EXPERIMENTAL RESULTS OF THE USAGE OF AN OXY-FUEL BURNER AT ELECTRICAL ARC FURNACES

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Abstract: Electric arc furnaces had, after the energy crisis emerged, a remarkable development in metallic materials industry. Among the procedures developed, with a major contribution in reducing the specific consumption of electricity, there is also the usage of the oxy-fuel burners. This paper presents advanced solutions and oxy-fuel combustion systems, used worldwide in electric arc furnaces. In the paper there are also described the combustion plants with liquid and gaseous fuels, mounted in the lid and on the electric arc furnace door, along with the main technical characteristics and results obtained experimentally. It also presents results obtained experimentally on an electric arc furnace equipped with an oxy-fuel burner.

Keywords: electric oven, burners, oxy-fuel.

1. INTRODUCTION

Increased productivity and reduced electricity consumptions of the electric arc furnaces has led to the transformation of this type of systems from furnace systems into equipment for intensive melting of the metallic load. Conventional electric ovens heat and melt the metallic load unevenly by forming a hot zone within the triangle electrodes. The melting of the metal load in the remote areas of electrodes occurs late, through the liquid metal bath. To compensate for non-uniform heating and to shorten the duration of heats, the oxy-fuel burners are used and they are placed in the oven door and on the walls or in the roof of the tank to heat the colder areas outside the arc triangle. The most important types of oxy-fuel burners, used for the electric arc furnaces and presented in the literature, are as follows [1,2,3,4]:

- ABB, working with liquid fuel, with flow rates up to 330kg / h;
- GSM, operating on heavy fuel oil with flow rates up to 360kg / h;
- ASEA, operating with light oil, with flows rates up to 280kg / h;
- Daniel, operating on natural gas, with flow rates up to 400 MCN / h;
- ICEM, operating on natural gas, with flow rates up to 330 MCN / h;
- Demag Mannesmann-, operating with natural gas, with flow rates up to 1200 MCN / h, with diesel or fuel oil with flow rates up to 100 kg / h, or coal dust, with flows up to 1000 kg / h;
- VAI, operating with natural gas, with flow rates up to 400 MCN / h.

2. SOLUTION AND EQUIPMENT FOR BURNING OXY FUEL USED WORLDWIDE FOR THE ELECTRIC ARC FURNACES.

The Oxy-fuel burners, used for electric arc furnaces are classified as follows.

Depending on the installation position of the burner:

- Electric furnace equipped with burners in the shell (one, two or three burners depending on the furnace capacity);
- Electric furnace equipped with burners in the door work;
- Furnace equipped with burners in shell and in the working door.

Depending on the ability to control the burner:
- Multi-stage power burners;
- Burners with a single power stage.

Depending on the type of fuel used:
- Gas: ABB, ICEM, Mannesmann-Demag and VAI
- Liquid light fuel: ABB, Mannesmann-Demag and ASEA;

- With heavy oil: Mannesmann-Demag and AGA;
- Coal dust: Demag Mannesmann-.

Depending on the mode
- Single burner - the burner (fuel and oxygen);
- Double burner - the burner and how supersonic lance (oxygen)

During melting, the oxy-fuel burners operate at maximum capacity, immediately after the introduction of scrap from the first bucket. As the temperature increases and scrap metal surface in contact with the flue gas decreases, the efficiency of the oxy-fuel burners decreases. To obtain a reasonable efficiency, fuel burners are used about 50% during melting [5]. Heat transfer from flame and exhaust gases to scrap is done through radiation and convection, depending on the flame and gas temperature and on the temperature and surface of the iron. The temperature of the flame of the oxy-fuel burners depends on the type of fuel used, on the average temperature of the solid scrap and of the melted scrap inside the furnace and on the flow of fuel and oxygen added inside (and through the ratio Oxygen / Carbon).

As the scrap temperature increases and the surface in contact with the flue gas decreases the temperature of flame of the oxy-fuel burner increases and can reach approx. 75% of the value of the fuel adiabatic temperature of combustion. In [6] it is presented the variation of adiabatic temperature of the flames of fuels depending on the oxygen / carbon ratio.

The efficiency of the oxy-fuel burners usage depends on the location they are set. The location of the oxy-fuel burners aims to warm the colder areas outside the arc triangle. In [3] it is highlighted the distribution of warmer and colder areas when melting through the electric arc only. To warm these colder areas, the oxy fuel burners are placed in the oven door and in the roof or on the tank walls.

The characteristics of the most important types of oxy-fuel burners used in electric arc furnaces, presented in the literature, are as follows [1,2,3,4]:
- ABB, operating with light oil, with supersonic speed and flow rates up to 330kg / h;
- GSM, operating on heavy fuel oil, with flow rates up to 360kg / h, the temperatures reaching up to 2800grd.C flame;
- ASEA, operating with light oil, with flows of up to 280kg / h and oxygen enriched air;
- Daniel, operating with natural gas, with flow rates up to 400 MCN / h and supersonic speeds;
- T-Melter, made by GRI-Termecon, operates with natural gas and increases the furnace productivity by 20-30% 100 t;
- ICEM, operating on natural gas, with flow rates up to 330 MCN / h and gas pressure below one bar;
- Demag Mannesmann-, operating on natural gas, with flow rates up to 1200 MCN / h, with diesel or fuel oil with flow rates up to 100 kg / h, or coal dust, with flows up to 1000 kg / h;
- VAI, operating with natural gas, with flow rates up to 400 MCN / h and with the usage of approx. MCN 150 / h compressed air for protection during downtime.

Three ICEM oxy-fuel burners, operating with natural gas, with characteristics from Table 1, were placed in a tank wall of an electric arc furnace of 100 t [4].

Table 1. Characteristics of the oxy-fuel burners operating with ICEM type fuel used for electric arc furnaces of 100 tons

Crt. No.	Name	U.M.	Value
1	Thermal Nominal Power	kW	1600
2	Maximum Thermal Nominal Power	kW	3000
3	Minimum Thermal Nominal Power	kW	400
4	Type of fuel	-	natural gas
5	Nominal fuel flow	m^3N /h	160
6	Maximum fuel flow	m^3N /h	300
7	Minimum fuel flow	m^3N /h	40
8	Nominal oxygen flow	m^3N /h	330
9	Maximum oxygen flow	m^3N /h	700

10	Minimum oxygen flow	m^3N /h	140
11	Adjustment ratio (minimum / maximum flow)	-	1/7,5
12	Fuel nominal pressures	mbar	40
13	Oxygen pressures	bar	2
14	Cooling water flow	m^3	8
15	Cooling water pressure	bar	5
16	Lungimea flacarii la putere Flame length to -nominal power /rated power -minimum power	m	0,9-1,2 1,6-2,0

Table 2. Results obtained on an experimental electric arc furnace of 100 t, using oxy-fuel burners.

Heat No.	Electricity specific consumption	Natural gas specific consumption	Additional specific consumption of oxygen	Consum specific total de energie echivalenta Total Specific Consumption of equivalent energy
	kwh/t	m^3N /h	m^3N /t	kwh/t
1	426	12,1	24,6	482,8
2	434	5,2	11,2	458,8
3	506	3,2	6,7	487,6

The experimental results obtained on an electric arc furnace of 100 t, using oxy-fuel burners are shown in Table 2. The results of those experiments showed an average equivalent consumption of 487.6 kWh / t, which represents a reduction of 12.77% versus the the average consumption achieved without the 559 kWh / t oxy-fuel burners.
The reduction of the specific energy consumption due to the usage of oxy-fuel burners is done for the 75 tons furnaces at the Imatra plants in Finland. Based on the specific fuel consumption and specific oxygen consumption the specific energy consumption of 392-465 kWh / t are made. The specific energy consumption is calculated based on a number of parameters, among which the specific consumption of gas and oxygen [7]. The usage of the oxy-fuel burners in steel industry is benefic as it leads to an increase of furnace productivity and cost reduction [8].

3. EXPERIMENTAL RESULTS OBTAINED ON AN ELECTRIC ARC FURNACE EQUIPPED WITH AN OXY-FUEL BURNER

This burner is designed to operate with propane and oxygen, having a large flexibility in terms of the delivered power and oxygen – gas ratio. Oxygen and propane are circulated into the burner through concentric pipes, the Oxygen in the inner part and the propane on the outer part, through Laval nozzle, which provides supersonic speeds. To protect the parts subject to thermal application, the flame stabilizer and combustion chamber are cooled. The flame temperature reaches 2300-2500 C.
The burner is mounted on a pivoting arm, so its working position is on the EAF door.
Specifications:
- Maximum delivered power = 1.1 MVA;
- Propane Pressure = max 5 barr;
- Oxygen Pressure = max 10 Barr;

- Adjustment Report = 1/5.1;
- Flame Length = 1.8 m.

Several different adjustment reports and melting times (burner mode and lance mode) were tested. The data from the different melting times in the two ways of using oxy-fuel burner (burner mode and Lance mode) are summarized in Table 3.

Tabelul 3. Data on the different melting times in the two ways of using the oxy-fuel burner (burner mode and lance mode).

Year	Total Heat Time	Burner module/ heat			Oxygen lance module / heat		
		Time Bucket No.1	Time Bucket No.2	total time/ heat	Time Bucket No.1	Time Bucket No.2	total time/ heat
	min	min	min	min	min	min	min
2007	155.14	17.39	8.51	25.9	0	0	0
2008	152.447	19.714	14.036	33.576	3.006	3.013	5.796
2009	146.401	10.144	6.278	16.755	12.707	13.337	26.119
2010	141.466	9.616	4.732	14.132	14.085	14.853	27.768

Tabelul 4. Consumption of fuel and oxygen when using the oxy-fuel burner in the two ways (burner mode and lance mode).

Year	Propane consumption	Oxygen Consumption		
		Burner mode	Lance mode	Total / heat
	Nm3/t	Nm3/t	Nm3/t	Nm3/t
2007	10.38	17.53	0.00	17.53
2008	11.026	21.693	4.195	25.888
2009	7.457	12.610	19.685	32.296
2010	7.188	11.616	23.378	34.994

In terms of using the oxy-fuel burner in two ways, burning mode and lance mode, with refer to the fuel and oxygen consumptions the data are presented in Table 4. After analyzing the Tables 3 and 4 one will notice a reduction in working time and a reduction of the propane flow for the burner mode and an increase in working time and in the oxygen flow, for the oxygen lance mode. The usage of the supersonic burner reduced the amount of total energy through reducing the energy used for melting.

Fig. 1 shows the total energy consumption versus the final product. Also, the usage of the supersonic burner reduced the heat time (increased productivity).

Fig. 2 shows an increase in productivity over the time, after using the supersonic burner.

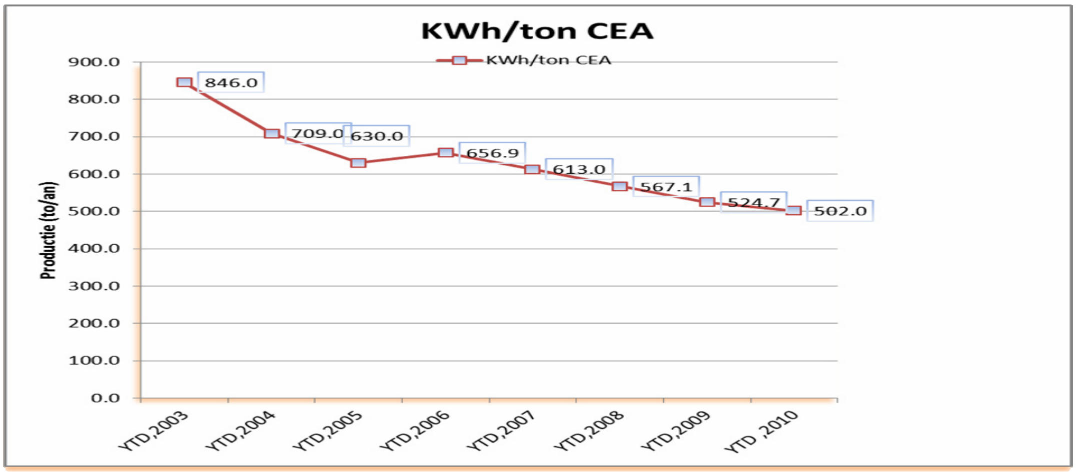

Fig. 1. Consumul total de energie raportat la produsul finit rezultat.

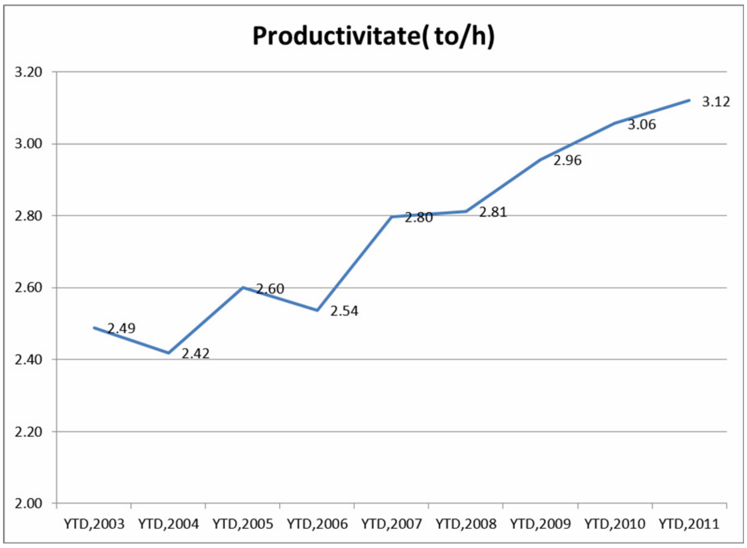

Fig. 2. Productivity increase over the time, after using the supersonic burner.

4. CONCLUSIONS

The electric arc furnaces have seen after the energy crisis emerged a remarkable development in metallic materials industry. Among the developed procedures, with a major contribution in reducing the specific consumption of electricity, there is the usage of the oxy-fuel burners.
The efficiency of the oxy-fuel burner depends on the burner, the type of fuel used, how the location of the burners and the operating mode (mode supersonic burner and oxygen lance mode).
Based on the specific fuel consumption and oxygen consumption the specific power consumptions were calculated: 392-465 kWh / t for 75 tons furnaces.

The burner used on an electric arc furnace is designed to operate with propane and oxygen, having a large flexibility in the terms of the delivered power and the oxygen - gas ratio. The usage of this type of burner reduced the amount of total energy by reducing energy consumption when melting and increasing the furnace productivity. The performance improved over the time by reducing the working time, while reducing the flow of propane for the burner mode and by increasing the working time, while increasing oxygen flow, for the oxygen lance mode.

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