THE IMPORTANCE OF THE THERMAL RESERVE ZONE POSITION DETERMINING IN BLAST FURNACE

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Abstract

The presented paper shows the way of determination of the thermo-chemical reserve zone location in the working space of blast furnace, using data from the horizontal probe. Reserve zone is the bottom boundary of the preparatory zone, and so the area of indirect reduction of iron oxides. Occurrence of these reactions also depends on the contact time between the gas and the solid phases, so it is extremely important for the smooth operation of the blast furnace process.

Keywords: Blast furnace, thermal reserve zone

1. INTRODUCTION

According to the Rist model, a blast furnace can be divided into two zones: preparatory and generating [1]. They are separated from each other by a thermal/chemical reserve zone. The reduction processes in both these zones are different from each other. This is determined by the thermodynamics of the Boudouard reaction which is involved in receiving oxygen from Fe oxides in the generating zone only. Its action has a strong influence on the processes of heat and mass transfer between the gas and the burden. As a result of this reaction, coke coal is consumed, which passes into the gas phase whose composition depends mainly on the balance of this reaction. In addition, the endothermic thermal effect of the Boudouard reaction has a major influence on the volume of heat transfer between the gas and the burden. For these reasons, the equations of mass and heat transfer between the gas and the burden in both these zones require separate treatment. However, determination of thermal reserve zone is very important because it fulfills the role of hypothetical boundary between the upper and lower areas of blast furnace, and thus, may constitute boundary conditions for the parameters calculation of high-temperature zone by numerical methods.

2. BASIC EQUATIONS FOR THE HEAT TRANSFER IN BLAST FURNACE STOCK

The preparatory zone includes temperatures in the following range:

- for the burden: from the surface temperature of the burden in the top of the furnace to a burden temperature of 1000^0C,
- for the gas: from the gas temperature at the surface of the burden in the top to a temperature in the zone in which the burden reaches a temperature of 1000^0C.

Under the assumptions that there is no direct FeO reduction reaction in this area, and the streams of thermal capacity of the gas and the burden are constants, the heat transfer between the gas and the burden can be written down by means of two differential equations:

$$\frac{d(W_g \cdot T)}{dz_{is}} = K_1 \cdot S \cdot (T - t) \qquad (1)$$

$$\frac{d(W_b \cdot t)}{dz_{is}} = K_1 \cdot S \cdot (T - t) \qquad (2)$$

where:
W_g - gas thermal capacity stream, kJ/h^{0}C,
T - gas temperature at the level of an appropriate burden isotherm, ^{0}C,
K_1 - coefficient of heat transfer between the gas and the burden in the preparatory zone, kJ/h m^3 ^{0}C,
S - the surface, on which the heat exchange takes place in a countercurrent, m^2,
t - burden temperature for the corresponding isotherm, ^{0}C,
W_b - burden thermal capacity stream, kJ/h ^{0}C,
Z_{is} - the level at which a corresponding burden isotherm is located, calculated from the actual surface of the materials, m

Assuming the initial conditions of the integral t_0 and T_0, the solution of the showed above system of equations (1) and (2) is followed [2]:

$$Z_{is} = \frac{W_b}{K_1 \cdot S \cdot (\alpha - 1)} \cdot \ln \frac{\alpha \cdot (t - t_0) + T_0 - t}{T_0 - t_0} \tag{3}$$

$$T = \frac{\alpha \cdot (T_0 - t_0)}{\alpha - 1} \cdot \exp\left[\frac{K_1 \cdot S}{W_b} \cdot (\alpha - 1) \cdot Z_{is}\right] + \frac{\alpha \cdot t_0 - T_0}{\alpha - 1} \tag{4}$$

where:
t_0 and T_0- the temperatures of the loaded charge and top gas respectively at the level of burden surface.
α- quotient W_b/W_g, which is always less than 1.

The value of W_g strongly depends on the gas temperature and composition, which determining is carried out by using horizontal under burden probe.

3. CALCULATION OF GAS AND BURDEN ISOTHERMS IN BLAST FURNACE STOCK

The horizontal probe is dislocated under burden surface at depth about 4.91 m. The probe allows to perform the measuring at eight measurement points, starting from the wall to the center of stock every 0.54 m.

According to situated points, the working volume of furnace is divided into eight hypothetical balancing parts. The parts differ from each other in geometric dimensions, so do in S value. In addition, heat and mass exchange in the balancing parts are strongly depend on the share of coke and ore charges. So, the radial dissimilarity of gas flow also takes place. It follows, that K_1 and α values are also different for each balancing part. To determine these parameters, it is necessary to know a value of gas temperature at level of burden surface for each balancing part. Simplified diagram of calculation shown in **Fig. 1**.

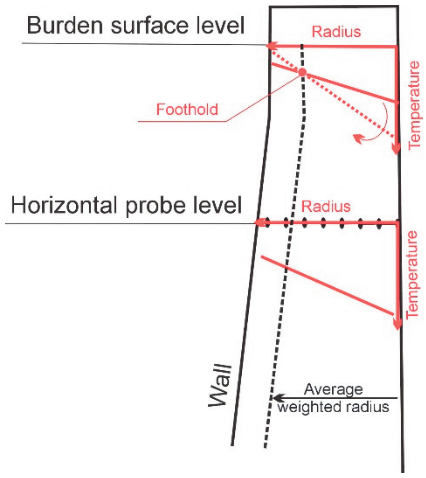

Fig. 1 Simplified diagram of the top gas temperature radial distribution calculation

One of initial conditions for calculation of top gas temperature radial distribution is that the temperature distributes at the level of burden surface in the same way as horizontal probe level, and for simplifying this distribution is linear. However, it is obvious, that this temperature distribution must correspond with overall top gas temperature, which is measured in top collecting pipeline. So, after pre-calculating, the temperature distribution is corrected by slope cange of the linear regression forming until weighted average temperature of calculated distribution will be comparable to overall top gas temperature (red dashed line at **Fig. 1**). The foothold of slope changing lays on the average weighted radius of stock, which might describe average blast furnace operation on its radius [3].

The next step of calculation is determination of burden temperature at the horizontal probe level t_{probe} according to derived equation:

$$t_{probe} = \frac{(1000 - t_0) \cdot (T_{probe} - T_{surface})}{(1020 - T_{surface})} + t_0 \qquad (5)$$

where:
1000 and *1020* - burden and gas temperature respectively at the thermal reserve zone;
T_{probe} and $T_{surface}$ - gas temperature at the level of horizontal probe and burden surface respectively.

Summing up the showed above, very helpful information in determination of coefficients K_1 and α is the level of horizontal probe, gas and burden temperature at this level. So does the same at the burden surface level. Substituting calculated by eq.(5) t_{probe} value to t and *4.91* to Z_{is} in eq. (3) it is possible to calculate K_1 and α by numerical method. Calculation is done in loop where α value starting from 1 is reducing by 0.0001 until T value, eq. (4), will be the same like measured by horizontal probe T_{probe} value [4].

Having the values of K_1 and α for preparatory zone it is possible to calculate any gas and burden isotherm in the blast furnace stock. The example of calculation showed at **Fig. 2**.

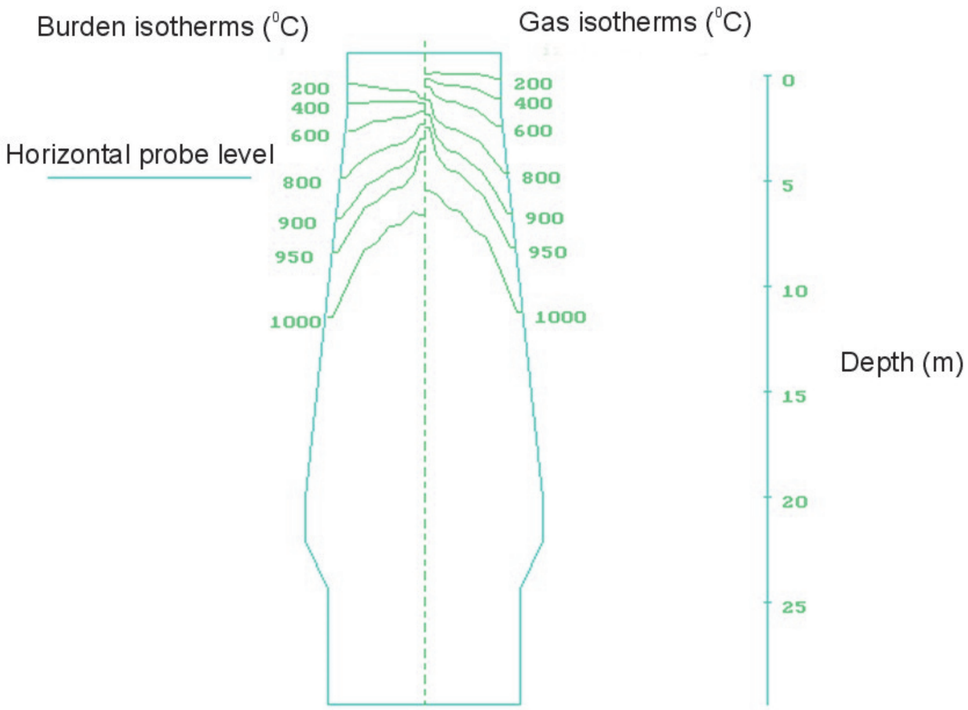

Fig. 2 Example of the reserve zone calculations with isotherms in the blast furnace stock

CONCLUSION

In the paper was presented calculation method of the thermal reserve zone range in blast furnace stock. For the most accurate determination of mass and heat exchange it is would be grate if blast furnace was equipped beside under burden horizontal probe also in top horizontal probe. But the cost of this investment mostly considered like inappropriate and usually blast furnaces are equipped exactly in under burden probe only. Showed in article method despite the used simplifications seems to be sufficient for determination of thermal reserve zone and isotherms in the upper part of blast furnace.

REFERENCES

[1] RIST, A., DANCOISN, P., JON, R., *State of Your Knowledge Concerning Blast Furnace*, Revue De Metallurgie Vol 64. Issue: 2, 1967 p. 97

[2] BENESCH, R., LEDZKI, A., KOPEC, R., STACHURA, R., WILKOSZ, A. *Identification of the Cohesive Zone in the Blast Furnace,* Archives of Metallurgy, vol 37, Issue 2, 1992 pp. 115-127

[3] ITAYA, H., ARATANI, F., KANI,A., KIYOHARA, S. *A Multi-Cylindrical Model of Blast Furnace,* Kawasaki Steel GIHO vol.13, No 4, 1981 pp. 49-58.

[4] STACHURA, R. *Determination of the reserve zone localization in the working area of blast furnace*. Hutnik-Wiadomości Hutnicze vol. 80, No. 11 2013 pp.752-756