REVERSE-FLOW CATALYTIC REACTOR FOR HYDROGEN PRODUCTION BY METHANE PARTIAL OXIDATION

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Introduction

The work is devoted to development of the original design of partial methane oxidation reactor, which operates in regime of periodical reverse-gas flow direction. The major task was to realize reactor's stable operation at atmospheric and higher pressures. Optimization of operation condition and parameters of the reactor was carried out to obtain maximal hydrogen yield.

Experimental setup

Reaction mixture preparation system was equipped with TYLAN flow controllers. The scheme of the experimental setup is presented on Fig. 1. Length of the reactor casing was 250-mm.

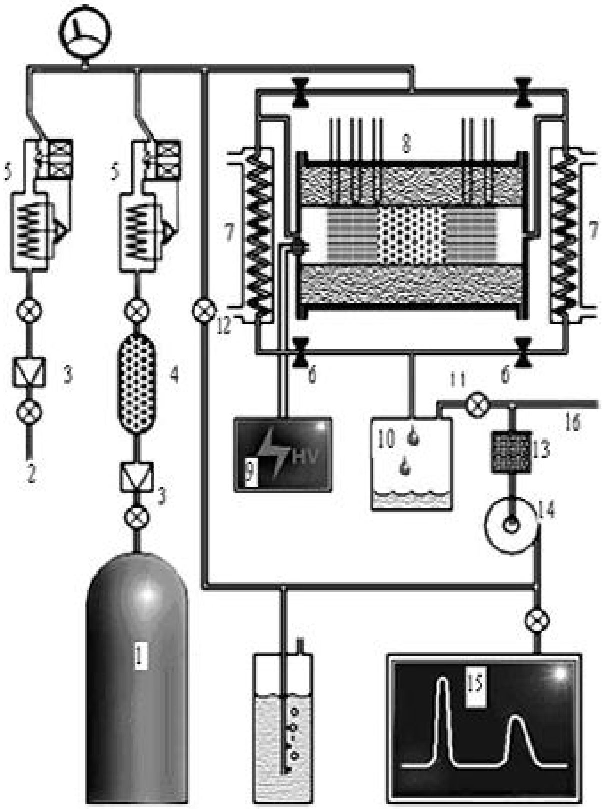

Fig. 1. Experimental setup: 1 - methane bottle, 2- pressurized air, 5 - TYLAN 2900 series flow controllers, 8 - reactor, 9 - ignition unit, 15 - chromatograph, 16 -reaction product outlet.

Size optimization allowed reducing length, to switch pressures over and to decrease the time of reactor heating. Improvement of the porous medium of the reactor permitted to stabilize the location of heat generation zone on the edge of the catalytic layer.

According to thermodynamic calculations made in our laboratory, to obtain 95% methane-to-hydrogen conversion at atmospheric pressure, 750 °C is enough, whereas at 10 bars the required temperature approaches 1000 °C. Such high temperature requires more heat-resistant nickel catalyst. All experiments describe below were made on the reactors with inert bed of quartz and a porous layer of nickel catalyst on alumina substrate.

Major results of experiments

Reactor's operation is defined by the properties and geometry of the working medium, reaction mixture flow rate and composition. The most important characteristic for the user is a yield of the target reaction product, i.e. hydrogen. The fact that the converter does not require external energy supply is an important feature and one of advantages of the design used. This ensures beneficial economical characteristics and quick regime setting.

An experimentalist can obtain only those parameters that indirectly influence the efficiency of converter's operation. These parameters are specific flow rate of reaction mixture, its composition and geometrical characteristics of the layers of reactor's working medium. The work aim is to study the effect of these parameters to obtain maximal hydrogen yield at stable operation modes not accompanied by soot deposition.

Fig. 2 shows the sequence of the temperature profiles in the reactor with the inert layers of 80 mm, operating at 10 atm and 0.26 kg/m^2s specific flow rate. The profiles are given starting from switching-over of reaction mixture flow direction (0s) with 10-second interval. The figure shows the formation of reaction zone in the inert layer. Temperature growth is possible only to the ignition temperature in noncatalytic layer.

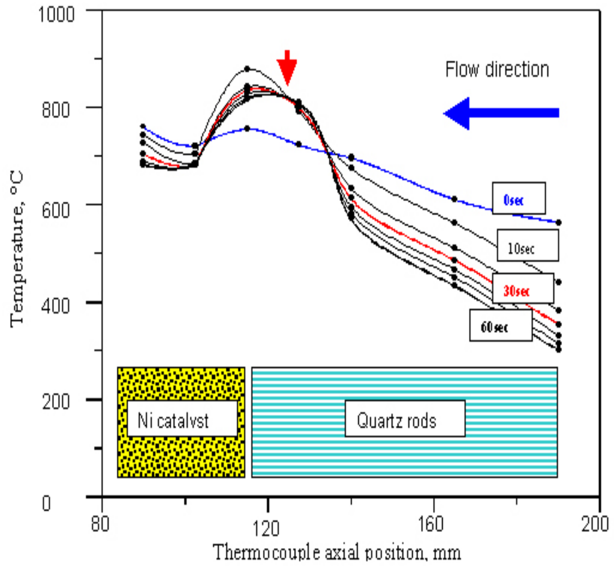

Fig. 2. Shift of the ignition point into inert layer. Ignition zone is marked by red arrow. Inert layer length - 80 mm, pressure - 10 bar, gas mixture flow rate - 3 m^3/hr

Similar effect occurs, when the flow rate through the reactor was increasing. It conditions on specific power growth, which in turn augments temperature and conversion degree α. Effect of flow rate at 10 atm is shown in Fig. 3. Heat losses from the reactor's porous body increases with specific flow rate growth, but slower than specific power.

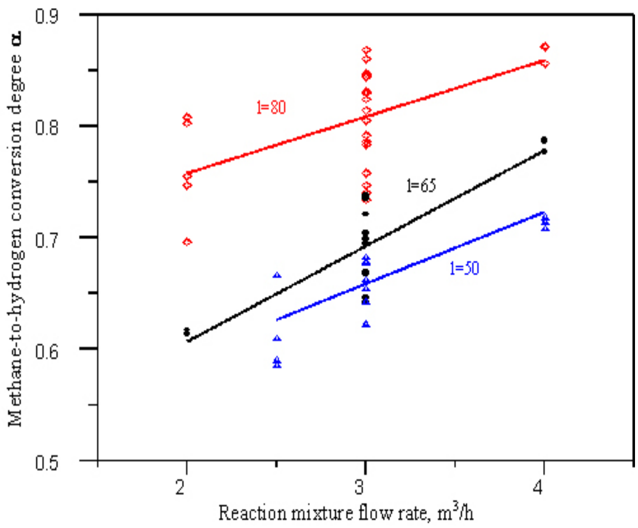

Fig. 3. Effect of reaction mixture flow rate on conversion degree for different thickness of inert layers

Conclusions

The most important result achieved at present is a stable hybrid reactor's operation at the pressure of 10 atm. And it is more important that methane-to-hydrogen conversion was not accompanied by prominent soot deposition, which was ensured by the reaction without reaction mixture overheating and high rate of reactants' heating and products' hardening in the used design of the reactor.