Journal Publication 4

The Chemical Engineering Journal, 44 (1990) B57 - B67

Modeling of Axial and Recycle Backmixing Effects in a Biological Packed Bed Loop Reactor

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(Received June 11, 1989)

ABSTRACT

A theoretical model for a packed bed biological loop reactor is presented by considering both external and internal resistances for the general case of Monod kinetics. Numerical solutions have been obtained by the method of orthogonal collocation for a wide range of saturation parameters to cover the two limiting cases of zero-order and first-order kinetics. The numerical solutions for the limiting cases were found to show good agreement with the analytical solutions. The effects of recycle ratio and axial dispersion on the performance of the reactor were studied parametrically. The results show that for low recycle ratios the conversion increases with decrease in Peclet number for first-order and Monod type kinetics; for zero-order kinetics, however, the conversion is independent of both Peclet number and recycle ratio. The effectiveness factor profiles along the length of the reactor were compared for Monod kinetics. It was found that an increase in recycle ratio tends to flatten the profile. The effect of axial dispersion on the concentration profiles at higher recycle ratio was found to be negligible. The dynamics of how steady state conditions are achieved in the reactor is also presented.

1. INTRODUCTION

Packed bed reactors, because of their simple mechanical configuration, together with low capital and operating costs are extensively used in the biological and other industries. A packed bed loop reactor has the added advantage of permitting high efficiency heat exchange. This is a major need for large-scale microbial cultivation of many substrates. The circulation loop also enhances definition of flow and mixing properties in the vessel [1].

A fixed-film packed bed loop reactor is essentially a tubular reactor where part of the exit fluid is recycled back to the inlet stream. The microorganisms grow in a thin biofilm attached to the solid packing material. Thus a fixed-film bioreactor differs from a suspended growth system and offers less handling and treatment problems.

The biofilm is heterogeneous due to the gelatinous matrix holding the microorganisms together. Hence, the organic matter in the bulk liquid phase must diffuse through a complex network of tortuous passages before reaching the microorganisms. Such a mass transfer process makes the response of a fixed-film bioreactor fundamentally different from that of a homogeneous reactor, because as the organic matter from the liquid phase moves into the biofilm, a substrate concentration gradient is produced in the two phases. Since the rates of the microbial reactions are determined by the concentration of substrate surrounding the microbes it is necessary to combine physical mass transport with microbial reactions to model fixed-film reactors [2].

In a fixed-film packed bed loop reactor, two different mixing effects superimpose on each other. One is the axial backmixing in each circulation and the other is backmixing due to recycle alone. The interactions of these two mixing phenomena make the modelling of loop reactors somewhat more difficult as compared to that of an unrecycled

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0300-9467/90/$3.50