

CONTROL OF BURN-THROUGH POINT FOR AGGLOMERATION BELT

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The paper describes the control of burn-through point for sinter on the agglomeration belt. This control is based on mathematical modelling of agglomeration process. The mathematical models and algorithms are derived from basic models of physical and chemical processes of agglomeration belt and they are based on directly and indirectly measured quantities of agglomeration belt. The feed-forward control is based on the quantity of the gas combusted in the ignition furnace and on the quantity and composition of the raw mix. This value is corrected according to the identified burn-through point. Output from the control system is the required value of turbo-exhausters operating speed.

Key words: *control, agglomeration process, mathematical model, indirect measurement*

Kontrola točke staljivanja na aglomeracijskoj traci. U radu se opisuje kontrola točke staljivanja sintera na aglomeracijskoj traci. Ta se kontrola zasniva na matematičkom modeliranju aglomeracijskog procesa. Matematički modeli i algoritmi su izvedeni iz temeljnih modela fizičkih i kemijskih procesa na aglomeracijskoj traci i osnivaju se na izravno i neizravno izmjerenim količinama na aglomeracijskoj traci. Kontrola kretanja naprijed se zasniva na količini plina izgorjenog u potpalnoj peći i na količini i sastavu sirove mješavine. Ta veličina se ispravlja prema utvrđenoj točki staljivanja. Izlaz iz kontrolnog sustava je tražena vrijednost operativne brzine turbo-puhala.

Ključne riječi: *kontrola, aglomeracijski proces, matematički model, neizravno mjerenje*

INTRODUCTION

Modernisation of the control of metallurgical processes is very desirable because of their high energy and material consumption. The agglomeration process control is one of the main contributors to the successful agglomeration plant operation and belongs to the key factors of its economic efficiency [1 - 5].

For most blast furnaces sinter is the basic metallic charge, which significantly influences the blast furnace process. The mechanical and metallurgical properties of the sinter depend on its composition and on the sintering process. For the blast furnace operation appropriate sinter chemical, mineralogical and mechanical properties are required, which can be significantly influenced by the sintering process [6 - 9].

Optimisation of the agglomeration process is oriented mainly toward sinter quality enhancement and fuel economy improvement. For the complex study of the ag-

glomeration process a mathematical model was developed which includes processes in ignition furnace and agglomeration belt. Optimal ignition and sintering conditions were determined by simulation. The results were used for the design of new ignition furnace, for a new organisation of the suction process, and for the development of adequate control strategy. The model was utilised also for the design of a new turbo-exhausters operating speed control and monitoring system [10].

AGGLOMERATION PROCESS

Agglomeration process is a set of physical, thermal, physicochemical, and chemical processes, through which the structure and composition of input raw material, is changed. The agglomeration process occurs in a heterogeneous sequence gaseous - liquid - solid stage, while the gaseous stage provides the flow of the most important processes, i.e. fuel combustion, heat transfer, and reduction-oxidation processes [6].

The transformation of the agglomeration burden into sinter takes place in the agglomeration plant. The main components of the agglomeration plant are the ignition

J. Terpák, E. Dorčák, I. Košťál, BERG Faculty Technical University of Košice, Košice, Slovakia, L. Pivka, Computing center Technical University of Košice, Košice, Slovakia

furnace, agglomeration belt and exhausting system. The sintering material creates a bed on the agglomeration belt and consists of metallic burden (concentrate, crushed ore), slag fluxes (mainly limestone), coke and water (moisture). The agglomeration process starts by the ignition of the upper surface of the agglomeration bed in the ignition furnace and it continues up to the bottom of the agglomeration bed. The sinter is then discharged on the cooling conveyor and is transported into the blast furnace bunkers.

The control system of agglomeration process is designed with the objective to maximize the sinter quality and fuel economy. The control system is divided into following subsystems:

- charging bunker control,
- mix component batching control,
- ignition control,
- agglomeration belt speed control,
- exhaustion control (Figure 1.).

EXHAUSTION CONTROL SYSTEM

Turbo-exhausters provide the waste gas exhausting from the exhausting chamber through the electro-filter. The real quantity of the exhaust gases depends on the operating speed of the turbo-exhausters and on the parameters of the agglomeration process. The main goal of the exhausting control system is the determination of the desired quantity of the exhaust gas from directly measured data and the desired and real process parameters and then the determination of the desired turbo-exhausters operating speed (Figure 1.).

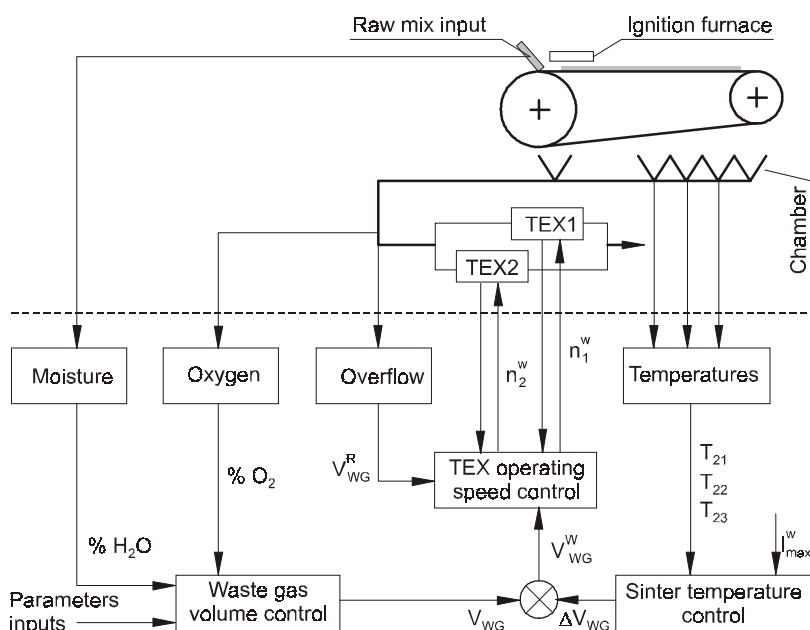


Figure 1. Control scheme
Slika 1. Shema kontrole

Waste gas volume control

The calculation of the desired quantity of the exhaust waste gas is based on the calculation of the waste gas volume from the ignition furnace (V_{WG_IF}) and from the remaining part of the agglomeration strand (V_{WG_AS})

$$V_{WG} = V_{WG_IF} + V_{WG_AS} \quad / \text{ (m}^3\text{/s)} \quad (1)$$

The determination of the waste gas volume from the ignition furnace consists of the waste gas volume for blast furnace gas (V_{WG_BG}) and for coke oven gas (V_{WG_CG}) calculation:

$$V_{WG_IF} = V_{WG_BG} + V_{WG_CG} \quad / \text{ (m}^3\text{/s)} \quad (2)$$

The determination of the waste gas from agglomeration strand consists of summary nitrogen, material volatile, oxygen surplus, moisture, dioxide sulphur, trioxide sulphur, dioxide and monoxide carbon from combustion carbon, and dioxide carbon from carbonate volume calculation:

$$V_{WG_AS} = V_{N_2} + V_V + V_{O_2} + V_{H_2O} + V_{SO_2} + V_{SO_3} + V_{CO_2} + V_{CO} + V_{CO_2_MeCO_3} \quad / \text{ (m}^3\text{/s)} \quad (3)$$

Sinter temperature control

The calculated desired waste gas exhausting volume for turbo-exhausters is corrected according to difference of the position of real and desired point of maximal waste gas temperature (Figure 2.). The standard position of this point is in the centre of the 22th chamber, in some cases in the 21th or 23th chamber.

The real position of this point we can identify from the parabolic approximation of the measured temperatures in three chambers

$$T(l) = a_2 l^2 + a_1 l + a_0 \quad / \text{ K} \quad (4)$$

From this parabolic approximation we can also compute the difference between the real and desired position at the point of maximal waste gas temperature

$$e_l = l_{max} - l_{max}^W \quad / \text{ m} \quad (5)$$

and then we determine the correction of desired waste gas exhausting volume

$$V_{WG} = V_{WG}^W \left(1 + \frac{e_l}{l_{belt} - l_{max}^W} \right) \quad / \text{ (m}^3\text{/s)} \quad (6)$$

where:

- T - the temperature of exhausted waste gas / K,
- l - the distance from the end of the belt / m,
- a_2, a_1, a_0 - the approximation coefficient / (K/m²), K/m, K,
- l_{max}, l_{max}^w - the real and desired position of maximal waste gas temperature / m.

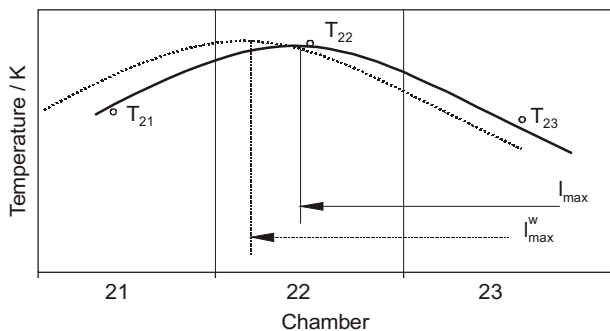


Figure 2. Burn-through temperature control
Slika 2. Kontrola temperature staljivanja

Turboexhauster operating speed control

There are several methods for the turbo-exhausters operating speed determination from the desired waste gas exhausting volume. If the dependency of the waste gas exhausting volume on the turbo-exhausters operating speed is known as a function $V = f(n, p)$, i.e. operating speed (n) and pressure (p), then we can compute the desired turbo-exhausters operating speed simply from the inverse function. In the case of unknown dependency, the computation is based on the direct proportion between the real and desired exhausting volume and the real and desired turbo-exhausters operating speed ($n^w/V^w = n/V$), thus the desired operating speed

$$n^w = n \left(1 + \frac{e_V}{V} \right) = n \left(1 + \frac{V_{WG}^w - V}{V} \right) / \text{min}^{-1} \quad (7)$$

executes the turbo-exhausters operating speed control.

Utilisation of measured raw mix moisture and waste gas oxygen content for control

The information about the measured moisture is an important input for the determination of the waste gas exhausting volume. The moisture level in the agglomeration mixture varies often and eventually it influences the resulting amount of the waste gas. So far the moisture level was assumed to be constant and the changes in moisture acted on the control system as a fault with significant in-

fluence on the total amount of waste gas. At present the moisture is measured and considered as another input into the control system. With regard to the fluctuating value of measured moisture level let us consider in the calculations sliding average of the moisture.

A significant component of the waste gas exhausting volume is the volume of false air. Its determination based on the conditions of layer resistance, leakage and missing belt links is very demanding and inaccurate. The utilization of the measured value of oxygen in exhaust waste gas makes it possible to determine more accurately the value of air.

The determination of the false air amount is based on the balance of waste gas volume

$$V_{TWG} = V_{WG} + V_{FA} / (\text{m}^3/\text{s}) \quad (8)$$

and on the partial balance of oxygen

$$V_{TWG} X_{TO_2} = V_{WG} X_{WO_2} + V_{FA} X_{AO_2} / (\text{m}^3/\text{s}) \quad (9)$$

where:

- V_{TWG} - the total volume of exhausted waste gas / (m³/s),
- V_{WG} - the volume of waste gas exhausted through the belt / (m³/s),
- V_{FA} - the volume of false air / (m³/s),
- X_{TO_2} - the percentage of oxygen measured in the total waste gas volume / %,
- X_{WO_2} - the percentage of oxygen in waste gas passing through the belt / %,
- X_{AO_2} - the percentage of oxygen in false air / %.

By solving the above equations we obtain the relation for the false air volume

$$V_{FA} = V_{TWG} \frac{X_{TO_2} - X_{WO_2}}{X_{AO_2} - X_{WO_2}} / (\text{m}^3/\text{s}) \quad (10)$$

The percentage of oxygen in the waste gas under the belt is given by the surplus of air, which is exhausted through the belt and is given by the relation

$$X_{WO_2} = \frac{V_{EA} (\lambda - 1) X_{AO_2}}{V_{WG}} / \% \quad (11)$$

where:

- V_{EA} - the calculated exhausted amount of air through the belt / (m³/s),
- λ - the surplus of exhausted air / (m³/m³).

CONCLUSION

The presented control system of the turbo-exhausters operating speed is a combined feedforward and feedback type. Acceptance run results are adequate for this control system design.

The industrial implementation of the control system proved the validity of these results and brought a significant improvement of the agglomeration process efficiency and quality. The fundamental prerequisite for the control system functionality is a functional measuring accuracy system of moisture and oxygen.

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