

A sodium borohydride hydrogen generation reactor for stationary applications: Experimental and reactor simulation studies

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HIGHLIGHTS

- Ru/Ni-foam catalyst was prepared by electrodeposition.
- Langmuir–Hinshelwood kinetic model proved to be the suitable kinetic model.
- The reaction rate was particularly affected by mass transport resistance.
- Reactor design played an important role on performance.

ARTICLE INFO

Article history:

Received 18 June 2012

Received in revised form

31 July 2012

Accepted 1 August 2012

Available online 10 August 2012

Keywords:

Kinetics

Sodium borohydride

Hydrolysis

Numerical simulation

Modelling

Hydrogen storage

ABSTRACT

Ruthenium on nickel-foam catalyst was prepared for hydrogen production from the hydrolysis reaction of an alkaline NaBH₄ solution. Experiments were carried out at five temperatures (30, 40, 45, 50 and 60 °C) in a 0.1 dm³ small batch reactor. To understand the kinetic behaviour of the hydrolysis reaction in the presence of this catalyst, the experimental data were fitted to three kinetic models (zero-order, first-order and Langmuir–Hinshelwood) using the integral method. Results showed that Langmuir–Hinshelwood model described fairly well the reaction for all tested temperatures and for the entire time range. Zero-order could be applied only at low temperatures or until the concentration of NaBH₄ remained high in the solution; first-order could be only applied efficiently at 60 °C.

In addition to the kinetic study, a dynamic, three dimensional and non-isothermal model was developed to describe a pilot scale reactor for stationary use. The experimental data was used to validate the numerical model which was developed using a commercial solver software. All relevant transport phenomena were treated in detail and the kinetic model developed previously was introduced into the algorithm. Results showed that the reaction rate was extremely affected by the mass transport resistance of sodium borohydride from the bulk to the catalyst surface.

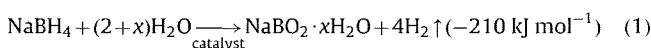
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1. Introduction

During the last two decades chemical hydrides have been considered as promising hydrogen storage materials. In particular, sodium borohydride (NaBH₄) has been widely studied due to its high gravimetric capacity (10.73 wt%). In 2001 Daimler Chrysler demonstrated successfully the Millennium Cell's NaBH₄ system in a minivan (Hyde, 2001). However, in 2007 the U.S. Department of Energy (DOE) recommended a no-go for NaBH₄ for on-board automotive hydrogen storage applications (DOE, 2007). This decision was based on the following observations (Demirci et al., 2009): (1) too low gravimetric hydrogen storage capacity (NaBH₄ solution is a convenient storage way but has a huge limitation, the low solubility of the NaBH₄ and by-products implies the use of

excess water, which leads to a massive decrease of the gravimetric capacity); (2) inefficiency of hydrolysis by-product (NaBO₂) recycling; (3) cost. This no-go decision was only based on specifications for on-board vehicular storage; for portable and niche applications there are not any specific targets, yet several authors believe that NaBH₄ can be a suitable storage material for this kind of applications (Demirci et al., 2009; Liu et al., 2008; Principi et al., 2009).

Typically, in NaBH₄ systems the chemical hydride is premixed with water to form a solution. To avoid auto-hydrolysis a small amount of NaOH is added to stabilise the solution. This solution in contact with a heterogeneous catalyst reacts rapidly according to Eq. (1).



where x is the hydration factor. Much work has been done in order to understand and increase the efficiency of this reaction

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