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THE METHOD TO OBTAIN OF THE AGGLOBURDEN SINTERING MATERIAL USING THE CONVERSION OF NATURAL GAS

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The paper considers the processes of direct production of iron from ores, which are called solid-phase reduction processes. A technology for the production of metallized agglomerate is proposed, consisting of two stages: sintering of agglomerate and subsequent metallization of hot intact sintered material. The combined sintering process and metallization with the products of natural gas conversion of the agglomerate at an elevated pressure of the gas phase resulted in the metallization of 50 - 68 % metallized sinter.

Key words: iron ore, agglomerate, sintered material, natural gas, pressure

INTRODUCTION

Technology enhancement in the ferrous metallurgy is aimed at the reducing the consumption of coke, industrial wastes and emissions which pollute the environment. There are three main types of raw materials are used in the metal products production: 1) liquid and solid steel-making iron, 2) steel scrap, 3) in smaller volumes of metallized iron ore material. The supply and demand for these materials are closely interrelated and determine in many aspects the situation in the world markets of both metallurgical raw materials and completed products. After analyzing the articles it can use similar methods of analysis and conducting the research. The process of increasing the iron content in the iron ore materials is called the metallization process, the resulting product is called metallized one. The percentage of iron in the product is usually understood as the degree of metallization. Some problems are published in advance in the article [1], it use their experience to solve their problems.

Metallized products are usually divided into three groups according to their needs:

1) The product with a metallization degree up to 85 % is used as a burden of blast furnace smelting;
2) The product with a metallization degree of 85 – 95 % is used as a charge during steel smelting;
3) The product containing more than 98 % of Fe is used to produce iron powder.

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Metallization processes of iron ore materials are carried out under the temperatures not more than 1 000 – 1 200 °C, in other words, in the conditions where both the raw materials (iron ore or iron ore concentrate) and the product are the solid phase, and there is no softening of materials, as well as their gluing or sticking to the walls of the aggregates. Such processes of direct iron getting from ores are called solid-phase restoration processes [2]. Coal (the solid restoration agent) or natural gas (gaseous restoration agent) is usually used as a restoration agent to restore iron oxides. In this case, it is preferable to use not “raw” natural gas but hot restoration gases, since heat is not spent to dissociate of hydrocarbons and the arrival of heat is determined by heating the restoration gases. Restoration gases are obtained by converting of gaseous hydrocarbons or by gasifying of solid fuels [3]. A conversion can be:

- an oxygen (air) conversion

$$CH_4 + 1/2O_2 = CO + 2H_2 + Q,$$

- a steam conversion

$$CH_4 + H_2O = CO + 3H_2 – Q \quad \text{or}$$

- a carbon dioxide one

$$CH_4 + CO_2 = 2CO + 2H_2 – Q.$$

The steam and carbon dioxide conversions require the heat cost for the reaction. The conversion is carried out in special devices with catalysts using. The examples of smelting are given in [4, 5]. They showed the direction of achieving the efficiency of metallization of the blast furnace burden. This reduces the specific consumption of coke and increases the productivity of blast furnaces. Similar examples of achieving a positive result in improving the economic efficiency of production are given in [6]. Using the scientific methods described in [7] and [8] it can be argued that the economic efficiency of the production and use of the metallized burden in the blast furnace production is to reduce the cost price of the metallized product [9, 10].

EXPERIMENTAL TECHNIQUE

The process of agglomerate metallization was tested in industrial conditions simultaneously with its sintering due to a sharp increase in the content of solid fuel in the aggloburden. Significant disadvantages of this technology such as

a) the reduction of sintermachine's productivity by 40 – 50 %;
b) the increase of sulfur content in the metallized product to 0,3 %

Large reserves and relatively low cost of natural gas stimulated the research in natural gas use in the processes metallization of iron ore materials including the sinter. In this case it is possible to obtain a metallized agglomerate with a given sulfur content and it is apparently possible to intensify the metallization process. The technology to obtain metallized agglomerate is proposed. This technology consists of two stages: of agglomerate sintering by heated to 1 000 – 1 100 °C and of following metallization of hot intact agglomerated cake by converted natural gas with the temperature of 1 100 – 1 200 °C. The experiments were condu-cted on the integrated laboratory installation of the retort type. The installation is the combination of sinter pot and burner device (Figure 1). The composition of the gas phase in the sintering stage of aggloburden is given in Table 1.

Table 1 **The composition of the gas phase in the sintering stage of aggloburden**

The method of gases producing	Content / %		
	CO_2	O_2	N_2
1. Burning of CH_4 by air and diluting of combustion products by secondary air	6,4 – 7,9	8,2 – 9,8	83,8 – 84,0
2. Burning of CH_4 by air and diluting of combustion products by oxygen	5,0 – 8,8	20,0 – 22,7	70,0 – 73,3

The moisture content (by calculation) in the gas mixture ranged from 8,0 to 12,5 %. The temperature of the gases above the burden layer varied from 1 000 to 1 100 °C.

The presence of carbon dioxide and water vapors in the gas phase inhibited the sintering process of aggloburden. By the end of the sintering stage, the temperature along the height of the aggloburden layer was equalized and was 1 020 – 1 125 ^{0}C with a difference of about 100 ^{0}C. The products of natural gas conversion by technical oxygen were used at the stage of metallization of the agglomerated cake with the coefficient of oxygen consumption of 0,39 – 0,41. The composition of dry products conversion was as follows (the average over the study period), in % ratio: CO_2 = 5,2 %; CO = 35 %; H_2 = 55 %; N_2 = 4,8 %.

It can be seen in the Table 2 that the series of experiments made it possible to reveal the influence on the metallization character, the pressure of the gas phase above the layer, the technological gas consumption, etc. The temperature of the gas phase and sintering decreases gradually although insignificantly during the process

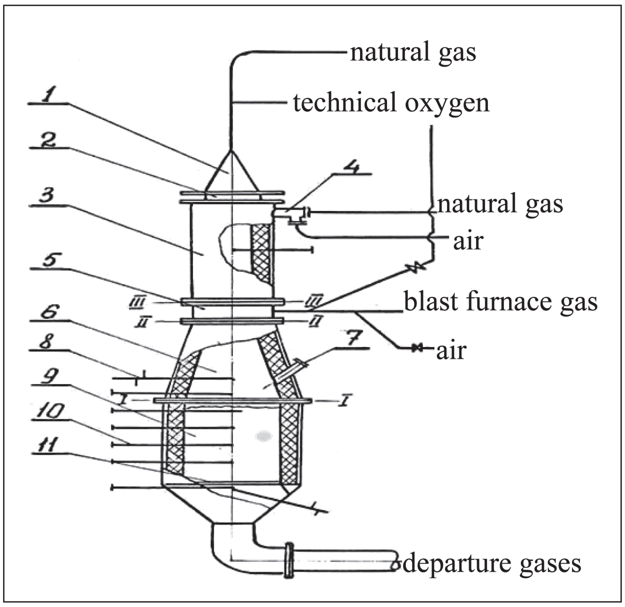

Figure 1 The scheme of the integrated laboratory installation of the retort type: 1 - gas mixer; 2 - stabilizing lattice; 3 - stabilizing grid; 4 - gas-air burner; 5 - mixer; 6 - intermediate cone; 7 - peeler; 8 - gas intake tubes; 9 - retort; 10 - thermocouples; 11 - grate

Table 2 **Results of experiments in agglomerate metallization by gases under the pressure**

№ experiments	Gas pressure / MPa	The duration of the process / min	The average temperature of gases / ^{0}C (1 point)	The average temperature in the layer on Points / ^{0}C				Degree of metallization	
				II	III	IV	V	Average layer	Top of layer
139	0,22	30	1 125	-	1 107	-	1 022	16,7	27,0
140	0,21	30	1 120	-	1 208	-	1 100	50,1	57,4
141	0,21	20	1 045	-	1 070	-	1 021	52,8	60,0
142	0,2	50	1 013	-	1 045	-	1 010	50,8	67,7
143	0,2	25	947	-	900	-	900	3,5	-
144	0,21	20	1052	-	1 070	-	1 087	46,0	49,4
145	0,23	40	1010	1 050	1 032	1 064	1 048	28,5	37,6
146	0,2	30	987	1 020	1 006	1 112	1 036	58,0	36,2
147	0,2	30	1020	1 036	1 036	-	966	68,7	98,7

of hot agglomerate metallization. In most experiments, the temperature difference in layer height obtained by the time of transition from the sintering stage to the metallization stage was maintained until the end of the experiment.

The moisture content in the conversion products was 12 – 14 %. The composition of the products of oxygen conversion of natural gas was distinguished by a high content of oxidizing components. Technological parameters of the experiments varied depending on the task. Table 2 shows the results of the experiments on agglomerate metallization by products of oxygen conversion of natural gas under the pressure. The Table 2 shows that it

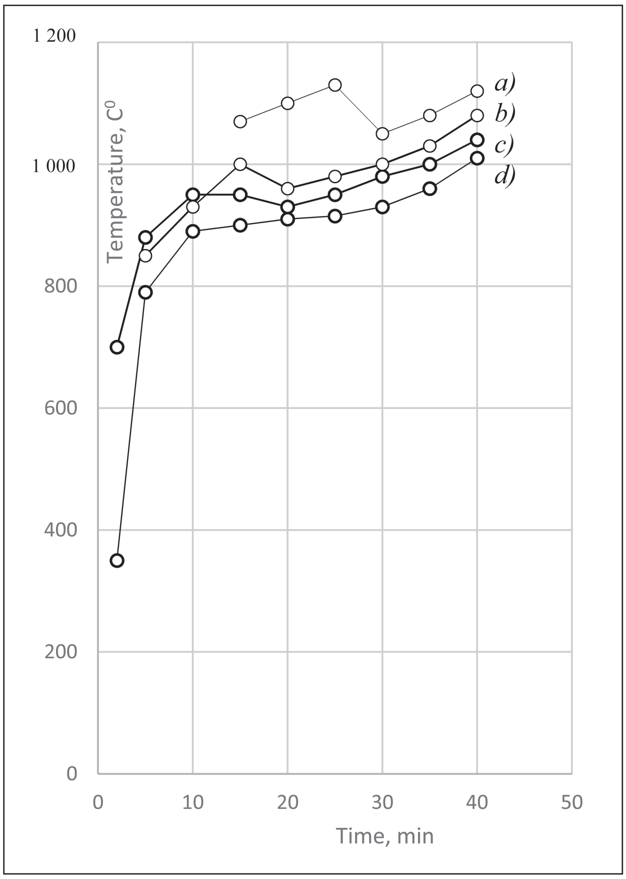

Figure 2 The change in the temperature of the gas phase and in the temperatures in the aggloburden layer during sintering: *a*) 4 - 10 - gases temperature above the layer; b) 3 - 9 - gases temperature at the top of the layer; c) 2 - 8 - gases temperature in the upper half of the layer; d) 1 - 7 - gases temperature in the lower half of the layer

is possible to achieve a metallization degree of the agglomerate of 46 – 58 % (on average by the layer) during 20 – 30 minutes. The low degree of agglomerate metallization in the experiment of 145 is the result of the blowing out of a part of the material (possibly in the sintering stage) and the formation of a "surface blowhole". The main part of the gas went out by the formed channel at the same time.

The changes in temperature of the gas phase and in temperatures in the layer of aggloburden during sintering are given in the Figure 2.

THE DISCUSSION OF RESULTS AND CONCLUSIONS

Figure 3 shows the dependence of agglomerate metallization degree on the temperature in sintering obtained by averaging the experimental data. For processing experimental data, methods were used.

The agglomerate metallization degree did not exceed 40 % at the temperatures in the layer below 1 000 °C and 30 minute duration of the metallization stage. A higher degree of metallization with the same duration of the process is achieved under the increase of layer temperature 1 030 – 1 100 °C.

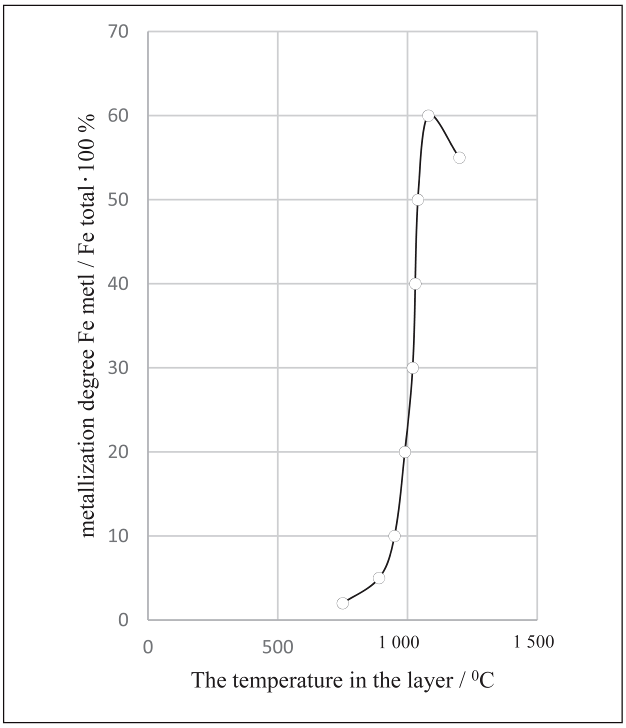

Figure 3 The effect of temperature in the layer on metallization degree of the agglomerate recovered by the products of oxygen conversion of natural gas

Using the fourth degree polynomial approximation method, it can obtain the dependence graph of changes in temperature the gas phase and in temperatures in the layer of aggloburden during sintering in the time range from 0 to 40 minutes (Figure 4).

Figure 5 shows the arrangement of thermocouples and the temperature dependence of the time of the metallization stage for layers I-IV in the layer of agglomerate and above the layer, as well as the temperatures change during agglomerate metallization. Above this temperature, the metallization process of the agglomerate slows down, apparently, as a result of the partial melting of sintering and the deterioration of its structure.

Using the method of polynomial approximation, we draw the graph of metalization dependence Fe metl / Fe total ·100 %. Thus, the metallized on 50 – 68 % agglomerate is received by the combined process of sintering and metallization by the products of natural gas conversion of the aggloburden under the increased pressure of the gas phase. The duration of the metallization stage was 20 - 30 minutes. The optimum temperature of agglosintering metallization was 1 030 – 1 100 °C.

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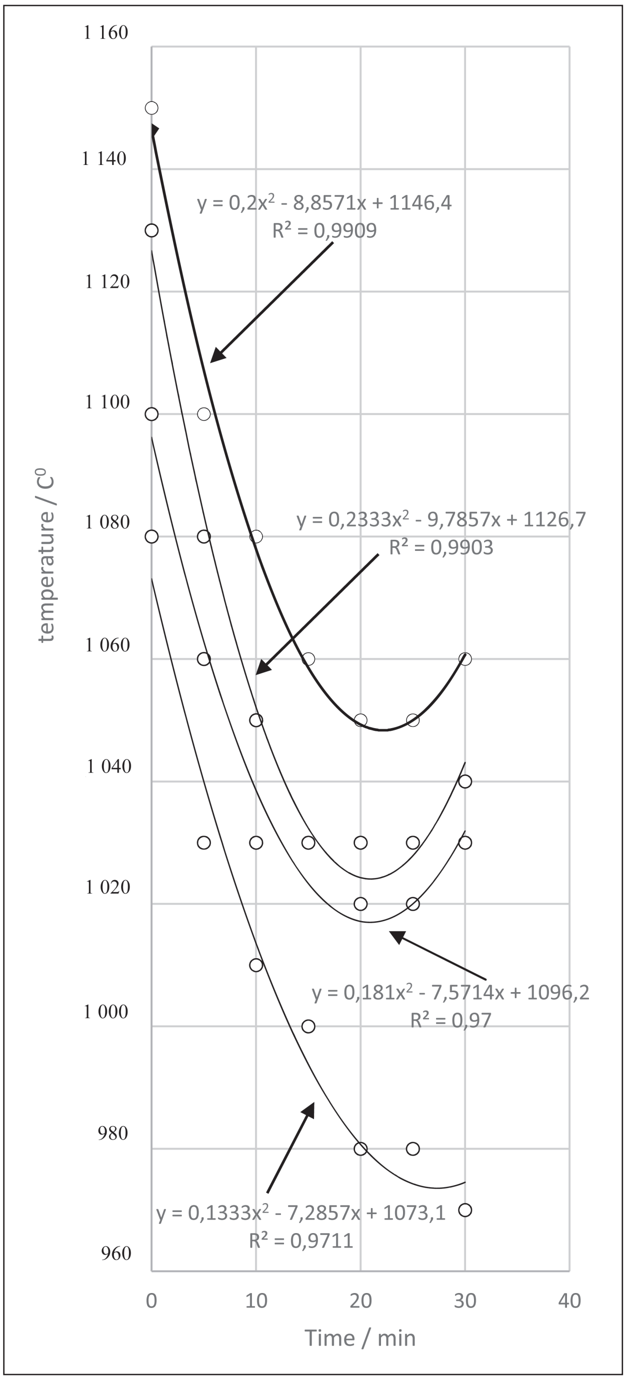

Figure 4 Temperatures change during the metallization process of the agglomerate by the products of oxygen conversion of natural gas

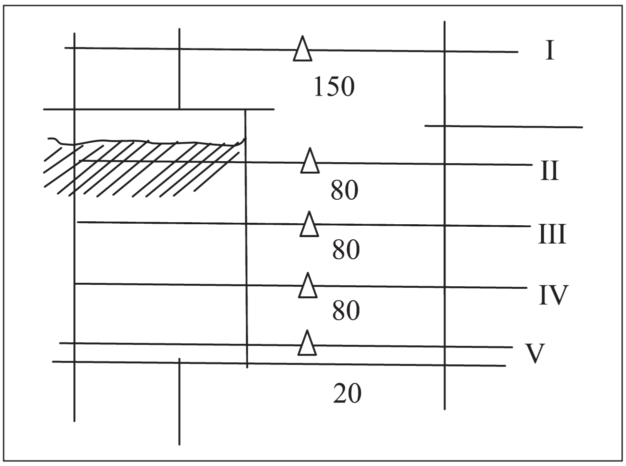

Figure 5 The arrangement scheme of thermocouples

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