CHARACTERISTICS OF SHOCK WAVE MOVEMENT

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Abstract. In this thesis, the Burgers equation representing nonlinear wave processes and the problem of its linearization are described. The solutions of the experimental wave equation and the heat diffusion equations are presented.

Key words: dissipative effect, Burgers equation, effort, viscosity, gas dynamics.

Ushbu ishda dissipativ effektlarni qat'iyroq hisobga olgan holda nazariyani takomillashtirishga bag'ishlangan. Buning asosiy modeli Burgers tenglamasidir [1]

$$u_t + uu_x = \nu u_{xx}, \qquad (1)$$

bunda "uzun to'lqinli" tenglamalarni olish imkonini beradigan asimptotik usullar o'rganiladi (Burgers, Korteweg-de Vries va boshqalar). (1) turdagi tenglamani

$$\rho_t + q_x = 0$$

saqlanish qonunidan olish mumkin, bu yerda ρ - saqlangan miqdorning zichligi, q - oqim, quyidagi tenglik o'rinli bo'ladi

$$q = Q(\rho) - \nu\rho_x.$$

Misol uchun bu yo'l harakati masalasi uchun, haydovchilar oldingi mashinalar sonining ko'payishi bilan sekinlashishini anglatadi.

Shunday qilib, (1) tenglama

$$u_t + \left(\frac{u^2}{2} - \nu u_x\right)_x = 0.$$

saqlanish qonuni shakliga ega.

Bundan kelib chiqadiki,

$$S = \int_{-\infty}^{\infty} u dx$$

kattalik harakatning integrali bo'lib, oddiy to'lqin tenglamasidagi kabi yechim profilining asimptotik shaklini aniqlaydi.

Burgers tenglamasini boshqa shaklda ham ifodalash mumkin:

$$u_x - \alpha u u_t = \delta u_{tt}, \qquad (2)$$

Endi u koordinataga nisbatan faqat birinchi tartibli hosilani o'z ichiga oladi va shuning uchun chegara sharti (signalning tarqalishi muammosi) bilan bog'liq masalani tahlil qilish uchun qulayroqdir, (1) tenglama esa koordinatali boshlang'ich shartli masala uchun ko'proq mos keladi. Burgers tenglamasi (2) ko'rinishida ko'pincha chiziqli bo'lmagan akustikada qo'llaniladi va silindrsimon, sferik to'lqinlar va relaksatsiya muhitidagi to'lqinlar holatiga umumlashtiriladi [2, 5].

Tenglamada dissipativ effektlar keskinlashuvni to'xtatishi va zarba to'lqinining shakllanishiga olib kelishi mumkin. Oddiy to'lqin tenglamasi Burgers tenglamasining chegarasi $v \to 0$ sifatida qaraladi va zarba to'lqinini oddiygina matematik uzilish sifatida ko'rib chiqiladi.

Shubhasiz, (1) Burgers tenglamasi

$$\varphi_t = v\varphi_{xx} \qquad (3)$$

issiqlik tarqalish tenglamasining chiziqli bo'lmagan modifikatsiyasidir.

Ammo bundan ham muhimi shundaki, uni Koul va Xopf tomonidan mustaqil ravishda topilgan maxsus transformatsiya yordamida (3) chiziqli tenglamaga keltirish mumkin. Ushbu transformatsiyani ikki bosqichda amalga oshiriladi. Quyidagi belgilash kiritiladi

$$u = \psi_x.$$

Bunda (1) tenglama bir marta integrallashdan keyin quyidagi shaklni oladi

$$\psi_t + \frac{1}{2}\psi_x^2 = v\psi_{xx}.$$

Endi $\psi = -2vln\varphi$ ni o‘rnatib,

$$-2v\frac{\varphi_t}{\varphi} + \frac{1}{2}\left(\frac{2v\varphi_x}{\varphi}\right)^2 = -2v^2\left(\frac{\varphi_x}{\varphi}\right)_x = -2v^2\frac{\varphi_{xx}\varphi - \varphi_x^2}{\varphi^2}$$

ifodani topamiz. $(\varphi_x)^2$ ni o'z ichiga olgan hadlar bir-birini bekor qiladi va φ bo’yicha tenglama chiziqli bo'ladi.

Shunday qilib, Burgers tenglamasi (1)

$$u = -2v\frac{\partial(ln\varphi)}{\partial x} \qquad (4)$$

o'zgarish yordamida (3) issiqlik tarqalish tenglamasiga keladi. Agar

$$u(x; t = 0) = F(x)$$

boshlang‘ich shart bo‘lsa, (4) munosabat φ funksiya uchun shartni bildiradi:

$$\varphi(x; t = 0) = \Phi(x) = exp\left[-\frac{1}{2v}\int_0^x F(\eta)d\eta\right] \qquad (5)$$

Issiqlik o’tkazuvchanlik tenglamasining boshlang'ich sharti (5) bilan yechimi quyidagi ko'rinishga ega

$$\varphi(x,t) = \frac{1}{\sqrt{4\pi vt}}\int_{-\infty}^{\infty}\Phi(\eta)\, exp\left[-\frac{(x-\eta)^2}{4vt}\right]d\eta.$$

Bundan $u(x,t)$ quyidagicha topiladi:

$$u(x,t) = \frac{\int_{-\infty}^{\infty}\frac{x-\eta}{t}exp[-G/2v]d\eta}{\int_{-\infty}^{\infty}exp[-G/2v]d\eta} \qquad (6)$$

$$G(\eta; x,t) = \int_0^{\eta} F(\eta')d\eta' + \frac{(x-\eta)^2}{2t}. \quad (7)$$

(6) va (7) munosabatlar, qoida tariqasida, ixtiyoriy boshlang'ich to'lqin profiliga mos keladigan Burgers tenglamasining yechimini olish imkonini beradi. Albatta, bu formulalarga kiritilgan integrallarni analitik tarzda hisoblash har doim ham mumkin emas. Biroq, bir qator muhim holatlarda buni amalga oshirish mumkin.

Foydalanilgan adabiyotlar

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