Chemical Engineering Journal 210 (2012) 597–609

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

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

Biodiesel synthesis in an intensified spinning disk reactor

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HIGHLIGHTS

- We demonstrate an improved design of spinning disk reactor for biodiesel synthesis.
- The geometric parameters of inter-disk space, and disk topology are shown to have a key effect on performance.
- The modeling provides new insights into the fluid mechanics of a constrained high shear two phase flow.
- A quantitative model for conversion as a function of disk speed and geometry is validated.
- The results raise questions on the extent of mass transfer limitation in biodiesel synthesis.

ARTICLE INFO

Article history:
Received 11 May 2012
Received in revised form 15 August 2012
Accepted 17 August 2012
Available online 28 August 2012

Keywords:
Process intensification
Spinning disk reactors
Liquid–liquid reactions
Biodiesel
Finite element modeling

ABSTRACT

In this paper we describe an innovation for the intensified synthesis of biodiesel, exploiting a two-disk spinning disk reactor. The reactor comprises two flat disks, located coaxially and parallel to each other with a small gap between the disks. The upper disk is located on a rotating shaft while the lower disk is stationary. The feed liquids are introduced coaxially along the center line of each disk, with mixing commencing in the center of the inter-disk gap. The mixed phases flow radially outwards for ejection and coalescence on the inner containment wall of the reactor. Performance results in the reactor for the continuous synthesis of biodiesel from canola oil and methanol in the presence of a sodium hydroxide catalyst are presented. The effects of disk speed, volumetric flowrate, temperature, disk design, and the gap width between the two disks in the reactor were evaluated. The results show potentially a 20–40-fold decrease in residence time for the attainment of equilibrium compared with that determined for a stirred batch reactor used as a "control". The mathematical modeling of the fluid flow conditions in the reactor is described. This provides further understanding of the potential importance of mixing in determining the reactor performance, pointing to some explanation of the relationship between conversion, flowrate, disk speed and geometry. The inter-disk gap, the reaction temperature, and the surface topology of the disks were the most important factors influencing reactor performance. Surprisingly, reactor performance increased as the inter-disk gap width was reduced. The results of the simulations gave an accurate fit with the experimental reactor performance data using true rate constants which were significantly higher than those reported in the literature. This suggests that some literature data may have not taken full account of mass transfer limitation during experimental determination of rate constants for biodiesel synthesis.

1. Introduction

Spinning disk reactors (SDRs) are one of the process intensification technologies employing high gravity fields. The concept has so far been shown as appropriate for fast and very fast liquid/liquid reactions involving large heat effects, such as polymerizations, synthesis of pharmaceutical products, and fine particle production [1,2]. In a spinning disk reactor, a high gravity field–centrifugal force is created by rotation of a disk surface on which liquid is dispersed as a thin film with the free surface of the liquid in contact with a gas. The gas may either be inert or contain a reactant, and may also act as a cooling or heating medium. Disk speeds can be up to 1000 rpm. Typically the liquid flows radially outward under the centrifugal force in the form of a thin film which may be less than 100 μm thick and so offer a short diffusion path length. The film is unstable and forms waves at the gas–liquid interface. Unsteady film surface waves on the disk surface, coupled with the shearing action of the rotating surface, ensure that micro-mixing and excellent mass and heat transfer are achieved. Extensive mass

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http://dx.doi.org/10.1016/j.cej.2012.08.058