Abstract

Most of the studies on flow through porous media dealing with hydrodynamics and mass transfer are limited to steady flow and linear systems. The main aim of the present thesis is to deal with the analytical treatment of the problems arising in porous media. The mathematical model is based on the coupling of Stokes–Darcy/ Stokes–Brinkman system. In order to deal with non–linear system in porous media, asymptotic expansions are very useful tools. This study reports the results extracted from the problems dealing with the hydrodynamics of flow through porous pellets of different geometries (spherical / cylindrical) and the corresponding mass transfer inside the porous pellets. A detailed understanding of the mass transfer inside porous pellets and effect of various parameters on the mass transfer is dictated.

The first part of the thesis explores the hydrodynamic problem, where the Stokes–Darcy/ Stokes–Brinkman coupled systems have been studied under the influence of oscillatory flow. The flow quantities obtained inside the porous pellet have been further used in subsequent chapters to deal with mass transfer. The corresponding convection–diffusion problems coupled with isothermal zero and first order reaction have been solved to deal with mass transfer inside spherical/ cylindrical porous pellet in absence/ presence of external mass transfer. In case of zero order reaction, starvation zones occur due to constant consumption of nutrient. An optimal criterion is proposed to avert the starvation so that the results are physically meaningful. A comparative study of the nutrient transport inside spherical and cylindrical pellet has been done.

The purpose of second part of the thesis is to use the method of matched asymptotic expansions (MMAE) in order to study the two–dimensional steady low Reynolds number flow of a viscous incompressible fluid past a porous circular cylinder. The force exerted by the exterior flow on the surface of the porous cylinder is shown to admit an asymptotic expansion with respect to Reynolds number. Finally, an important hydraulic parameter called the overall bed permeability (OBP) has been obtained for the flow through beds of porous particles via two different models namely cell model and effective medium model. The interparticle interaction has been taken into account via suitable boundary conditions. Various limiting cases have been derived in order to check the correctness of our expressions.

Keywords: Stokes flow, Darcy's law, Brinkman equation, Oscillatory flow, Faxén's laws, Porous pellet, Starvation zone, External mass transfer, Matched asymptotic expansions, Stress jump condition, Overall bed permeability.