

ANALYSIS OF BIOGAS USE IN A STEAM BOILER

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Abstract

The use of biogas as a fuel for steam boilers is a promising direction of energy transformation, which contributes to reducing dependence on fossil energy resources and reducing greenhouse gas emissions. The relevance of this problem is due to the need to introduce renewable energy sources to reduce the burden on the environment and the economic benefits of using biogas, in particular in the context of rising prices for imported energy resources.

Keywords: biogas, fuel, steam boiler, heat of combustion.

Introduction

Recent research into the use of biogas for heating and power shows the significant potential of this renewable energy source in the context of reducing greenhouse gas emissions and reducing dependence on fossil fuels. It has been established that biogas has a high calorific value, but its combustion is accompanied by low efficiency due to the high content of carbon dioxide (CO₂), which reduces the efficiency of boilers.

The purpose of the work is to analyze the heat balance of a steam boiler when using biogas as fuel, assess its efficiency in comparison with natural gas, and identify the main factors that affect the reduction in the boiler efficiency.

Research results

Biogas is a renewable energy source based on light hydrocarbons produced by anaerobic digestion of organic matter. The typical composition of biogas varies depending on the composition of the feedstock and the conditions in the anaerobic reactor. In addition to traditional applications such as heating, cooking, lighting, etc., biogas is considered a leading gaseous source of bioenergy because it is easily synthesized from a wide range of feedstocks and has the potential to reduce the fossil carbon footprint of the energy sector [1].

With the increasing global concern for environmental protection, the use of fossil fuels is facing increasing constraints. In this context, biomass fuels, as a renewable energy source, are becoming a viable alternative to traditional fossil fuels. Studies show that the use of biomass energy not only reduces the dependence on traditional fossil fuels, but also effectively reduces carbon emissions [1].

Today, Ukraine is only 50% self-sufficient in fuel, and the prices of imported fuel are constantly increasing. One of the promising ways to use biogas is to burn it in steam boilers to generate heat. The use of steam boilers of various capacities on traditional and alternative fuels will allow achieving high economic and energy efficiency while ensuring reliability during operation [2]. Bioconversion of organic waste is one of the progressive, cost-effective and environmentally acceptable solutions to prevent environmental pollution. At the same time, it is possible to rationally use organic substances and release the energy accumulated in them. A significant increase in prices for primary energy sources requires the search for alternative fuels: one of the promising ones is biogas. The efficiency and reliability of the bioconversion process largely depends on the organization of the use of biogas in the production of heat in steam boilers [3-4].

The chemical composition of biogas obtained from biogas plants is represented by methane and carbon dioxide with a small content of hydrogen sulfide and ammonia. Biogas also contains traces of elements such as hydrogen, nitrogen, carbon monoxide. The gas mixture is saturated with water vapor, and dust particles may also be present. The specific heat of combustion (Q) is determined mainly by the CH₄ content, since small amounts of H₂ and H₂S have practically no effect on this indicator. Accordingly, the ignition temperature and ignition limit also depend on the CH₄ content [5].

An important role is played by biogas purification, since its composition determines the efficiency of combustion. The main pollutants are moisture, carbon dioxide (CO₂) and hydrogen sulfide (H₂S). The main methods of biogas purification are: membrane, chemical and cryogenic. For drying, it is also possible to use the separation of components by distillation from the condensed phase, in which the yield of the useful product (methane) is 70%. Biogas can also be enriched with methane and reach concentrations of 90%, which eliminates the main problems of its combustion compared to natural gas [5].

In the equivalent of 1000 m³ of natural gas, 1500 m³ of biogas is equal to [6].

As a renewable energy source, biogas has the advantages of high calorific value and less environmental pollution, and can be used as boiler fuel. A boiler is an industrial equipment with high energy consumption. As a boiler fuel, biogas will contribute to a certain extent to the sustainable use of resources and fuel cost savings. However, there are still some technical barriers to the large-scale application of biogas boilers.

Biomass boilers cannot respond quickly to changes in the heat loads of consumers, unlike gas boilers. They work much more efficiently if stable continuous operation lasts as long as possible. Constant change in the thermal load of the biomass boiler can affect its efficiency. Biomass boilers work more efficiently as a technology for providing the base load (heating, hot water supply) of the heating system [7].

The work has carried out a numerical study of the operation of the Invest steam boiler on biogas and natural gas using the calculation method [8].

The calculation was carried out for:

- natural gas with the composition: CH₄ = 98.3%; C₂H₆ = 0.28%; C₃H₈ = 0.11%; C₄H₁₀ = 0.14%; C₅H₁₂ = 0.03%; C₆H₁₄ = 0.02%; N₂ = 1%; CO₂ = 0.1%; H₂S = 0%; CO = 0%; O₂ = 0.02%; Q = 35716 KJ/m³, with an excess air coefficient $\alpha = 1$;

- biogas with the following composition: CH₄ = 60%; H₂ = 0.02%; H₂S = 0.96%; CO = 0.02%; N₂ = 2%; CO₂ = 37%; and the heat of combustion Q = 24000 KJ/m³, excess air $\alpha = 1.15$.

In [3] it is indicated that the replacement of natural gas with biogas has both obvious advantages – a cheaper price, and disadvantages – a decrease in boiler productivity. The efficiency of the steam boiler decreases by 4...5%, and the environmental performance of the boiler also deteriorates. A lower adiabatic temperature of biogas combustion leads to an increase in CO emissions into the atmosphere.

In a numerical study, when calculating biogas combustion, different values of the percentage of chemical unburnt fuel were given. The obtained efficiency values on biogas and natural gas at different values of unburnt fuel were compared. The calculations have established that the percentage of chemical unburned fuel q₃ is 5% with a difference in efficiency of 5%. The result obtained corresponds to the specified range when using the calculation method.

Conclusions

Therefore, the decrease in boiler efficiency when switching from natural gas to biogas is explained by the presence of a high content of carbon dioxide CO₂ in biogas. During combustion, CO₂ prevents the access of oxygen molecules O₂ to methane molecules CH₄, which affects the efficiency of biogas combustion.

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