RESEARCH ON THE LOADING WITH POLLUTANTS AND DUST OF FLUE GASES RESULTING FROM THE PROCESS OF STEEL PRODUCTION IN THE LD-TYPE CONVERTER

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Flue gases resulting from the process of steel production in the oxygen converter consist mainly of carbon oxide (over 70%). When leaving the converter workspace they are loaded with about 15 - 25 g dust/Nm3 of which over 90% are iron oxides from the vaporization of about 1% of the metal charge in the area of the impact of the oxygen jet with the metal bath but also from the oxidation of iron in the converter working area. These are captured at the top of the converters and subjected to primary treatment operations that are mostly performed in a wet system and only in certain situations in dry systems.

This paper presents the experimental research carried out regarding the traits of the dust trapped in the treatment systems of the LD converters from Arcelor Mittal Steel Galați.

Keywords: steelmaking process, basic oxygen furnace, waste gas, dust, CO, CO2

1. Introduction

The flue gases resulting from the steel production process in the LD-type converter are charged with NOx and dust. From a granulometric point of view, the dust particles are 80 ... 90% below 1 μm, and the rest, from 1 to 1.5 μm and give the gases a characteristic brown color [1,2]. These are trapped at the top of the converters and subjected to primary treatment operations that are mostly performed in a wet system and only in certain situations in dry systems (electrostatic precipitation). The wet treatment is usually done in two stages. In the first stage, the gas is cooled and the course granulometric fractions recover, as in the second stage, the fine dust fractions are separated [3]. The cooling water charged with the collected dust is directed into sedimentation basins, the resulting slurry is subjected to filtration operations. The sludge recovery with coarse granulometric fractions is carried out in raclette classifiers. Fig. 1 shows the technological flow of steel production in oxygen converters.

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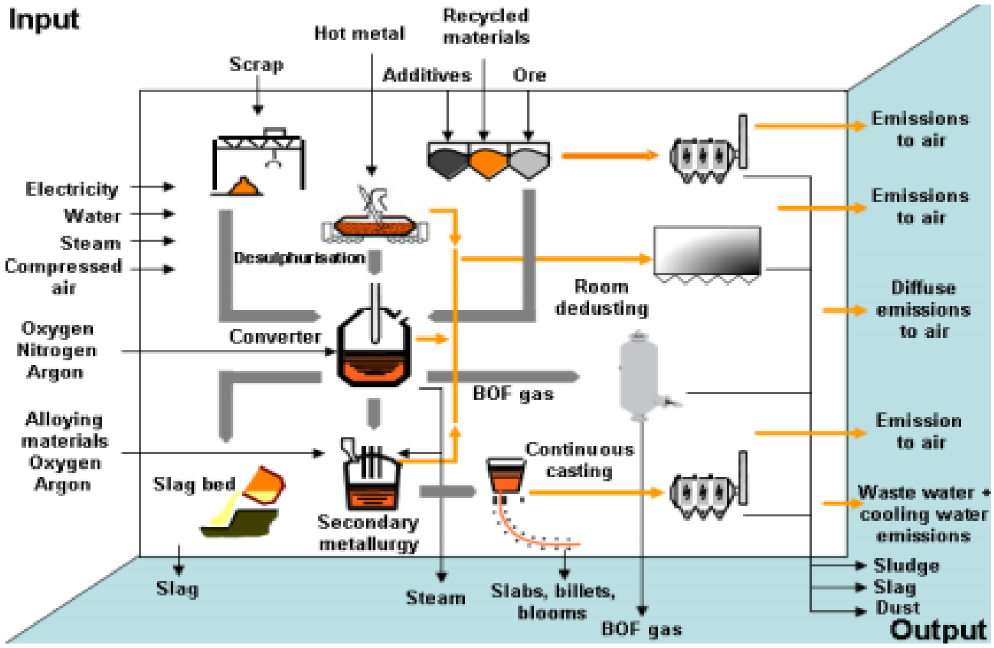

Fig.1 Technological flow of steel production in oxygen converters. [1]

The flue gases resulting from the process of steel production in the oxygen converter consist mainly of carbon oxide (over 70%). When leaving the workspace of the converter they are loaded with about 15 - 25 g dust/Nm^3 of which over 90% are iron oxides from the vaporization of about 1% of the metal charge in the area of the impact of the oxygen jet with the metal bath but also from the oxidation of iron in the converter working area [4].

The gases leave the converter working area and enter the hood at its mouth with a temperature of 1700 - 1800^{o}C. Here, their combustion takes place with the air extracted from the outside, which results in an increase of the temperature up to 2500 ^{o}C but also of their volume.

Depending on the technology adopted, there are situations in which the gases are not burned at the mouth of the converter but the objective is to use their chemical energy and also to keep a low volume with effects on the treatment plant [5,6,7]. For purification, the gases (burned or unburned) must be cooled below 300^{o}C. Trapping unburnt gas at the mouth of the converter is ensured by preventing the access of air to the mouth of the converter, realized so far in two ways:

- by inserting a movable hood between the mouth of the converter and the fixed hood which seals with a nitrogen curtain; required nitrogen at least 6 ... 8 Nm^3/t;

- by creating slight overpressure (about 1 mm H_2O) by adjusting the gas absorption in the system with the help of the Venturi treatment plant or by using a flap in the pipe before the absorption fan; the overpressure is measured with probes and the position of the flap is adjusted by means of an automatic installation, which also controls the lifting system of the hood.

In both cases, the hood leaves only a circular opening for observing the phenomena at the mouth of the converter.

2. Experimental

Research on the quantity and composition of flue gases

In order to determine the content of iron oxides in the dust from the converter's flue gas and to find the equations of the global mathematical model, samples were taken and determinations of chemical composition of the gases were made at the mouth of the converter and at level +24. In this regard, an industrial plant for the sampling of gas samples from the mouth of the converter was chemically designed and manufactured in the central laboratory of Arcelor Mittal Steel Galați. This installation consists of a metal spear of special construction, lined inside with a ceramic tube and cooled with water. The hot gas taken into a primary cooling and dusting chamber is followed by an advanced dusting in a bag system and then collected in double-tap glass flasks, Fig. 2

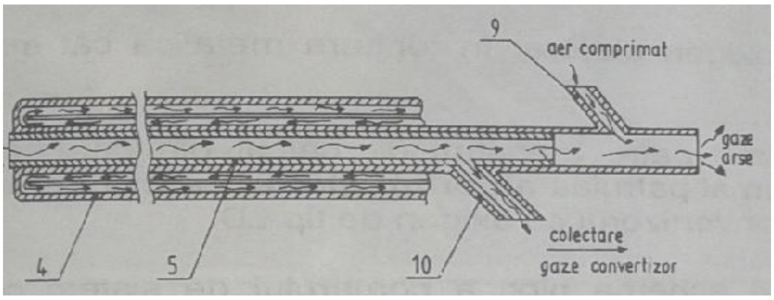

Fig.2 Metal spear for the sampling of gas [3]

The principle of operation of the gas sampling lance consists in creating a depression at its mouth by the injection of compressed air at high pressure through the socket (9) in the air circuit and collecting the converter gas upstream of the mixing area, through the nozzle (10). Technical traits: compressed air pressure: 5 – 10 atm; ceramic tube diameter: 25 mm; cooling water flow: 0.20 l/sec.

Gas analysis at the mouth of the converter

For the preparation of the study, a series of gas samples were taken from the mouth of the converter and from level +24 m. These samples were analyzed in the laboratory of ArcelorMittal Steel Galati and the results are presented in table 1.

Table 1.

Gas analysis at the mouth of the converter

Crt. No.	Nature of gas	The moment of oxigen blowing (min)						Medium value
		2	3	6	9	14	15	
1	%CO	58.8	61.9	64.4	69.8	72.4	80.4	67.90
2	$\%CO_2$	26.1	24.0	16.0	21.4	18.0	15.2	19.60
3	$\%O_2$	6.3	6.5	8.1	4.2	3.4	3.1	5.93
4	$\%H_2$	2.7	1.2	0.03	0.01	0.0	0.0	0.30
5	Δt		1	3	3	5	1	

Based on the data presented in table 1, the {% CO} and {% CO_2} graphs were plotted in Fig. no. 3 according to the oxygen blowing time.

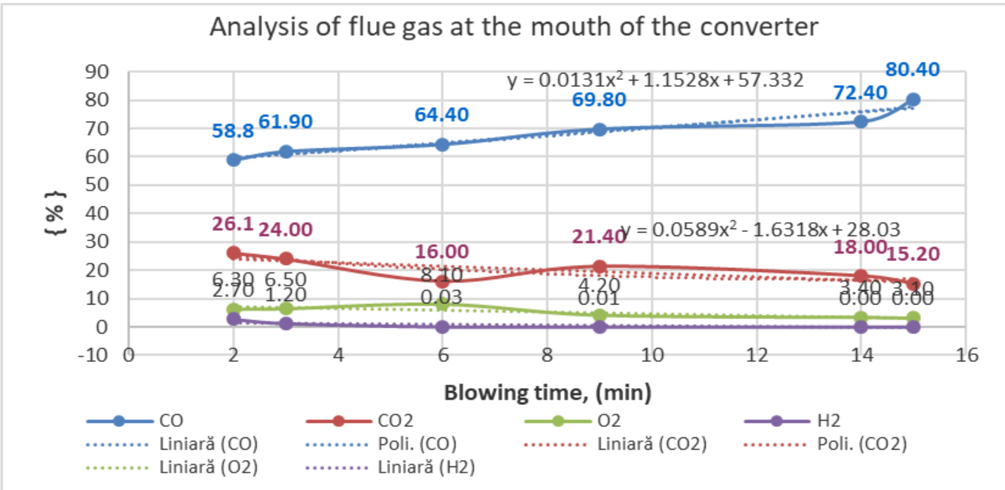

Fig. 3. Variation of the concentration of CO, CO_2 O_2 and H_2 at the mouth of the converter

During the process of steel elaboration in the converter, the CO and CO_2 concentrations vary according to the thermodynamic conditions existing at one moment in the working area. One can observe that in the first moments of blowing, the concentration of the carbon oxide has values of over 58%, while the carbon dioxide is located around 26%. After only one minute, the concentrations of the two gases are inversely proportional. Thus, in the third minute of oxygen inhalation, approx. 62% CO and 24% CO_2. Further, the concentration of carbon oxide increases, while the carbon dioxide reaches a minimum in minute 6. After another three minutes it reaches about 21% and will continue its rate inversely proportional to the CO concentration recorded. The average values of this analysis, collected from the mouth of the converter, are 67.9% CO and 19.6% CO_2.

The variation of CO and CO_2 concentrations during the production process is explained by kinetic and thermodynamic factors that influence in one way or another how the oxidation reactions of carbon take place. The concentrations of the two types of gases and the look of the graphs in Fig. no. 3 are in full agreement with data from the specialized literature [8, 9, 10].

Also, chemical analyzes were performed for the oxygen and hydrogen concentrations of the gases taken at the mouth of the converter, graphically, their evolution showing as in Fig. no. 3.

As can be seen, oxygen varies during inhalation. It increases to minute seven, then drops to a value close to 3%. The explanation is given that at the beginning of the process of elaboration the reactions in the metal bath are not primed and as such a part of the oxygen is found in the gases that are evacuated from the workspace. As the chemical reactions start, oxygen uptake increases, it reacts with the elements dissolved in the metal bath and forms oxides. This leads to lower oxygen concentration in the flue gas.

The analysis of flue gas at level +24

Following the analyzes carried out on the samples taken at level +24 m, the results presented in table no. 2 were obtained.

Tabel 2

Flue gas analysis at level +24

Crt no.	Nature of the gas	Blowing oxigene moment (mm)				Middle value
		4	8	12	16	
1	CO	22	20.2	16.5	11.9	17.9
2	CO_2	13.8	22.2	26.6	16.3	21.23
3	O_2	5.4	11.8	7.8	10.4	9.25
4	H_2	0.18	0.11	0.04	0	0.08
5	Δt		4	4	4	

The measurements were made every four minutes. It is observed that during steel production, the CO concentration decreases from 22% at minute four to 11.9% at minute sixteen.

As for the CO_2 concentration, it has up values until minute 12 minute of blow, and in the last period it reaches 16.3%. Based on the data presented in table 2, the graph in Fig. no. 4 was plotted to show the variation of the concentration of CO, CO_2, O_2 and H_2 at level +24.

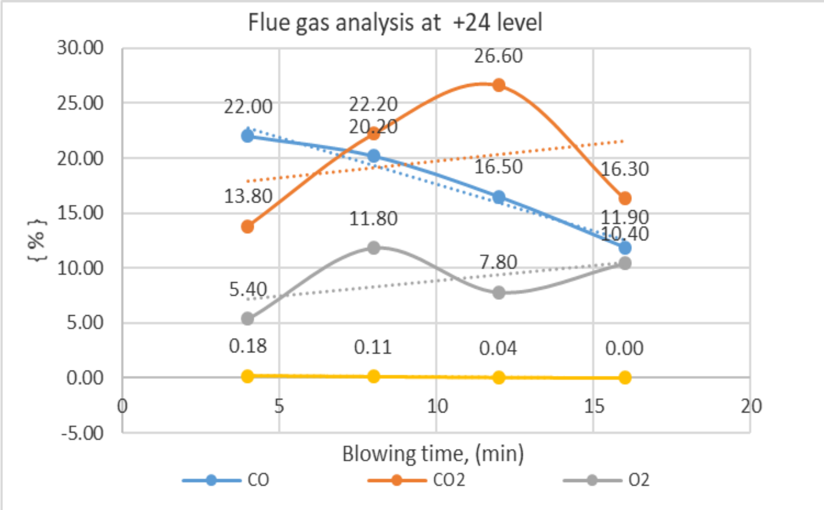

Fig. 4 Variation of the concentration of CO, CO_2 O_2 and H_2 at +24 level

Research on the loading of dust and solid pollutants of converter gases

In addition to the analyzed gases, respectively CO and CO_2, the flue gases of the converter contain solid elements in the form of powdery dust with a granulation ranging from 0 to 1.5 μm. This dust is made up of various oxides resulting in the elaboration process and driven by the flue gases on their way to the hood. This dust is collected in the dust removal system of the converter. The present work aims to analyze this converter dust and establish ways to capitalize on it by reintroducing in the manufacturing flow of steel products.

Chemical analysis of the converter dust

With the device shown in Fig. 2, several dust samples were taken from the mouth of the converter, of which, for analysis, a number of three were retained. With the help of the fluorescence spectrometer, analyzes were performed regarding the composition of the converter dust, these being grouped on both elements, table no.3, and oxides, table no. 4.

The analyzes show what the paper intends to highlight, respectively possibilities of recovering the dust from the converter gases. Tables 3 and 4 show that the converter dust contains important quantities of Fe and Fe_2O_3.

Table no. 4 summarizes the data on the oxide concentrations (Fe_2O_3, MgO, CaO, MnO, ZnO) of the converter dust. You can see the high amounts of Fe_2O_3, which represents an important factor in the economy of the production facility by capitalization.

Table 3

Sample concentrations analyzed chemically

The chemical element	Sample no.1	Sample no.2	Sample no.3
	46.11	41.49	47.01
Ca	17.41	20.53	16.88
Mg	2.13	2.57	2.1
Zn	1.83	2.72	1.82
Mn	1.47	1.82	1.44
Si	1.42	2.5	1.46
Pb	0.54	0.61	0.54
Al	0.44	0.76	0.44
S	0.27	0.35	0.25
P	0.19	0.21	0.19
K	0.13	0.31	0.15
Ti	0.07	0.08	0.06
Cl	0.06	0.36	0.08
Cr	0.04	0.04	0.04
Cu	0.02	0.02	0.02

Table 4.

Oxide concentrations of converter dust samples

The oxide	Sample no.1	Sample no.2	Sample no.3
Fe_2O_3	51.80	46.26	52.95
CaO	20.18	23.67	19.63
MgO	3.38	4.02	3.26
SiO_2	2.78	4.91	2.86
ZnO	1.76	2.60	1.76
MnO	1.51	1.85	1.48
Al_2O_3	0.79	1.36	0.79

In addition to this table, the diagram of these oxides was presented, shown in Fig. 5. It can also be observed that the percentage of CaO is an important one, reaching an average of about 20%.

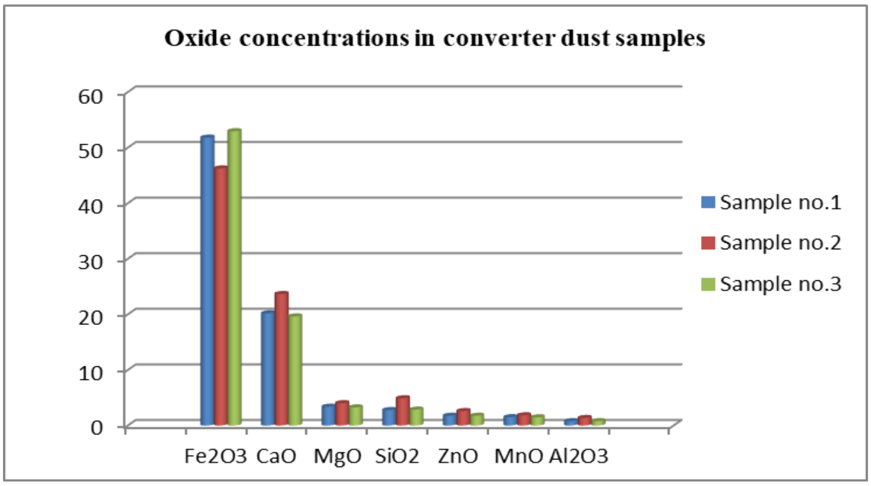

Fig. 5 Diagram related to the concentrations of oxides in the dust of the converter

Micrographic aspects of converter dust

The micrographic analyzes revealed the structure of the dust from the converter flue gases, presented in Fig. 6.

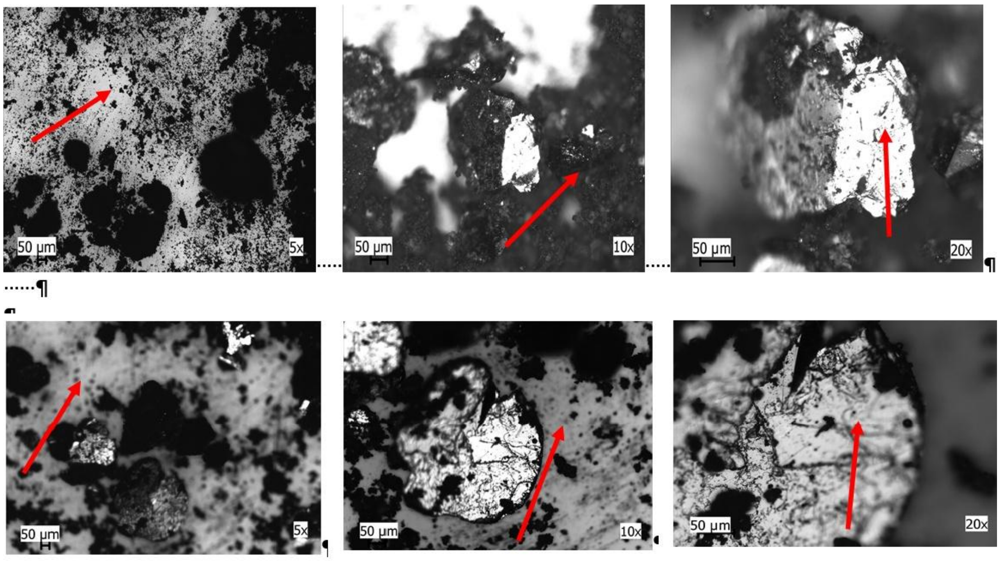

Fig.6 Micrographic aspects of converter dust

The collected samples were prepared and analyzed at ECOMET Laboratory, micrographs were made at sizes 50, 100 and 200. The images highlight the massive presence of iron oxides.

4. Conclusions

The development of the metallurgical industry is conditioned by the solution of the major problems arising from the relation between industry and nature, the metallurgical industry having to give up the concept of waste, more correctly the notion of by-product. Following the study and the research carried out, the following conclusions can be drawn regarding how the environment can be protected, and the methods of recovering the dust and flue gases resulting from the process of steel production in the oxygen converter:

- converter gases can be subsequently used as energy sources;
- the process of steel production in the converter generates considerable quantities of particles during the loading of the scrap iron and cast iron, during the blowing and during the casting of the sinter and liquid steel, which shows that the working environment of platform +9.000 could be protected;
- following the chemical analyzes, it turned out that the converter dust contains about 45% Fe, which supports the economy of the production facility by its capitalization, by the reintegration into the circuit of obtaining first fusion iron;
- the dust can be recovered by sintering, pelletising and briquetting;
- currently, the working platform of the converters represents a polluted environment, and by implementing the casing/enclosing system could be improved, and the personnel working on platform + 9.000 would be protected from the emissions resulting from the process of obtaining steel in the oxygen converter.

Developing high-performance technologies that reduce emissions substantially is the current focus. Also, the recovery and reintegration of the by-products into the integrated flow must have a high efficiency, close to 100%. These two aspects represent the challenges environmental engineers must deal with in order to protect the environment.

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RE F E R E N C E S

[1 *Mustață, C.*, Particularitățile proceselor fizico-chimice la elaborarea oțelului în convertizorul cu insuflare combinată a oxigenului, Metalurgia, România, nr. 2, 1993

[2]. *C. Stanasila, N. Constantin, O. Stanasila, R.Petrache*, „A new method to dry some granular materials", U.P.B. Sci. Bull., Series B, Vol. 69, No. 4, 2007, pag.71-77

[3]. *Mustață, C.*, Instalație pentru prelevare și analiză probe de gaze arse de la gura convertizorului, Dosar OSIM

[4]. *Mustață, C.*, Tehnici moderne de conducere automată a proceselor siderurgice, Editura Tehnică, București, 2007

[5]. *M. Nicolae, C. Dobrescu, V. Rucai, A. Nicolae*, „Use of Ecological Paradigm in Material Degradation Engineering", Data publicării 2018/3/15, The Annals of "Dunarea de Jos" University of Galati. Fascicle IX, Metallurgy and Materials Science, Volumul 41, Numărul 1, Pagini 10-15

[6]. *A. Nicolae, C. Dragan, C. Stefan Gradinaru, V. Rucai, M. Nicolae*, „Ecotechnologies - a major route for durable-sustainable development in the metal materials industry ", Annals of the University Dunarea de Jos of Galati: Fascicle IX, Metallurgy & Materials Science. 2016, Vol. 34 Issue 1, p27-34.

[7]. *M. Costoiu, A. Ioana, A. Semenescu, N. Constantin, B. Florea, V. Rucai, C. Dobrescu, Massimo Polifroni, Lucian Păunescu*, „Environmental performance indicators for decision making and stakeholder interests" in Environmental Engineering & Management Journal (EEMJ), Volume 15 Issue10, Pag. 2279-2284.

[8[. *C. Stănăşilă, N. Constantin, O. Stănăşilă*, „Alternative iron making technologies", U.P.B. Sci. Bull., Series B, Vol. 70, No. 1, pag.55-62

[9]. *Rău, A., Tripșa, I.*, Metalurgia oțelului, Editura Didactica pedagogică, București, 1973

[10]. *D. Vonica, M. Hritac, V. Rucai, N. Constantin*, „Proposal for improvement of current technology of processing oxide ashes", in: ANNALS of Faculty of Engineering Hunedoara –International Journal of Engineering (online ISSN 1584 – 2673), Tome XVI (year 2018, Fascicule 3/2018 [August], BDI, http://annals.fih.upt.ro/ANNALS-2018-3.html