NEW METHODS FOR THE ASSESSMENT AND THE REDUCTION OF THE CO_2 EMISSIONS IN IRON AND STEEL PROCESSES AND THERMO-ELECTRIC POWER STATIONS, BASED ON AN INTEGRATED APPROACH

Ion MELINTE[1], Mihaela BĂLĂNESCU[2], George DARIE[3], Carmencita CONSTANTIN[4]

Lucrarea prezintă noi metode de evaluare şi de reducere a emisiei de CO_2 din sectoarele industriei metalurgice şi a centralelor termoelectrice. Analiza se bazează pe un model care abordează în mod integrat aspectele tehnologice şi energetice. Sunt utilizate programe de calcul în care sunt simulate datele de intrare în procese (cantităţi de materie primă şi de combustibil, conţinut de carbon în materiile prime şi în combustibili).

Sunt abordate metode primare de reducere a emisiilor de CO_2, cum ar fi modificarea parametrilor de intrare în proces sau modificarea actualelor procese (tehnologii sau sisteme de ardere), în scopul creşterii eficienţei din punct de vedere tehnologic sau energetic.

This paper presents new methods for the assessment and the reduction of the CO_2 emissions in iron and steel processes and in thermo-electric power stations, based on a conceptual model for an integrated, technological and energetic system, using the calculus programs and patterns and simulations of the process input parameters (quantities of raw materials, fuel feeds, carbon content in the raw materials and in the fuels).

There are approached primary methods for reducing the CO_2 emissions, namely the modification of the process input parameters or the modification of the actual process (technological or combustion), for improving its technologic or energetic efficiency.

Keywords: new methods, CO_2 emissions reduction, integrated approach, iron and steel

1. Introduction

The reduction of the CO_2 emissions generated within a technological or combustion process from an industrial unit can be done by acting on the **process input parameters** (raw material quantities, fuel consumptions, type of fuels, of used raw materials, carbon content from raw materials or fuels, etc.) or by

[1] PhD, Metallurgical Research Institute, Bucharest, Romania
[2] PhD, Metallurgical Research Institute, Bucharest, Romania
[3] Prof., Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania
[4] Eng., Institute of Power Studies and Design, Bucharest, Romania

modifying the existent combustion or technological process, with the purpose of improving it, for increasing the energetic and technological results.

Besides these methods – **primary methods**, approached within this paper, there are also modern technologies for the capture and the storage of CO_2 (**secondary methods**). This last method is one that is enforced on output, after the CO_2 emissions have been released by the process.

In **the conceptual model** presented in the figure 1 has been considered as input parameters all the types of raw materials containing carbon, such as: coal use in coke plants, iron ores, ferro-alloys, powdered coal blasted in furnace, graphite electrodes, pitch, tar and others.

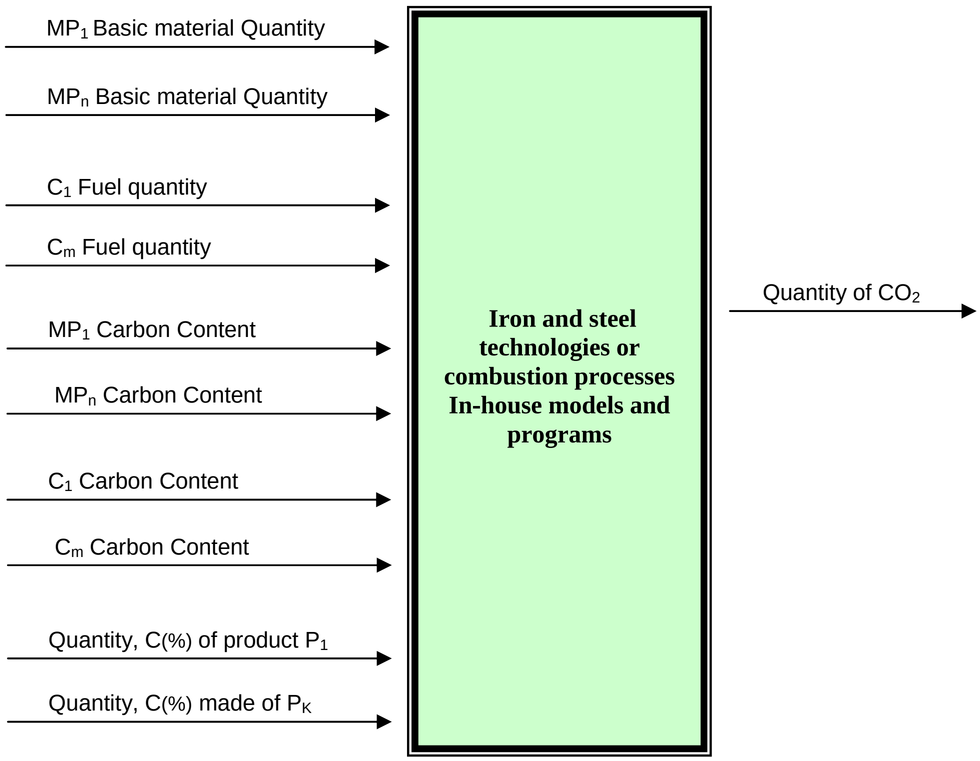

Fig. 1. The conceptual model of enforcing the different methods for reducing the CO_2 emissions, proposed in the iron and steel processes (process inputs, process itself or process output)

Moreover, it has been considered that a certain type of raw material can have different values of the carbon content, based on the sort and batch, which increases the complexity in approaching the problem. Besides the quantities of raw materials, there must be taken into consideration also the inlets of used fuels containing carbon in their structure: coal, natural gas, coke gas, blast-furnace gas.

It is also considered the fact that the natural gas is delivered by Transgaz to ArcelorMittal Galati (AMG) in a variable composition (different percentage values for CH_4, C_3H_8, C_6H_{14}, C_2H_6, etc.), which modifies the content of carbon of the respective sample.

Otherwise, it is mandatory that there are always enforced *all the possible primary measures*, and only then, if necessary, the *secondary ones* (methods for the capture and storage of CO_2), recommendation also applicable for the iron and steel units and thermo-electric power stations, included in the National Allocation Plan for the CO_2 emission certificates.

2. New methods for the reduction of the CO_2 emissions resulted in the combustion processes of gaseous fuels, by modifying the process input parameters

Such a calculation is performed by the Metallurgical Research Institute (ICEM) program, which starts from the percentage composition of the gaseous fuel. Besides, other value calculated by the program is the value of the CO_2 energy-ecologic emission factor (g/MJ equivalent of kg/GJ).

The program's ***imput data*** are either *fixe (*thermal-physical values), or *variable* (the functional, construction and combustion installation parameters).

a) Thermal-physical constants: inferior calorific values, equilibrium values, coefficients from the calculus of the thermal capacities.

b) Constructive parameters: type of the burner, recycling degree of the flue gas.

c) Functional parameters: nature of the used fuel, chemical analysis of the fuel, temperature of the fuel, coefficient of air excess, percentage of oxygen from the air, exhaust temperature of the flue gas, fuel flow.

The program's ***output data*** are:

a) Energetic parameters and indicators: combustion air flow, temperature of the process, specific fuel consumption.

b) Transfer parameters of the combustion process : emission factor, related to the unit of fuel quantity, **energy-ecologic emission factor** for **CO_2,**CO, NO_x and SO_2.

In the figure 2 it is presented the way the CO_2 emission factor varies, upon modifying the percentage of the oxygen from the combustion air from a heating furnace using natural gas as fuel, from AMG.

The decrease of the CO_2 emission factor in case of increase of the percentage of the oxygen from the combustion air is due to reducing the quantity of natural gas needed for obtaining the necessary process temperature. This way the quantity of carbon introduce in the process is reduced too, so that on output, namely in the flue gas, the quantity of exhausted CO_2 decreases (in this case the level of the flue gas exhausted from the furnace also decreases). Although the specific emission factor (kg CO_2 / Nm^3 fuel gas) remains the same, the energy-ecologic emission factor (kg CO_2 / GJ) decrease, due to the increasing of the net calorific value on using the oxygen for combustion.

Besides evaluating the quantities of the CO_2 emissions, for larger combustion installations, the ICEM calculus program also allows performing simulations in case of using different mixtures of fuel gas, with different compositions and upon modifying the values of the air excess coefficient, **simulations based on which there can be chosen primary methods for reducing the CO_2 emissions, simultaneously with the reduction of specific fuel consumption**.

As we can see, according to figure 2, one of these methods is to use oxy-fuel burners, another method being performing the combustion process of the fuel gas so that the air excess coefficient has optimal values /2/.

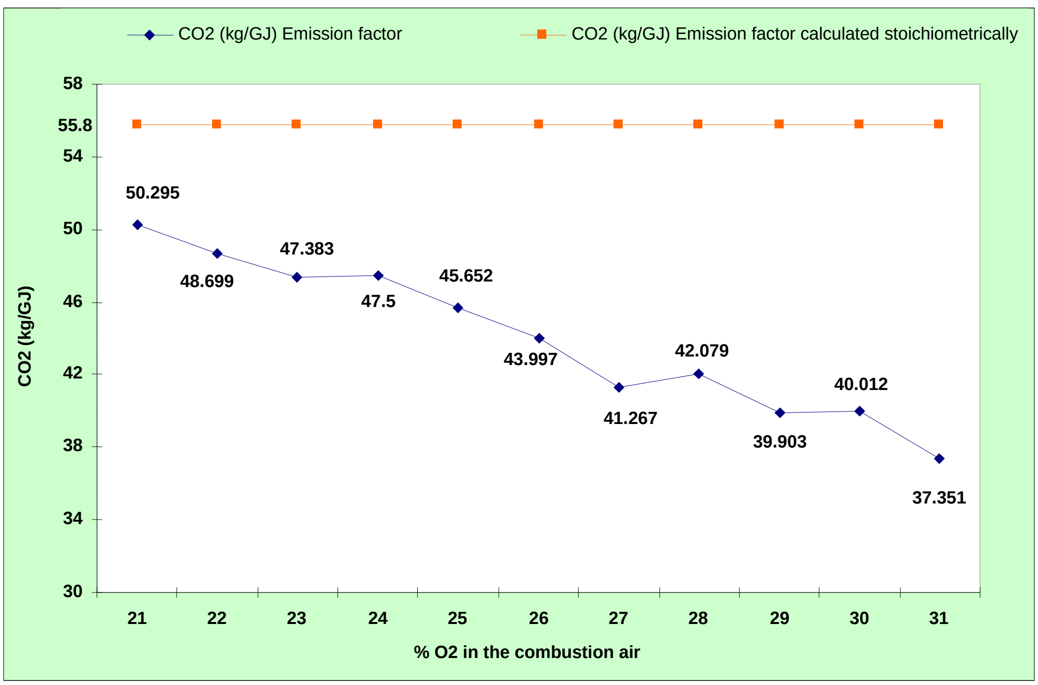

Fig. 2. Variation of the CO_2 emission factor upon modifying the percentage of the oxygen from the combustion air

The above theoretical concepts have been validated through experiments performed at a furnace from ArcelorMittal Galati.

3. Methods for the reduction of the CO_2 emissions released in the technological processes from Electric Arc Furnaces

One of the most important technology, which is to be approached in these paper, and which can improve the energetic indicators and the electrical regime in the supplying circuit of the Electric Arc Furnaces (EAF), is the using of the foaming slag in the final stage of the charge drawing up (during the melting of the metallic charge, after the introduction of the second skip and after the liquid bath setting up, for the furnaces with two skips).

It is very important /2/ that the slag should be foam stable and efficient, during the melting, and especially after the melting period, due to the blowing of the oxygen and coal powder, in order to shield the long electric arcs, when is working with high voltage (U > 600 V), reaching to high energetic efficiencies, decreasing the energy consumption with 10 – 30 kWh / t.

The favourable effects of the foaming slag are both energetically, namely the increasing of thermal efficiency (the reduction of thermal losses to the walls and to the furnace vat), and electrically, due to the appearance of some current ways, if the foaming slag has conductive properties. In this case the charge is heated through Joule effect.

Otherwise, it is possible to assess the direct and indirect environmental effects of the improvment of the energy efficiency of the EAF, namely the reduction of CO_2 emissions in the steel plant, respectively in thermal power plants, where the electric power is produced (at source).

As for **the direct environmental effects** of the improvement of the energy efficiency of the Electric Arc Furnace, an in-house model could be used to assess the reduction of CO_2 emissions due to the modernization applied.
The block diagram of the model is shown in the figure 3.

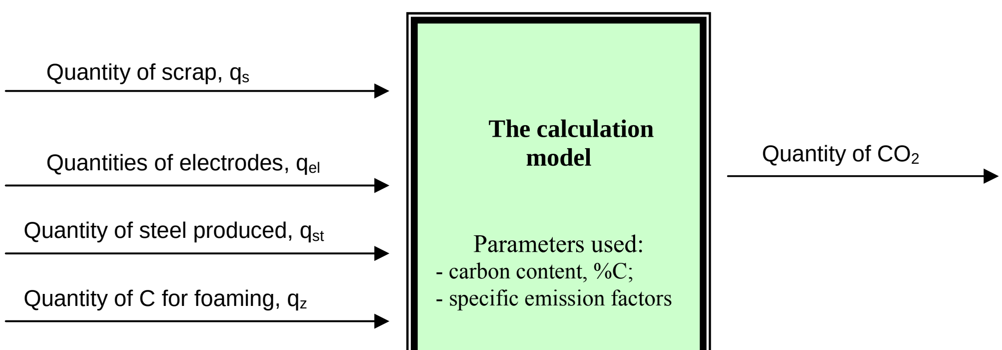

Fig. 3. The block diagram of the in-house model for the calculation of the CO_2 emissions released during the steel melting into EAF

The block diagram reffers only to the main raw materials with carbon content, used into EAF.

The evaluation of the CO_2 emissions produced during the steel melting in EAF, is based on a carbon balance done for the contour of the furnace:

Therefore, the proposed equation is /2/:

$$E_1 = a \times q_s + b \times q_{el} + c \times q_z - d \times q_{st} \quad (1)$$

where

E_1 – the quantity of the CO_2 emissions produced during the steel melting, t

a,b,c,d – specific emission factors, t CO_2/ t material;

q_s – the quantity of scrap used, t;

q_{el} – the quantity of electrodes, t;

q_z – the quantity of coal powder blowed to foam the slag, t;

q_{st} – the quantity of steel produced, t

The amounts of the specific emission factors **a**, **b** and **c,** have been calculated as the product between carbon content of inputs of the raw materials (scrap, electrodes), coal powder or of the outputs - finished product (steel), and the value of the stoicheometric coefficient at the conversion of the carbon in carbon dioxide (3.667). Taking into account amounts of 0.29% average carbon content for the scrap, 97.8% for the elecrodes, 99.5% for the coal powder blowed and 0.074% average carbon content for the steel, characteristic for the Romanian iron and steel plants with EAF route /2/, we can get the emission factors amount, namely values of 0.0106 t CO_2/ t scrap, 3.5883 t CO_2/ t electrodes, 3.6847 t CO_2/ t coal blowed to foam slag, respectively 0.0027 t CO_2/ t steel produced.

Generally, the quantity of direct CO_2 emissions is reduced during the melting charge, when the technology with foaming slag is used, due to the reduction of the quantity of electrodes consumed.

As for the **indirect environmental effects** of the improvement of the energy efficiency of the EAF using the method proposed, taking into account that during the burning of lignite in thermal power plants /3/, the emission factor is 27.6 kg C / GJ (corresponding to 101.2 kg CO_2/GJ) and the saving of energy (ex. 111 kWh / t charge), corresponding to an amount of 399.6 GJ / t charge, than we can get the possible reduction of CO_2 annual emissions at source, due to the constructive or tedhnological upgradings of the furnace.

If the technology with foaming slag is applied for a Electric Arc Furnace with 100 t capacity (hence the annual production is 300 000 t steel, for a plant like Mechel Otelu Rosu), the annual benefit obtained becomes about 240 000 EUR.

Moreover, for **the correlations between energy efficiency and the technological level of the installations from thermo-electric power stations and the CO_2 emissions** amounts, the conclusions of the researches done, are:

For the case of the **thermo-electric power stations using coal**:

a) in the case of the groups of 330 MW (12 groups into the Romanian thermo-electric power stations), the replacement of these with a performant technology, namely steam cycle with over-critical parameters, leads to a reduction of CO_2 emissions annual quantities of about 24 %;
b) the set up of Integrated Gasification Combined Cycle (IGCC) will lead, for the same situation, to a reduction of CO_2 emissions with about 32%;
c) one of the very important measures for the CO_2 emissions reduction in thermo-electric power stations is the replacement of the old technologies with low performances, with the new ones, efficient from the point of vue of energy consumption.

For the case of the **thermo-electric power stations using natural gas**:

a) the replacement of a conventional group with steam, with undercritical parameters, with a combined cycle gases-steam group without postcombustion, leads to a reduction of CO_2 emissions annual quantities of about 27 %;
b) for a cycle with steam with under-critical parameters, the replacement of the coal with natural gas as fuel, leads to the reduction of specific CO_2 emission of about 59 %. This reduction is due to:
    - the increase of gross electric efficiency (from 34 % to 40 %);
    - the use of a fuel with low carbon content.

4. Conclusions

The primary methods for reducing the CO_2 emissions from the technological and combustion processes from the iron and steel industry and thermo-electric power stations from Romania, must be used within the near future, especially in those units that are part of the European Trading Scheme for CO_2 Emissions (EU-ETS), in order not to risk exceeding the emission level allotted in the NAP, with major penalties.

The benefits of the primary solutions (modifying the parameters on process inlet or improving the process), also approached in this paper, are those that, besides the effects of reducing the CO_2 emissions, they simultaneously lead to other benefits (technological, energetic and economic). The other types of methods for reducing the CO_2 emissions (on the process output – methods for the capture and the storage of CO_2), have only environment effects, and the important investment is not always justified.

Both the analysis of the methods for reducing the CO_2 emissions from the combustion processes and the one for technological processes (e.g. producing sinter and pig iron on the integrated iron and steel route), have proven that consolidating these methods and evaluating the effects of their enforcement must be done within an integrated, technological and energetic approach, using the calculus models and program and by performing simulations on modifying the different input parameters, either by increasing or by decreasing them, until obtaining the optimal values for controlling the combustion processes or technological processes, by minimizing the CO_2 emissions.

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