C1-O-030501

ELECTRIC ARC HYDROGEN PRODUCTION FROM NATURAL GAS AND GAS CONDENSATES

S.D. POPOV[1], V.E. POPOV[1], D.I. SUBBOTIN[1], A.V. SUROV[1], E.O SERBA[1], A.V. NIKONOV[1], GH.V. NAKONECHNY[1], V.A. SPODOBIN[1]

[1] *Institute for Electrophysics and Electric Power of the Russian Academy of Sciences (IEE RAS), St. Petersburg, Russia*

In the 21st century, the role of alternative energy and, especially, hydrogen energy is growing significantly. The main methods for producing hydrogen are steam catalytic reforming of natural gas [1] and electrolysis of water [2]. Steam reforming is a large-scale production, however, it has significant disadvantages: a high carbon footprint, incomplete methane conversion, and heating of steam to high temperatures [3]. At the same time, electrolysis has low productivity and high energy consumption [4].

At present, a number of methods for obtaining hydrogen from hydrocarbons by plasma pyrolysis are proposed [5, 6]. However, these methods are severely limited by the productivity of the facilities and the period of their continuous operation. Features of power sources and the design of plasma devices significantly affect the efficiency of the overall process. At the same time, plasma methods ensure the creation of small local production facilities. Such plants can meet the demand for hydrogen for the production of small-scale chemical products.

The report discusses a plasma-chemical facility for the pyrolysis of natural gas and light hydrocarbons. It consists of a high-voltage AC plasma torch, a plasma-chemical reactor, a plasma torch power supply system, a system for supplying reagents and analyzing reaction products.

The plasma torch consists of three water-cooled arc channels with end copper electrodes [7]. The plasma torch has two zones for the supply of plasma-forming media. A shielding gas (argon) is supplied to the near-electrode zone, and hydrocarbons are supplied to the electric arc burning zone. Thus, the electrode insulators are protected from the ingress of electrically conductive graphitized soot into them. The power of the plasma torch depends on the flow rates of plasma-forming media and the value of the electric current regulated by the power source.

The plasma-chemical reactor is a hollow lined cylinder equipped with pressure sensors, high-temperature thermocouples, and sampling probes [8]. The content of solid particles in the produced products was determined gravimetrically using a thimble quartz filter. The composition of the gas phase was determined with a calibrated quadrupole mass spectrometer.

Four experiments were carried out with natural gas and propane-butane fraction. The conversion of hydrocarbons primarily depended on the temperature in the plasma-chemical reactor. When the reactor was preheated, the conversion of methane increased from 65% to 75%, and the conversion of the propane-butane fraction increased from 75% to 85%. The analysis showed that the produced carbon black consists of two fractions with different properties: graphite (70%) and polyaromatic hydrocarbons (30%). Also traces of iron (up to 0.07% wt.) and other metals were found in the carbon black. This indicates the erosion of the metal walls of the plasma torch during its operation.

Thus, it can be concluded that the plasma pyrolysis of hydrocarbons can be used to produce hydrogen and carbon black. To accomplish this task, it is necessary to combine efforts in the development of high-power high-voltage plasma torches and their integration into the renewable energy system.

REFERENCES

[1] S. A. Ghoneim, R. A. El-Salamony, S. A. El-Temtamy, “World Journal of Engineering and Technology,” Review on Innovative Catalytic Reforming of Natural Gas to Syngas, vol. 4, no 1, pp. 116-139, 2016.

[2] M. M. Rashid, M. K. Al Mesfer, H Naseem, “Hydrogen Production by Water Electrolysis: A Review of Alkaline Water Electrolysis, PEM Water Electrolysis and High Temperature Water Electrolysis,” IJEAT, vol. 4, Is. 3, 2015.

[3] H. Zhang, Z. Sun, Y. H. Hu, “Steam reforming of methane: Current states of catalyst design and process upgrading,” Renewable and Sustainable Energy Reviews, vol. 149, pp. 111330-111353, 2021.

[4] M. Eyvaz, Advances In Hydrogen Generation Technologies, London: IntechOpen, 2018.

[5] A. Górska, K. Krawczyk, S. Jodzis, K. Schmidt-Szałowski, “Non-oxidative methane coupling using Cu/ZnO/Al2O3 catalyst in DBD,” Fuel, vol. 90, Is. 5, pp. 1946-1952, 2011.

[6] Morgan, N. N. Hydrogen Production from Methane Through Pulsed DC Plasma,” Plasma Chemistry and Plasma Processing, vol. 37, Is. 5, pp. 1375-1392, 2017.

[7] A.V. Surov, S.D.Popov, V.E.Popov, D.I.Subbotin, E.O.Serba, V.A.Spodobin, Gh.V.Nakonechny, A.V.Pavlov,“ Multi-gas AC plasma torches for gasification of organic substances,” Fuel, vol. 203, pp. 1007-1014, 2017.

[8] P. G. Rutberg, V. A. Kuznetsov, V. E. Popov, S. D. Popov, A. V. Surov, D. I. Subbotin, A. N. Bratsev,“ Conversion of methane by CO2 + H2O + CH4 plasma,” Applied Energy, vol. 148, pp. 159-168, 2015.