

QUVURLARDAGI IKKI FAZALI MUHITDA VAQTINCHALIK HARAKAT

TRANSIENT FLOW OF A TWO-PHASE MEDIUM IN PIPELINES

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Annotatsiya: Ushbu maqola filtrlash uchun suv yo'qotilishini hisobga olgan holda turbulent beqaror harakatni (ikki o'lchovli holat) tavsiflovchi differentsial tenglamalar tizimini yechish yo'llari yoritiladi. Variatsion-farq usuli qo'llaniladi va sonli natijalar keltiriladi.

Annotation: This article solves systems of differential equations that describe turbulent unsteady motion (two-dimensional case), taking into account water losses due to filtration. The variational-difference method is applied and numerical results are presented.

Kalit so'zlar: kvazy bir o'lchovli vaqtinchalik harakat, quvurlardagi ikki fazali muhit, gidravlik qarshilik, quvurlar kesishgan maydoni, Laplas transformatsiyasi, qutblar.

Keywords: quasi-one-dimensional transient motion, two-phase media in pipes, hydraulic resistance, pipe cross-sectional area, Laplace transform, poles.

Kirish.

Ushbu maqolada, ikki fazali muhitning kvaziyali bir o'lchovli beqaror harakatining tenglamalari gidravlik qarshilik (1) hisobga olingan holda kvazistatsion gipotezani qo'llash asosida olingan.

ADABIYOTLAR TAHLILI VA METODOLOGIYA

Silindrsimon trubadagi ikki fazali suyuqlikning harakat tenglamalari (2) shaklga ega ekanligi ma'lum.

$$\rho_1 \frac{\partial u_1}{\partial t} = f_1 \mu_1 \left(\frac{\partial^2 u_1}{\partial r^2} + \frac{1}{r} \frac{\partial u_1}{\partial r} \right) + k(u_2 - u_1) - f_1 \frac{\partial p}{\partial z}, \quad (1)$$

$$\rho_2 \frac{\partial u_2}{\partial t} = f_2 \mu_2 \left(\frac{\partial^2 u_2}{\partial r^2} + \frac{1}{r} \frac{\partial u_2}{\partial r} \right) + k(u_1 - u_2) - f_2 \frac{\partial p}{\partial z}, \quad (2)$$

Bu yerda $\mu_1, \mu_2, \rho_1, \rho_2$ – birinchi va ikkinchi fazalarning yopishqoqligi va zichligi;

f_1, f_2 – g‘ovakliligi; k – o‘zaro ta’sir koeffitsienti.

MUHOKAMA VA NATIJALAR

(1) va (2) tengliklarni ko‘paytirib $2\pi f_1 f_2 r dr$ va 0 dan R gacha integrallab, (2) dan foydalanib, oddiy o‘zgarishlardan keyin biz quyidagi natijani olamiz

$$-f_1^2 f_2 \frac{\partial p}{\partial z} = f_2 \rho_1 \frac{\partial W_1}{\partial t} - f_1 f_2 \mu_1 A_1 W_1 - k(f_1 W_2 - f_2 W_1). \quad (3)$$

$$-f_2^2 f_1 \frac{\partial p}{\partial z} = f_1 \rho_2 \frac{\partial W_2}{\partial t} - f_1 f_2 \mu_2 A_2 W_2 - k(f_2 W_1 - f_1 W_2). \quad (4)$$

Bu yerda,

$$A_1 = \frac{\alpha_1^0 \frac{mI_1(mR)}{I_0(mR)} - \frac{kR}{2f_1 f_2 \mu_1 \mu_2}}{\alpha_1^0 \frac{I_1(mR)}{mI_0(mR)} + \left(\frac{kR^2}{8f_1 f_2 \mu_1 \mu_2} - \alpha_1^0 \right)}; A_2 = \frac{\alpha_2^0 \frac{mI_1(mR)}{I_0(mR)} - \frac{kR}{2f_1 f_2 \mu_1 \mu_2}}{\alpha_2^0 \frac{I_1(mR)}{mI_0(mR)} + \left(\frac{kR^2}{8f_1 f_2 \mu_1 \mu_2} - \alpha_2^0 \right)};$$

$$\alpha_1^0 = \frac{1}{f_1 \mu_1 + f_2 \mu_2} - \frac{1}{\mu_1}; \alpha_2^0 = \frac{1}{f_1 \mu_1 + f_2 \mu_2} - \frac{1}{\mu_2};$$

W_1, W_2 – birinchi va ikkinchi fazalarning o‘rtacha tezligi.

Ikki fazali muhit uchun doimiylik tenglamasi quyidagi shaklga ega

$$\frac{\partial p_i}{\partial t} + \frac{\partial(\rho_i u_i)}{\partial r} + \frac{\partial(\rho_i u_i)}{\partial z} + \frac{\rho_i u_i}{r} = 0, \quad (i=1,2). \quad (5)$$

(5) ni $2\pi f_i r dr$ ga ko‘paytirib va 0 dan R gacha integrallab, har bir tarkibiy qism uchun alohida, quyidagilarni yozamiz

$$f_1 s \frac{\partial \rho_1}{\partial t} + \frac{\partial M_1}{\partial z} = 0. \quad (6), \quad f_2 s \frac{\partial \rho_2}{\partial t} + \frac{\partial M_2}{\partial z} = 0. \quad (7)$$

Bu yerda $M_i = 2\pi f_i \int_0^R \rho_i u_i r dr$ – massa xarajatlari, s- truba kesimining yuzi.

, aralashmaning o‘rtacha zichligi va trubaning maydoni uchun Гук Aytaylik

qonuni amal qiladi $\rho_{cm} = \rho_0 \left(1 + \frac{p - p_0}{K_{\text{жс}}} \right), s = s_0 \left(1 + \alpha \frac{p - p_0}{E} \right),$

Bu yerda ρ_0 - P_0 bosim zichligi s_0 - $p = p_0$ bo'lgandagi yuza. $K_{\text{жс}}$ - suyuqlikni siqish moduli, E-elasticlik moduli, α - o'lchovsiz koeffitsient. (1) tenglamaga ko'ra $\alpha \frac{(p-p_0)^2}{K_{\text{жс}} E}$, bundan,

$$\rho_{cm} s = s_0 \rho_0 \left[1 + \left(\frac{1}{K_{\text{жс}}} + \frac{\alpha}{E} \right) (p - p_0) \right]. \quad (8)$$

(6) va (7) ni qo'shib, (8) ni hisobga olgan holda va ba'zi o'zgarishlardan keyin quyidagini yozamiz

$$-\frac{1}{c^2} \frac{\partial p}{\partial t} = \frac{\partial(\rho_1 W_1)}{\partial z} + \frac{\partial(\rho_2 W_2)}{\partial z}, \quad \text{bu yerda} \quad c^2 = \frac{k}{\rho_0}, \quad k = \frac{K_{\text{жс}}}{1 + \alpha \frac{K_{\text{жс}}}{E}}$$

(3), (4) va (9) tenglamalar - bu ikki fazali muhitning o'rtacha tezligi, zichligi va bosimi kesishishlariga taalluqli kvazyozometrik harakat.

Olingan tenglamalar, gaz quvurining boshida va oxirida bosim yoki suyuqlik oqimining o'zgarishini o'rganish, shuningdek, ikki fazali muhit (k, μ, ρ va boshqalar) parametrlarini aniqlash uchun teskari muammolarni yechishda qiziqish uyg'otadi.

Quvurlardagi ikki fazali muhitning beqaror harakati masalasini yechishni ko'rib chiqamiz, buning uchun (3), (4) va (9) tenglamalarni quyidagicha yozamiz:

$$\begin{aligned} -\frac{\partial p}{\partial t} &= \frac{\rho_1}{f_1^2} \left(\frac{\partial W_1}{\partial t} + a_1 W_1 + b_1 W_2 \right), \quad -\frac{\partial p}{\partial t} = \frac{\rho_2}{f_2^2} \left(\frac{\partial W_2}{\partial t} + b_2 W_1 + a_2 W_2 \right), \\ -\frac{\partial p}{\partial t} &= c_2 \left(\rho_1 \frac{\partial W_1}{\partial z} + \rho_2 \frac{\partial W_2}{\partial z} \right), \quad \text{где} \quad a_1 = \frac{k - f_1 \mu_1 A_1}{\rho_1}, \quad a_2 = \frac{k - f_2 \mu_2 A_2}{\rho_2}, \\ b_1 &= -\frac{k f_1}{\rho_1 (1 - f_1)}, \quad b_2 = -\frac{k f_2}{\rho_2 (1 - f_2)}. \end{aligned} \quad (10)$$

Biz boshlang'ich va chegara sharoitida (10) sistema uchun yechimni qidirmoqdamiz:

$$W_1(z, 0) = W_2(z, 0) = 0, \quad p(z, 0) = 0, \quad p(0, t) = \phi(t), \quad W_1(l, t) = f(t), \quad (11)$$

Bu yerda $\phi(t)$, $f(t)$ -ma'lum farqlanadigan funktsiyalar Laplas transformatsiyasi hisoblanadi.

t, c o'zgaruvchilari bo'yicha Laplas qoidasini (10) tenglamaga qo'llab (II) hisobga olib, biz quyidagini yozamiz

$$\left. \begin{aligned} -\frac{\partial p}{\partial z} &= \frac{\rho_1}{f_1^2} (s + a_1) W_1(z, s) + \frac{\rho_1 b_1}{f_1^2} W_2(z, s) \\ -\frac{\partial p}{\partial z} &= \frac{\rho_2 b_2}{f_2^2} W_1(z, s) + \frac{\rho_2}{f_2^2} (s + a_2) W_2(z, s) \\ -sp &= c^2 \left(\rho_1 \frac{\partial W_1}{\partial z} + \rho_2 \frac{\partial W_2}{\partial z} \right) \end{aligned} \right\} \quad (12),$$

$$p(0, s) = \Phi(s); \quad W_1(l, s) = F(s). \quad (13)$$

(12) sistemaning birinchi ikki tenglamasidan topamiz

$$W_1 = -\frac{\partial p}{\partial z} \cdot \frac{\Delta_1}{\Delta}; W_2 = -\frac{\partial p}{\partial z} \cdot \frac{\Delta_2}{\Delta}; \quad (14)$$

bu yerda

$$\Delta(s) = \alpha_1 s^2 + \alpha_2 s + \alpha_3; \Delta_1(s) = \beta_1 s + \beta_2; \Delta_2(s) = c_1 s + c_2, \quad \alpha_1 = \frac{\rho_1 \rho_2}{f_1^2 f_2^2}; \quad \alpha_2 = \alpha_1 (a_1 + a_2);$$

$$\alpha_3 = (a_1 a_2 - b_1 b_2), \quad \beta_1 = \frac{\rho_2}{f_2^2}; \beta_2 = \frac{\rho_2 a_2}{f_2^2} - \frac{\rho_1 b_1}{f_1^2}; \quad c_1 = \frac{\rho_1}{f_1^2}; c_2 = \frac{\rho_1 a_1}{f_1^2} - \frac{\rho_2 b_2}{f_2^2}.$$

$$\text{systemadan} \quad W_2 = \frac{\Delta_2}{\Delta_1} W_1 = \frac{c_1 s + c_2}{\beta_1 s + \beta_2} W_1 \quad \text{или} \quad W_2 = \frac{c_1}{\beta_1} W_1 + \frac{c_2 \beta_1 - c_1 \beta_2}{\beta_1^2} \cdot \frac{1}{s + \frac{\beta_2}{\beta_1}} \cdot W_1.$$

(14)

undan kelib chiqadiki, $W_1(z, t)$ va $W_2(z, t)$ asl nusxalar funktsional munosabatlar bilan bog'langan

$$W_2(z, t) = \frac{c_1}{\beta_1} W_1(z, t) + \frac{c_2 \beta_1 - c_1 \beta_2}{\beta_1^2} \int_0^1 e^{-\frac{\beta_2}{\beta_1}(t-\tau)} W_1(z, \tau) d\tau. \quad (15)$$

(12) sistemaning uchinchi tenglamasini (14) ga qo'yamiz $\frac{\partial^2 p}{\partial z^2} - \lambda^2 p = 0.$ u

holda $P(z, s) = Ae^{\lambda z} + Be^{-\lambda z}$, $W_1(z, s) = \frac{\lambda \Delta_1}{\Delta} (-Ae^{\lambda z} + Be^{-\lambda z})$.

$$\text{Bu yerda} \quad \lambda(s) = \frac{1}{c} \sqrt{\frac{\alpha_1 s^3 + \alpha_2 s^2 + \alpha_3 s}{\gamma_1 s + \gamma_2}}, \quad (16)$$

$\gamma_1 = \rho_1 \beta_1 + \rho_2 c_1; \gamma_2 = \rho_1 \beta_2 + \rho_2 c_2.$ (13) shart bizga A va B o'zgarmaslarni topishga yordam beradi:

$$A + B = \Phi(s); \quad \frac{\lambda \Delta_1}{\Delta} (-Ae^{\lambda \ell} + Be^{-\lambda \ell}) = F(s), \quad A = \Phi(s) - \Phi(s) \frac{e^{\lambda \ell}}{2ch \lambda \ell} - \frac{\Delta}{\lambda \Delta_1} \cdot \frac{1}{2ch \lambda \ell} F(s).$$

$$B = \Phi(s) \frac{e^{\lambda \ell}}{2ch \lambda \ell} + \frac{\Delta}{\lambda \Delta_1} \cdot \frac{1}{2ch \lambda \ell} F(s).$$

Topshiriqlarning yechimi quyidagi ko'rinishga ega:

$$P(z, s) = s\Phi(s) \frac{ch \lambda (\ell - z)}{sch \lambda \ell} - sF(s) \frac{\Delta}{\lambda \Delta_1} \frac{sh \lambda z}{sch \lambda \ell},$$

$$W_1(z, s) = s\Phi(s) \frac{\lambda \Delta_1}{\Delta} \frac{sh \lambda (\ell - z)}{sch \lambda \ell} + sF(s) \frac{sh \lambda z}{sch \lambda \ell}, \quad (17)$$

Tasvirlar uchun asl nusxalar $S\Phi(s)$ va $SF(s)$ vazifalari mavjud $\phi'(t)$ va $f'(t)$, va tasvirlar mahsuloti asl nusxalarning yaxlit yig'ilishiga mos keladi.

(17) da turgan $S\Phi(s)$ va $SF(s)$ omillarni tahlil qilish kerak.

$\frac{ch \lambda(\ell-z)}{sch \lambda \ell}$, $\frac{sh \lambda z}{sch \lambda \ell}$ funksiyalar tenglamaning ildizlariga mos keladigan oddiy S_η qutblarga ega, $ch[\lambda(s)\ell]=0$ (18)

$$S_0=0, \text{ qutb va funktsiyalar } \frac{\Delta}{\lambda \Delta_1} \frac{sh \lambda z}{sch \lambda \ell}, \frac{\lambda \Delta_1}{\Delta} \frac{sh \lambda(\ell-z)}{sch \lambda \ell}, \quad (19)$$

$$\text{qutblardan tashqari mos ravishda } S = -\frac{\beta_2}{\beta_1} \text{ va } S = -\frac{\gamma_2}{\gamma_1}$$

$$\text{Darhaqiqat, } \frac{\lambda \Delta_1}{\Delta s} \frac{sh \lambda(\ell-z)}{ch \lambda \ell} = \frac{\lambda^2 \Delta_1}{\Delta s} \frac{sh \lambda(\ell-z)}{\lambda ch \lambda \ell} = \frac{\beta_1 s + \beta_2}{\gamma_1 s + \gamma_2} \cdot \frac{sh \lambda(\ell-z)}{\lambda ch \lambda \ell} \cdot i \cdot i \quad s \neq 0, \text{ qiymat}$$

buning uchun $\lambda(s)=0$ funktsiyasi uchun (19) qutb emas, chunki $\lim_{\lambda \rightarrow 0} \frac{sh \lambda z}{\lambda} = z$. (18)

$$\text{dan esa } \cos i \lambda \ell = 0. \text{ bundan } \lambda^2 + \left(\frac{\pi}{2\ell}\right)^2 (2n-1)^2 = 0; \quad n=1,2,\dots \quad (20)$$

Qutblar S_η (20) tenglama yechimlari bo'lib, bunda u (16) tenglik bilan aniqlanadi.

Ushbu funktsiyalarning qoldiqlarini hisoblab, konvolyutsiya teoremasini qo'llasak, masalaning yechimini asl nusxada topamiz.

$$p(z,t) = \phi(t) - \frac{\alpha_3 z}{\beta_2} f(t) + \frac{\Delta \left(-\frac{\beta_2}{\beta_1}\right) sh \left[\lambda \left(-\frac{\beta_2}{\beta_1}\right) z\right]}{\beta_2 \lambda \left(-\frac{\beta_2}{\beta_1}\right) ch \left[\lambda \left(-\frac{\beta_2}{\beta_1}\right) \ell\right]} \cdot \int_0^t f'(\tau) e^{-\frac{\beta_2}{\beta_1}(t-\tau)} d\tau +$$

$$- \frac{2}{\pi} \sum_{k=1}^{\infty} \frac{(-1)^{k-1} i}{2k-1} \cdot \frac{\Delta(S_k)}{S_k \Delta_1(S_k)} \cdot \frac{\sin \left[\frac{\pi z}{2\ell} (2k-1)\right]}{\frac{d\lambda(S_k)}{ds}} \cdot i \cdot \int_0^t f'(\tau) e^{S_k(t-\tau)} d\tau; \quad i$$

$$W_1(z,t) = f(t) + \frac{(\gamma_1 \beta_2 - \gamma_2 \beta_2) sh \left[\lambda \left(-\frac{\gamma_2}{\gamma_1}\right) (\ell-z)\right]}{c^2 \gamma_1^2 \lambda \left(-\frac{\gamma_2}{\gamma_1}\right) ch \left[\lambda \left(-\frac{\gamma_2}{\gamma_1}\right) \ell\right]} \cdot \int_0^t \phi'(\tau) e^{-\frac{\gamma_2}{\gamma_1}(t-\tau)} d\tau +$$

$$+ \sum_{k=1}^{\infty} \frac{(-1)^{k-1} i \cos \left[\frac{\pi z}{2\ell} (2k-1)\right]}{\ell \cdot S_k \frac{\alpha \lambda(S_k)}{ds}} \int_0^t f'(\tau) e^{S_k(t-\tau)} d\tau +$$

$$+\frac{2}{\pi c^2} \sum_{k=1}^{\infty} \frac{(-1)^{k-1}}{2k-1} \cdot \frac{\beta_1 S_k + \beta_2}{\gamma_1 S_k + \gamma_2} \sin \left[\frac{\pi}{2} \left(1 - \frac{z}{\ell} \right) (2k-1) \right] \int_0^t \phi'(\tau) e^{S_k(t-\tau)} d\tau;$$

Ikkinchi fazaning tezligi (15) tenglikdan aniqlanadi.

XULOSA

Muammoning aniq yechimidan bir qator amaliy masalalarni ko‘rib chiqishda foydalanish mumkin, masalan, suv bosimi, quvurlardagi bosim o‘zgarishi.

REFERENCES

1. Чарный И.А. Неустановившееся движение реальной жидкости в трубах. М., «Недра», 1975.
2. Файзуллаев Д.Ф. Ламинарное движение многофазных сред в трубопроводах. Ташкент, «Фан» УзССР, 1966.