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RAQAMLI JAMIYATDA FAN VA TA’LIMNING INTEGRATSIYALALASHUVI: MATEMATIKA, IQTISOD, PEDAGOGIKA VA PSIXOLOGIYANING YANGI YONDASHUVLARI

mavzusidagi Respublika ilmiy-texnik anjuman materiallari to‘plami

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Respublika miqyosidagi ilmiy-texnik anjuman materiallarida zamonaviy kompyuter ilmlari va muhandislik texnologiyalari sohasidagi innovatsion tadqiqotlar aks etgan.

Globallashuv sharoitida davlatimizni yanada barqaror va jadal sur’atlar bilan rivojlantirish bo‘yicha amalga oshirilayotgan islohotlar samarasini yaxshilash sohasidagi ilmiy-tadqiqot ishlariga alohida e’tibor qaratilgan. Zero iqtisodiyotning, ijtimoiy sohalarni qamrab olgan modernizatsiya jarayonlari, hayotning barcha sohalarini liberallashtirishni talab qilmoqda.

Ushbu ilmiy ma’ruza tezislari to‘plamida mamlakatimiz va xorijlik turli yo‘nalishlarda faoliyat olib borayotgan mutaxassislar, olimlar, professor-o‘qituvchilar, ilmiy tadqiqot institutlari va markazlarining ilmiy xodimlari, tadqiqotchilari, magistr va talabalarning ilmiy-tadqiqot ishlari natijalari mujassamlashgan.

Mazkur to‘plamga kiritilgan ma’ruza tezislarining mazmuni, undagi statistik ma’lumotlar va me’yoriy hujjatlarning to‘g‘riligi hamda tanqidiy fikr-mulohazalar, keltirilgan takliflarga mualliflarning o‘zlari mas’uldirlar.

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KOSSERA MUHITIDA HARAKATLANUVCHI YUKDAN HOSIL BO'LADIGAN DINAMIK JARAYONLAR XUSUSIYATLARI

[1]Choriyev M., [2]Kubaymurodov D.I., Bayali A.T.

[1]TKTI Oliy matematika kafedrasi katta o'qituvchisi f.-m.b.f.d. (PhD),
tel:+9989744778894, *e-mail:* choriyevm56@gmail.com

[2]O'zR VM huzuridagi Samarqand viloyati qurilish va kommunal xo'jaligi nazorati inspeksiyasi yetakchi mutaxasissi e-mail: dkubaymurodov@gmail.com

[3]Q.A. Yassaviy nomidagi Xalqaro qozoq-turk universiteti katta o'qituvchisi, e-mail: azimkhan.bayaly@ayu.edu.kz

Annotatsiya. Ushbu ishda harakatlanuvchi yuk ta'sirida Kossera muhitida hosil bo'ladigan kuchlanish-deformatsiya holati masalasi o'rganilgan. Qovushqoq-elastik yarim tekislikda to'lqin tarqalishi masalalarini yechish metodikasi va algoritmi ishlab chiqilgan, shuningdek analitik va sonli hisoblash usullari keltirilgan.

Kalit so'zlar: Kossera muhiti, kuchlanish-deformatsiya holati, yarim tekislik, qovushqoq-elastiklik, to'lqin tarqalishi.

1. Kirish.

Klassik elastiklik nazariyasi modeli ideallashtirilgan bo'lib, materialni zarralardan tuzilgan deb qaraydi va zarralar orasida yuzaga keladigan o'zaro ta'sir kuchlarini to'liq hisobga olmaydi [1,2]. Tajriba natijalari bilan nazariy hisoblashlar o'rtasidagi nomuvofiqlik, ayniqsa, yuqori chastotali (yoki qisqa to'lqin uzunlikdagi) to'lqinlarni tadqiq etishda kuzatiladi. Klassik elastiklik nazariyasi doirasida to'lqinlarning tarqalishida dispersiya hodisasini hamda antiplastik (yoki antiplanar) sirt to'lqinlarining mavjudligini to'liq tushuntirib bo'lmaydi [3–5]. Mazkur holat eksperimental jihatdan tasdiqlangan bo'lsa-da, hozirgacha yetarli darajada o'rganilmagan.

2. Masalaning qo'yilishi va yechish metodikasi

Faraz qilaylik, yarim tekislik sirtida nuqtaviy kuch Dtezlik bilan harakatlansin. Uning tezligi bo'ylama va ko'ndalang to'lqinlar tezligidan oshmaydi. Bu holda muhitda to'lqin tarqalishini ifodalovchi tenglamalar quyidagi ko'rinishga ega bo'ladi:

$$\frac{\partial\sigma_{x'x'}}{\partial x'}+\frac{\partial\sigma_{y'x'}}{\partial y'}=\rho\frac{\partial^2 u}{\partial t^2},\frac{\partial\sigma_{x'y'}}{\partial x'}+\frac{\partial\sigma_{y'y'}}{\partial y'}=\rho\frac{\partial^2\vartheta}{\partial t^2}. \qquad (1)$$

Kuchlanish komponentlari ham quyidagi ko‘rinishda bo‘ladi:

$$\sigma_{x'x'}=\bar\lambda\left(\frac{\partial u}{\partial x'}+\frac{\partial\vartheta}{\partial y'}\right)+2\bar\mu\frac{\partial u}{\partial x'},\sigma_{y'y'}=\bar\lambda\left(\frac{\partial u}{\partial x'}+\frac{\partial\vartheta}{\partial y'}\right)+2\bar\mu\frac{\partial\vartheta}{\partial y'},$$

$$\sigma_{x'y'}=\bar\mu\left[\frac{\partial\vartheta}{\partial x'}+\frac{\partial u}{\partial y'}-l^2\left(\frac{\partial^2}{\partial x'^2}+\frac{\partial^2}{\partial y'^2}\right)\left(\frac{\partial\vartheta}{\partial x'}-\frac{\partial u}{\partial y'}\right)\right]$$

$$\sigma_{y'x'}=\bar\mu\left[\frac{\partial\vartheta}{\partial x'}+\frac{\partial u}{\partial y'}+l^2\left(\frac{\partial^2}{\partial x'^2}+\frac{\partial^2}{\partial y'^2}\right)\left(\frac{\partial\vartheta}{\partial x'}-\frac{\partial u}{\partial y'}\right)\right]$$

$$\mu_{x'}=2\bar\mu l^2\frac{\partial}{\partial x'}\left(\frac{\partial\vartheta}{\partial x'}-\frac{\partial u}{\partial y'}\right),\mu_{y'}=2\bar\mu l^2\frac{\partial}{\partial y'}\left(\frac{\partial\vartheta}{\partial x'}-\frac{\partial u}{\partial y'}\right).$$

O‘rganilayotgan masala uchun chegaraviy shart quyidagicha bo‘ladi:

$$\sigma_{y'y'}=-P\delta(x),\ \sigma_{y'x'}=0,\mu_{y'}=0.$$

Bo‘ylama va ko‘ndalang to‘lqin potensiallari orqali ko‘chishlar quyidagicha aniqlanadi:

$$u_{xk}=\frac{\partial\varphi_k}{\partial x'}-\frac{\partial\psi_{zk}}{\partial y'},\qquad u_{y\kappa}=\frac{\partial\varphi_\kappa}{\partial y'}-\frac{\partial\psi_{z\kappa}}{\partial x'}. \qquad (2)$$

Agar to‘lqin tenglamalaridan foydalansak, ular quyidagi ko‘rinishga keladi [6]:

$$\begin{gathered}\left(\frac{\partial^2}{\partial x'^2}+\frac{\partial^2}{\partial y'^2}-\frac{1}{c_{p1}^2\Gamma_{k\lambda\mu}}\frac{\partial^2}{\partial t^2}\right)\varphi=0,\\ \left(\frac{\partial^2}{\partial x'^2}+\frac{\partial^2}{\partial y'^2}-l^2\left(\frac{\partial^4}{\partial x'^4}+\frac{\partial^4}{\partial x'^4\partial y'^4}+\frac{\partial^4}{\partial y'^4}\right)-\frac{1}{c_{s2}^2\Gamma_{k\mu}}\frac{\partial^2}{\partial t^2}\right)\varphi=0.\end{gathered} \qquad (3)$$

Harakatlanuvchi koordinatalar sistemasi (x,y) qo‘zg‘almas koordinatalar sistemasi bilan Galiley almashtirishi orqali bog‘langan.

$$x=x'-Dt,\ y=y' \qquad (4)$$

U holda dinamik jarayonni ifodalovchi tenglamalar quyidagi ko‘rinishga ega bo‘ladi:

$$\begin{gathered}(\bar\lambda+2\bar\mu-\rho D^2)\frac{\partial^2 u}{\partial x^2}+\bar\lambda\frac{\partial^2\vartheta}{\partial x\partial y}+\bar\mu\left[\frac{\partial^2\vartheta}{\partial x\partial y}+\frac{\partial^2\vartheta}{\partial y^2}+l^2\Delta\left(\frac{\partial^2\vartheta}{\partial x\partial y}-\frac{\partial^2 u}{\partial y^2}\right)\right]=0,\\ (\bar\lambda+2\bar\mu)\frac{\partial^2\vartheta}{\partial y^2}+\bar\lambda\frac{\partial^2 u}{\partial x\partial y}+\bar\mu\left[\frac{\partial^2 u}{\partial x\partial y}+\left(1-\frac{\rho D^2}{\bar\mu}\right)\frac{\partial^2\vartheta}{\partial x^2}-l^2\Delta\left(\frac{\partial^2\vartheta}{\partial x^2}-\frac{\partial^2 u}{\partial x\partial y}\right)\right]=0,\end{gathered} \qquad (5)$$

Yuqorida keltirilgan tenglamaning yechimini quyidagicha topamiz [7].

$$u=Ae^{kqy}\sin(kx),\ \vartheta=Be^{kqy}\cos(kx). \qquad (6)$$

Shu holda, (5)-tenglama quyidagi ko‘rinishga ega bo‘ladi.

$$\begin{aligned}&\left[-\bar{\mu}l^2k^2q^4+\bar{\mu}q^2(1+l^2k^2)-(\bar{\lambda}+2\bar{\mu}-\rho D^2)\right]A+\\&+\left[\bar{\mu}l^2k^2q^3+q(\bar{\lambda}+\bar{\mu}-\bar{\mu}l^2k^2)\right]B=0,\\&\left[-\bar{\mu}l^2k^2q^3-q(\bar{\lambda}+\bar{\mu}-\bar{\mu}l^2k^2)\right]A+\\&+\left[q^2(\bar{\lambda}+2\bar{\mu}-\rho D^2)-(\bar{\lambda}+\bar{\mu}l^2k^2-\rho D^2)\right]B=0,\end{aligned}\tag{7}$$

Bir xil turdagi (7)-tenglamalar sistemasining yechimi mavjud bo‘lishi uchun uning asosiy aniqlovchisi nolga teng bo‘lishi kerak. Shu holda, quyidagi dispersiya tenglamasini olamiz.

$$\begin{aligned}&(l^2k^2-\gamma+\beta_1^2)l^2k^2q^6+(l^2k^2(1+l^2k^2-\beta_1^2)+\gamma(1+l^2k^2)(1-\gamma\beta_1^2)+\\&+2l^2k^2(\gamma-l^2k^2))q^4+((1+l^2k^2)(1+l^2k^2-\beta_1^2)-(\gamma-\beta_1^2)^2+(\gamma-l^2k^2)^2)q^2+\\&+(\gamma-\beta_1^2)(1+l^2k^2-\beta_1^2)=0.\end{aligned}\tag{8}$$

Bu yerda $\beta_1^2=\dfrac{\rho D^2}{\bar{\mu}},\gamma=\dfrac{\bar{\lambda}+2\bar{\mu}}{\bar{\mu}}$.

Ushbu (8)-transsendent tenglamaning ildizlari cheksiz ko‘p bo‘ladi. Murakkab ildizning haqiqiy qismi $q>0$ bo‘lsin deb qabul qilamiz. Shu holda, bo‘ylama va kundalang kuchlanishlar quyidagicha ifodalanadi.

$$u=\sum_{i=1}^{\infty}\int_0^{\infty}A_ie^{kq_iy}\sin kxdk,\vartheta=\sum_{i=1}^{\infty}\int_0^{\infty}\alpha_iA_ie^{kq_iy}\cos kxdk.$$

Yangi koordinatalar sistemasida potensiallar orqali ifodalangan tenglamalar va chegaraviy shartlar quyidagicha bo‘ladi.

$$\begin{aligned}&((\eta_2^2-2)\frac{\partial^2\varphi}{\partial x^2}+2\frac{\partial^2\psi}{\partial x\partial y})\varphi=-\frac{P}{\bar{\mu}}\delta(x),\\&(2\frac{\partial^2\psi}{\partial x\partial y}+\eta_2^2\frac{\partial^2\psi}{\partial x^2}-2\frac{\partial^2\psi}{\partial y^2})\Big|_{y=0}=0,(\frac{\partial^3\psi}{\partial x^2\partial y}+\frac{\partial^2\psi}{\partial y^2})\Big|_{y=0}=0,\end{aligned}\tag{9}$$

$$(\lambda_1^2\frac{\partial^2}{\partial x^2}-\frac{\partial^2}{\partial y^2})\varphi=0,(\lambda_2^2\frac{\partial^2}{\partial x^2}-\frac{\partial^2}{\partial y^2}+l^2(\frac{\partial^4}{\partial x^4}+\frac{\partial^4}{\partial x^2\partial y^2}+\frac{\partial^4}{\partial y'^4}))\psi=0,$$

Bu yerda $\eta_\alpha=\dfrac{D}{c_\alpha},\lambda_1^2=\sqrt{(\eta_\alpha^2-1)},\alpha=1,2.$

Yuqorida keltirilgan (7)-differensial tenglamaning yechimi quyidagicha bo‘ladi.

$$\varphi(x,y)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}Ae^{-i\alpha(x-\lambda_1y)}d\alpha,\psi(x,y)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}Be^{-i\alpha(x-\lambda_2y)}d\alpha.\tag{10}$$

Ushbu yechim Furye integrali orqali topilgan. Ushbu yechimdan ko‘rinib turibdiki, u cheksizlikda to‘lqin yutilish shartini bajaradi. Shuningdek, harakatlanuvchi yukdan integral transformatsiyani olish mumkin.

$$F\left[\delta(x)\right]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}\delta(x)Be^{-i\alpha x}dx=\frac{1}{\sqrt{2\pi}}.$$

Shu holda, quyidagi tenglamalar sistemasini olamiz.

$$-\alpha(\eta_2^2-2)A+2\alpha^2\lambda_2 B=\frac{P}{\bar{\mu}\sqrt{2\pi}}0,\ 2\alpha^2\lambda_1 A-\alpha(\eta_2^2+2)B=0.$$

Ushbu tenglamalar sistemasidan *A* va *B* ixtiyoriy o'zgarmaslarini topamiz.

$$A=\frac{(\eta_2^2-2)P}{\mu\alpha^2\sqrt{2\pi}\left[(\eta_2^2+2)(\eta_2^2-2)+4\lambda_1\lambda_2\right]},B=\frac{4\lambda_1 P}{\mu\alpha^2\sqrt{2\pi}\left[(\eta_2^2+2)(\eta_2^2-2)+4\lambda_1\lambda_2\right]} \quad (11)$$

Hisoblashlarda quyidagi belgilashlardan foydalanilgan.

$$\gamma_1=\eta_2^2+2,\gamma_2=\eta_2^2-2,\Delta=\gamma_1\gamma_2+4\lambda_1\lambda_2.$$

Shu holda, *A* va *B* quyidagi ko'rinishga ega bo'ladi.

$$A=\frac{\gamma_2 P}{\mu\alpha^2\sqrt{2\pi}\Delta},B=\frac{4\lambda_1 P}{\mu\alpha^2\sqrt{2\pi}\Delta} \quad (12)$$

Agar kiritilgan bo'ylama va kundalang to'lqin potensiallarini hisobga olsak, muhit nuqtalaridagi kuchlanishlarni quyidagicha ifodalash mumkin.

$$u=\frac{iP}{2\pi\bar{\mu}\Delta}\int_{-\infty}^{\infty}(\gamma_2 e^{i\lambda_1\alpha y}+2\lambda_1\lambda_2 e^{i\lambda_2\alpha y})\frac{e^{-i\alpha x}}{\alpha}d\alpha,\vartheta=\frac{iP}{2\pi\bar{\mu}\Delta}\int_{-\infty}^{\infty}(\gamma_2 e^{i\lambda_1\alpha y}-2\lambda_1 e^{i\lambda_2\alpha y})\frac{e^{-i\alpha x}}{\alpha}d\alpha.$$

(13)

3. Sonli natijalar va ularning tahlili: Materialning qovushoqligini hisobga olish uchun Rjanitsyn–Koltunov uch parametrli kuchsiz singulyar yadrosi qo'llaniladi: $R(t)=\frac{Ae^{-\beta t}}{t^{1-\alpha}}$.

Parametrlar quyidagi ko'rinishda qabul qilingan: $A=0,048;$ $\beta=0,05;$ $\alpha=0,1,$ $\nu_1=\nu_2=0,14$

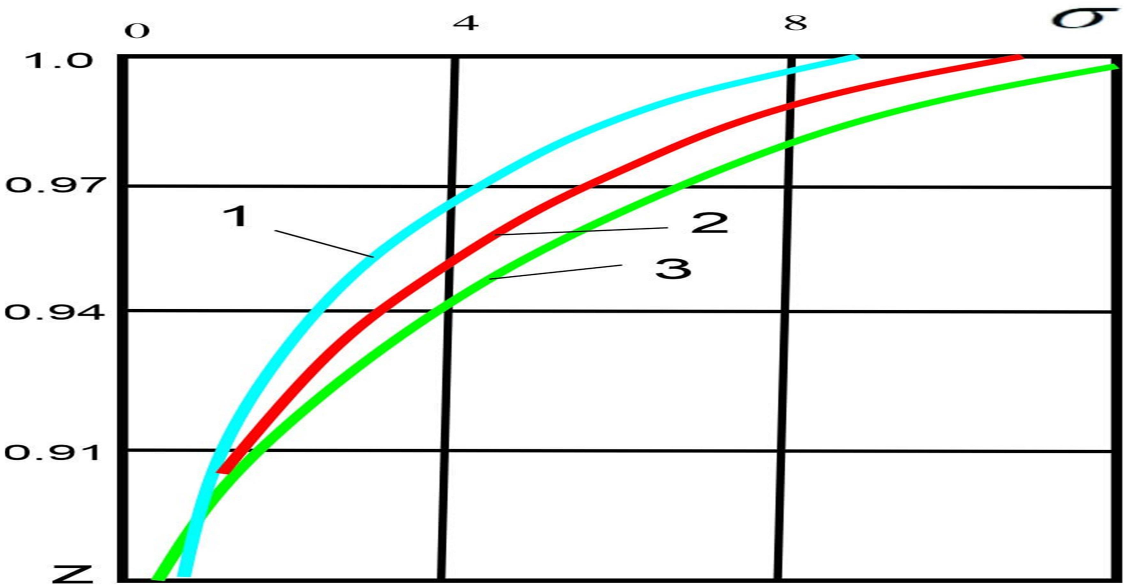
Buning uchun quyidagi kattaliklardan foydalanilgan.

$$\bar{\rho}=19250kg/m^3,\rho=2700kg/m^3,\bar{\lambda}=1994\cdot10^9 Pa,\lambda=55.94\cdot10^9 Pa,$$

$$\bar{\mu}=158.56\cdot10^9 Pa,\mu=23.94\cdot10^9 Pa,\bar{c}_l=5180m/s,c_t=3100m/s.$$

Qovushoq-elastik yarim muhitda joylashgan doirasimon, ko'ndalang kesimli quvurga garmonik to'lqin ta'sirida hosil bo'ladigan kuchlanish-deformatsiya holatini ko'rib chiqamiz. Normal kuchlanishning chuqurlik bo'yicha o'zgarishi 1-rasmda keltirilgan:

1. Klassik muhit; 2.Gradiyentli qovushoq-elastik muhit; 3.Kossera qovushoq-elastik muhit.



1-rasm. Normal kuchlanishning chuqurlik bo'yicha o'zgarishi

Xulosalar: Harakatlanuvchi kuch ta'siridagi neosesimmetrik kuchlanishga ega bo'lgan yarim tekislikda hosil bo'ladigan kuchlanish-deformatsiya holatini aniqlash metodikasi va algoritmi Furye integrali, Romberg usuli, shuningdek Gauss va Muller usullariga asoslangan holda ishlab chiqildi va dasturiy ta'minoti yaratildi. Natijalar shuni ko'rsatdiki: kuchlanishlar va kuchishlar yarim tekislik sirtidan chuqurlikka qarab eksponentsial ravishda kamayadi. Gradiyentli elastik muhitga nisbatan Kossera muhitida kuchlanishlar va kuchishlar 10–20% ko'proq bo'lishi aniqlangan.

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UCH QATLAMLI QOVUSHQOQ - ELASTIK PLASTINKANING MAJBURIY TEBRANISHLARI

[1]Safarov I.I., [2]Baialy A.T., [3]Mirzakabilov B.N., [4]Uralov U.A.
[1,3,4]Toshkent kimyo - texnologiya instituti
[2]Xo'ja Ahmed Yasaviy nomidagi xalqaro Qozog'iston-Turkiya universiteti
safarov54@mail.ru., azimkhan.bayaly@ayu.edu.kz.,
bmirzakabilov@inbox.ru., legolas0810@mail.ru