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The heating furnaces operating parameters optimization issue

Paramonov A.M.[a]*

[a]*Omsk State Technical University, 11, Mira Pr., Omsk 64405, Russian Federation*

Abstract

The ways of thermal efficiency and economy improving of flaming metal heating are considered. The expanded technical and economic optimization problem of furnace units having metal heating chamber operation is solved. The method and optimization algorithm analytically considering the correlation of thermal, design, operating parameters and discounted costs for the furnace unit were developed. The obtained optimization functionality provides the achievement of furnace units appropriate thermal indices at minimum discounted costs. The results of the carried out research prove the expediency of proposed solutions, make it possible to decide on the most profitable parameters of the heating furnaces thermal conditions.

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Keywords: optimization; a heating furnace; heat exchange; temperature; fuel; efficiency; recovery

1. Introduction

The heating furnaces having chamber temperature conditions are used to heat the metal for metal forming and thermal treatment in forging and heat-treatment shops. According to cost the metal heating makes up a significant proportion of forging and thermal manufacture output production costs (up to 35 %). One of the ways to improve the thermal and economical efficiency is the temperature and thermal conditions optimization.

The series of papers [1-6] is devoted to this issue investigation. The ways to improve the efficiency of fuel use and to reduce the specific fuel consumption as well as economic efficiency and airheaters application optimal conditions are examined in the above-mentioned papers. The heating furnaces optimization problem has not yet been solved without taking into account the correlated parameters and factors, their influence on the thermal conditions and furnaces design.

* Corresponding author. Tel.: +7-961-882-9029.
E-mail address: amparamonov@mail.ru

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This study presents the solving of expanded technical and economic optimization problem of heating furnaces having metal heating chamber operation. The method and optimization algorithm analytically correlating thermal, design, operating parameters and discounted costs for the furnace unit were developed. The obtained optimization functionality provides the achievement of furnace units appropriate thermal indices at minimum discounted costs taking into consideration the actual operation conditions changing depending on the furnace design, capacity and cost, on the recuperator design and cost, on the cost and kind of the fuel, on the maximum capacity utilization period and other factors. The comparative cost-effectiveness analysis of the furnace unit capital investments at minimum discounted costs is accepted as the optimality criterion.

2. The study subject (Model, Process, Device, Synthesis, Experimental procedure, etc.)

The study subject is the heating furnace. In order to get the appropriate furnace working method, it is necessary to define objectively its best temperature required for the body heating technology and capacity providing, and to choose the structural design requiring least costs. The furnace capacity is defined by the heat-exchange conditions and by the working space temperature t_w in particular. The furnace working space exit gases temperature t_g influences both t_w and metal heating time. The increase of t_g results in the rising of t_w, in heat transfer enhancement and furnace specific capacity increasing. If the furnace capacity is set, the heat transfer enhancement results in furnace size reduction and provides construction and operation cost savings. But simultaneously the heat loss grows which effects the furnace operating economy. However, owing to the wide application of recuperators for air heating by means of exit gases heat recovery it is possible and economically feasible to have higher temperature of exit gases. Meanwhile, it is appropriate to obtain the maximum possible and reasonable heat recovery rate. Consequently, furnace working space exit gases temperature and heat recovery rate (r) determine the furnace, recuperator, fuel and draft equipment costs to a large extent.

3. Methods

Therefore, the adequate choice of the furnace working space exit gases temperature as well as of their heat recovery rate gives the significant effect.

The more complete heating furnaces optimization problem solution is attained only if each value of the furnace working space exit gases optimal temperature t_g^{opt} corresponds to their heat optimal recovery rate R_{opt}. This is achieved by solving the system of equations obtained according to the necessary optimality conditions (1) and expressions for the furnace unit discounted costs (2, 3) and recuperator and fuel total costs (4):

$$\begin{cases} \dfrac{\partial E_{f.u.}}{\partial t_g} = C_m \dfrac{\partial C_f}{\partial t_g} + C_p \dfrac{\partial S_r}{\partial t_g} + C_n \dfrac{\partial V_{f.w.}}{\partial t_g} = 0; \\ \dfrac{\partial E_r}{\partial p} = C_m \dfrac{\partial C_f}{\partial p} + C_p \dfrac{\partial S_r}{\partial p} = 0. \end{cases} \qquad (1)$$

$$E_{f.u.} = \left(E_f + E_{dep} + E_{air}\right) + R_i I_{f.u.} \qquad (2)$$

$$E_{f.u.} = A_f C_f + A_r S_r + A_{f.w.} V_{f.w.} \qquad (3)$$

$$E_r = A_f C_f + A_r S_r \qquad (4)$$

$$E_f = A_f C_f \qquad (5)$$

$$A_f = C_{f.q.} h \qquad (6)$$