# GELMGOLS TENGLAMASI UCHUN INTEGRAL FORMULA

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**Annotasiya:** *Gel'mgolts tenglamasi uchun integral formula keltirilgan.*

*Barcha koeffisentlari o’zgarmas elliptik tenglamalarni almashtirish yordamida Gelm’golts tenglamasiga keltiriladi*

**Kalit so’zlar:** *Gelm’golts tenglamasining yechimining yagonaligi*.

$$\Delta v + cv = 0$$

Bu tenglamaning yechimining xossalari $c$ ga bog’liqdir. Tenglama uchun $\Delta v + k^2 v = 0$ $(k^2 = c > 0)$ (1) masalaning yagonaligini qarab chiqamiz. Maksimum qiymat prinsipiga ko’ra (1) – masalaning yechimi $\Delta v + cv = 0$ $(c < 0)$ biror $T$ sohada va uning chegarasida uzluksiz bo’lsa u holda u o’zining maksimum va minimum qiymatlariga sohaning chegarasida erishadi.

Faraz qilaylik $(M_0)_n$ sohaning ichki sohasi bo’lib $V(M)$ maksimum qiymat bo’lsa ya’ni $v(M_0) > v(M)$ va $[v(M_0) > 0]$ bu nuqtada quyidagi shartlar bajariladi:

$$\frac{\partial^2 v}{\partial x^2} \le 0; \qquad \frac{\partial^2 v}{\partial y^2} \le 0; \qquad \frac{\partial^2 v}{\partial x^2} \le 0$$

Bunda $\Delta v < 0$ kelib chiqadi. Bu esa tenglamaning yechimiga qarama qarshisiz maksimum prinsipidan foydalanish Gelm’golts tenglamasining yechimining yagonaligini ko’rsatamiz. Faraz qilaylik $v(x, y)$ sohada $\Delta v + cv = 0$ $(c < 0)$ tenglamani qanoatlantirib $T + \sum$ uzluksiz bo’lib , $\sum$ qiymati $v\big|\sum = f$ berilgan bo’lsa u holda bu masalaning yechimi $v_1$ va $v_2$ bo’ladi. Teskarisini faraz qilamiz. $v_3 = v_1 - v_2$ yechim bo’lsa $v_3 = v_1 - v_2$ u holda $v_3$ , $\Delta v_3 = 0$. tenglamani qanoatlantiradi va chegarada $v\big|\sum > 0$ qiymatga erishadi. Maksimum prinsipiga ko’ra $v_3(x, y) = 0$ $v_1 \equiv v_2$ agar $c > 0$ bo’lsa u holda yagonalik mavjud emas.

Laplas tenglamasi va Grin formulalaridan foydalanib, Gelmgols tenglamasini Grin formulasidan keltirib chiqaramiz. Buning uchun belgilash kiritamiz.

$L(u) = \Delta u + cu$ (1) tenglama uchun Grin formulasi quyidagi ko’rinishda bo’ladi.

$$\int_T (uL(v)) - vL(u)d\tau = \int_\Sigma \left(u\frac{\partial v}{\partial \text{v}} - v\frac{\partial u}{\partial \text{v}}\right) d\tau$$

Grin formulasidagi $v$-funksiya o’rniga $\frac{e^{-KR}}{R}$ ni olamiz va uning garmonik funksiya ekanini hisobga olsak quyidagi formula hosil bo’ladi.$M_0$

$$u(M_0) = -\frac{1}{4\pi}\int\limits_{\Sigma}\left[u\frac{\partial}{\partial \vee}\left(\frac{e^{-KR}}{R}\right) - \frac{e^{-KR}}{R}\frac{\partial u}{\partial r}\right]\partial v_M +$$

$$+\frac{1}{4\pi}\int_T f(M)\frac{e^{-KR}}{R}\,\partial\tau_M \qquad (R = R_{MM_0}) \qquad (2)$$

Bu yerda $u(M_0)$ $L(u) = f(M)$ tenglamaning yechimidan iborat. $c = k^2$ bo'lgan holda integral formula quyidagi ko'rinishda bo'ladi:

$$u(M_0) = -\frac{1}{4\pi}\int_\Sigma \left[u\frac{\partial}{\partial \vee}\left(\frac{e^{ikR}}{R}\right) - \frac{e^{-ikR}}{R}\frac{\partial u}{\partial r}\right] d\sigma_M + \frac{1}{4\pi}\int_T f(M)\frac{e^{-ikR}}{R}\,d\tau_M \qquad (3)$$

$L(u) = 0$ tenglama uchun integral formuladan foydalanib Manba funksiyani keltirib chiqaramiz. Agar $v(M)$ va $L(v) = 0$ tenglamaning yechimi bo'lsa, u holda Grin formulasidan:

$$0 = -\int_\Sigma \left(u\frac{\partial v}{\partial r} - v\frac{\partial u}{\partial r}\right) d\sigma + \int_T f v\,d\tau \qquad (4)$$

ga ega bo'lamiz.

(4) va (3) formulalarni hadma-had qo'shsak quyidagiga kelamiz:

$$u(M) = -\int\limits_{\Sigma}\left[u\frac{\partial}{\partial \vee}\left(\frac{e^{-KR}}{4\pi R} + v\right) - \left(\frac{e^{-KR}}{4\pi R} + v\right)\frac{\partial u}{\partial r}\right] d\sigma_M +$$

$$+\int_\Sigma \left(\frac{e^{-KR}}{4\pi R} + v\right) f(M)\,d\tau_M \qquad (R = R_{MM_0}) \qquad (5)$$

Bu yerda $v(M)$ funksiya ixtiyoriy regulyar funksiya bo'lib, $-\Delta v - kv = 0$ tenglamani qanoatlantiradi.Agar $v(x)$ ixtiyoriy tanlab olsak, u holda quyidagi formulaga ega bo'lamiz.

$$u(M_0) = -\int_\Sigma u(M)\frac{\partial G(M_0, M)}{\partial r} d\sigma_M + \int_T G(M_0, M) f(M)\,d\tau_M \qquad (6)$$

Bu yerda

$$G(M_0, M) = \frac{e^{-KR}}{4\pi R} + v \qquad (7)$$

manba funksiyasi bo'lib, quyidagi xossalarga ega:

1. $G(M_0, M)$ $M = M_0$ teng bo'lganda bu funksiyaning qiymati cheksizlikka teng.
2. $G(M, M_0)$ $T$ sohada $L(u) = 0$ qanoatlantiradi.
3. $G(P, M_0)$ chegarada nol qiymat qabul qiladi.

Agar Manba funksiyasi ma'lum bo'lsa u holda Dirixle masalasining yechimi bo'lishi mumkin. U holda $v$ funksiya $T$ sohada $L(v) = 0$ tenglamani qanoatlantirib, sohani chegarasida,ya'ni

$$u = -\frac{e^{-KR}}{4\pi R}$$

shartni qanoatlantiradi. Masalan yarim fazoda Grin funksiyasini tuzish mumkin. $z > 0$ yarim fazoda Manba funksiyasi quyidagicha bo'ladi:

$$G(M, M_0) = \frac{e^{-KR}}{4\pi R} - \frac{e^{-KR_1}}{4\pi R_1} \qquad (8)$$

**Gelmgols tenglamasi uchun manba funksiyasi.**

Laplas tenglamasining potensiallar nazariyasidan foydalanib Gelmgols tenglamasi uchun manba funksiyasini tuzamiz. Buning uchun Gelmgols tenglamasini sferik kordinatalar sistemasiga o'tamiz va faqat $r$ ga bog'liq deb hisoblasak, u holda quyidagiga kelamiz:

$$\frac{1}{r^2}\frac{d}{d^r}\left(r^2\frac{dv_0}{dr}\right)=\frac{1}{r}\frac{d_2(rv_0)}{dr^2}$$

Bu quyidagi tenglamaga keladi:

$\frac{d^2w}{dr^2}+cw=0 \quad (w=v_0r) \;\; c=k^2$ bo'lsa, $c>0$ va $c=k^2$ bo'lsa, $c>0$ va $c=-k^2$ bo'lsa $c=0$ almashtirishni olamiz, u holda tenglama quyidagi ko'rinishga ega bo'ladi.

$$\frac{d^2w}{dr^2}+k^2w=0 \quad (c>0) \qquad (9)$$

$$\frac{d^2w}{dr^2}-k^2w=0 \quad (c<0) \qquad (9.1)$$

(9) tenglamaning umumiy yechimi:

$$w=c_1e^{ikr}+c_re^{-ikr} \qquad (10)$$

(9.1)tenglamaning umumiy yechimi:

$$v_0=c_1\frac{e^{ikr}}{r}+c_2\frac{e^{-ikr}}{r} \qquad (11)$$

Agar $k$ haqiqiy qiymatga ega bo'lsa $\frac{e^{ikr}}{r}$ lar ikkita o'zaro chiziqli bog'lanmagan $\frac{\cos kr}{r}$ va $\frac{\sin kr}{r}$ funksiyalarga ajraladi. (1.4.9)tenglama 2 ta chiziqli bog'lanmagan $\frac{e^{-kr}}{r}$ va $\frac{e^{kr}}{r}$ $(k>0)$ funksiyalarga ajraladi.

Funksiya

$$\frac{e^{\pm kr}}{r} \;\; (c>0) \text{ va } \frac{e^{\pm kr}}{r} \;\; (c<0) \qquad (12)$$

Funksiyalar $r=0$ da xuddi $\frac{1}{r}$ ga o'xshash maxsus nuqtaga ega bo'ladi va u Laplas tenglamasiga ko'ra manba funksiyasi bo'ladi.

Bu funksiyani $(c<0)$ bo'lganda bitta $r\to\infty$ da nolga intiladi. Agar $|c|=k^2$ bo'lsa, u holda $r\to\infty$ da bu funksiya $\infty$ intiladi.

**$\Delta v+cv=0$ ga keltiriladigan masalalar.**

Mexanikada shunday tebranma harakatlar mavjudki, uning tenglamasi quyidagi formula orqali ifodalanadi:

$$\Delta v+k^2v=0 \;\; (k^2=c>0) \qquad (13)$$

Chetlari mahkamlangan membrananing tebranish tenglamasi, agar tashqi kuch bo'lsa quyidagicha bo'ladi:

$$\Delta_2\bar{u}=\frac{1}{a^2}\bar{a}_{tt}-F_0(x,y)\cos wt \qquad (14)$$

Eyler formulasidan foydalanib, kompleks ko'rinishdagi ifoda quyidagicha:

$$\Delta_2u=\frac{1}{a^2}u_{tt}-F_0(x,y)e^{iwt} \qquad (15)$$

Bundan ko’rinadiki $\bar{u}$ haqiqiy qismining yechimidir. Yechimni quyidagi ko’rinishda izlaymiz:

$$u = ve^{iwt} \qquad (16)$$

Tebranma harakatning amplitudasi quyidagicha bo’ladi:

$$\Delta_2 u + k^2 v = -F_0(x, y) \qquad \left(k = \frac{w}{a}\right) \qquad (17)$$

Bunga $\frac{v}{c} = 0$ shartni qo’yish lozim, agar membrananing chetlari mahkamlanmagan bo’lsa, u holda chastotasi $w$ ga teng bo’lgan tebranma harakat hosil bo’ladi. Uning yechimi:

$$\frac{u}{c} = f_0 e^{iwt} \qquad (18)$$

Bir jinsli bo’lmagan tenglama uchun quyidagi shartni qo’yish lozim:

$$\frac{v}{c} = f_0 \qquad (18.1)$$

**Gelmgols tenglamasi uchun tashqi masalani qo’yish.**

Barcha koeffitsentlari o’zgarmas elliptik tenglamalarni almashtirish yordamida Gelmgols tenglamasiga keltiriladi, ya’ni

$$\Delta v + cv = 0 \qquad (19)$$

(19) tenglama yechimining xossalari $c$ ga bog’liqdir. Tenglama uchun (13) masalaning yagonaligini qarab chiqamiz. Maksimum prinsipiga ko’ra (19) masalaning yechimi $\Delta v + cv = 0$ $(c < 0)$ biror $T$ sohada va uning chegarasiga uzluksiz bo’lsa, u holda u o’zining maksimum va minimum qiymatlarini sohaning chegarasida erishadi.

Faraz qilaylik $(M_0)_n$ sohaning ichki sohasi bo’lib, $V(M)$ maksimum qiymat bo’lsa, ya’ni $v(M_0) > v(M)$ va $[v(M_0) > 0]$ bu nuqtada quyidagi shartlar bajariladi:

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