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Influence of Catalysts on Water-Gas Shift Reaction and Hydrogen Recovery

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Abstract

This study is focused on the water-gas shift reaction (WGSR), occurring in the chemical kinetics equipment, which is used to increase hydrogen recovery from industrial processes. The research deals with comparing hydrogen recovery with the use of three different catalysts. The amount of the produced hydrogen depends considerably on the reaction state and the catalyst composition. To improve the course of the reaction, natural catalysts – calcite, coal char (unburned residues from coal) and modified olivine – are added to the gasification process and heated to the process temperature of 800, 850 and 900°C.

Keywords: Catalysts; Water-gas shift reaction (WGSR); hydrogen

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1. Introduction

The consumer way of life and increasing standard of living requires more and more sources of energy. The energy consumption is growing, while the amount of the existing fossil fuels is decreasing, therefore it is necessary to search for efficient power equipment and ecological energy sources as an alternative for fossil fuels. [1],[2] With respect to wide application and on the basis of environmental aspects, it is the hydrogen that seems to be a suitable source of pure energy used e.g. for the production of electric power and heat in rocketry, as a reducing agent in chemical syntheses and in metallurgy, transport and power equipment. [3],[4]

Hydrogen can be produces in many ways from a wide range of feedstock. At present, 96 % of hydrogen is produced by conversion of fossil fuels [5],[6],[7], mainly by steam reforming of natural gas, as shown by the Eq. 1, which occurs at temperatures ranging from 1,200 to 1,400°C. The catalyst reforming is carried out at temperatures ranging from 700 to 900°C in the presence of the catalysts consisting of nickel + magnesium oxide. [8],[9],[10],[11]

$$C_xH_y + H_2O \rightarrow CO + yH_2 \tag{1}$$

Hydrogen can also be obtained by partial oxidation of heavy carbon residues (Eq. 2), which occurrs at normal pressure at temperatures around 1,300°C. The catalyst partial oxidation is carried out at the pressure between 6 to 8 MPa and at the temperature ranging from 700 to 1,000°C at the presence of the catalyst nickel, cobalt or magnesium. [10],[11]

$$2C_xH_y + nO_2 \rightarrow 2nCO + yH_2 \tag{2}$$

Another way of production is the conversion of water gas acquired during coal gasification, which is carried out by water steam at temperatures ranging from 400 to 500°C (Eq. 3), and is referred to as WGS reaction. This reaction plays an important part in the area of increasing hydrogen recovery. It is the case of slightly exothermic reversible reaction moving to the left at lower temperatures, thus supporting formation of oxygen and carbon dioxide. On the contrary, at higher temperatures, the balance of this reaction moves to the left, which results in limiting the total conversion with the change of Gibbs energy. [11],[12],[13]

$$CO + H_2O \leftrightarrow H_2 + CO_2 \tag{3}$$

As some studies show, acquiring hydrogen from biomass and enzymatic processes becomes more and more important. Using renewable sources of energy, e.g. from biomass as the feedstock for the production of oxygen, should eliminate the environmental problems. [14] Demirbas wrote that hydrogen will play an important role in a future energy economy mainly as a storage and transportation medium for renewable energy sources. Renewable shares of 69% on the total energy demand will lead to hydrogen shares of 34% in 2050. [15]

2. The Description of Measurement and Experiments

Hydrogen recovery was monitored in the equipment for measuring chemical kinetics. (Fig. 1). The experiment was carried out for three types of catalysts: calcite, coal char (unburned residues from coal) and modified olivine, which are present in the gasification process. In industrial and pilot equipment, calcined olivine is used as a catalyst [8],[16], because it shows significant lowering of contents of tars and lowering