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ECOLOGICAL EFFECT OF MODERNIZATION OF A METALLURGICAL FURNACE

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In the paper, a feasible ecological effect of modernization of a conventional metallurgical furnace intended for charge material preheating before plastic working processes is described. The modernization activities involved replacement of the previous recuperator, the negative pressure control system of the furnace and a proposal for application of modern low emission burners. The suggested design of a recuperator with a higher energy recovery level due to a decreased flue gas temperature will contribute to reduced consumption of electrical energy that is necessary for the extraction ventilator drive. The modernization activities led to decreased total process-induced CO_2 emissions resulting from lower consumption of gas and electrical energy (nearly 11 % in relation to the state before the modernization).

Keywords: metallurgical furnace, recuperator, energy saving, ecology, reduction of emissions: CO, CO_2, NO_x

INTRODUCTION

Benefits from application of flue gas recuperation or regeneration units in the industrial furnace design and other energy systems are well-known and described in literature [1,2]. Ecological requirements and a fierce market competition regarding metal processing industry result in a strong pressure to reduce consumption of every kind of energy and production costs. This creates good conditions for technical modernization of furnaces as well as the applied algorithms of their control. In the paper, total effects of the furnace modernization, i.e. the use of a new recuperator and replacement of gas burners with low emission ones, are discussed. In addition, the flue gas duct system was modernized, which resulted in a reduced consumption of electrical energy in the ventilator engine.

The objective of the paper was to present the effects of comprehensive modernization of the metallurgical furnace infrastructure systems on a reduced consumption of energy necessary for its operating.

COURSE AND EFFECTS OF MODERNIZATION

The subject of the paper i.e. a pusher furnace for charge preheating before rolling processes was periodically modernized due to changes of the applied gas fuel over time and technical wear of the components. Any modernization activity is a costly process requiring a comparison of its effects and expenditure incurred. New solutions and financial outlays should contribute to a higher energy efficiency of the modernized unit, which has been described in literature [3,4]. Restoration of the previous infrastructure during repair works frequently requires the same capital outlays as the use of technically newer solutions. Moreover, the restoration activities may generate additional costs resulting from unavailability of spare parts for the older components on the market.

Therefore, a comprehensive furnace modernization should be considered in the process of repair planning as technically and economically justified. Regarding the discussed furnace unit, the previous needle recuperator (Figure 1) was replaced with a tube recuperator (Figure 2). The new recuperator was designed based on many previous experiences [5,6].

The previous recuperator demonstrated unsatisfactory combustion air heating temperatures of 250 to 300 °C. Such low values resulted from the furnace design as well as problems with proper pressure control in the furnace chamber, which led to dilution of the flue gases by the air sucked from the atmosphere and a decrease of their temperature before the recuperator. Another problem was the leaky recuperator due to its technical wear.

Application of the new recuperation system and pressure control in the furnace operating space ensured considerable higher temperatures of the combustion air. Time dependencies important for the operation of parameter systems are presented in Figure 3.

As expected, the temperature of the air supplied to the burner systems resulted in a lower gas fuel consumption. The savings of combusted air amounts reached 9 to 10 % compared to the system before the modernization. The respective absolute values ranged from 180 to 200 m^3_n/h. A high combustion air heating temperature may lead to higher NO_x concentrations in the flue gases that leave the furnace chamber [7,8]. Application of new GAFT (Gas-dynamic Abated Flame Temperature) burners was proposed as a target compre-

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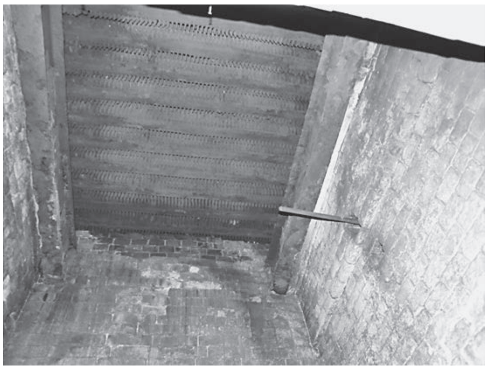

Figure 1 The needle recuperator of the pusher furnace before modernization

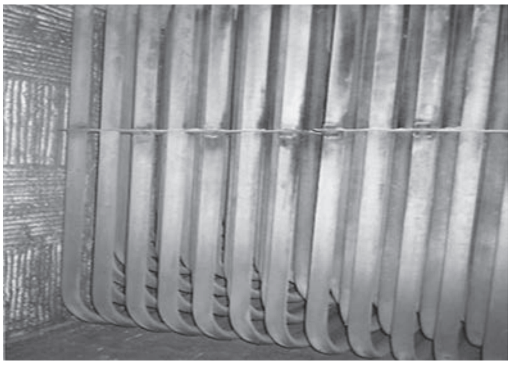

Figure 2 The tube recuperator in the furnace being modernized

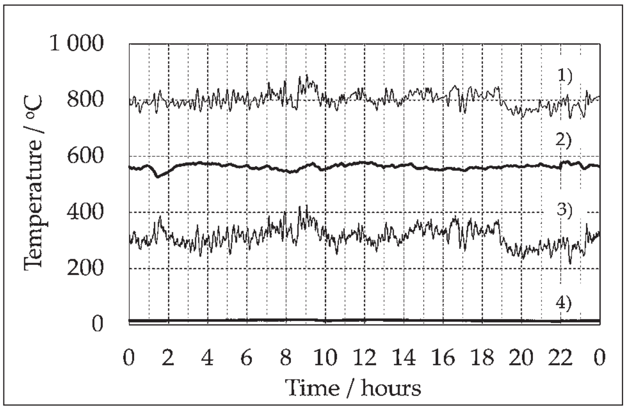

Figure 3 Average temperatures in the recuperation system of the heating furnace: 1) the flue gas temperature before the recuperation system, 2) the air temperature at the recuperation system outlet, 3) the flue gas temperature within the recuperation system, 4) the air temperature at the recuperation system inlet

hensive solution [9,10]. Comparisons of CO and NO_x concentrations in the flue gases for the standard and GAFT burners at various combustion air heating temperatures are presented in Figure 4. Regarding the GAFT burners with the combustion air temperatures above 500 °C, recorded CO and NO_x concentrations fall below 10 ppm with respect to 3 % O_2 in the flue gases.

In order to reduce the unbeneficial uncontrolled suction of the ambient air into the furnace operating space, utilization of the flue gas pressure control system was necessary. Previously, the ambient air caused dilution of the flue gases and a decrease of their tem-

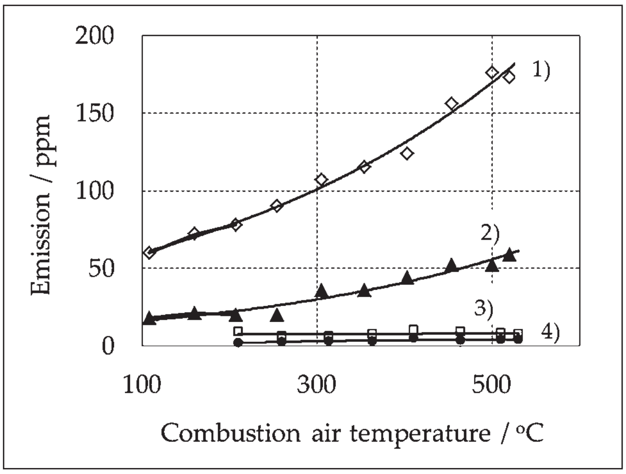

Figure 4 Influence of the combustion air temperature on NOx and CO emissions [11]: 1) NOx standard burner, 2) CO standard burner, 3) CO GAFT burner, 4) NOx GAFT burner

perature before the recuperator. Its control was difficult as a counterflow of the flue gases in relation to the charge material movement was observed and their intake system was located above the furnace charge door. This phenomenon was rather neglected in the old solution of the flue gas removal as the flue gases were diluted by the air following the flow through the recuperator so that their temperature before the extraction ventilator would not exceed 250 °C. It is a threshold value for a safe operation of the ventilator and the flue gas purification system.

Operation of the new recuperator in the modified energy recovery system led to a better utilization of the flue gas waste enthalpy, which resulted in smaller amounts of the sucked air necessary for stabilization of the temperature before the ventilator and the flue gas purification system. The measurements and energy balance parameters showed a necessity for suction of over 15 kmol of the air to decrease the flue gas temperature for each 1 kmol of the combusted gas fuel before the modernization. This value was reduced to 4,3 kmol after the modernization, which significantly limited amounts of flue gases flowing through the extraction ventilator. As a result, it was possible to reduce the consumption of electrical energy necessary for the ventilator drive. Based on the measurements, a 35 to 40 % decrease of the electrical energy consumption was demonstrated. This result was affected by smaller amounts of pumped flue gases and a smaller drop of the pressure generated during the flue gas flow through the new recuperator. The new recuperator design features better gas dynamics and smaller flow resistances compared to the previous solution. A difference in the shape of flue gas flow spaces is clearly observed while comparing Figures 1 and 2. In addition, the new recuperator demonstrates a better resistance to dusts generated during the furnace operation. Pressure drops regarding the flue gases recorded during their flow through the recuperation system are illustrated in Figure 5.

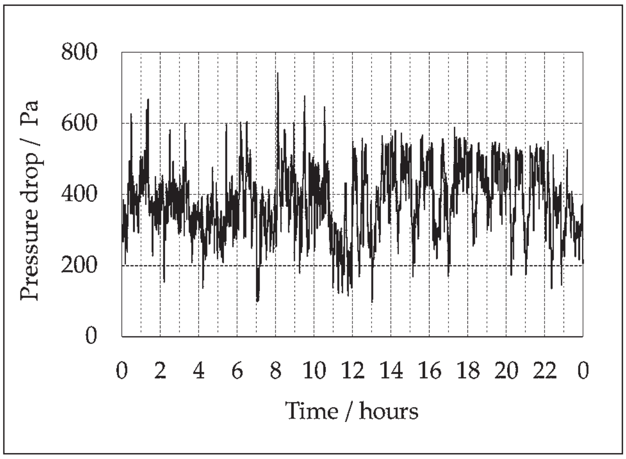

Figure 5 Loss of flue gas pressure recorded between the inlet and outlet of the recuperation system

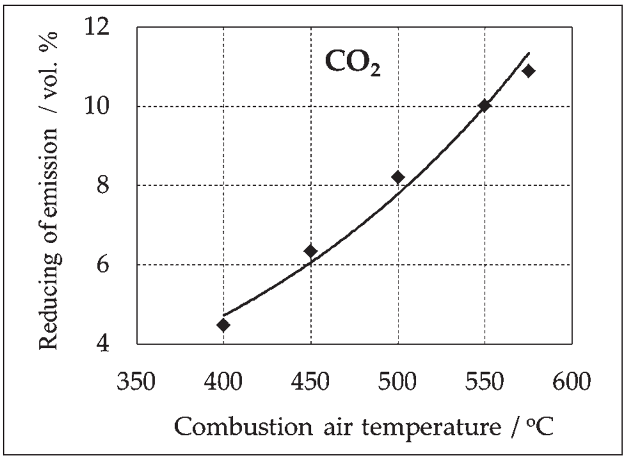

Figure 6 Influence of the combustion air temperature on CO_2 emission

A reduced consumption of chemical and electrical energy in the process of the charge heating in the furnace means lower total carbon dioxide emissions that negatively affect the natural environment [12,13]. Figure 6 illustrates the effects of combustion air temperature on the total reduction of the process-induced carbon dioxide emissions. Total reduction of the relative CO_2 emissions from the furnace after the modernization was nearly 11 % for the combustion air heating temperature above 570 °C. The reference value was the computational emission of CO_2 generated when the previous recuperator was operated with the assumed combustion air heating temperature of 300 °C which was a slightly excessive value.

While planning modernization of industrial furnaces, it should be known that only comprehensive solutions guarantee desired effects.

CONCLUSIONS

Application of new systems of energy recovery from flue gases that leave the furnace operating space ensures a higher temperature of the combustion air supplied to the burners.

Due to utilization of modern low emission burners, the combustion air temperature above 500 °C not necessarily means increased NO_x emissions in flue gases.

The new design of the recuperator with lower flue gas flow resistances and a higher energy recovery level contribute to reduced consumption of electrical energy that is necessary for the extraction ventilator drive.

The modernization activities led to reduction of total process-induced CO_2 emissions resulting from the lower consumption of gas and electrical energy. For the analyzed furnace, it was nearly 11 % compared to the state before the modernization.

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Note: The responsible translator for English language is Olga Rochowska-Siwiec, Katowice, Poland.