Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 105 (2017) 544 – 550

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

Optimizing Acoustic Energy for Better Transesterification: A Novel Sono-Chemical Reactor Design

Mohammed Noorul Hussain[a], Salem Al Kaabi[b], Isam Janajreh*[a]

[a]*Masdar Institute of Science and Technology, Masdar City, Abu Dhabi UAE 54224*
[b]*The Center of Waste Management, Abu Dhabi,UAE 48448*

Abstract

Sono-chemical conversion is a process intensification technique increasingly being applied to several reactions due to its characteristic ability to reduce process time and increase production. Its application to the transesterification reaction (vegetable oil to biodiesel) has been widely studied and it is proven to give better results. Although this provides an advantage in processing time, the production volumes are still limited due to the existing inefficient reactor designs which are mostly batch type. In this work, we design a novel continuous flow sonochemical reactor with the aim to have higher biodiesel production. The uniqueness in the design comes from the shape and the addition of a static mixer. The variations in design (i.e. inclusion and exclusion of static mixer) is studied through numerical simulation of the acoustic wave, cavitation bubble temperature, reactive flow and chemical kinetics in a 2D axi-symmetric model of the reactor. Acoustic pressure, cavitation bubble temperature and biodiesel concentration are studied. It is noticed that the static mixer, which is made of a sound reflecting material, provides several physical advantages which positively affect the biodiesel formation. Due to the static mixer the peak acoustic pressure was higher (1.93 MPa) and also more regions of the reactor experienced acoustic pressure exceeding the blake. This enhanced the cavitation bubble temperatures and the biodiesel mole fractions.

Keywords: Process intensification, Sono-chemical conversion, Transesterification, Acoustic energy, Reactive Flow, Cavitation.

1. Introduction

Sono-chemical conversion is a process intensification technique increasingly being applied to several reactions due to its characteristic ability to reduce process time and increase production. Its application to the transesterification reaction has been widely studied and it is proven to give better results. Transesterification is the reaction between a mole of glycerides in a feedstock like vegetable oil and 3 moles

* Isam Janajreh. Tel.: +971-2-810-9130; fax: +971-2-810-9101.
E-mail address: ijanajreh@masdar.ac.ae.

doi:10.1016/j.egypro.2017.03.354

of an alcohol such as methanol to produce 3 moles of Fatty Acid Alkyl Esters (biodiesel) and one mole of glycerol. This is usually carried out in the presence of a homogenous or heterogeneous catalyst. The production biodiesel is increasingly being carried out through the sono-chemical process as many researchers have established its superiority [1] [2]. However the production volumes are still limited to the batch type sono-reactors. To increase production, continuous reactors need to be designed which process higher volume of species. The Eq. 1 shows the reaction considered.

$$\text{Vegetable oil} + 3\ \text{Methanol} \rightarrow 3\ \text{Biodiesel} + \text{Glycerol} \quad (1)$$

Research on continuous sono-chemical conversion has been carried out experimentally in previous works [1]. Ataya et al [3-5] worked on experimental testing of a continuous packed bed reactor. They studied the effect of having a co-solvent in such a reactor, they found that having a packed bed reactor could provide similar results as in that of a co-solvent. Recent works have used numerical simulation of multiphysics to design and test sono-reactors. For instance Jamshidi et al. [6] used the complex wave number approach to simulate acoustic phenomena in a continuous flow sonochemical reactor for homogenizing nano particle solutions. They tested different geometries for optimizing the reactor design. They also analyzed the effect of rated power and frequency on the acoustic profile. Jordens et al [7] used the same approach to design a continuous flow sonochemical reactor for degradation of CCl4 (Carbon Tetra-chloride). They tested their design at multiple frequencies, rated power and also multiple transducers. Additional to the acoustic simulation, they also evaluated the kinetics of the reaction in correlation to the cavitation bubble temperature and pressure.

In this work we use the approach followed by [6] [7] [8] to test the variants of an indigenously designed sono-reactor. The variations are based on the inclusion and exclusion of a component in the design, which is the static mixer. The modelling is based on the Helmholtz equation, Navier-Stokes equations, species distribution and Arrhenius kinetics. A complex wave number is added to account for wave attenuation. The simulation studies the acoustic pressure cavitation bubble temperature and the biodiesel mole fractions.

2. Methodology

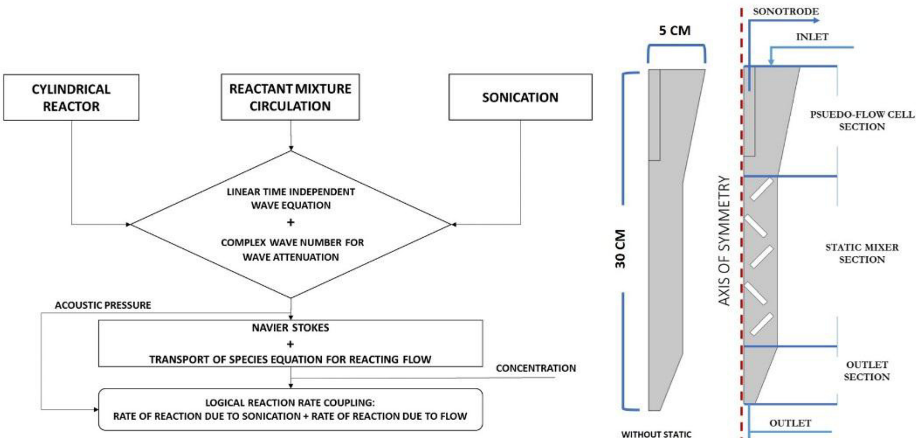

Fig. 1. (left) Schematic of analysis; (center) Design-1 geometry; (right) Design-2 geometry