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Flue gas treatment multi-criteria analysis

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Abstract

Energy is the main factor effecting national economies of countries, therefore it is in everyone's best interest to improve energy efficiency. One way to do that is by developing and implementing heat recovery from industrial processes, rather than creating waste heat in industry. There are different technologies available for heat recovery, for example, heat pumps, heat exchangers, boilers, etc. [1]. The choice of a certain technology is dependent on the heat source. In this paper, focus is brought to heat recovery from power industry, more precisely – heating system, with a condenser. An evaluation of direct contact flue gas condenser (KE) from emission reduction perspective was performed. The best KE alternative has been found using multi-criteria analysis method, based on analysis of 14 chosen quantitative and qualitative criteria.

Keywords: condensers; multi-criteria analysis; emissions reduction

1. Introduction

Condenser (condensing economizer) is a heat exchanger used for energy recovery from boiler outlet flue gas. It reduces the temperature of water vapor below the dew point, recovering sensible and latent heat from the flue gas in the process. The use of condensing economizers also reduces amount of particulate matter in the flue gas.

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These actions improve the overall efficiency of the boiler system [2]. The heat in flue gas is in the temperature range from 30 °C to 250 °C and it makes up about 15–40 % of total heat content in the fuel used [3].

Flue gas contains acids and particulates which are mostly removed by the use of scrubbers and filters, travelling to condenser after cleaning. The heat recovery that can be obtained by condenser is usually between 10 % and 15 %, when natural gas is used as a fuel. In the case of biomass, these showings are similar, but it is possible to recover energy from two sources – moisture evaporation and water from fuel components, therefore decreasing necessity of fuel drying before combustion [4].

There are two types of condensers in use – direct and indirect contact economizers. Cooling matter in condensers is either air or water. Indirect contact condensers are more common in real life applications, because they recover latent heat from flue gas by letting gas through condensing heat exchangers. They can be divided in groups such as pipe, lamella and combi condensers [2, 5]. Direct contact condensers consist of two chambers, first is meant for vapour conditioning, but second is meant for flue gas cooling with counter – current sprays. They can be with or without fillings and are mostly applied to gas-fired equipment, with new and developing applications to wood-fired and oil-fired boilers as well [4].

Main advantage of a condenser is the recovery of latent heat that leads to thermal efficiency improvement, which can exceed 100 %, when referencing to the fuels' lowest heating value. Another advantage is increase of environmental benefits, created by decreased amount of flue gas emissions. This is due to condensate that creates a film, removing particle matter and dissolving acids [6].

A disadvantage is that bigger amount of sensible heat is transferred to non-condensable gas, leading to smaller vapour amounts and higher thermal conductivity coefficient (λ), that effects efficiency of the boiler. Another disadvantage of the technology is high corrosion risk caused by combustion products. It can lead to creation of cracks in exchangers, if the material is not strong enough or the damaged point has high mechanical stress [7]. This disadvantage can be reduced by detailed and precise installation and choice of corrosion-resistant materials, however, that might lead to higher costs [8]. When using indirect condensers, there is a possibility of fouling in the tubes, therefore extra attention should be brought to the feed water characteristics [9].

One of the most important factors in operation of heating systems is the return water temperature, which should be about 30 °C. It serves as a heat sink in the system. If water temperature is below desired, a heat pump has to be added to the system, increasing energy consumption and costs [10].

Condensers, their possible applications and types have been studied in various cases. A lot of research devoted to condensing heat exchangers, their application and possible implementation has been done in Lehigh University in Bethlehem, USA. Some of the studied topics are described further. Jeong and Levy have worked on determination of acid condensation, to make it possible to create a suitable heat exchanger for use in predicted conditions. They used mass and energy balances of the system to study characteristics of flue gas and their condensation, leading to conclusion, that modelling methodology can be applied to real life heat exchangers, because theoretically obtained data of acids and water condensation are in agreement with experimental data [11]. Samuelson has extendedly studied recovery of water from boiler flue gas in his thesis, focusing on condensing heat exchanger for use in oil fired boiler. Designed equipment lead to 80 % water recovery and the same efficiency for acid condensation that were done separately [12]. Hazell has modified an existing computer simulation code for heat exchanger to predict condensation rates, heat transfer and pressure changes in full scale. The costs of the heat exchanger were studied, that showed that the biggest costs for implementing a condensing heat exchanger is capital costs, while operating costs make up a small part of total costs. Heat exchanger was optimized by using of corrosive resistant materials and calculations of tube spacing, water temperature effects on heat and mass transfer and implementation place. It was concluded that the most cost effective solution for condensing heat exchanger placement is in downstream of the flue gas desulfurization unit [13].

Hill has studied heat recovery and its possible applications in real life systems in his master thesis, creating a design of heat recovery system for a power plant. However, issues noted previously, were brought to attention in the paper, because they slow down wide implementation of heat recovery systems in power plants [14].

Li, et al. have studied vapour condensation theoretically in environment containing non-condensable gas. Mass and heat balance equations have been used to develop a mathematical model to predict results and make comparison to existing experimental results. Developed model can be applied for co-current and counter flow condensers. Predicted results agree with experimental data available [15]. Osakabe has developed a heat exchanger for latent heat recovery