

CONTRIBUTION TO METALLURGICAL TECHNOLOGY CONTROL PROBLEMS

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PŘÍSPĚVEK K PROBLEMATICE ŘÍZENÍ METALURGICKÝCH TECHNOLOGIÍ

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Abstrakt

Měření emisí se v současnosti využívá pro mapování množství škodlivých látek vypouštěných do ovzduší za účelem jejich minimalizace. V předloženém článku je popsán princip využití měření množství emisí a rychlosti změn těchto hodnot k řízení metalurgických technologií, hlavně výroby ocele. Je popsán princip identifikace změn koncentrace prvků v oceli pomocí měření změn koncentrací složek emitujících plynů. Jsou odvozeny základní vztahy a souvislosti v oblasti chemické kinetiky. Z uvedených vztahů vyplývá nutnost měření celé řady technologických parametrů. Popsaná teorie je použitelná i pro jiné metalurgické technologie.

Abstract

At present the emission measuring is used for mapping the injurants in order to minimize that. This article describes principle of utilization the emission measuring and speed of changes monitoring for metallurgical technologies control, steel production mainly.

The principle of identification the components concentrations changes in steel bath is described. It is based on measuring the component concentrations changes in outlet gas.

Elementary relationships in the field of chemical kinetic are deduced.

It shows necessity to measure much more other technological parameters, not only emissions. The theory described in this contribution is also applicable for other metallurgical technologies.

Key words: proceedings of metallurgical technologies, emissions, analysis of gases, kinetic equations

Introduction

On the basis former emission measurement, it was found, that the results could help to control metallurgical technologies. The theoretical basis is the equations developed by VD process mathematical description. [1, 2].

Analysis and solution of problem

The starting concentration X_{0i} and the concentration at the end of process $X_{\infty i}$ are generally known, where X_i means the concentration of compound or element i. [3]. Because of technical problems combined with continuous process control only limited concentration are disposal. The aim of metallurgical technologies is decreasing of X_{0i} concentration to required level. Such a decreasing is by mass transport through the phases interface.

Required direction and course of chemical reaction is further in suitable way realized - gaseous compound or slag removal or let us say by bounding into stable compounds.

Such a process can be described by formally as consecutive chemical reaction:

(1)

Where A, B a C are generally reacting compounds or elements and [A], [B] a [C] their concentration. The following differential equation scheme can be accepted:

(2)

(3)

(4)

The solution of equation (2) is:

(5)

Equation (3) is non homogeneous (with right side), which can be solved using constant variation by respecting initial conditions in time $t=0$, $[B]=[B_0]$:

(6)

Using substitution eq. (6) into (4) by respecting the initial concentration, we can find the time dependency of compound C concentration:

(8)

Remark: introduced mathematical description can be generalized for random amount of subsequent reaction.

In case of special constants k_1 and k_2 ratio, the situation can take place, where the intermediate product B can not be detected at all. It means that this intermediate product is faster reacted than created. Such a system study is in this case much more easy. The next figure shows time dependency of intermediate product concentration using various k_1 and k_2 ratios (in the Table 1). The values are for the initial concentration of compounds A: $A_0=100\text{mol.l}^{-1}$ calculated.

Fig.1 Intermediate product concentration

Table 1 Reaction velocity constants k_1 , k_2 and their ratio

From metallurgical refining process view the meaning of the constant k_1 , which determines the removing velocity the compound X_i from steel, is evident. The second one k_2 responds to the velocity of product removal out of the second phase e.g. from vacuum. The physical dimension of particular derivatives 1 (equation 2 - 4) can be understood as the amount per time unit of released compound X_i e.g. $[\text{mol.s}^{-1}]$. This value has the velocity dimension. Regarding the fact that the gases are removed from the reaction area, it is possible to describe the whole process as product flow.

In this case it can be accepted:

(9)

It means the i -th product flow is equal to product of total volume flow and the X_i concentration in out gas ($[\text{m}^3.\text{s}^{-1}][\text{mol.m}^{-3}] = [\text{mol.s}^{-1}]$), the index *out* is used for out gas concentration. The immediate X_i content in the steel bath is equal the initial concentration decreased by reacted and emitted amount.

So e.g. the carbon content in steel bath can be calculated according to the following equation:

(10)

Using of both carbon oxides kinetically equation we receive:

(11)

By substitution of carbon concentration in steel bath from equation (10) it can be the implicit relation of actual oxygen concentration in steel bath:

(12)

It is possible to generalize these relations:

Basic mass balance of random compound X can be defined by equation (13)

(13)

Where is: $m_{0,1}$ initial mass of compound X in steel
 m_1 immediate mass of compound X in steel
 m_{out} emitted mass (reacted)

The total emitted mass m_{out} in time t is:

(14)

This formula enables to define the dependency of compound X decrease in steel bath:

(15)

From graphical representation of X concentration development $[X]_g = f(t)$ and the integrated equation (14) the total process flow can be determined.

The comparison of integrated value (14) to the compound "C" results from the next speculation: The integral is a picture of mass amount of compound [X] removed from steel. If we realize hypothetical condition, that the mass is cumulated in ambient area of volume V, then it is evident, that for random volume V, the ratio of mentioned integral and the volume represents the concentration of "product C".

To explain this totally, it is necessary to define relationship between mass and concentration. It is evident that this system is considered as flow system and in this case the emitted amount is dependent on the total system mass. The relation for total amount of compound X e.g. in ppm units is determined by grams of X per steel tone.

In the simplified form it is possible to formulate these relations on the first order kinetically equation basis (without evaluation of metallurgical influences, H means in this case hydrogen). The basic equations are valid in this case:

(16)

Solution of equation (16) is the dependency (17).

(17)

By respecting of equation (13) and (14) the relation (17) is possible to modify as:

(18)

(19)

The relation (20) is possible to approximate using exponential function in form:

(20)

It is not possible to solve these equations using least square method in linearized form we can use some of optimization method only. As the best suitable way the optimization of constant k_1 was found to reach maximal correlations coefficient of regression function:

(21)

where:

Summary

The above-mentioned relationships define basic task [4] necessary to make. From the equation (9) results the necessity of off gas volume determination. From theoretical point of view results, that the constant k_1 from (2) depends on number of parameters - Ar flow, end point vacuum, steel quality and probably the velocity of carbon oxide production. The next step is development of suitable software and pilot plant installation on chosen technology.

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