Non-Local Heat/Mass Transfer Equation with Time Delay Applied to Gentamicin Relase from Hydrogel

Teodor M. Atanckovic[1] , Vesna Mišković-Stanković[2]

[1]Serbian Academy of Sciences and Arts, Belgrade, Serbia

[2]University Union-Nikola Tesla, Belgrade, Serbia

e-mail address[1] atanackovic@uns.ac.rs

e-mail address[2] vesna.miskovicstankovic@unionnikolatesla.edu.rs

EXTENDED ABSTRACT

Recently we developed non-local elasticity if Eringen type with special type of time delay function [1],[2]. In this work we developeda Cattaneo type non-local heat/diffusion equation with time delay. Thus the mass flux $q(x,t)$ at the point x and time t depends of the concentration gradient at the point ξ and time $t-|x-\xi|/c$ that is $\partial c(\xi, t-|x-\xi|/c)/\partial\xi$ where $\xi \neq x$ and $|x-\xi|$ is the distance between points x and that is ξ and c is the finite speed of propagation of non-local action. Therefore the mass flux is given as

$$q(x,t-\tau_Q) = -D\int_{-\infty}^{\infty} K_{\alpha,\lambda}(x-\xi)\frac{\partial c(\xi, t-[\tau_c+|x-\xi|/c])}{\partial\xi}\,d\xi.$$

Here τ_Q and τ_c denote the relaxation times and D is the diffusion coefficient. The constant τ_Q is interpreted as the relaxation time due to the fast-transient effects (inertia) while τ_c is interpreted as time delay caused by the micro-structural interactions. This equation removes the paradox of the infinite speed of propagation of the non-local action and together with the mass balance equation $\partial c(x,t)/\partial t = -\partial q(x,t)/\partial x$ defines that complete set of equations that are solved. The krnel function $K_{\alpha,\lambda}(x-\xi)$ is taken in the form of General fractional derivative. The parameters α and λ denote the order of the general fractional derivative and the fading parameter, respectively [3]. Generalization presented here allow us to obtain classical Fick's diffusion and Eringen type non-local diffusion as special cases.

This sistem of equations is applied to the problem of release of antibiotic gentamicin in poly (vinylalcohol)/gentamicin (PVA/Gent) hydrogel aimed for wound dressing in medical treatment of deep chronical wounds. The PVA/Gent hydrogel was prepared by physical crosslinking of poly (vinyl alcohol) dispersion using freezing-thawing method in 5 cycles. One cycle consisted of freezing for 16 h at -18 ºC, followed by thawing for 8 h at 4 ºC. Then, the PVA/Gent hydrogel was swollen in gentamicin solution at 37 Cº during 48 h [4]. For the drug release monitoring the PVA/Gent hydrogel was immersed in deionized water and kept at 37°C. The concentration of released gentamicin with time was determined using a high-

performance liquid chromatography (HPLC) coupled with mass spectrometer (MS). The experimental profile of gentamicin release was fitted with proposed mathematical model.

REFERENCES

[1] T. M. Atanackovic, A Non-Local wave equation with General fractional derivatives and time delay (Proceedings Paper) IFAC PAPERSONLINE, (2024), vol. 58 br. 12, str. 364-367.

[2] A note on the non-local heat equation with time delay / T. M. Atanackovic, Enes Kacapor, Diana Dolicanin Djekic, Ersin Gilic, Mathematical Methods in the Applied Sciences. ISSN 0170-4214. https://doi.org/10.1002/mma.70304

[3] Vesna Mišković-Stanković, Teodor Atanackovic, *Novel Antibacterial Biomaterials for Medical Applications and Modeling of Drug Release Process,* Taylor & Francis/CRC Press, Boca Raton, USA, 2024, ISBN 1032668873, 9781032668871. https:// doi.org/ 10.1201/ 9781032668895

[4] Vesna Miskovic-Stankovic, Marko Janev, Teodor M. Atanackovic, Two compartmental fractional derivative model with General fractional derivative, *J. Pharmacokinet. Pharmacodyn.* **50** (2023) 79- 87. https://doi.org/10.1007/s10928-022-09834-8