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Production of hydrogen by autothermal reforming of biogas

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Abstract

In this paper the results of the operation of a pilot-plant with a hydrogen output of 50 Nm³/h are discussed. This plant shows the possibility of distributed production of hydrogen for the powertrains based on hydrogen. The focus of the investigations is the long-term behavior of the novel Nickel-based catalyst. This includes experimental studies of the impact of the start-up sequence on the reforming performance after the necessary activation of the catalyst. Additionally the prospective demand of hydrogen requires an analysis of the start-up time of the plant. The focus was a short start-up time without harming the catalyst.

Keywords: Autothermal reforming; hydrogen production; renewables

1. Introduction

The enhanced efforts in the decarbonisation of the traffic sector is a strategy of the European Union to reduce the anthropogenic part of the climate change. Therefore several ways for the powertrains of the future have been developed. One option is the fuel cell. The fuel cell uses hydrogen and during the energy release only water is produced. To support the strategy, the scope of the project BioRobur (Biogas robust processing with combined catalytic reformer and trap), funded by the European Commission, is the decentralized production of hydrogen for these vehicles. To reduce the impact of this path of travelling on the environment, the production path for this project requires a location next to a biogas fermentation [1]. During the reforming of the biogas, which is supported by a catalyst, the hydrogen rich synthetic gas is produced. Several purification steps like water-gas-shift reaction or pressure swing adsorption can be added to fit the requirements of the fuel cell vehicles.

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In this paper the investigation of the boundary conditions for the efficient reforming of biogas to a hydrogen rich gas are summarized. Therefore the experimental results of a pilot-plant are analyzed. This plant takes the educt pretreatment and the autothermal reforming into account. The steps of hydrogen purification are skipped. The focus is the long-term behavior of the novel Nickel-based catalysts. This includes the investigation of the impact of the start-up sequence on the reforming performance after the necessary activation of the catalyst. Additionally the cold and the warm start time of the pilot-plant have been measured and optimized. Several investigations regarding the overall plant efficiency will finalize the paper.

2. Experimental method

The main part of the block flow diagram depicted in Figure 1 is the reactor (R-700) for autothermal reforming (ATR). The ATR of methane is taking place by following the chemical equation:

$$2CH_4 + {}^1\!/_2\, O_2 + H_2O \rightleftarrows 2CO + 5H_2$$

The required inlet flows of hydrogen, carbon dioxide, methane, air, nitrogen and water are shown on the left side. The hydrogen is for the activation of the Nickel-based catalysts. The carbon dioxide and the methane are mixed with a ratio of 40 vol.-% to 60 vol.-% to produce a representative synthetic biogas. The air is used for the partial oxidation (POX) of the reforming educts. In case of an emergency shutdown the nitrogen is used to flush all vessels and pipes and remove any combustible fluid. The last inlet flow is water, which is transformed to steam to have all inlet flows in gaseous state.

All educts for the ATR are entering the plant through flow controllers, are mixed in an ejector (J-700) and are preheated by heat integration with the heat exchanger (H-700) or by an electrical heater (E-700). The downstream following ATR reactor (R-700), the soot trap (S-700) as well as the educt heat exchanger (H-700) are one vessel made of Alloy 800H. The produced synthetic gas with a volume fraction of hydrogen in the dry gas of about 35 vol.-% is cooled down by superheating the steam in the heat exchanger H-100 and is finally combusted in a flare.

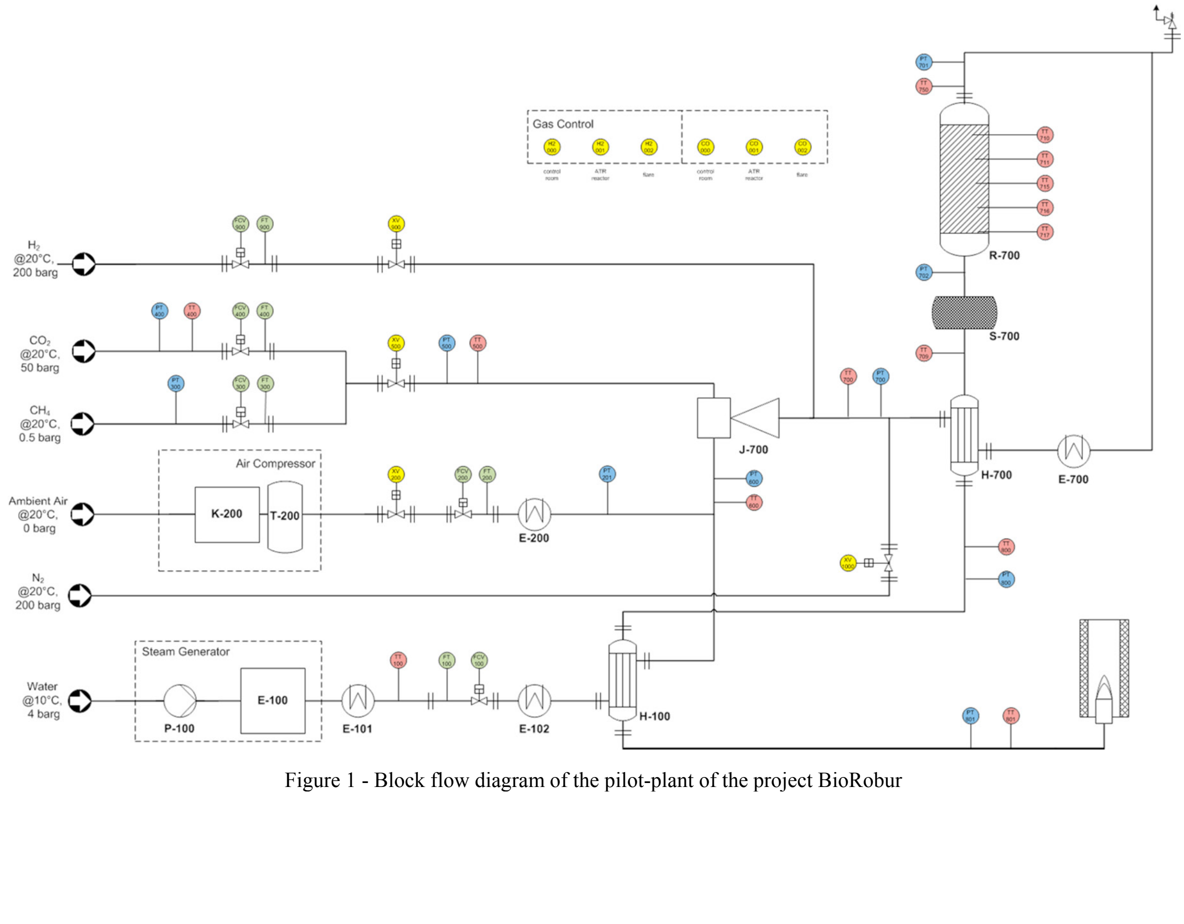

Figure 1 - Block flow diagram of the pilot-plant of the project BioRobur