8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

THE MARGINATION DYNAMICS OF NON-SPHERICAL PARTICLES IN LAMINAR FLOWS

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Key Words: *Transport, Particle Dynamics, Nanomedicine, Finite Element Methods.*

ABSTRACT

The intravascular delivery of nanoparticles for biomedical imaging and therapy is being recognized as a powerful and promising tool in cardiovascular and oncological applications [1,2]. Nanoparticles can be loaded with drug molecules and contrast agents and transported by the blood flow through the circulatory system. They are generally decorated with ligand molecules which are able to interact specifically with antigens expressed over diseased cells (target cells). Several different particles have been presented in the literature and developed that may be used for both delivery and medical diagnosis, ranging in size from few tens of nanometers to hundreds of nanometers and up to few microns; with different shapes, from the classical sphere, to spheroids and even more complex shapes; and with different compositions and chemico-physical properties. Despite this wide variety, the preferential localization of drug molecules at the biological target has not been achieved yet. And this is mainly related to the several sequential biobarriers that may prevent even the smallest nanoparticles to reach the biological target.

As leukocytes during and inflammatory process, optimal nanoparticles should be engineered to marginate (i.e., drift towards the vessel walls) spontaneously. By doing so, a marginating nanoparticle has the ability of sensing the blood vessel walls for biological and biophysical diversities, such as the overexpression of specific antigens or the presence of openings and fenestrations in the endothelium. Indeed the margination of leukocytes is an active process, but an effective way to induce particles margination is the control of their size, shape and density [3].

This work elucidates the process of particle motion and margination as a function of their size, shape and relative density in microchannels. Different shapes of the particles are considered (ellipsoidal, discoidal, cylindrical) and compared with the classical spherical shape. The finite element (FE) and element-free Galerkin (EFG) methods are employed [4]. Strong coupling between the fluid and solid domains is used with the condition that the common nodes (in the FE method) or free points (in the EFG) have the same increments of velocity and displacement within the current time step.

Accuracy of the solutions is studied with respect to the mesh refinement (in FE) and number of free points (in EFG). The results are compared with those available in literature and with experimental observations, derived using in-vitro flow chamber system (Fig.1). Fig.2 gives some preliminary results for the trajectories of a spherical and ellipsoidal particles (2D representation).

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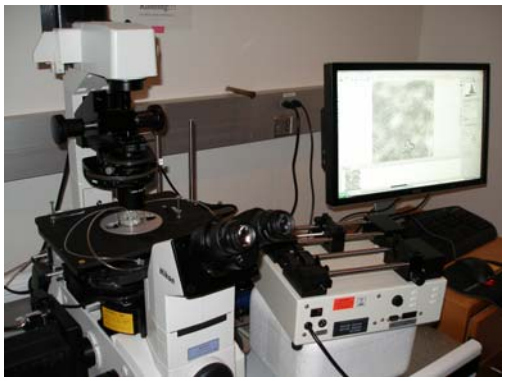

Fig.1 Experimental Apparatus for tracking in-vitro the dynamics of the Particles

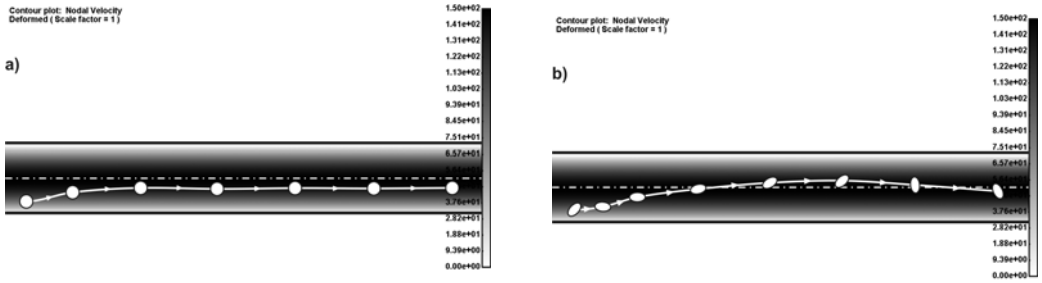

Fig.2 Trajectories of the spherical (a) and elliptical (b) particles within steady fluid flow in a microchannel