Chapter 3

Electrical and Heat Power Production Using the Products of Air Conversion of Motor Diesel Fuel and Electrochemical Generator for Agricultural Consumers

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ABSTRACT

At present, the production of electricity for agricultural consumers remote from the centralized electrical power grid is carried out using diesel-generator technology with a limited service life of engines and extremely low efficiency of the expensive fuel used. In this chapter, an innovative technology has been considered for the combined electrical and heat power production using the preliminary conversion of diesel fuel into synthesis gas with its subsequent supply to a high temperature electrochemical generator (ECG). Synthesis gas for the operation of the electrochemical generator was produced by air conversion of motor diesel fuels in a catalytic burner reactor. On the basis of heat balances of the burner, ECG and waste-heat boiler-utilizer, electrical efficiency of the solid oxide fuel cells’ (SOFC) battery, chemical efficiency of the burner, the temperature at the SOFC anode, the EMF of the planar cell, a portion of hydrogen oxidized at the SOFC anode, specific consumption of diesel fuel for the production of electrical and heat power were calculated.

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INTRODUCTION

At present, the production of electric energy consumer remote from agro-based centralized networks is done using diesel-generator technology with limited service life of the engine and the extremely low efficiency in the use of expensive fuel. In this paper, is considered an innovative technology of combined production of electricity and heat using a preliminary conversion of diesel fuel in the synthesis gas and then serving it at high temperature electrochemical generator. Essential progress in considerate use of organic fuels with simultaneous simplification of the power plant design can be achieved by using technologies for the direct electrical power production with the help of electrochemical generators or their combination with GTP and STP (Shpil’rain et al., Malyshenko, & Kuleshov, 1984; Lisbona & Romeo, 2008; Promes et al., 2015).

Recently, the test study of the electrical power installation of the electrochemical generator based on the SOFC with the power of 5 kW were performed on the natural gas steam conversion products (Munts et al., 2015) and calculations were carried out on the products of steam gasification of coal of the Borodinskoye coal deposit (Dubinin & Shcheklein, 2015). This study presents a mini-CHPP, where direct conversion of the energy of the chemical reaction of hydrogen oxidation from synthesis gas obtained by air conversion of motor diesel fuel is carried out. This project allows prediction of the required ECG parameters: electrical efficiency of the SOFC battery, chemical efficiency of the burner, the temperature at the SOFC anode, EMF of the planar cell, a portion of hydrogen oxidized at the SOFC anode, specific consumption of diesel fuel for the production of electrical and heat power.

MODELLING OF PHYSICOCHEMICAL PROCESSES IN THE UNITS OF THE MINI-CHPP BASED ON THE CATALYTIC BURNER FOR AIR CONVERSION OF MOTOR DIESEL FUEL AND ELECTROCHEMICAL GENERATOR

Principle and Technological Model of the Process

In (Peters et al., 2013) more than 220 variants of the SOFC operation with recirculation of anode gases and without it have been calculated. It has been concluded that the choice of the scheme has little effect on the process efficiency, thus it is advisable to choose the simplest scheme. In the scheme proposed the anode gases recirculation is not considered. Planar fuel cells with direct flow of fuel and oxidizer are used. Catalysts at the anode and cathode are made of Ni-YSZ and \((\text{ZrO}_2\text{, Sc}_2\text{O}_3)\_0.1\) is used as an electrolyte.

Figure 1 presents a schematic diagram of conversion of the motor diesel fuel into synthesis gas by the process of air conversion in the catalytic burner in order to ensure the operation of the electrochemical generator. The main units of the installation for the synthesis gas production are a catalytic burner for conversion of the diesel fuel vapor - 1, a blower - 3, a synthesis gas cooler - 4, an electrical customer - 5, an electrochemical generator based on SOFC - 6, a waste-heat boiler-utilizer (WHB) - 7, a diesel fuel filter - 9, a fuel pump - 10, a network heater – 12 and thermal insulation - 13.

Motor diesel fuel is supplied to WHB for heating to boiling and evaporation and enters the catalytic burner in a vaporized form. There also comes the air heated in WHB. When the air flow rate \(\alpha = 0.4\) diesel conversion occurs with the formation of synthesis gas. Then the synthesis gas is cooled from 1284 °C to 800 °C in the cooler by the air supplied to the cathode channel.