ENERGY-TECHNOLOGY INSTALLATIONS FOR COMBINED PRODUCTION OF HYDROGEN AND ELECTRICITY WITH CO_2 REMOVAL SYSTEMS[1]

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Introduction

The necessity to increase the use of coal in energy and industry has been confirmed by the comparison of data on oil, gas, and coal reserves and by the analysis of their world consumption. However, coal consumption growth is accompanied by the increase of the environmental burden including the increase in greenhouse gas emissions. In this connection the use of fossil coals as a raw material for hydrogen production is getting urgent.

The works on the study of technologies for synthetic fuel production that have been performed at Energy Systems Institute SB RAS show that it is expedient to combine their large-scale production with electricity production at energy technology installations [1, 2]. This makes it possible to utilize a considerable amount of thermal energy and combustible waste released at synthetic fuel production. In doing so energy and economic efficiency of the combined production appears to be essentially higher than that of separate productions. The optimization technical and economic studies have been conducted for energy technology installations (ETI) intended for coal-based production of methanol, dimethyl ether (DME) and hydrogen. The synthetic fuel price ranges have been determined depending on the conditions of energy-technology installation operation.

Optimization studies of ETI

In the context of Kyoto agreements on reduction of greenhouse gas emissions one of the most important points in the studies of hydrogen production technologies is determination of the cost of electricity and hydrogen to be produced at the energy technology installations taking into account the costs of CO_2 removal.

Previously the hydrogen and electricity production ETI was studied disregarding CO_2 removal [2] (Fig.1).

Taking into account the above circumstances the decision was made to add the CO_2 removal system to the given diagram.

In this connection the mathematical models of the system for CO_2 removal from combustion products within the hydrogen and electricity production ETI were developed and the main technical and economic parameters of ETI were optimized on the basis of the CO_2 removal system costs.

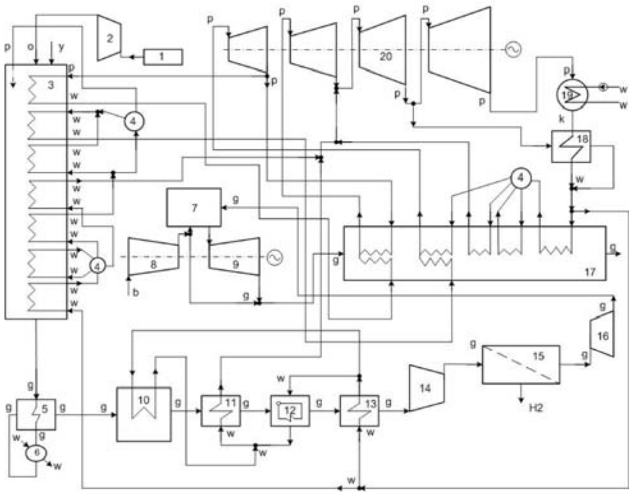

Fig.1. The design diagram of hydrogen and electricity production ETI:
1 – block for oxygen production, 2 – oxygen compressor, 3 – gas generator, 4 – drum-separator, 5 – dry ash collector, 6 – regenerative gas - gas heat exchanger, 7 – system for thorough cleaning of gasification products; 8 – gas turbine combustion chamber, 9 – air compressor, 10 – main gas turbine, 11 – CO conversion reactor, 12 – 14 – convective heat exchanger on gasification products, 16 – block of membrane separation of conversion products, 17 – gas turbine expander, 18 – recovery boiler, 19 – low pressure regenerative heater, 20 – steam turbine condenser, 21 – steam turbine, w – water, steam, p – steam, k – condensate , g – gas, z – ash, y – coal, o – oxygen.

The cryogenic method is applied for CO_2 removal. This method seems to be more efficient to remove large amounts of CO_2 since, based on the preliminary estimations, it is cheaper compared to the other methods (absorption, adsorption, membrane, etc.). We use the system of expander type with an external cooling circuit and cold regeneration at the last stages of cooling (Fig.2). Liquid nitrogen is used as a cooling agent.

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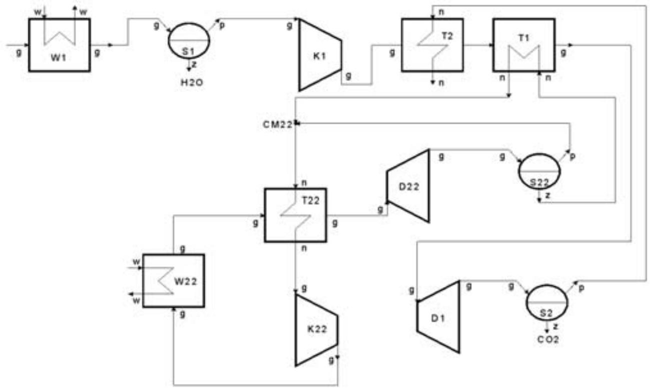

Fig.2. System intended for CO2 removal:
W1, W22 – gas-water heat exchanger, K1 – compressor of combustion products, K22 – compressor of nitrogen refrigeration cycle, S1, S2, S22 – liquid phase separators, T1 – group of coolers on the external refrigerant, T2 – regenerative gas-gas heat exchanger T22 – group of coolers of the nitrogen refrigeration cycle, D1, D22 – turbine expanders.

Methanol and dimethyl ether produced at ETI intended for combined methanol and electricity production and ETI intended for combined DME and electricity production are considered as alternative variants of environmentally friendly fuels [2].

The variants of methanol and DME production differ essentially in the proportions of synthetic fuel and electricity produced. The DME synthesis installations are characterized by the production of a larger amount of synthetic liquid fuel (in energy equivalent) as compared to the methanol synthesis installations. In turn the methanol synthesis installations produce larger amounts of electricity (1.5-2 times larger depending on the type of fuel consumed). This is because practically all CO is consumed in synthesis reactor for production of DME. In the methanol synthesis installations a considerable amount of CO after synthesis goes to the combustion chamber of gas turbine.

Production of gaseous hydrogen is characterized by lower capital investments, hence by lower price. Here it should be noted that further use of gaseous hydrogen as an energy carrier generates the necessity to develop efficient methods for storage and transportation. This will essentially increase its final price for consumers versus synthetic liquid fuel since the transportation and storage of liquid fuels is considerably cheaper than those of gaseous ones.

Conclusions

As the studies show the CO_2 removal systems are characterized by considerable capital investments and power consumption for auxiliaries. Specific capital investments in the CO_2 removal systems make up about 35-40 USD /t of CO_2 yearly depending on the composition of combustion products. Larger part of electricity supplied to auxiliaries of the ETI intended for combined production of synthetic fuels and electricity is consumed by compressors of combustion products and larger amount of nitrogen is consumed in the nitrogen cooling cycle. Net generation in the expanders of CO_2 removal system does not compensate for this power consumption. Additional investments in the CO_2 removal system within ETI make the price of the ETI products higher by 11.3%, 7% and 6.5% for the hydrogen production ETI, DME synthesis ETI and methanol synthesis ETI, respectively, as compared to the installations without CO_2 removal systems.

References

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2. Kler A.M., Tyurina E.A., Mednikov A.S. Study on the technology of combined coal-based production of hydrogen and electricity // Izv. RAS. Energeikta. 2007; 2: 145-153.