Diodda asosiy zaryad tashuvchilar temperaturasi T_n=750 gacha qiziydi deb oldik. 2-rasmdan shu xulosaga kelish mumkinki, agar p-n o‘tishli diodga magnit maydon ta’sir etganimizda Nernst-Ettingsgausen effekti natijasida zaryad tashuvchilar qizishi hisobiga o‘zgarmas kuchlanishda ham tok ortishini ko‘rishimiz mumkin.

Xulosa. Yuqorida olingan tahlillar shuni ko‘rsatdiki, magnit maydon va harorat gradiyenti birgalikda zaryad tashuvchilarning harakatlanish dinamikasini, ularning diffuziya jarayonini hamda hajmiy zaryad sohasidagi taqsimotini o‘zgartiradi. Natijada diodning volt-amper xarakteristikasi sezilarli darajada siljiydi va o‘zgarmas kuchlanishda ham tok qiymatining ortishi kuzatiladi. Bu esa Nernst-Ettingsgauzen effekti ta’sirida zaryad tashuvchilar energiyasining oshishi va ularning harakatchanligining ortishi bilan izohlanadi. Olingan natijalar bir jinsli hamda bir jinsli bo‘lmagan yarimo‘tkazgichlar uchun taqqoslanib, p–n o‘tishli diodlarning termomagnit xususiyatlarini chuqurroq tushunishga imkon beradi.

Tadqiqot natijalari magnit maydonga sezgir yarimo‘tkazgichli datchiklar, yuqori aniqlikdagi elektron qurilmalar hamda yangi avlod termomagnit elementlarini yaratishda nazariy asos sifatida xizmat qilishi mumkin. Kelgusida ushbu modelni tajriba natijalari bilan solishtirish va turli magnit maydon induksiyasi hamda harorat oralig‘ida eksperimental tekshirish ilmiy natijalarning ishonchliligini yanada oshiradi.

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TIPINING O‘ZGARISH CHIZIG‘I UCHTA BO‘LGAN PARABOLIK-GIPERBOLIK TENGLAMA UCHUN BITSADZE-SAMARSKIY SHARTIGA O‘XSHASH SHARTLI MASALA

Annotatsiya. *Ushbu ishda tipining o‘zgarish chizig‘i uchta bo‘lgan ikkinchi tartibli parabolik-giperbolik tenglama uchun bir xil xarakteristik yo‘nalishdagi izlanayotgan funksiya hosilalari qatnashgan Bitsadze-Samarskiy shartiga o‘xshash shartli masalaning bir qiymatli yechilishi isbotlangan. Masala shartida soha chegarasidagi qiymatlar soha ichki nuqtalari yoki xarakteristikalardagi qiymatlar bilan bog‘langan. Yechimning yagonaligi energiya integrallari usuli yordamida ko‘rsatilgan. Yechimning mavjudligi esa masalani Volterra tipidagi integral tenglamalar sistemasiga keltirish va ularning yechimga egaligini isbotlash orqali asoslangan.*

Kalit so'zlar: *parabolik-giperbolik tenglama, nolokal masala, Bitsadze-Samarskiy sharti, uchta o'zgarish chizig'i, integral tenglamalar, yechimning yagonaligi va mavjudligi.*

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ЗАДАЧА С УСЛОВИЯМИ ТИПА БИЦАДЗЕ-САМАРСКОГО ДЛЯ ПАРАБОЛО-ГИПЕРБОЛИЧЕСКОГО УРАВНЕНИЯ С ТРЕМЯ ЛИНИЯМИ ИЗМЕНЕНИЯ ТИПА

Аннотация. *Работа посвящена изучению одного класса задач с условиями типа Бицадзе-Самарского для смешанного параболо-гиперболического уравнения второго порядка с тремя линиями изменения типа. Основным результатом работы является доказательство однозначной разрешимости задачи с условиями типа Бицадзе-Самарского с производными искомой функции по одинаковым характеристическим направлениям для параболо-гиперболического уравнения.*

Ключевые слова: *параболо-гиперболическое уравнение, нелокальная задача, условие Бицадзе-Самарского, три линии изменения типа, интегральные уравнения, единственность и существование решения.*

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A PROBLEM WITH BITSADZE-SAMARSKII TYPE CONDITION FOR PARABOLIC-HYPERBOLIC EQUATION WITN THREE LINES OF TYPE CHANGING

Annotation. *This work establishes the unique solvability of a boundary-value problem of Bitsadze–Samarskii type for a second-order parabolic-hyperbolic equation with three lines of type change, in which derivatives of the unknown function along the same characteristic direction are involved. In the formulation of the problem, the values on the boundary of the domain are related to the values at interior points of the domain or on characteristic lines.*

The uniqueness of the solution is proved by means of energy integral methods. The existence of the solution is justified by reducing the problem to a system of integral equations of Volterra type and proving the solvability of the resulting system.

Keywords: *Parabolic-hyperbolic equation, nonlocal problem, Bitsadze-Samarskiy condition, three lines of type change, integral equations, uniqueness and existence of solution.*

1. Kirish. A.V.Bitsadze va A.A.Samarskiy [1] maqolasida elliptik tenglamalar uchun chiziqli chegaraviy masalalarni umumlashtirishdi va ular bu masalani "Bitsadze-Samarskiy masalasi" deb nomladi. Ushbu maqoladan so'ng, bu masalaga doir bir necha turli formulalardagi ko'plab tenglamalar uchun bir qator tadqiqotlar paydo bo'ldi [2].

Ushbu maqolada parabolik-giperbolik tipdagi uchta o'zgarish chiziqli tenglama uchun Bitsadze-Samarskiy tipidagi shartlar bilan bog'liq masala o'rganiladi. Biz [3–7]da bir va ikki tipi o'zgarish chiziqli parabolik-giperbolik tenglamalar uchun turli xil lokal va nolokal chegaraviy masalalar o'rganilgan. Shuningdek, tipining o'zgarish chizig'i uchta bo'lgan parabolik-giperbolik tenglama uchun bir xil xarakteristik yo'nalishdagi funksiya hosilalari qatnashgan Bitsadze-Samarskiy shartiga o'xshash shartli masalaning bir qiymatli yechilishi isbotlangan.

Quyidagi tenglamani

$$Lu = 0 \tag{1}$$

Ω sohada qaraymiz.

Bu yerda, Ω - AB, AA_0, BB_0 kesmalar va $\Omega_i, (i = \overline{0,3})$ sohalar birlashmasidan iborat: $\Omega_0 = \{(x,y): 0 < x < 1, 0 < y < 1\}, \Omega_1$, Ω_2, Ω_3 – uchlari, mos ravishda, A, B, C; A, A_0, D; va B, B_0, E bo'lgan xarakteristik uchburchaklar, bunda $A(0,0)$, $A_0(0,1)$, $B(1,0)$, $B_0(1,1)$, $C\left(\frac{1}{2}, -\frac{1}{2}\right)$, $D\left(-\frac{1}{2}, \frac{1}{2}\right)$, $E\left(\frac{3}{2}, \frac{1}{2}\right)$.

Lu funksiya esa quyidagi ko'rinishga ega:

$$Lu = \begin{cases} u_{xx} - u_y, (x,y) \in \Omega_0, \\ u_{xx} - u_{yy}, (x,y) \in \Omega_i \ (i = \overline{1,3}), \end{cases}$$

Masala B. berilgan (1) tenglamani, Ω sohada

$$[u_x - u_y]\theta_1(t) + \mu_1(t)[u_x - u_y]\theta_1{}^*(t) = \varphi_1(t), \tag{2}$$

$$[u_x - u_y]\theta_2(t) + \mu_2(t)[u_x - u_y]\theta_2{}^*(t) = \varphi_2(t), \tag{3}$$

$$[u_x + u_y]\theta_3(t) + \mu_3(t)[u_x + u_y]\theta_3{}^*(t) = \varphi_3(t), \tag{4}$$

$$u(A) = 0, \text{ и } u(B) = 0. \tag{5}$$

shartlarni qanoatlantiruvchi muntazam yechimini topish.

Bu yerda $\theta_1(t), \theta_2(t), \theta_3(t)$ и $\theta_1^*(t), \theta_2^*(t), \theta_3^*(t)$lar, mos ravishda $(x,0) \in AB$, $(0,y) \in AA_0$, $(1,y) \in BB_0$ nuqtalardan chiquvchi, AC, AD, BE $[AN, AK, BM]$ harakteristik to'g'ri chiziqlar bilan kesishish nuqtalari affikslari; $AN: y = -\gamma_1(x)$, $AK: x = -\gamma_2(y)$, $BM: x = -\gamma_3(y)$, $\mu_i(t)$ va $\varphi_i(t)$ esa berilgan funksiyalar bo'lib, $i - 1, 2$ va 3 qiymatlarni qabul qiladi.

$\gamma_i(t)$, $(i = \overline{1,3})$ egri chiziqlarga nisbatan quyidagi talablar bajarilsin:

- ular qat'iy ravishda xarakteristik uchburchaklar ichida joylashgan;
- $\gamma_i(t)$, $(i = \overline{1,3})$ ikki marta uzluksiz differensiallanuvchi;
- $t \pm \gamma_i(t)$, $(i = \overline{1,3})$ monoton o'suvchi;
- $\gamma_1(0) = 0$ va $\gamma_2(0) = 0, \gamma_3(0) = 1, l_1 + \gamma_1(l_1) = 1, l_2 + \gamma_2(l_2) = 1, l_3 - \gamma_3(l_3) = 2$, $0 < \gamma_i'^{(0)} < 1$ $(i = \overline{1,3})$.

B masalaning Ω sohadagi muntazam yechimi deganda

$$W = C^1(\overline{\Omega}) \cap C^{2,1}_{x,y}(\Omega_0) \cap C^2(\Omega_i), \ (i = \overline{1,3})$$

sinfga tegishli bo'lgan va (1) tenglamani qanoatlantiruvchi funksiya.

Teorema. Agar $\mu_i(t) \neq -1$ va $\mu_i(t), \varphi_i(t) \in C^1[0,1]$ $(i = \overline{1,3})$ bo'lsa, u holda B masalaning muntazam yechimi mavjud bo'ladi.

Quyidagi belgilashlarni kiritamiz:

$$u(\pm 0, y) = \tau_2^{\pm}(y), \ u_x(\pm 0, y) = \nu_2^{\pm}(y);$$
$$u(1 \pm 0, y) = \tau_3^{\pm}(y), \ u_x(1 \pm 0, y) = \nu_3^{\pm}(y);$$
$$u(x, \pm 0) = \tau_1^{\pm}(x), \ u_y(x, \pm 0) = \nu_1^{\pm}(x).$$

Isbot. Isbot qilish uchun, birinchi navbatta, Dalamber formulasidan foydalanib [1], Ω_i sohalardan olingan va AB, AA_0, BB_0 kesmalaridagi $\tau_i^{\pm}(t)$, $\nu_i^{\pm}(t)$ funksiyalar orasidagi asosiy funksional munosabatlarni topib olamiz.

Ω_1 sohada (1) tenglama uchun Koshi masalasining yechimi quyidagi ko'rinishda ifodalanadi:

$$u(x,y) = \frac{1}{2}\left[\tau_1^-{}'(x+y) + \tau_1^-{}'(x-y) + \int_{x-y}^{x+y} \nu_1^-(t)dt\right] \quad (6)$$

(6) dan foydalanib, (2) shartni qanoatlantiramiz, AB kesmadagi $\tau_1^-(x)$ va $\nu_1^-(x)$ orasidagi funksional munosabat o'rinli boladi:

$$\big(1 + \mu_1(x)\big)\nu_1^-(x) = \big(1 + \mu_1(x)\big)\tau_1^-{}'(x) - \varphi_1(x), 0 < x < 1. \quad (7)$$

Xuddi shuningdek, AA_0 va BB_0 kesmalaridagi funksional munosabatlarga ega bo'lamiz:

$$\big(1 + \mu_2(y)\big)\nu_2^-(y) = \big(1 + \mu_2(y)\big)\tau_2^-{}'(y) - \varphi_2(y), 0 < y < 1. \quad (8)$$
$$\big(1 + \mu_3(x)\big)\nu_3^+(t) = -\big(1 + \mu_3(y)\big)\tau_3^+{}'(y) - \varphi_3(y), 0 < y < 1. \quad (9)$$

Yechimning yagonaligi funksiya integrallari yordamida isbotlanadi. Odatdagidek, bir jinsli masalani ko'rib chiqib, bu masalaning faqat trivial yechimga ega ekanligini isbotlaymiz. Buning uchun Ω_0 sohadagi (1) tenglamani $u(x,y)$ funksiyasiga ko'paytirib, shu soha bo'yicha integrallaymiz. Grin formulasidan [8] foydalanib, quyidagini hosil qilamiz:

$$\iint_{\Omega_0} u_x^2(x,y)dxdy + \int_0^1 \tau_2^+(y)\nu_2^+(y)dy - \int_0^1 \tau_3^-(y)\nu_3^-(y)dy +$$
$$+\frac{1}{2}\int_0^1 u_x^2(x,1)dx - \frac{1}{2}\int_0^1 [\tau_1^+(x)]^2 dx = 0 \quad (10)$$

Endi esa $\tau_1^+(x) = 0$, $\int_0^1 \tau_3^-(y)\nu_3^-(y)dy \leq 0$ va $\int_0^1 \tau_2^+(y)\nu_2^+(y)dy \geq 0$ larni isbotlab, almashtirishlardan so'ng (10)dan, Ω_0 da $u(x,y) \equiv 0$ tenglik o'rinli bo'ladi. So'ngra, Koshi masalasi uchun olingan tengliklardan foydalanib, $\overline{\Omega_i}$ $(i = \overline{1,3})$da $u(x,y) \equiv 0$ ekanligini aniqlaymiz. Bulardan esa qaralayotgan masalaning yechimining yagonaligi kelib chiqadi.

Masala yechimining mavjudligi integral tenglamalar usuli bilan isbotlanadi. Buning uchun (7)-(9) funksional munosabatlardan va Ω_0 sohadagi (1) tenglama uchun birinchi chegaraviy masala yechimi

$$u(x,y) = \int_0^1 \tau_1^+(x_1)G(x,y;x_1,0)dx_1 + \int_0^y \tau_2^+(y_1)G_{x_1}(x,y;0,y_1)dy_1 -$$

$$-\int_0^y \tau_3^-(y_1)G_{x_1}(x,y;1,y_1)dy_1, \tag{11}$$

bu yerda

$$G(x,y;x_1,y_1)=\frac{1}{2\sqrt{\pi(y-y_1)}}\sum_{n=-\infty}^{\infty}\left[e^{-\frac{(x-x_1+2n)^2}{4(y-y_1)}}-e^{-\frac{(x+x_1+2n)^2}{4(y-y_1)}}\right]$$

issiqlik o‘tkazuvchanlik tenglamasi uchun birinchi chegaraviy masalaning Grin funksiyasidir.

Dastlab $\tau_1^{\pm}(x), \nu_1^{\pm}(x)$ funksiyalarini topamiz. Buning uchun Ω_0 sohada $y\to 0$ da limitga o‘tib, (1) dan quyidagini olamiz

$$[\tau_1^+(x)]''=\nu_1^+(x) \tag{12}$$

(7)ni (12)ga qo‘yib, $\tau_1^+(x)$ga nisbatan ikkinchi tartibli oddiy differensial tenglamani hosil qilamiz:

$$\tau_1^{+\prime\prime(x)}-\tau_1^{+\prime(x)}=-\frac{\varphi_1(x)}{1+\mu_1(x)}. \tag{13}$$

(13) tenglamaning yechimi, $\tau_1^+(0)=0$ va $\tau_1^+(1)=0$ sharti bilan, quyidagi ko‘rinishda ifodalanadi

$$\tau_1^+(x)=\int_0^x \frac{\varphi_1(t)[1-e^{x-t}]}{1+\mu_1(t)}dt+\frac{e^x-1}{e-1}\int_0^1 \frac{\varphi_1(t)[e^{1-t}-1]}{1+\mu_1(t)}dt. \tag{14}$$

(7) funksional munosabatdan foydalanib,

$$\nu_1^+(x)=-\int_0^x \frac{\varphi_1(t)[1-e^{x-t}]}{1+\mu_1(t)}dt+\frac{e^x-1}{e-1}\int_0^1 \frac{\varphi_1(t)[e^{1-t}-1]}{1+\mu_1(t)}dt-\frac{\varphi_1(x)}{1+\mu_1(x)} \tag{15}$$

ni topamiz.

$\tau_i^{\pm}(t)$, $\nu_i^{\pm}(t)$ $(i=2,3)$ funksiyalarini topish uchun (11) ni bir marta x bo‘yicha differensiallaymiz:

$$u_x(x,y)=\int_0^1 \tau_1^+(x_1)G_x(x,y;x_1,0)dx_1+\int_0^y \tau_2^+(y_1)G_{x_1x}(x,y;0,y_1)dy_1-$$

$$-\int_0^y \tau_3^-(y_1)G_{x_1x}(x,y;1,y_1)dy_1.$$

Quyidagi belgilashni kiritamiz

$$N(x,y;x_1,y_1)=\frac{1}{2\sqrt{\pi(y-y_1)}}\sum_{n=-\infty}^{\infty}\left[e^{-\frac{(x-x_1+2n)^2}{4(y-y_1)}}+e^{-\frac{(x+x_1+2n)^2}{4(y-y_1)}}\right].$$

$G_{x_1x}(x,y;x_1,y_1)=N_{y_1}(x,y;x_1,y_1)$ va $G_x(x,y;x_1,y_1)=-N_{x_1}(x,y;x_1,y_1)$

bo‘lgani uchun, kiritilgan belgilashlarni hisobga olgan holda, qo‘shiluvchi integrallarni bo‘laklab integrallaganda, quyidagi tengliklarga ega bo‘lamiz:

$$\nu_2^+(y)=\int_0^1 \tau_1^{+\prime}(x_1)N(0,y;x_1,0)dx_1-\int_0^y \tau_2^{+\prime}(y_1)N(0,y;0,y_1)dy_1+$$

$$+\int_0^y \tau_3^{-\prime}(y_1)N(0,y;1,y_1)dy_1,$$

$$\nu_3^-(y)=\int_0^1 \tau_1^{+\prime}(x_1)N(1,y;x_1,0)dx_1-\int_0^y \tau_2^{+\prime}(y_1)N(1,y;0,y_1)dy_1+$$

$$+\int_0^y \tau_3^{-\prime}(y_1)N(1,y;1,y_1)dy_1.$$

So‘ngra, oxirgi ikkita tenglikdan (8) va (9)dan foydalanib, $\nu_i^{\pm}(t)$ $(i=2,3)$ni chiqarib tashlab, $\tau_i^{\pm}(t)$, $(i=2,3)$ga nisbatan quyidagi integral tenglamasini hosil qilamiz:

$$\begin{cases} \tau_2^+{}'(y) + \int\limits_0^y \tau_2^+{}'(y_1) N(0,y;0,y_1)dy_1 - \int\limits_0^y \tau_3^-{}'(y_1) N(0,y;1,y_1)dy_1 = F_1(y), \\ \tau_3^-{}'(y) + \int\limits_0^y \tau_3^-{}'(y_1) N(1,y;1,y_1)dy_1 - \int\limits_0^y \tau_2^+{}'(y_1) N(1,y;0,y_1)dy_1 = F_2(y). \end{cases}$$

Bu yerda

$$F_1(y) = -\int\limits_0^1 \tau_1^+{}'(x_1) N(0,y;x_1,0)dx_1 + \frac{\varphi_2(y)}{1+\mu_2(y)},$$

$$F_2(y) = -\int\limits_0^1 \tau_1^+{}'(x_1) N(1,y;x_1,0)dx_1 + \frac{\varphi_3(y)}{1+\mu_3(y)}.$$

Xulosa. Integral tenglamalarning nazariyasiga ko‘ra [9], yuqorida keltirilgan Volterra tipidagi integral tenglamalar sistemasi bir qiymatli va qo‘shimcha shartlarsiz yechimga ega bo‘ladi.

Keyin masalaning yechimini Ω_0 soha ichida (11) formula orqali, qolgan sohalarda esa Dalamber formulasi yordamida Koshi masalasining yechimi sifatida topamiz. Teorema to‘liq isbotlandi.

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MONOKRISTALL KREMNIYDA RUX VA SELEN ATOMLARINI DIFFUZION LEGIRLASH ORQALI Si_2ZnSe BINAR NANOKLASTERLARNI HOSIL QILISH VA ULARNING ELEKTROFIZIK XOSSALARI

Annotatsiya. *Ushbu maqolada monokristall kremniy (Si) panjarasida rux (Zn) va selen (Se) kirishma atomlarini ikki bosqichli past haroratli diffuzion texnologiya yordamida kiritish asosida Si^2ZnSe tuzilishidagi nanoo‘lchamdagi binar birikmali elementar yacheykalarni shakllantirish natijalari bayon etilgan. Tajribalar KEF-100 ($N_P=4\cdot10^{13}$ sm^{-3}) va KDB-0,5 markali monokristall kremniyda T=1150°C haroratda, t=1÷4 soat davomida gaz fazasidan diffuziya usulida amalga oshirilgan. Skanerlovchi elektron mikroskop (SEM JSM-IT 200), rentgenfazaviy tahlil (XRD PANalytical Empyrean), Raman spektrometri va UV-1900i Shimadzu spektrofotometri yordamida olingan kremniy namunalarining element tarkibi va optik xossalari o‘rganildi.*

Kalit so‘zlar: *kremniy, diffuzion legirlash, ZnSe binar birikma, nanoklaster, taqiqlangan soha kengligi, fotoelektrik xossalar, infraqizil fotodetektor.*