International Journal of Mathematics and Computer Research
ISSN: 2320-7167
Volume 09 Issue 10 October 2021, Page no. – 2439-2442
Index Copernicus ICV: 57.55, Impact Factor: 7.184
DOI: 10.47191/ijmcr/v9i10.08

Modelling of Nonlinear Problem Masstransfer in Three-Layer System

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ARTICLE INFO	ABSTRACT
Published Online: 28 October 2021 Corresponding Author: **Rustam Karjavovich Berdiev**	This article discusses modeling of nonlinear system of the differential equations in private derivatives of parabolic type. Especially, modelling of nonlinear problem masstransfer in three-layer system will be analyzed in details.

KEYWORDS: Modeling Of Nonlinear System, Parabolic Type, Masstransfer

INTRODUCTION

We proceed from the following nonlinear system of differential equations

$$\left.\begin{aligned} &\varepsilon(t) - w_0\left(1 - \frac{m_в - y}{m_в - y_{кр}}\right) + \frac{k_1}{2}\frac{\partial^2 y^2}{\partial x^2} = \mu_1 \frac{\partial y}{\partial t} + k_2 \frac{y-h}{m_2} \\ &\frac{T}{a}\frac{\partial h}{\partial t} = T\frac{\partial^2 h}{\partial x^2} + T\chi(H-h) + \frac{k_2}{m_2}(y-h) \end{aligned}\right\}, \qquad (1)$$

Where $w_0, m_в, y_{кр}, k_1, k_2, m_2, \mu_1, a, T, \chi, H$ - some positive constants; $\varepsilon(t)$ - continuous differentiable function ; t ; $y(x,t),\ \ h(x,t)$ - the desired functions. Introducing notation

$$a_1 = \frac{w_0 y_{кр}}{m_в - y_{кр}}; \quad b_1 = \frac{a_1}{y_{кр}}; \quad \mu_2 = \frac{k_2}{m_2}; \quad \mu_3 = \frac{T}{a};$$

The main results and findings

We will rewrite the system (1) in the form

$$\left.\begin{aligned} &\mu_1 \frac{\partial y}{\partial t} = \frac{k_1}{2}\frac{\partial^2 y^2}{\partial x^2} - \mu_2(y-h) + a_1 - b_1 y + \varepsilon(t) \\ &\mu_3 \frac{\partial h}{\partial t} = T\frac{\partial^2 h}{\partial x^2} + T\chi(H-h) + \mu_2(y-h) \end{aligned}\right\} \qquad (2)$$

are looking for the solution of system (2) in the form

$$\left.\begin{aligned} &y(x,t) = \alpha(t)(L-x)^2 + \beta(t) \\ &h(x,t) = \varphi(t)(L-x)^2 + \psi(t) \end{aligned}\right\}, \qquad (3)$$

Where $\alpha(t),\ \beta(t),\ \ \varphi(t)$ и $\psi(t)-$ doubly differentiable functions to be defined. In this case, system (3) automatically satisfies the conditions

$$\frac{\partial y}{\partial x}\Big|_{x=L} = \frac{\partial h}{\partial x}\Big|_{x=L} = 0$$

From (3) we find

$$y^2(x,t) = \alpha^2(t)(L-x)^4 + 2\alpha(t)\beta(t)(l-x)^2 + \beta^2(t);$$

$$\frac{\partial^2 y^2}{\partial x^2} = 12\alpha^2(t)(L-x)^2 + 4\alpha(t)\beta(t) \qquad (4)$$

Substituting (3) into (2) taking into account (4) we get

$$\mu_1\left[\dot{\alpha}(L-x)^2 + \dot{\beta}\right] = 6k_1\alpha^2(t)(L-x)^2 + 2k_1\alpha(t)\beta(t) + a_1 - b_1\left[\alpha(t)(L-x)^2 + \beta(t)\right] +$$

$$+ \varepsilon(t) - \mu_2[\alpha(t) - \varphi(t)](L-x)^2 - \mu_2[\beta(t) - \psi(t)];$$

$$\mu_3\left[\dot{\varphi}(L-x)^2 + \dot{\psi}\right] = 2T\varphi(t) + T\chi H - T\chi\varphi(t)(L-x)^2 - T\chi\psi(t) +$$

$$+ \mu_2[\alpha(t) - \varphi(t)](L-x)^2 + \mu_2[\beta(t) - \psi(t)].$$

Equating the coefficients at $(L-x)^2$ and coefficients independent of $(L-x)^2$, we obtain the following nonlinear system of ordinary differential equations

$$\mu_1\dot{\alpha} = 6k_1\alpha^2(t) - b_1\alpha(t) - \mu_2[\alpha(t) - \varphi(t)]; \qquad (5)$$

$$\mu_1\dot{\beta} = 2k_1\alpha(t)\beta(t) + a_1 - b_1\beta(t) + \varepsilon(t) - \mu_2[\beta(t) - \psi(t)]; \qquad (6)$$

$$\mu_3\dot{\varphi} = -T\chi\varphi(t) + \mu_2[\alpha(t) - \varphi(t)]; \qquad (7)$$

$$\mu_3\dot{\psi} = 2T\varphi(t) + T\chi H - T\chi\psi(t) + \mu_2[\beta(t) - \psi(t)]. \qquad (8)$$

From equation (5) we find

$$\varphi(t) = \frac{1}{\mu_2}\left(\mu_1\dot{\alpha} + b_1\alpha - 6k_1\alpha^2\right) + \alpha = \frac{1}{\mu_2}\left(\mu_1\dot{\alpha} + 6k_1\alpha^2\right) + \frac{b_1+\mu_2}{\mu_2}\alpha \qquad (9)$$

From where follows

$$\dot{\varphi}(t) = \frac{1}{\mu_2}\left[\mu_1\ddot{\alpha} - 12k_1\alpha\dot{\alpha} + (b_1+\mu_2)\dot{\alpha}\right] \qquad (10)$$

Relations (9) and (10) are substituted in (7)

$$\frac{\mu_3}{\mu_2}\left[\mu_1\ddot{\alpha} - 12k_1\alpha\dot{\alpha} + (b_1+\mu_2)\dot{\alpha}\right] = -\frac{T\chi}{\mu_2}\left[\mu_1\dot{\alpha} - 6k_1\alpha^2 + (b_1+\mu_2)\alpha\right] -$$

$$-\mu_1\dot{\alpha} - b_1\alpha + 6k_1\alpha^2.$$

After the reduction of such, we come to the equation

$$\frac{\mu_1\mu_3}{\mu_2}\ddot{\alpha} - \frac{12k_1\mu_3}{\mu_2}\alpha\dot{\alpha} + \frac{1}{\mu_2}\left[\mu_3(b_1+\mu_2) + \mu_1T\chi + \mu_1\mu_2\right]\dot{\alpha} -$$

$$-\frac{6k_1}{\mu_2}(\mu_2 + T\chi)\alpha^2 + \frac{1}{\mu_2}\left[b_1\mu_2 + (b_1+\mu_2)T\chi\right]\alpha = 0,$$ or abbreviating to μ_2, we get

$$\mu_1\mu_3\ddot{\alpha} - 12k_1\mu_3\alpha\dot{\alpha} + \left[\mu_3(b_1+\mu_2) + \mu_1T\chi + \mu_1\mu_2\right]\dot{\alpha} - 6k_1(\mu_2 + T\chi)\alpha^2 +$$

$$+\left[b_1\mu_2+\left(b_1+\mu_2\right)T\chi\right]\alpha=0 \tag{11}$$

Regarding the function $h(x,t)$ let's introduce an additional condition

$$\frac{\partial h}{\partial x}\Big|_{x=0}=\varpi(t), \tag{12}$$

where $\varpi(t)-$ a known doubly differentiable function of t, then it follows from the second equation of system (3) that

$$\varphi(t)=-\frac{1}{L}\varpi(t) \tag{13}$$

As a result, the general Riccati equation follows from (9)

$$\dot{\alpha}=A_1\alpha^2-A_2\alpha+\lambda(t) \tag{14}$$

By staging $\alpha=E(t)\,u(t)$, где $E(t)=\exp\int(-A_2)dt$

leads equation (14) to the form

$$\dot{u}=A_1e^{-A_2t}u^2+\lambda(t)e^{A_2t}, \quad \text{т.е.} \tag{15}$$

the linear term vanishes. By asking $\varpi(t)$, and therefore and $\lambda(t)$ decision $u(t)$ you can write out $[1]$ and write on the basis of (11) the following equation

$$\ddot{\alpha}-12\frac{k_1}{\mu_1}\alpha\dot{\alpha}+B_1\dot{\alpha}-6\frac{k_1}{\mu_1\mu_3}\alpha^2=A_3\zeta(t), \tag{16}$$

which, when substituting solution (14), turns into an identity.

We are interested in an independent solution with a possible change in the right part (16)

Conclusion

In $[1]$ the method of obtaining the solution of equation f. 6.37 is specified (p.490)

$y''+2yy'+f(x)(y'+y^2)=g(x)$ using substitution

$$v(x)=y'+y^2, \text{ which boils down to } v'+f(x)v=g(x). \tag{17}$$

In our case , it is necessary to use the substitution

$w(t)=\alpha'-\dfrac{6k_1}{\mu_1\mu_3B}$ and counting the variations of the left honor constant (16) of consciousness alignment to (17).

Functions $\beta(t)$ and $\psi(t)$ are found by integrating (6) and (8).

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