STUDY ON THE USE OF OXYGEN-ENRICHED COMBUSTION AIR AT THE IGNITION INITIATOR FURNACE FROM THE AGGLOMERATION MACHINE

Adrian VASILIU

"Dunarea de Jos" University of Galati, Romania
email: avasiliu@ugal.ro

ABSTRACT

Comparative study on the use of oxygen-enriched combustion air at the homogenization coal ignition coil from Dwight-Lloyd agglomeration No 5 from the ArcelorMittal Galati metallurgic plant to reduce fuel consumption, increase machine productivity and agglomerate quality.

KEYWORDS: agglomeration process, ignition furnace, oxygen enriched air, heat balancing furnace

1. Introduction

Sintering iron ore is a thermal treatment process for agglomerating fine particles into larger pieces, which then serve as raw material for the furnace. High quality sintering is essential for efficient furnace operation. The quality and yield of the agglomerate are largely determined by the iron ore's chemical properties, such as physical behaviors and chemical reactions of the sintering materials during the process. The thermal treatment and treatment of the material deposited on the agglomeration machine affects the structure and mineralization at temperatures high and has a high influence on quality indices, sintering efficiency and fuel consumption.

The sintering process consists of combining iron-bearing fines with a solid fuel and igniting the mixture on a traveling grate with a downdraft of air. As the fuel burns, the temperature in the bed increases to about 1300 ºC to 1480 ºC, sintering the fines into a porous, clinker-like material that is suitable for use as blast furnace feed. The bonding between the particles is by recrystallization and partial melting, and so no additional binder needs to be added in this process.

Sintering is a continuous agglomeration process in which mixtures of fine iron ores, streams, coke and recycled materials are melted together to produce a porous material designated as sinter. A scheme of the process is shown in Figure 1. A raw sinter mixture of raw materials is placed on a continuous grate which moves slowly (sintering wire) typically 40-60 cm deep and 4-5 m wide.
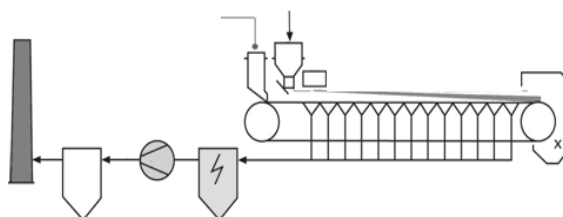

***Fig. 1.** Dwight - Lloyd agglomeration band*

2. Objectives

In the agglomeration process, ignition and thermal treatment of the sintered layer is of great importance in achieving high productivity, low coke consumption and superior agglomeration quality.

The purpose of this paper is to develop methods for calculating fuel gas consumption to ignite the sintered load and the specific energy consumption of the process as well as to determine the main parameters that affect this value.

In order for the furnace to have a high ignition temperature, optimal use of gaseous fuel is required, therefore a complete gas burning. Without unbound gas, it increases fuel consumption, delays the burning of coke and lowers the furnace temperature.

Decreasing coke consumption is achieved by better use of gaseous fuel and by increasing the percentage of oxygen at the same ignition heat.

Currently, the energetic performance of the ignition of the load is empirically determined, which does not allow the identification of the factors that influence the sintering process and the reduction of the energy consumption for its implementation.

By modifying the percentage of oxygen in the air, the ratio between the thermal wave travel rate and the combustion rate is changed. Oxygen can increase specific agglomeration production, promote a better oxidized useful sinter with better reducibility. If a higher temperature is reached at the front of the flame, the fuel consumption will be reduced, but more NOx will be produced in the flue gases.

The presence of air enriched in a small amount of oxygen in the front of the flame is a means of raising the temperature in the ignition furnace of the homogenized layer and to obtain a better quality of the agglomerate. In this paper, oxygen-enriched air was used, between 21% and 24% of the total oxygen.

From experiments at agglomeration plants in the world, it was concluded that adding oxygen to combustion air leads to an increase in productivity by 3-4% for each additional oxygen percentage.

3. Theoretical considerations

The adiabatic flame temperature is calculated at different oxygen concentrations. The results show that the adiabatic flame temperature increases with a higher concentration of oxygen in the combustion air as shown in the green line in Figure 2. The red line shows how the adiabatic temperature changes with different oxygen concentrations when considering the gas dissociation (H_2O, CO_2 SO_2).
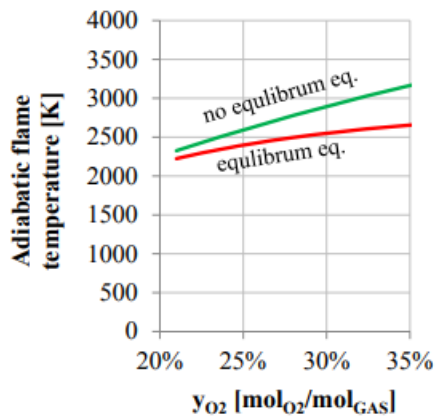

Fig. 2. Adiabatic flame temperature

What we are most concerned about possible energy savings is how much fuel we can save with oxygen-enriched combustion. The amount of energy leaking with the exhaust gas decreases as the oxygen concentration increases as the resulting amount of nitrogen decreases (Figure 3).

The amount of energy produced by combustion with 21% oxygen in the combustion air is used as a reference. With increasing oxygen concentration in the combustion air, more energy is available from the combustion so that less fuel is needed.
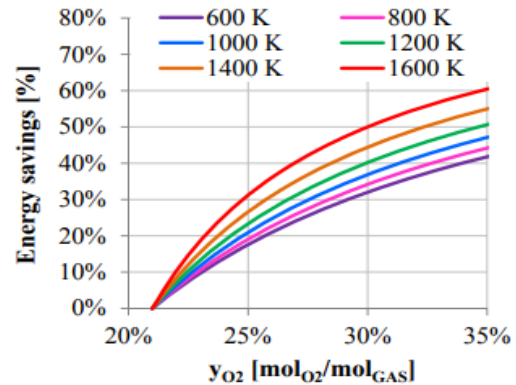

Fig. 3. Energy savings

Burning of hydrocarbons. For a hydrocarbon consisting solely of carbon and hydrogen, of the formula CxHy, the combustion reaction is (Figure 4).
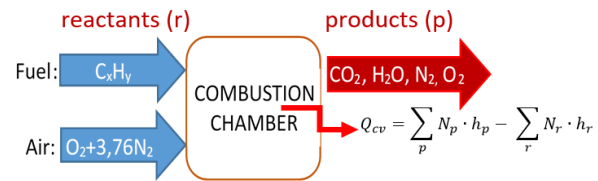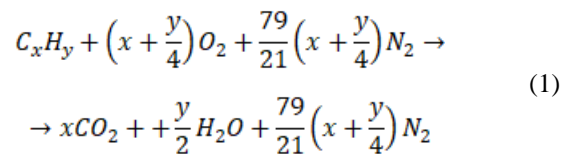

Fig. 4. The hydrocarbon burning equation

The composition of the air is in molar fractions, 21% oxygen, 78% nitrogen and 1% argon. These two substances are supposed to be inert, and for simplicity, air is considered to be composed of 21% oxygen and 79% nitrogen to which a fictitious molar mass is attributed, the presence of argon. The combustion reaction of a hydrocarbon with air thus becomes:

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 + \frac{79}{21}\left(x + \frac{y}{4}\right)N_2 \rightarrow$$
$$\rightarrow xCO_2 + +\frac{y}{2}H_2O + \frac{79}{21}\left(x + \frac{y}{4}\right)N_2$$

(1)

It is said that the reaction is complete if the exhaust gases contain, in addition to inert elements, only fully oxidized products.

To achieve complete combustion with theoretical air, a perfect blend would be needed. In practice, to ensure complete firing, you need an excess of air (λ). This is characterized by the theoretical air coefficient or the excess air coefficient:

$$\lambda = \frac{used\ air}{theoretical\ air} \qquad (2)$$

Regarding the adiabatic flame temperature, the adiabatic combustion reaction is without the kinetic and potential energy variation. The temperature of products of this type of reaction is called adiabatic flame or combustion temperature. In this hypothesis, the absence of work and variations in kinetic energy is the maximum temperature that can be reached for a certain type of fuel at its pressure and temperature.

Adiabatic flame temperature (t_a) is no longer theoretical and is maximum for a stoichiometric mixture. It is calculated based on the first principle with the equation:

$$t_a = \frac{Q_i - Q_{dis} + L_{min} \cdot i_a + i_c}{c_{smga} \cdot v_{ga}} \ [\ ^oC] \qquad (3)$$

Heat required for ignition. Heating the layer with an external heat source is required to create a sufficiently high temperature to ignite the solid fuel (coke) at the top of the layer and heat it to a sufficient depth to provide additional fuel ignition in the lower. In this combustion process, the gases resulting from the combustion burned in the ignition furnace are absorbed through the homogenized layer (hearth).

The characteristic dimensions that are taken into account when heating the layer from an external heat source. The intensity of ignition is:

$$I = 60 \cdot c_h \cdot t_c \cdot w_h \ [kJ/m^2\ min.] \qquad (4)$$

is directly proportional to the gas flow rate through the homogenized layer, w_h, (m^3/m^2s) and the specific heat of the flue gas c_h (kJ/m^3K).

The heat received by the homogenized to ignite the coating is:

$$Q' = I \cdot \tau_{ig} \ [kJ/m^2] \qquad (5)$$

- t_c - furnace temperature ($t_c \approx 1250 \div 1300\ ^oC$);
- τ_{ig}, - ignition time ($\tau_{ig} = l_h\ /\ w_h$) (min);
- I, - specific ignition intensity ($kJ\ /\ m^2$ min).

4. Method of research

4.1. Thermal check of the ignition furnace

Before the actual balancing of the agglomeration machine was made, the firing furnace was chosen as a balance sheet, whose thermal balance led to the highlighting of the energy consumptions

made for the ignition of the batch layer and the determination of the furnace's energy efficiency (Figure 5). Because the agglomeration manufacturing process is of a continuous nature, the balance is made per unit of product, that is, per ton of agglomerate. The batch sintering process is carried out on an agglomeration machine having an active surface area of 300 m².
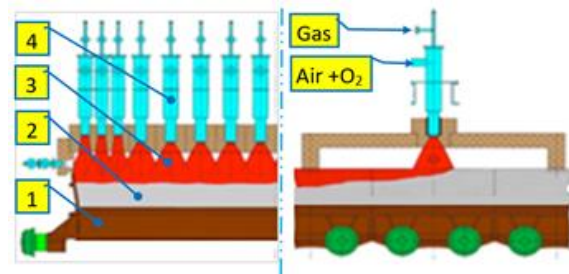

Fig. 5. *Ignition furnace. 1. Pallet; 2. Sinter mixture; 3. Flame cycle; 4. Burners*

4.2. Combustion of gas

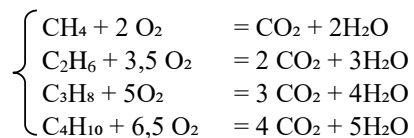The average chemical composition of the fuel gas is shown in table no. 1.

Table 1

Elements	N_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}	O_2	Hi [kJ/m³N]
(%)	8.3	87.94	0.69	0.28	0.19	2.6	
c_{sp} (25 ºC)	1.04	2.17	1.75	1.672	1.828		35635
q (x 10³)	-	39.8	70.5	101.8	134.0	-	

Combustion heat (lower calorific value):

$$H_i = \sum_{i=1}^{n} H_{ik} \cdot r_k = 35635 \ [kJ/m^3_{Ncb}] \qquad (6)$$

Combustion reactions (equation 1):

$$\begin{cases} CH_4 + 2\ O_2 & = CO_2 + 2H_2O \\ C_2H_6 + 3,5\ O_2 & = 2\ CO_2 + 3H_2O \\ C_3H_8 + 5O_2 & = 3\ CO_2 + 4H_2O \\ C_4H_{10} + 6,5\ O_2 & = 4\ CO_2 + 5H_2O \end{cases}$$

Stoichiometric oxygen required for combustion:

$$O_{nec} = \sum_{i=1}^{n} \left(x + \frac{y}{2}\right) \cdot \%C_xH_y = 1{,}7833 \ m^3_{NO2}/\ m^3_{Ncb}$$

Actual air required for combustion (equation 2):

Table 2

The real air [m^3_{Naer} / m^3_{Ncb}]	
(21 % O_2)	(24 % O_2)
$L_{nec} = \dfrac{100}{21} \cdot O_{nec} = 8,49$	$L_{nec} = \dfrac{100}{24} \cdot O_{nec} = 7,43$
$L_{real} = \lambda \cdot O_{nec} = 9,34$	$L_{real} = \lambda \cdot O_{nec} = 8,17$

Flue gas volume resulting from combustion:

$$V_{ga} = V_{CO2} + V_{H2O} + V_{N2} + V_{Oex} \tag{7}$$

Table 3

21 % O_2	V_{CO_2}= (CH4+2C2H6+3C3H8+4C4H10)/100 = 0.9092
	V_{H2O}= (2CH4+3C2H6+4C3H8+5C4H10)/100 =1.8002
	V_{N2}= (L_{real} 79) / 100 + N_i/100 = 7.4616
	V_{Oex}= $L_{nec}\cdot(\lambda$ -1)$\cdot$21/100$\cdot$= 0.17829
TOTAL	Vga = 10.34929

Table 4

24 % O_2	V_{CO_2}= (CH4+2C2H6+3C3H8+4C4H10)/100 = 0.9092
	V_{H2O}= (2CH4+3C2H6+4C3H8+5C4H10)/100 =1.8002
	V'_{N2}= ($L_{real} \cdot$76) / 100 + N_i / 100 = 6.2922
	V'_{Oex} = $L_{nec}\cdot$ (λ -1)$\cdot$24 / 100 = 0.17832
TOTAL	**Vga = 9.17992**

The share of each gas in the flue gas volume:

$$x_i = \frac{V_i}{V_{ga}} \cdot 100 \ [\%] \tag{8}$$

Table 5

Percent [%]		X_{CO2}	X_{H2O}	X_{N2}	X_{Oex}	Total
Oxygen [%]	21	8.792	17.394	72.095	1.724	100
	24	9.904	19.611	68.543	1.942	100

Temperature resulting from combustion (equation 3):

Table 6

Oxygen [%]	Enthalpy [kJ/ m^3_N]		Temperature [^{0}C]	
	air *	gas **	theoretical	real ***
21	26.021	1.651	2050	1558
24	26.022	1.705	2349	1785

* i_a - combustion air enthalpy (i_a = $t_a \cdot c_a$; at t_a = 20 ºC)
** i_g - combustion gas enthalpy (i_g = $t_g \cdot c_g$; at t_g = t_a ºC)
*** t_r – real combustion temperature (t_r = $\eta \cdot t_a$; η = 0.76)

4.3. Heat kiln heat exchanger

Characteristics of the furnace:
- type: room with burners in the vault;
- destination: ignition of the batch layer;
- working regime: continuous;
- focal size: 7 m x 3 m x 1,5 m (l x b x h);
- operating temperature: 1250 ºC;
- gas consumption: average 785 m³N / h;
- air consumption (λ = 1,1): 8500 m³N / h.

Characteristics of the agglomeration machine:
- productivity 1600 t / h (850 t / h with exhaust);
- specific productivity: $20 \div 40$ t / m^2 per day;
- area: 300 m^2;
- speed: 1.5 - 6.5 m / min;
- maximum useful floor height: 550-600 mm;
- trolley length: 1500 mm;
- trolley width: 3000 mm;
- trolley height: 600 mm.

4.4. Heat balance of the furnace (O_2-21%)

Heat inputs: The lack of oxygen in the area of the furnace contributes to delaying the ignition of the superficial layer, which implicitly determines the delay of the firing front transmission to the grills. The heat enters the outline are:
- the chemical heat of the fuel gas (Q_1);
- physical heat of the fuel gas (Q_2);
- sensible heat of combustion air (Q_3).

Chemical Heat of Gas (Q_1):

$$Q_1 = \frac{B_{CH4} \cdot H_i}{P_{aglo}} = 163643{,}72 \ [kJ/t_{aglo.}]$$

where:
- fuel gas - methane gas;
- B_{gaz} - specific fuel gas [m^3_N / h];
- H_i - heat fuel efficiency [kJ / m^3_N];
- P_{aglo} production of agglomerate [t / m²zi];

Physical Heat of Gas (Q_2):

$$Q_2 = \frac{B_{CH4} \cdot i_{CH4}}{P_{aglo.}} = 260{,}75 \ [kJ/t_{aglo.}]$$

The enthalpy of gas is calculated by:

$$i_{CH4} = \sum x_n \cdot c_n \cdot t_n = 51{,}12 \ [kJ/m^3_n]$$

where:

i_{CH4}-enthalpy of gas at temperature [kJ/m³$_N$];

x_n - percent of gases n in the gas composition [%];

c_n - the specific heat of component n, [kJ/m³$_N$ grd];

t_n – temperature of gas from the entrance, [ºC].

Physical Heat of combustion air (Q₃):

$$Q_3 = \frac{L_{real} \cdot B_{CH4} \cdot i_a}{P_{aglo.}} = 1539,08 \; [kJ/t_{aglo.}]$$

where:

L_{real} - the amount of air required, [m³$_N$ air/ m³$_N$ gaz];

i_a - enthalpy of combustion air at t=20 ºC [kJ/m³$_N$].

Total heat entering the contour:

$$\sum_{i=1}^{3} Q_{Ti} = Q_1 + Q_2 + Q_3 = 165443,55 \; [kJ/t_{aglo.}]$$

Table 7. Entry in the account balance

No. crt.	Inputs			
	Heat	Symbol	Quantity	
			kJ/t $_{agl}$	%
1	The chemical heat of methane gas	Q_1	163643,72	98,91
2	Physical heat of methane gas	Q_2	260,75	0,157
3	Physical heat of combustion air	Q_3	1539,08	1,6
	TOTAL	$\sum Q_{Ti}$	165443,55	100

Heat outputs:
- heat loss through radiation (Q₄);
- heat lost through trolley walls (Q₅);
- heat lost with the gases from the layer (Q₆);
- heat loss through furnace walls (Q₇);
- useful heat (firing layer) (Q₈).

Heat loss through radiation through holes (Q4):

$$Q_4 = \frac{C_0 \cdot S \cdot \varphi \cdot \left[\left(\frac{T_c}{100}\right)^4 - \left(\frac{T_a}{100}\right)^4\right] \cdot \tau}{P_{aglo}} = 1587,26$$

where:
- C_0 – emission factor, (C_0 = 5.67), [W/m² h K⁴];
- S - opening area [m²];

- τ - the time at which the opening (τ = 1 h);
- T_c - radiator wall temperature (T_c = 273 + t_c), [ºK];
- T_a - ambient temperature (T_a = 273 + t_a), [ºK].

The surface of the apertures and the aperture coefficient are calculated separately for the furnace front apertures and for the visors practiced in the side walls of the furnace.

Heat lost through the troller walls (Q₅):

$$Q_5 = \frac{M_c \cdot c_c \cdot (t'_p - t''_p)}{P_{aglo.}} = 12525,90 \; [kJ/t_{aglo.}]$$

where:
- Mc - mass of trolleys
$$M_c = V \cdot \rho = 190 \; [kg];$$
- V - volume of side walls (V = 0.025 m³)
- ρ_c - wall material density (ρ_c = 7600 [Kg/m³]
- c - specific heat (c = 0.56916 kJ/kg grd);
- t_p', t_p'' - the temperature of the side walls [ºC];
- (t'_p = 194 ºC; t''_p = 77 ºC).

Heat lost with the gases coming out of the layer (Q₆):

$$Q_6 = \frac{B \cdot (0,1 \cdot c_{ga}^{tp} \cdot t_p + 0,9 \cdot c_{ga}^{ts} \cdot t_e)}{P_{aglo}} = 24285,13$$

where:
- B = specific gas consumption [m³$_N$ / t $_{aglo}$];
- c_{gae}, c_{gap} - heat-specific gas that is lost and drawn by the exhaust (t_e = 125 ºC and t_p = 1067 ºC).

Heat lost through the walls of the furnace (Q₇):

$$Q_7 = Q_{71} + Q_{72} + Q_{73} + Q_{74} + Q_{75} \; [kJ/t_{aglo}]$$

in which:
- Q_{71} - lost through the right wall, [kJ / t$_{aglo}$];
- Q_{72} - lost through the left wall [kJ / t$_{aglo}$];
- Q_{73} - lost through the kiln vault [kJ / t$_{aglo}$];
- Q_{74} - lost through the front wall [kJ / t$_{aglo}$];
- Q_{75} - lost through the back wall [kJ / t$_{aglo}$].

$$Q_7 = \sum_{i=1}^{5} Q_{7i} = \sum_{i=1}^{5} \frac{\alpha_{ci}(t_{ei} - t_{ai})}{P_{aglo}} \cdot S_i = 2797,75$$

where:
- α_c - coefficient of exchange by convection;
- t_e - the outer wall temperature, [ºC];
- t_a - air temperature, [ºC];

- S - heat exchange area, [m²].
Heat released to the layer band - ignition (Q_8):

$$Q_u = Q_8 = \sum_{i=1}^{3} Q_i - \sum_{i=4}^{7} Q_i = 124247,51 [kJ/t_{aglo}]$$

Total heat consumed:

$$Q_{Tc} = \sum_{i=4}^{8} Q_i = 165443,55 \; [kJ/t_{aglo}]$$

The furnace's thermal yield - η_t:

$$\eta_t = \frac{Q_u}{B \cdot v_{ga} \cdot (i_0 - i_{gc})} \cdot 100 = 76,5 \; [\%]$$

Specific fuel consumption:

$$B_{sp} = \frac{B \cdot H_i \cdot \rho_{gaz}}{H_{cc}} = 683,7 \; [kg_{cc} / t_{aglo}]$$

Table 8. *Outputs in the account balance*

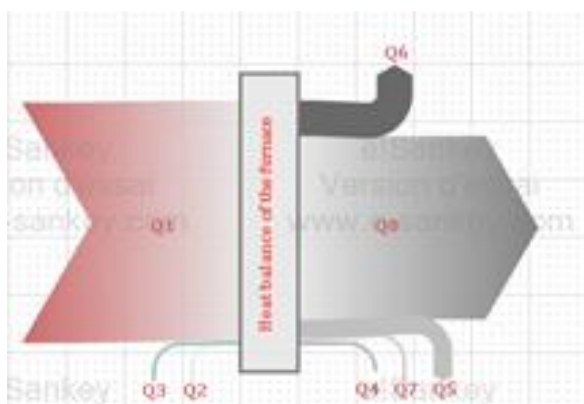| No. crt.	OUTPUTS			
	Heat	Symbol	Quantity	
			kJ/t agl	%
1	Heat loss through radiation	Q_4	1587,26	1,259
2	Heat lost through the troller walls	Q_5	12525,90	7,572
3	Heat lost by the gas through the layer	Q_6	24285,13	14,678
4	Heat loss through furnace walls	Q_7	2797,75	1,691
5	Heat released to the layer band - ignition	Q_8	124247,51	75,467
	TOTAL	$\sum Q_{Tc}$	165443,54	100

Fig. 6. *Heat balance of the furnace (21% Oxygen)*

Sankey diagram (O_2-free): Heat consumed and generated during the combustion process is estimated by thermal balances. The heat is released mainly due to the combustion of gas in the ignition furnace. A typical heat balance in the firing furnace at sinter plants is shown in Table 7 and Table 8 and is graphically represented in Figure 6.

4.5. Heat balance of the furnace (O_2-24%)

Heat inputs
- the chemical heat of the fuel gas (Q_1^{ox});
- physical heat of the fuel gas (Q_2^{ox});
- sensible heat of combustion air (Q_3^{ox});
- chemical heat resulting from the combustion of CO from the atmosphere of the furnace (Q_4^{ox});
- the physical heat of carbon dioxide (Q_5^{ox}).

Chemical Heat of Gas (Q_1^{ox}):

$$Q_1^{ox} = \frac{B_{CH4} \cdot H_i}{P_{aglo}} = 163643,72 \; [kJ/t_{aglo.}]$$

Physical Heat of Gas (Q_2^{ox}):

$$Q_2^{ox} = \frac{B_{CH4} \cdot i_{CH4}}{P_{aglo.}} == 260,75 \; [kJ/t_{aglo.}]$$

Physical heat of combustion air (Q_3^{ox}):

After the introduction of oxygen, an increase in air oxygen percentage of 3.8% was found to result in 22.4% in the combustion air, which corresponds to an oxygen flow of 969 m³ / h. So, at an excess of $\lambda = 1.4$, the air required to burn a m³_N CH4 will be:

$$Q_3^{ox} = \frac{L_{real}^{ox} \cdot B_{CH4} \cdot i_a}{P_{aglo}} = 3670,24 \; [kJ/t_{aglo.}]$$

where:

- L_{real}^{ox} - the amount of air required, [m³_N air/ m³_N gaz];
- i_a - enthalpy of combustion air at t=20 ºC [kJ/m³_N].

Table 9

No. crt.	Oxygen flow		
	m³N/h	%	O in air %
1	35.05	21.79	3.4
2	39.17	22.44	3.8
3	45.36	23.20	4.4

Heat of combustion of CO in the furnace (Q_4^{ox}):
We calculate the excess air, (λ_1), resulting from flue gas analyzes, after the introduction of oxygen.

The volume of CO corresponding to 1.8% of the flue gases before the introduction of oxygen.

$$Q_4^{ox} = \frac{V_{CO} \cdot q_{CO}}{P_{aglo}} = 17694,18 \ [kJ/t_{aglo}]$$

where:
- V_{CO} - volume of carbon dioxide no burn, [m^3_{NCO}];
- q_{CO} - thermal effect of combustion, CO [kJ/m^3_{CO}].

The physical heat of carbon dioxide (Q_5^{ox}):

$$Q_5^{ox} = \frac{V_{CO} \cdot i_{CO}}{P_{aglo}} = 2120,95 \ [kj/t_{aglo}]$$

i_{CO} – enthalpy CO la $t_{ga} \approx 1050$ ºC ($i_{CO}=1520$) [kj/m^3_N]

Total heat entering the contour:

$$\sum_{i=1}^{5} Q_i^{ox} = 165443,55 \ [kJ/t_{aglo.}]$$

Table 10. *Entry in the account balance*

No. crt.	INPUTS			
	Heat	Symbol	Quantity	
			kJ/t agl	%
1	The chemical heat of methane gas	Q_1^{ox}	163643,72	87,328
2	Physical heat of methane gas	Q_2^{ox}	260,75	0,139
3	Physical heat of combustion air	Q_3^{ox}	3670,24	1,958
4	Heat of combustion of CO in the furnace	Q_4^{ox}	17694,18	9,442
5	Physical heat of carbon dioxide	Q_5^{ox}	2120,95	1,132
	TOTAL	$\sum Q_{Ti}^{ox}$	187389,66	100

Heat outputs:
- heat loss through radiation (Q_6^{ox});
- heat lost through the furnace walls (Q_7^{ox});
- heat lost through the trolley walls (Q_8^{ox});
- heat lost with the gases from the layer (Q_9^{ox});
- useful heat (firing layer) (Q_{10}^{ox}).

Heat loss through radiation (Q_6^{ox}):

$$Q_6^{ox} \frac{C_0 \cdot S \cdot \varphi \cdot \left[\left(\frac{T_c}{100}\right)^4 - \left(\frac{T_a}{100}\right)^4\right] \cdot \tau}{P_{aglo}} = 1587,26$$

Heat loss through the walls of the furnace (Q_7^{ox}):

$$Q_7^{ox} = \sum_{i=1}^{5} \frac{\alpha_{ci}(t_{ei} - t_{ai})}{P_{aglo}} \cdot S_i = 2797,67 \ [kJ/t_{aglo.}]$$

Heat accumulated in the trolley walls (Q_8^{ox}):

$$Q_8^{ox} = \frac{M_c \cdot c_c \cdot (t_p' - t_p'')}{P_{aglo.}} = 12525,9 [kJ/t_{aglo.}]$$

Heat lost with the gases coming out of the layer (Q_9^{ox}):

$$Q_9^{ox} = \frac{M_c \cdot c_c \cdot (t_p' - t_p'')}{P_{aglo.}} = 24285,13 \ [kJ/t_{aglo.}]$$

Heat released to the layer band - ignition (Q_{10}^{ox}):

$$Q_u = Q_{10}^{ox} = \sum_{i=1}^{9} Q_{Ti} - \sum_{i=4}^{9} Q_i = 124247,5 [kJ/t_{aglo}]$$

Total heat consumed:

$$Q_{Tc} = \sum_{8}^{i=4} Q_i = 146182,67 [kJ/t_{aglo}]$$

The furnace's thermal yield - η_t:

$$\eta_t = \frac{Q_u}{B \cdot v_{ga} \cdot (i_0 - i_{gc})} \cdot 100 = 78,4 \ [\%]$$

Table 11. *Outputs in the account balance*

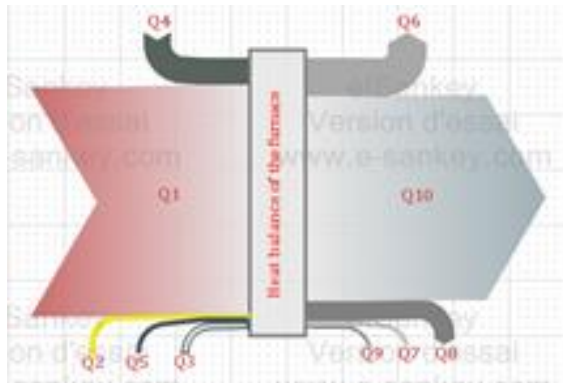| No. crt.	OUTPUTS			
	Heat	Symbol	Quantity	
			kJ/t agl	%
1	Heat loss through radiation	Q_6^{ox}	1587,26	0,847
2	Heat lost through the walls of the furnace	Q_7^{ox}	2797,67	1,493
3	Heat lost through the trolley walls	Q_8^{ox}	12525,90	6,684
4	Heat lost by the gas through the layer	Q_9^{ox}	24285,13	12,959
5	Heat released to the layer band - ignition	$Q_{10}(Q_u)$	146182,67	78,017
	TOTAL	$\sum Q_{Tc}^{ox}$	187389,66	100

Fig. 7. *Heat balance of the furnace (24% Oxygen)*

5. Conclusions

The influence of ignition on the sintering process, and thus the quality of the agglomerate, is manifested at the temperature at which the superficial layer of the agglomeration mixture is heated at the time of ignition. This value has a limited variation of variation and overcoming the upper bound leads to the formation of a compact, slightly permeable but extremely brittle crust, and an intermittent temperature below the lower limit leads to the formation of a layer of non-sintered material that completely passes in the return. From the above, the following resulted:

- the optimal percentage of oxygen in the combustion air is 22.4%;
- the amount of air required to burn the gaseous fuel decreases as the air enriches the oxygen;
- the amount of combustion gases decreases as the percentage of oxygen in the combustion air increases, thus reducing the heat loss by evacuating them;
- by increasing the oxygen content, complete combustion of the fuel is achieved;
- heat yield of the furnace improves from 75.72% to 78.4%;

- the introduction of oxygen leads to increased reaction rates in the layer, increasing the vertical sintering speed and thus increasing the agglomeration machine productivity.

The ignition furnace is compact. The volume has been reduced and the length of the oven has been reduced by reducing the burner flame, reducing the ceiling height of the furnace and shortening the ignition time by igniting at high temperatures. To meet the above requirements, the ignition furnace must be equipped with the following features:

- the flame burner should operate at a low speed to avoid disruption of the gross feed bed;
- the flat flame is advantageous for rapid and uniform ignition of the green supply;
- proper provision is essential to obtain regular cooling air supply with the burners to achieve the desired flame temperature;
- there must be adequate burner controls that are easy to handle;
- all oven controls must be safe.

The advantages are: reduced size (length), low energy consumption, CO_2 reduction, superior sintering, low return, less maintenance, short return time.

In view of the findings of the experiments, it is necessary to apply this oxygen injection system to the combustion air at agglomeration machine.

References

[1]. ***, *Documentation form ArcelorMittal Galati*.
[2]. **Xinyu Ming**, *Possibility of Combustion Furnace Operation with Oxygen*, University of Michigan, Mechanical Engineering, p. 3-2.
[3]. **Berinde T.**, *et al.*, *Întocmirea şi analiza bilanţurilor energetice în industrie*, Editura Tehnică, 2006.
[4]. **Vegman E. F.**, *Theory and practice of agglomeration*, Moscow, Metallurgy, p. 288, 1974.
[5]. **Gerasimov L. K.**, *Experience of the design and development of ignition furnace for sintering machines*, Steel, no. 3, p. 23-27, 2010.
[6]. **Frolov Yu. A.**, *Thermal aspects of the initial period of agglomeration*, Steel, no. 1, p. 2-10, 2004.