Identification of the influence of blast-furnance working parameters upon the supply and net calorific value of blast furnance gas

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Identifikácia vplyvu pracovných parametrov vysokej pece na dodávanú výhrevnosť vysokopecného plynu

The application of theoretical empirical mathematical model the of blast furnace and energy characteristics of a Cowper stove to identify the influence of working parameters upon the supply and net calorific value of blast furnace-gas has been discussed. Results of exemplary calculations have also been presented.

Key words: *blast furnace, energy management, empirical characteristics, blast-furnace gas.*

Introduction

The blast-furnace process (BF) is the dominant technology of pig iron production. Pig iron is the main product of BF. Simultaneously BF gas is produced which is a by-product of BF. The net calorific value of BF gas changes in the range from 60 MJ/kmol to 90 MJ/kmol or higher. First of all, BF gas is consumed in Cowper stoves (CS). The surplus of BF-gas is transferred to the gas-subsystem of the ironworks. Blast furnace gas is an important source of chemical energy consumed outside the balance shield of the BF process. First of all, the surplus of BF gas is consumed in metallurgical furnaces together with natural gas and coke oven gas, and in ironworks power plant. The main parameter deciding about the usefulness of BF gas is its calorific value.

The calorific value of BF gas depends on the working parameters of BF, among others on: amount of auxiliary fuel injected into the BF, the temperature of hot blast, the oxygen content in the blast.

The identification of the influence of the working parameters of the blast furnace upon the net calorific value of BF-gas is of great practical importance from the point of view of energy management of ironworks. For this purpose the mathematical model of a blast furnace has been used (Szargut, 1983).

The amount of BF-gas transferred to external consumers depends on the amount of gas produced in the BF and on the amount of BF gas consumed in a Cowper stove.

The paper presents the identification of the influence of the working parameters of a blast furnace upon the supply and net calorific value of BF-gas. The influence of amount the of auxiliary fuels injected into the BF, the temperature of hot blast, oxygen content in the blast upon composition and flux of BF gas transferred to external consumers are determined making use of the mathematical model of the blast furnace (Ziębik, 1997) and empirical characteristics of Cowper stoves (Ziębik, 1996).

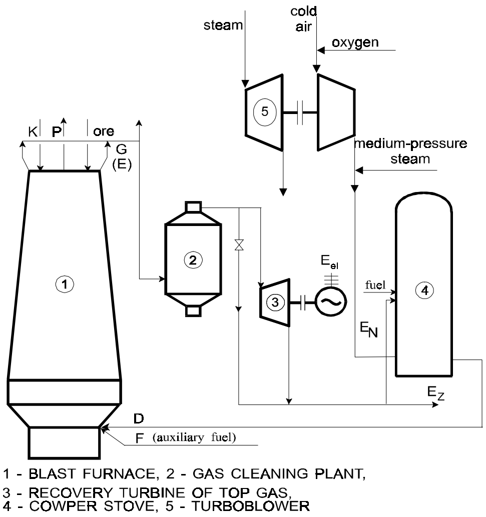

Fig.1. Blast furnace plant.

Characteristics of a Blast Furnace plant

Fig. 1 presents a schematic diagram of a blast furnace plant. The flux of BF gas produced in the BF ($\dot{G}$) as well as its calorific value W_{dG} depend on the working parameters of the BF. The influence of these parameters upon the energy characteristics of the BF can be determined making use of the "input-output" model of the blast furnace. This model consists of a theoretical part (balances of energy and elements) and an empirical part (empirical equations describing the composition and temperature of the BF gas. These empirical equations are derived basing on the results of thermal measurements of several blast furnaces. The knowledge of the composition of BF gas is necessary to determine the net calorific value of BF gas - parameters deciding about the usefulness of fuels.

Eg. 1 presents an empirical equation describing the ratio CO_G/CO_{2G} in BF gas in the case of injecting pulverized coal as auxiliary fuel:

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$$\varphi = \frac{CO_G}{CO_{2G}} = 0.1174\exp(-0.0364F) + 8.93\exp[-0.0053(T_D - 273)] + 69.01(O_{2D} - 0.2576)^2 + \varphi_0 \quad (1)$$

where: F - amount of auxiliary fuel, T_D - blast temperature, O_{2D} - molar fraction of oxygen in dry blast.

Empirical equation describing the molar fraction of H_2 in BF gas:

$$GH_{2G} = \left[\left(K - P\frac{c_P}{c_K}\right)\frac{h_K}{2} + F\left(\frac{h_F}{2} + \frac{w_F}{18}\right) + DX_{ZD}\right]\left[\psi_0 - \frac{1,08}{(1+\varphi)}\right] \quad (2)$$

where: G - specific production of BF-gas, K - specific consumption of coke, P - quantity of flue dust, c_P, c_K - mass fraction of carbon in the dust and coke, h_F, w_F - mass fraction of hydrogen and moisture in auxiliary fuel.

The flux of chemical energy of BF-gas can be calculated by means of the following formula:

$$\dot{E}_Z = \zeta\dot{E} - \frac{\dot{D}\Delta i_D}{\eta_N}\frac{(1 - z_b)W_{dG}}{z_b W_{db} + (1 - z_b)W_{dG}} \quad (3)$$

where: ζ - index of top-gas losses, $\dot{E}, \dot{E}_Z$ - flux of the chemical energy of top gas produced in the BF and BF gas transferred to external consumers, $\dot{D}$ - flux of blast, Δi_D - increase of the specific enthalpy of the blast, η_N - energy efficiency of a Cowper stove, W_{dG}, W_{db} - net calorific value of BF gas and coke oven gas consumed in a Cowper stoves, z_b - molar fraction of coke oven gas in mixed gas consumed in Cowper stove.

The energy efficiency of a Cowper stove is determined basing on the thermal characteristics (Ziębik, 1996) of the following form:

$$\eta_N = a_0 + a_1 t_D + a_2\dot{D} + a_3 W_D + a_4 t_D\dot{D} + a_5\dot{D}W_D + a_6 t_D W_D + a_7 t_D^2 \quad (4)$$

where: $a_0 ... a_7$ - empirical coefficients, W_D - net calorific value of gas consumed in CS.

The empirical coefficients are determined using stepwise regression.

The mathematical model of the BF and characteristics of the Cowper stove have been used to identify the influence of working parameters of the blast furnace upon the supply and net calorific value of BF-gas.

Results of example calculation

Fig. 2 ÷ 5 presents the results of exemplary calculations of the influence of the working parameters of the blast furnace upon the supply, composition and net calorific value of BF-gas. The effects of the injection of auxiliary fuel (pulverized coal - p. c. i., coke oven gas - c. o. g.) and increase of the blast temperature have been considered. The increase of the amount of auxiliary fuel results in an increase of the flux of gas transferred to external consumers (Fig. 1). If Cowper stove is fired only with BF gas increase of blast temperature results in decrease of flux of BF gas transferred to external consumers. A further increase of the blast temperature may require an enrichment of fuel gases for the Cowper stoves. In this case an additional flux of BF gas (replaced by coke oven gas) is available for external consumers.

The injection of auxiliary fuels leads to a decrease of the molar fraction of CO in the BF gas and simultaneously leads to an increase of the molar fraction of H_2 (Fig. 2) in the BF-gas. The increase of the chemical energy of H_2 in BF-gas is greater than the decrease chemical energy of CO therefore the net calorific value of BF gas increases (Fig. 4). The changes in the flux of chemical energy of gas transferred to external consumers (Fig. 5) result from changes of the gas flux (Fig. 2) and changes of its net calorific value (Fig. 4).

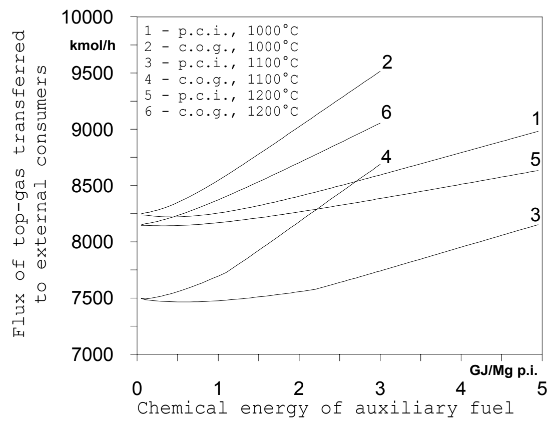

Fig.2. Flux of BF transferred to external consumers.

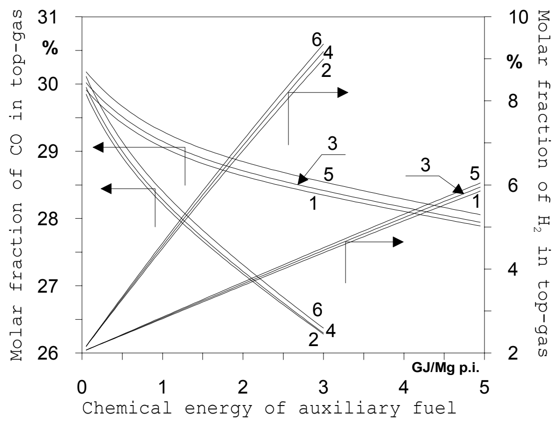

Fig.3. Molar fraction of CO and H_2 in top-gas.

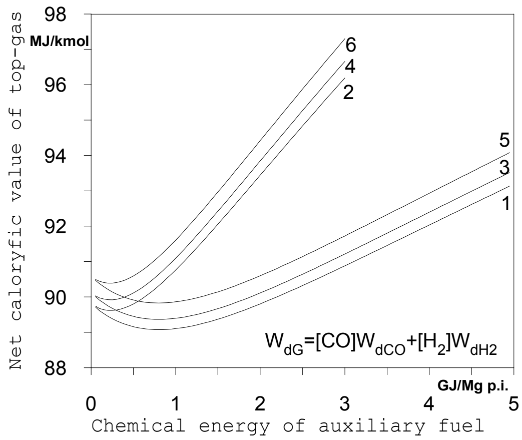

Fig.4. Net calorific value of BF-gas.

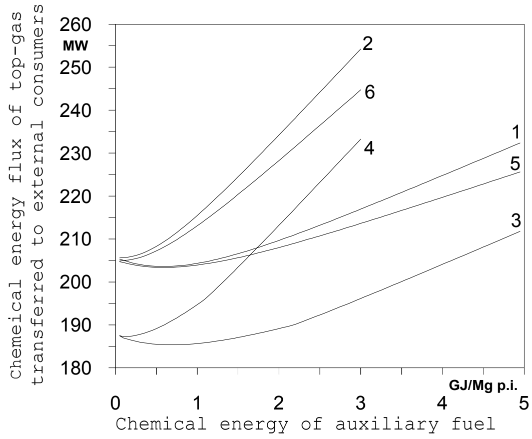

Fig.5. Flux of chemical energy of BF gas transferred to external consumers.

Final remarks

The application of the theoretical empirical mathematical model of a blast furnace and energy characteristics of a Cowper stove to identifying the working parameters of BF upon the supply and net calorific value of BF-gas has been discussed.

Exemplary calculations have also been carried out. The paper presents the influence of injection of auxiliary fuel and increase of the blast temperature upon the flux of chemical energy of BF gas transferred to external consumers, its composition and net calorific value. The discussed algorithm may be applied in the energy management of ironworks.

References

SZARGUT, J. and ZIĘBIK, A.: *The Influence of the Blast Parameters and of the Injection of Auxiliary Fuels and Hot Reducing Gas on the Energy Characteristics of a Blast-Furnace Plant.* (in Polish), Ossolineum Wrocław, 1983.

ZIĘBIK, A., RUSINOWSKI, H. and STANEK, W.: Empirical Thermal Characteristics of Cowper Stoves. *Archives of Thermodynamics*, No 1-2, 1996.

ZIĘBIK, A., STANEK, W. and SZEGA, M.: Simulated Investigation Concerning the Influence of the Thermal Parameters of the Blast on the Energy Characteristics of a Blast-Furnace Plant and the Energy System of Ironworks. *Proceedings of TAIES'97*, Beijing, 1997.