www.elsevier.com/locate/yjtbi

BACTERIAL GLIDING FLUID DYNAMICS ON A LAYER OF NON-NEWTONIAN SLIME: *PERTURBATION AND NUMERICAL STUDY*

N. Ali, Z. Asghar, O. Anwar Bég, M. Sajid

PII: S0022-5193(16)00101-6
DOI: http://dx.doi.org/10.1016/j.jtbi.2016.02.011
Reference: YJTBI8540

To appear in: *Journal of Theoretical Biology*

Received date: 10 November 2015
Revised date: 8 February 2016
Accepted date: 11 February 2016

Cite this article as: N. Ali, Z. Asghar, O. Anwar Bég and M. Sajid BACTERIAL GLIDING FLUID DYNAMICS ON A LAYER OF NON-NEWTONIAN SLIME: *PERTURBATION AND NUMERICAL STUDY*, *Journa of Theoretical Biology,* http://dx.doi.org/10.1016/j.jtbi.2016.02.011

BACTERIAL GLIDING FLUID DYNAMICS ON A LAYER OF NON-NEWTONIAN SLIME: *PERTURBATION AND NUMERICAL STUDY*

N. Ali[a], Z. Asghar[a*], O. Anwar Bég[b] and M. Sajid[c]

[a] *Department of Mathematics and Statistics, International Islamic University, Islamabad 44000, Pakistan.*

[b] *Fluid Mechanics Group, Mechanical and Aeronautical Engineering Department, Newton Building, The Crescent, Salford University, Manchester, M54WT, England, UK*

[c] *Theoretical Physics Division, PINSTECH, P.O. Nilore, Islamabad 44000, Pakistan.*

Abstract:

Gliding bacteria are an assorted group of rod-shaped prokaryotes that adhere to and glide on certain layers of ooze slime attached to a substratum. Due to the absence of organelles of motility, such as flagella, the gliding motion is caused by the waves moving down the outer surface of these rod-shaped cells. In the present study we employ an undulating surface model to investigate the motility of bacteria on a layer of non-Newtonian slime. The rheological behavior of the slime is characterized by an appropriate constitutive equation, namely the Carreau model. Employing the balances of mass and momentum conservation, the hydrodynamic undulating surface model is transformed into a fourth-order nonlinear differential equation in terms of a stream function under the long wavelength assumption. A perturbation approach is adopted to obtain closed form expressions for stream function, pressure rise per wavelength, forces generated by the organism and power required for propulsion. A numerical technique based on an implicit finite difference scheme is also employed to investigate various features of the model for large values of the rheological parameters of the slime. Verification of the numerical solutions is achieved with a variational finite element method (FEM). The computations demonstrate that the speed of the glider decreases as the rheology of the slime changes from shear-thinning (pseudo-plastic) to shear-thickening (dilatant). Moreover, the viscoelastic nature of the slime tends to *increase* the swimming speed for the *shear-thinning* case. The fluid flow in the pumping (generated where the organism is not free to move but instead generates a net fluid flow beneath it) is also investigated in detail. The study is relevant to marine anti-bacterial fouling and medical hygiene biophysics.

Keywords: *Carreau non-Newtonian fluid, bacterial gliding, shear-thinning, shear-thickening, perturbation expansions, finite difference method (FDM), finite element method (FEM), propulsive force.*

*Corresponding author. Tel.: + 92 051 9019756; E-mail address: zeeshan.asghar@nu.edu.pk.

1. INTRODUCTION

Gliding is a mode of locomotion adopted by taxonomically heterogeneous rod-shaped prokaryotic bacteria on solid substrata. Gliding bacteria are generally Gram-negative and do not possesses organelles of motility, such as flagella. Some common examples of gliding bacteria