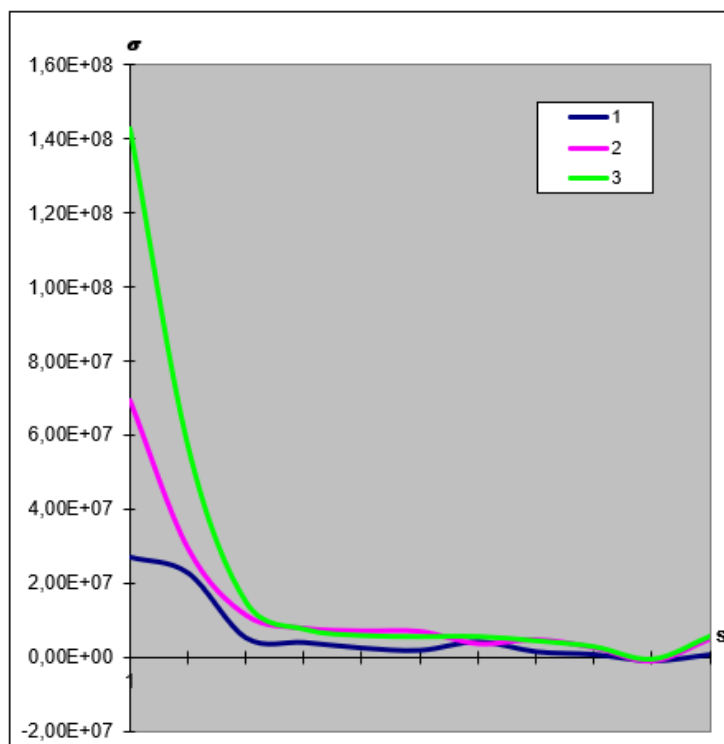
III. NATIJALAR TAHLILI

Statsionar bo'lmagan mexanik, issiqlik va elektromagnit jarayonlar o'rtasidagi bog'liqli

murakkab o'zaro ta'sirini miqdoriy o'rganish va baholash, hamda qobiqlarning magneto-elastikligining tegishli nohiziqli muammolarini sonli yechish uchun ishlab chiqilgan metodologiyasi Nyumarkning sxemasini izchil qo'llash, chiziqli va diskret ortogonalizatsiya usuliga asoslangan [2-12].

Magnit maydonda o'zgaruvchan qalinlikdagi o'tkazuvchan qobiqning elektrodinamik kuchlar ta'siridagi harakatini o'rganamiz.

1-rasmda $t = 5 \cdot 10^{-3} \text{ sek}$ vaqt momentida qobiq meridiani bo'ylab maksimal kuchlanish qiymatlarining taqsimlanishi ko'rsatilgan. Rasmdagi grafiklar: 1 - berilliydan yasalgan tok o'tkazuvchi ortotropik konus, 2 - alyuminiydan yasalgan tok o'tkazuvchi izotrop konus, 3 - magnit maydon va tashqi oqim yo'qligida izotrop alyuminiydan yasalgan konus. Berilgan egri chiziqlardan ko'rinib turibdiki, kuchlanish o'zgarishlarining tarqalish sxemasi miqdoriy va sifat jihatidan farq qiladi. Taqdim etilgan natijalar tashqi elektr toki va magnit induksiyaning qobiqqa ta'sirini, shuningdek ularning birgalikdagi ta'sirini baholashga imkon beradi.



1-rasm. Kuchlanish taqsimoti

IV. XULOSA

Jismning deformatsiyasi paytida uning sirtining shakli o'zgaradi, bu magnit oqimi yo'nalishining o'zgarishiga olib keladi, jismning elektromagnit maydoni o'zgaradi, uyirmaviy oqimlarni paydo bo'ladi, ular tashqi magnit maydon bilan o'zaro ta'sirlashadi, natijada elektromagnit kuchlarning paydo bo'lishiga olib keladi. Bu kuchlar tananing stress holatini va undagi elektromagnit maydonni o'zgartiradi. Ishda magnit va mexanik kuchlar ta'sirida bo'lgan qobiq magnitoelastik tebranishi modellashtirilgan. Masalani sonli yechish algoritmlari ishlab chiqilgan. Qobiq materialining magnit holati va mexanik kuchlanish o'rtasidagi bog'liqliklar natijasida vujudga keladigan magnitoelastiklik effektlari tahlil qilgan. Tok o'tkazuvchi berilliydan yasalgan ototrop konus va toktashuvchi alyuminiydan yasalgan izotrop konus hamda magnit maydoni va tashqi begona tok mavjud bo'lmaganda alyuminiydan yasalgan izotrop konuslar uchun olingan sonly yechimlar natijalari taqqoslangan.

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MODELING OF MAGNETOELASTIC OSCILLATIONS OF A CONDUCTIVE MICROELEMENT BY A MAGNETIC FIELD

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Abstract. Magnetoelastic materials are gaining significant importance in research aimed at utilizing new technologies, such as smart materials and nanotechnology, which may lead to the development of new devices and systems in the future. A variable magnetic field induces currents that can result in additional mechanical stresses and deformations in a conductive material. The size and shape of a magnetoelastic material can change under the influence of a magnetic field. The reverse effect of magnetostriction causes mechanical stress in the material to alter its magnetic properties. The interaction between mechanical vibrations and electromagnetic fields can lead to resonance phenomena. In this work, the magnetoelastic vibrations of a shell-shaped microelement have been mathematically modeled, taking into account magneto-electro-thermo-elastic couplings. Numerical results were analyzed.

Keywords: shell, deformation, stress, electromagnetic field, magnetoelasticity.

МОДЕЛИРОВАНИЕ МАГНИТОУПРУГИХ КОЛЕБАНИЙ ТОКОПРОВОДЯЩЕГО МИКРОЭЛЕМЕНТА МАГНИТОМ ПОЛЕ

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Аннотация. Магнитоэластические материалы приобретают важное значение в исследованиях, направленных на использование таких новых технологий, как умные материалы и нанотехнологии, которые могут привести к развитию новых устройств и систем в будущем. Переменное магнитное поле вызывает появление индукционных токов, которые могут привести к дополнительным механическим напряжениям и деформациям в проводящем материале. Под воздействием магнитного поля размеры и форма магнитоэластического материала могут изменяться. Обратное влияние магнитоупругости приводит к тому, что механические напряжения в материале изменяют его магнитные свойства. Взаимодействие между механическими колебаниями и электромагнитными полями может вызывать резонансные явления. В работе математически смоделированы магнитоэластические колебания микроэлемента в форме оболочки с учетом магнитно-электро-тепло-упругих связей. Проведен анализ численных результатов.

Ключевые слова: оболочка, деформация, напряжение, электромагнитное поле, магнитоупругость.