 Proceedings of ICCES'08, pp.1529-1529

Mechanical behaviour of an adhering cell with consideration of damping

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Summary

The purpose of this contribution is the description of the rolling of a single cell by a stochastic approach of the cell-extracellular wall interface behaviour, in both cases of an elastic and a viscous interface. Cell rolling corresponds to the slowing down of the cell during its motion (along the wall of an extracellular matrix, e.g. an artery) followed by the capture of the cell. These stages are greatly influenced by the molecular rupture and adhesion kinetics, occurring at the interface between the cell and the wall of the ECM. Those kinetics correspond to the succession of creation and rupture of molecular bonds, under the effects of mechanical and chemical external actions. The molecular connections (ligand receptor pairs) are modelled as elastic springs in association with a viscous analogical element. A three-dimensional model of these interfacial kinetic events is developed in the present contribution, as an extension of a 2D model, considering an elastic behaviour of the connections (Mefti et al. Int. J. Solids Struc., 2006). This model describes the behaviour of the cell-wall interface in terms of the time evolution of the creation of new molecular connections and the rupture of the existing connections, under the combined effects of the fluid pressure and physical interactions (Van der Waals forces, electrostatic repulsion). From a mechanical point of view, we assume that the cell-wall interface is composed of two elastic shells, namely the wall and the cell membrane, linked by rheological viscous elements, which represent the molecular connections. Both the time and space fluctuations of several parameters (amongst of them the rupture threshold of the bonds) are described by the stochastic field theory. Numerical simulations emphasize the rolling phenomenon, in terms of the time evolution of the number of molecular connections - broken or created - and of the rolling angle. The influence of the mechanical damping of the connections on the behaviour of the contact interface is further highlighte