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Hydrogen production from steam reforming of bio-oil model compound and byproducts elimination

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ABSTRACT

Highly efficient hydrogen production can be produced via catalytic steam reforming of bio-oil. On the basis of fixed-bed reactor system, a bio-oil model compound (m-cresol) was steam reformed on commercial Ni–Co/MgO catalyst. Under the optimal reaction conditions of 850 °C and steam to carbon ratio 5:1, as high as 79.8% of hydrogen yield and 96.8% of carbon conversion can be obtained during 5 h time-on-stream. The results indicated that carbon elimination appears in temperature range of 400–600 °C, and the carbon can be removed completely through its combustion in the air flow at 600 °C. By using the recycling and secondary steam reforming of liquid toxics, the organic pollutants can be eliminated perfectly, and additional hydrogen production was recovered at 850 °C. The compositions of H_2, CO, CH_4 and CO_2 in recovered gas production were 71.5%, 3.7%, 0.2% and 25.0%, respectively. High hydrogen composition of 71.5% was obtained due to the water–gas shift reactions to form hydrogen.

Introduction

In recent years, hydrogen production from biomass has become a new hotspot. Compared with biomass, bio-oil has much higher energy density. Highly efficient hydrogen can be produced via catalytic steam reforming of bio-oil. In addition, the complex feeding system for biomass will be avoided and a simple liquid pump can be qualified for the feeding work. Some researchers have developed the fixed-bed [1,2] or fluidized-bed [3–5] reactor to carry out the bio-oil steam reforming. As a research hotspot, new-type catalyst preparation can be found in many literatures [6–9] in recent years.

In steam reforming of bio-oil or some model compound, as high as 50–60% of hydrogen composition and 70–80% of hydrogen yield can be obtained using Ni-based catalysts. However, some byproducts such as carbon or liquid pollutants will make troubles for continuous operation and sustainable hydrogen production. The blockage of carbon deposition will lead to catalyst deactivation and low reaction efficiency. With the accumulation of carbon, the reactor tube can be finally blocked and the phenomena such as hot spot and pressure

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rising will reduce the reactor service life. Some liquid pollutants formed due to the secondary reactions which are generally toxic will be a threat to the environment. Therefore, in order to achieve continuous bio-oil steam reforming and sustainable hydrogen production, some assistant procedures including carbon elimination and liquid toxics elimination should be carried out after a long-term reaction duration [10].

The objective of this research was to study on the effect of catalyst regeneration and secondary pollution elimination using hydrogen production from steam reforming of bio-oil model compound (m-cresol) in order to achieve a green steam reforming of bio-oil model compound for Hydrogen production and byproducts elimination.

Experimental

Flow sheet and operation

The steam reforming work was carried out on the basis of a set of fixed-bed reactor system. The schematic diagram of experimental apparatus is shown as Fig. 1. The reactor is made of stainless steel with height of 600 mm and inner diameter of 15 mm. A catalyst support is fixed in the reactor tube to support the catalyst grains. The feeding rates of m-cresol and water are controlled by two syringe pumps. The catalyst grains loaded in reactor tube should be reduced in H_2/N_2 (1:1) gas flow (50 mL/min) for 5 h prior to steam reforming. The reforming products were firstly condensed and the liquid condensate was collected in the liquid receiver. The gas products were dried and their accumulative volume can be recorded by a wet gas flow meter. Through GC analysis, the gas products yield can be determined. When the reaction was completed and the reactor temperature dropped to ambient value, certain content of carbon deposition can be formed on catalyst bed. A procedure aiming at carbon elimination was then applied. In order to eliminate these organic toxics, a procedure of liquid condensate recycling was then applied. As two green processes, the byproducts elimination procedures are also indicated in Fig. 1 in green font.

Materials

Generally, the organic compounds in bio-oil are numerous and complex. In our previous research [10], it has been proved that m-cresol belongs to a component difficult to steam reform. In this paper, in order to obtain obvious carbon deposition and toxic organics formation in relatively shorter

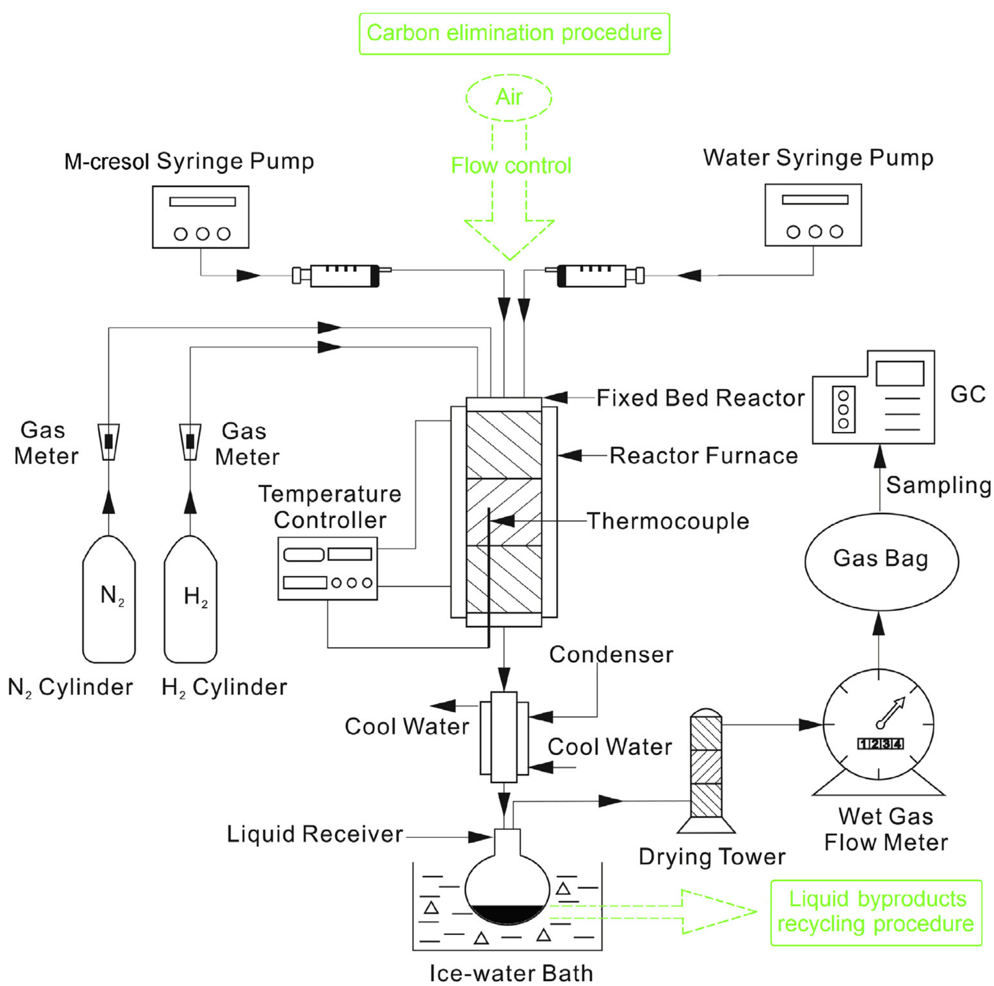

Fig. 1 – Schematic diagram of experimental apparatus for catalytic steam reforming of bio-oil and byproducts elimination procedures.