CHEMICAL ENGINEERING RESEARCH AND DESIGN 90 (2012) 1918–1922

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Research and Design

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

Physicochemical processes in a flow reactor using laser radiation energy for heating reactants

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ABSTRACT

The use of argon as a buffer gas for isolating of the reaction zone from chemical reactor walls for ethane conversion process was studied experimentally. Gas-phase conditions are ensured for realization of chemical processes in such reactors. Reagents are heated by radiation from a continuous CO_2 laser. The value of ethane conversion changes upon variation in the flow rate of argon. Changing the laser generation wavelength in the range of 938–972 cm^{-1} was shown to affect the degree of ethane conversion at close values of laser radiation power. It was found that ethane can be used instead of argon to form the reaction zone.

Keywords: Ethane pyrolysis; Ethylene production; Natural gas production; CFD modeling

1. Introduction

It is well known that the pyrolysis of light hydrocarbons is a gas-phase process. In actually hot walls of pyrolytic furnaces tubes have an effect on chemical processes. As it is generally known, reactions of a radical initiation are facilitated on a surface. At the same time hot surfaces stimulate a synthesis of longer hydrocarbons including soot. A creation of homogeneous conditions is possible with using laser energy.

In our earlier work (Snytnikov et al., 2009) pyrolysis of ethane to ethylene was performed in a flow reactor with energy supplied by laser radiation, which is absorbed directly by the gas. Formation of the reaction zone in the center of reactor was demonstrated. A good agreement of experimental and calculated data for gas flow mixing was obtained. The high-temperature reaction zone in the reactor was insulated via argon supercharging as a buffer gas at the sites of laser radiation input. The other walls were insulated by a relatively cold mixture of reactants. The transformation of laser energy into thermal power occurred due to ethylene. Ethylene absorbed laser radiation energy and heated the gas medium at collisional relaxation. Under such mode of "energetic catalysis", an increase of energy absorption in the reaction volume is related with increasing content of ethylene as the reaction product. The mechanism of ethane dehydrogenation was shown to have the autocatalytic nature with respect to ethylene (Snytnikov et al., 2010, 2011). Three-dimensional calculation of the gas-dynamic reactants flows and their mixing in reactor with a specified geometry was made using the FLUENT software package.

Nevertheless, some factors that may affect the ethane conversion remained unexplored, among them are gas flow rates, laser radiation wavelength, and replacement of argon by other gas. To answer these questions, we constructed a flow reactor. Its geometry implies mainly a rectilinear flow of reactants with the possibility to form a compact reaction zone. The work was aimed at studying the operation of the flow laser reactor in different modes of physicochemical parameters affecting the degree of ethane conversion in a mixture with ethylene under the gas-phase conditions.

2. Experimental

2.1. A reactor with laser input of energy for ethane pyrolysis

A scheme of experimental setup for studying the pyrolysis of light hydrocarbons is presented in Snytnikov et al. (2009). The setup includes a continuous CO_2 laser, a gas flow former, an infrared Fourier spectrometer Infralum FT-801 for control of

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Received 7 April 2011; Received in revised form 3 February 2012; Accepted 1 March 2012
0263-8762/$ – see front matter
doi:10.1016/j.cherd.2012.03.001