GROWTH AND SHEAR LOSS CHARACTERISTICS OF AN AEROBIC BIOFILM

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1990

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A Thesis
submitted in partial fulfilment
of the requirements for the degree of
MASTER OF TECHNOLOGY in Biotechnology
at Massey University

by

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March, 1990

ABSTRACT

The application of biofilms in fermentation and waste treatment processes has been increasingly considered in recent years due to several inherent advantages over suspended growth systems. For example, they enable higher biomass hold-up providing larger quantity of cell per unit reactor volume which allows high loading rates. The biofilm systems , with fixed or immobilised cells, avoid washout conditions. The often difficult problems of sludge thickening, separation, recycle, and wasting associated with suspended growth systems are eliminated for biofilm systems. However, the major drawback lies in the control of film thickness in order to maintain high reactor productivities.

The attached film thickness depends on both the biological parameters such as growth rate, and physical parameters such as hydrodynamic shear. The understanding of the growth and shear loss characteristics is a prerequisite for effective film thickness control.

The main objective of this work therefore is to investigate the growth and shear loss characteristics of an aerobic biofilm utilizing phenol in a concentric cylindrical bioreactor. The growth and detachment of the

biofilm was studied at different shear stresses, and their relationships were established. Detachment by shear was studied under two different conditions. One was examined simultaneously with growth under a constant shear stress where the biofilm detachment and growth occurred at the same time in the bioreactor. The other was examined via a separate shear test performed on the biofilm initially grown at a shear stress lower than that applied during the test. A method for measuring the torque exerted on the biofilm surface was first developed to enable computation of the related shear stress necessary for the study.

The effect of film thickness on torque at film surface for a constant rotational speed was not significant. Shear stress can be conveniently determined from a quadratic relationship between torque and rotational speed for the range of film thickness studied.

The substrate consumption is directly proportional to film thickness up to about 0.050 to 0.100 mm only, and beyond that it becomes independent of film thickness.

The mass transfer resistance in the liquid phase appears to reach a minimum at shear stress greater than 3.44 N/m^2 coinciding with the maximum steady-state substrate removal rate.

The shear loss resistance of the biofilm increases with increasing shear stress during growth. The ultimate shear loss rate and shear stress relationship follows approximately:

$$R_S = (40.82 - 2.75\sigma + 0.15\sigma^2 - 31.83e^{-0.61\sigma}) \times 10^{-2}$$

The net growth rate varies with shear stress according to a parabolic function which predicts a shear stress of 19 N/m^2 is required to achieve zero net growth.

The biofilm-support adhesion must remain stronger than the film layer adhesion, otherwise, detachment will occur at the film-support interface rendering it impossible to control the film thickness.

ACKNOWLEDGEMENTS

I am greatly indebted to my supervisor, Dr S. M. Rao Bhamidimarri for his advice, guidance and inspiration during the course of this study, and to the Department of Biotechnology for providing the facilities to enable this research.

I also like to extend my appreciation and gratitude to the staff of Biotechnology Department and fellow students who had given me their help and support generously whenever required.

My special thanks to Mr John Algers for his technical assistance and expedious job in organizing the experimental equipment, without whom, the timely completion of this project will not be possible. Thanks also for his pleasant friendship and sense of humour that made my stay at Massey most comfortable and enjoyable.

The invaluable assistance of Mr Sridhar Susarla and Mr Wayne Mallet in the use of computers are gratefully acknowledged.

Last of all, my heartfelt thanks to my wife, Hong Kiow, for her love, patience, and cheerful endurance during the

many evenings and weekends when I have to work late on this project; and also to my parents for their never-ending support throughout the course of this graduate study.

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CHAPTER 1

INTRODUCTION

In an aquatic environment, there is a tendency for the microorganisms to adsorb and colonize on submerged surfaces. The immobilized cells grow to form layer-like aggregates known as biofilm. Biofilms present in the natural environment consist of a complex community of primarily bacteria with other organisms such as fungi, algae and protozoa, and utilize the nutrients present in the bulk liquid medium for growth and reproduction. Such activity has its importance in the recycling of organic and inorganic substrates in the natural environment. These processes have been exploited to considerable industrial advantage in various fermentation and wastewater treatment systems e.g. trickling filters, rotating biological contactors and fluidized bed reactors.

Although biofilm or fixed-film biological processes found early application to wastewater treatment, their use declined with the development of suspended growth systems. The earliest application of biofilm system was that of trickling filter and later the rotating biological contactor was developed to achieve higher degree of treatment, eliminating some of the disadvantages of

trickling filters. The fluidized bed being the most recently introduced process, is essentially a hybrid of suspended growth and attached growth system. However, in recent years with the increasingly stringent discharge standard and high strength effluents from expanding manufacturing and processing industries, the application of biofilm or fixed-film has been increasingly considered due to certain inherent advantages over suspended growth systems. For example, they enable higher biomass hold-up, thus providing larger amount of cell per unit reactor volume, and thereby permitting high loading rates and treatment of inhabitory wastes and avoiding washout conditions. The often difficult problems of sludge thickening, separation, recycle, and wasting associated with suspended growth systems are eliminated for biofilm or fixed-film systems.

The major operational problem in fixed film systems is the control of film thickness. Biofilm thickness is thought to affect the performance of the system for a given loading rate and there is an optimum thickness beyond which substrate utilization rate will not increase any further. The mechanisms which act to remove the biomass such as decay, sloughing and attrition are still generally beyond operational control and in many cases they are not sufficient for removal of all excess

biomass. In the foregoing aerobic systems, the rapid consumption and stabilization of the organic substrate inevitably result in rapid cell growth. Thus problem of plugging or clogging of filter beds such as in trickling filters arises due to excessive growth and irregular dislodging/sloughing of thick films, whilst in other fixed-film systems periods of unsteady state system may arise resulting in fluctuating performance.

The accumulation or net attachment of biofilm on surfaces depends on both the biological parameters such as growth rate, and physical parameters such as hydrodynamic shear. The understanding of the growth and shear loss characteristics is a prerequisite for effective control of the film thickness. The existing knowledge of these is limited and no universal model has yet been developed for such control.

The objectives of this research are therefore to:

1. develop a reactor system in which biofilms of required thickness can be obtained under defined shear conditions,
2. develop a method for measuring shear stress in the reactor,
3. study the aerobic biofilm growth characteristic under different shear conditions,

4. study the aerobic biofilm loss characteristic due to hydrodynamic shear,
5. establish relationships between growth rate and shear stress, detachment or shear loss rate and shear stress.