Chemical Engineering Journal 218 (2013) 99–107

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

A fundamental analysis of continuous flow bioreactor models governed by Contois kinetics. IV. Recycle around the whole reactor cascade

Rubayyi T. Alqahtani *, Mark I. Nelson, Annette L. Worthy

School of Mathematics and Applied Statistics, University of Wollongong, Wollongong, NSW 2522, Australia

HIGHLIGHTS

- Examined reactor cascade where recycle from the last reactor to the first reactor.
- Showed that it can improve performance at low residence times.
- At high residence time: a cascade performance with recycle is worse than no recycle.
- For a two-reactor cascade is it better to add a settling unit or a third reactor?

ARTICLE INFO

Article history:
Received 17 August 2012
Received in revised form 23 November 2012
Accepted 5 December 2012
Available online 17 December 2012

Keywords:
Bioreactor
Chemostat
Contois growth kinetics
Nonlinear dynamic
Recycle

ABSTRACT

Prior to discharge into rivers municipal and industrial waste waters may be treated in a reactor cascade that employs a settling unit to recycle biomass from the final cascade reactor to the first. In this paper we use steady-state analyse to examine the process efficiency of such a reactor configuration. The Contois specific growth rate model is used to describe biomass growth.

It is found that there is a critical value of the total residence time which identifies a turning point in the performance of the reactor cascade. In particular, if the total residence time is below the critical value then the settling unit improves the performance of an n-reactor cascade ($n = 2, \ldots, 5$), whereas, if the residence time is above the critical value then the performance of an n-reactor cascade ($n = 2, \ldots, 5$) with the settling unit is inferior to that of a cascade without one. It is shown that the critical values of residence time depends upon the values of the recycle ratio R and the concentration factor C.

We compare the performance of a reactor configuration employing recycle around the whole cascade with that of a cascade in which the settling unit recycles the effluent stream leaving the ith reactor into the feed stream for the ith reactor.

1. Introduction

The industrial treatment of wastewaters typically employs a reactor cascade. In a reactor cascade of n reactors the effluent stream from the ith reactor in the cascade acts as the feed stream for the $(i + 1)$th reactor, i.e. the next reactor. The efficiency of the reactor cascade may be improved by using a settling unit. The settling unit 'captures' and concentrates the microorganisms in the effluent stream of reactor (i) and recycles it into the influent stream of reactor $(j, j \leqslant i)$. The benefit of using the settling unit is that it increases the concentration of microorganisms in reactor j, hopefully leading to an improvement in the performance of the cascade.

In this paper we investigate the use of a recycling unit to reduce the effluent concentration leaving a reactor cascade. We consider a commonly used industrial configuration in which the settling unit is placed after the final reactor of the cascade and recycles a proportion of the effluent stream into the feed stream of the first reactor. This process is illustrated for a two reactor cascade in Fig. 1. We call this scenario configuration (1). This configuration differs from that considered in an earlier paper [20], in which the effluent stream leaving any reactor in the cascade was recycled into its own feed stream. We call this scenario configuration (2). In configuration (2) a settling unit is characterised by a single number, the dimensionless recycle parameter, which ranges between zero (no recycle) and one (perfect recycle) whereas in configuration (1) it is characterised by two parameters: a concentrating factor (C) and a recycle parameter (R). The governing equations concerning the performance of an n-reactor cascade cannot be solved analytically. Therefore, we have illustrated the results numerically for two reactors. Subsequent studies using 3, 4 and 5 reactors (not included) did not influence the findings reported here.

* Corresponding author.
E-mail addresses: rtaa648@uowmail.edu.au (R.T. Alqahtani), mnelson@uow.edu.au (M.I. Nelson), annette_worthy@uow.edu.au (A.L. Worthy).

1385-8947/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cej.2012.12.022