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Research Article

Research of The Possibilities of Reducing the Quantity of CO_2 in the Premises of the E&E Foundry in Gjakova

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Abstract:

The cupola furnace is a type of melting furnace used in foundries for melting cast iron. The primary purpose of studying the emission of gases in the cupola furnace is to understand and mitigate environmental and operational impacts. Emission research in the cupola furnace involves the analysis of gases released during the melting process. The key gases of interest include carbon dioxide (CO2), carbon monoxide (CO), sulfur dioxide (SO2), and nitrogen oxides (NOx). Environmental Impact: Understanding the composition and quantity of emissions helps in assessing the environmental impact of cupola furnace operations. This is crucial for compliance with environmental regulations and standards. Studying gas emissions provides insights into the combustion efficiency and overall performance of the cupola furnace. It allows for optimization of the process to enhance energy efficiency and reduce emissions. Worker Health and Safety: Monitoring emissions is essential to ensure a safe working environment for foundry workers. At Foundry E&E, a total of 7800 kg of pig iron is produced during one scrap smelting. Measurements of process gases in the working spaces and in the chimney exceed the standard values of CO2 and CO quantities. We performed the measurements with the "aeroqual-gas sensing" series 500 apparatus. The amount of CO2 near the scarp melting cupola furnace was 325 ppm, while the amount of CO2 in the chimney reached the value of 2047 ppm. The aim of the work is to achieve the reduction of metallurgical coke, and the return of the process gas through the blowers in the areas of the cupola furnace in the Foundry E&E, and with this we will achieve the reduction of CO2

1. Introduction

The low level of utilization of production capacities, the high level of heat losses, metal losses in slag, and environmental pollution in the "E&E Foundry" Gjakova in Kosovo has encouraged us as part of the program "teaching-based research", financed from MESTI with the project: Research of the impact of return gas (CO) through fryers in the scrap melting area in "Foundry E&E" to research the technical-technological possibilities of thermal energy recovery, its use for pre-heating the air for burning of coke in the hearth of the furnace as well as the return of the process gas or its utilization for enriching and heating the air that is blown through the blowers in thedome furnace in this foundry [1-13]. The cupola furnace, installed in "Foundry E&E" Gjakova, in terms of its constructive and principled context is similar to a small blast urnace, and is used for the production and processing of gray cast iron.

Foundry E&E is a unique business that deals with the production of metals:

- iron,
- cast iron
- aluminum.

Foundry "E&E" was established in 2014, where for these years it has managed to create a loyal clientele and is well appreciated in the domestic market. The products of the foundry "E&E" are of a specific nature and require special skill and dedication from the moment of melting the metal until the final product is obtained. The characteristics of foundry products are quality and durability since these products are mainly used for heavy machinery parts that must be durable against heavy weight (such as wells). Therefore, since the beginning, the foundry has been certified with the ISO 9001: 2015 standard for quality management. E&E Foundry initially started work with a cupola furnace, and a manual molding system, in an operating area of only 400m², and in small production capacities. Seeing the interest in its unique products, the "E&E Foundry" developed rapidly where it now operates in a 4000m² facility, with a semi-automatic molding line, and automatic sand preparation system [2]. Cupolas have been associated with high emissions due to the chemical reactions in their combustion chambers. This has raised alarm in many countries and has caused foundries to move to the use of induction furnaces. The control of cupola emissions has led to improvements in the cupola design. In a cupola furnace, return gases refer to the gases that are produced during the combustion and reduction processes and are circulated back into the furnace to contribute to the heating and melting of the materials. These return gases play a significant role in the overall efficiency of the cupola furnace. Here's how return gases are typically managed in a cupola furnace: In the lower part of the cupola furnace, coke (carbonaceous material) is burned in the presence of air to generate heat. This combustion process produces gases, including carbon monoxide (CO) and carbon dioxide (CO_2), as well as other by products [10]. The generated carbon monoxide (CO) plays a crucial role in the reduction of iron ore into molten iron. The CO gas reacts with the iron ore (usually in the form of iron oxides) to produce molten iron and additional CO_2 [11]. The generated gases, including CO and CO_2, rise through the furnace, and their hot and combustible nature is utilized for heating and melting the charge materials, which may include scrap iron and other components. To improve the efficiency of the cupola furnace, some of the hot gases, particularly carbon monoxide (CO), can be recirculated or returned to the lower part of the furnace. This recirculation helps maintain a reducing atmosphere within the furnace, which is essential for the reduction of iron ore. The control of return gases is critical for achieving the desired temperature and composition within the furnace. Operators can adjust the airflow, fuel input (coke), and the rate of return gas circulation to optimize the melting process.

It's important to note that while returning gases can improve efficiency, cupola furnaces are not the most environmentally friendly option due to the emissions of carbon monoxide and other pollutants. Modern environmental regulations often require the installation of pollution control devices, such as baghouses, to capture and treat emissions [3-4]. In summary, return gases in a cupola furnace refer to the gases generated during the combustion and reduction processes, which are circulated back into the furnace to contribute to the heating and melting of materials. Proper control and management of these gases are essential for the efficient operation of the furnace while addressing environmental concerns [3-4]. Till the 1900s the cupola furnace was used to melt the metal in foundries. After the 1900s, foundries began to install induction furnaces. In induction furnaces electrical coils are used to burn metals [3]. Global energy-related CO_2 emissions grew by 0.9% or 321 Mt in 2022, reaching a new high of over 36.8 Gt. Following two years of exceptional oscillations in energy use and emissions, caused in part by the Covid-19 pandemic, last year's growth was much slower than 2021's rebound of more than 6%. Emissions from energy combustion increased by 423 Mt, while emissions from industrial processes decreased by 102 Mt [5]. Emissions from the industry declined by 1.7% to 9.2 Gt last year. While several regions saw manufacturing curtailments, the global decline was largely driven by a 161 Mt CO_2 decrease in China's industry emissions, reflecting a 10% decline in cement production and a 2% decline in steel making [5]. The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for carbon monoxide of 35 ppm (40 mg/m(3)) as an 8-hour TWA and 200 ppm (229 mg/m(3)) as a ceiling. The NIOSH limit is based on the risk of cardiovascular effects [6]. An induction furnace is best suited for ductile iron and steel melting which requires a temperature in excess of 1500°C, whereas for graded cast iron (≤1450°C) both a cupola and induction furnace can be used. An increase in demand, lack of skilled labor, and ease of operation have made many foundries shift from cupola to induction furnaces which is facilitated by equipment manufacturers and pollution boards [7]. The analysis shows that the total CO_2 emissions with electric induction melting are 10 and 18% less for Germany and USA respectively, when compared to cupola melting in India. This also implies that cupola melting in India is equivalent to 38% higher emissions from induction furnaces in China [7]. While figure 1 is the schematic diagram of a conventional cupola furnace, the figure 2 shows sectional views of the zones of the furnace[4].

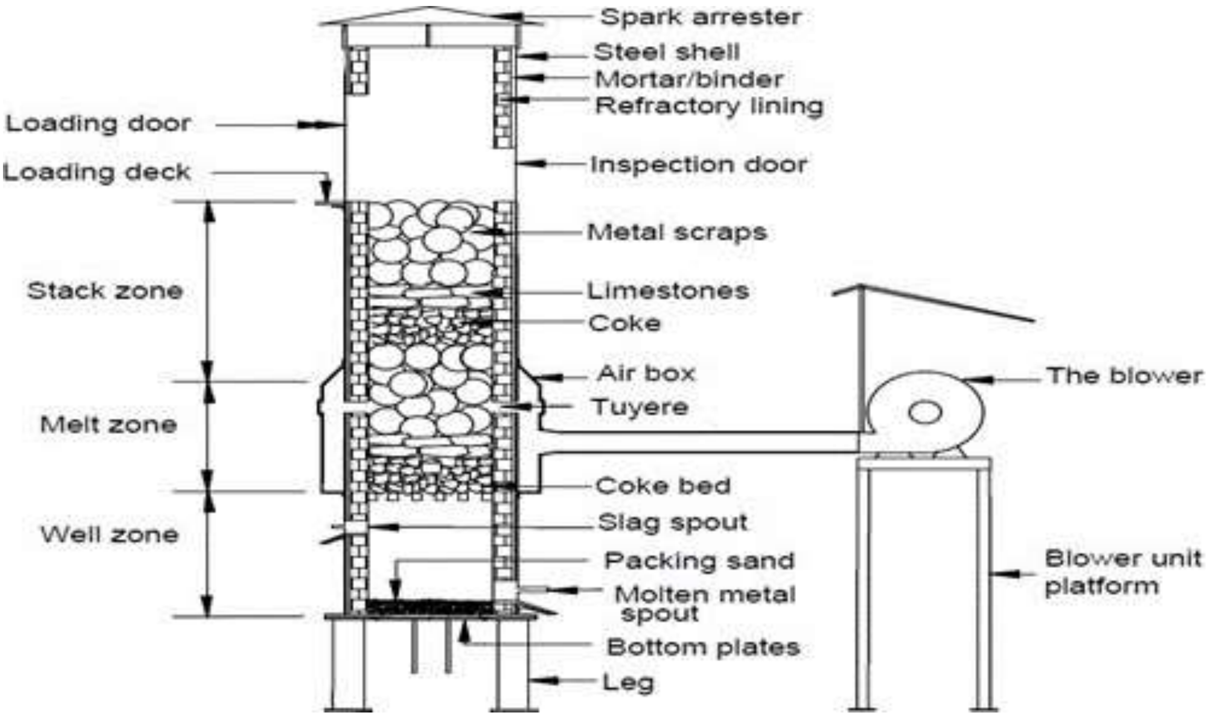

Figure 1. *Schematic diagram of a conventional cupola furnace [4]*

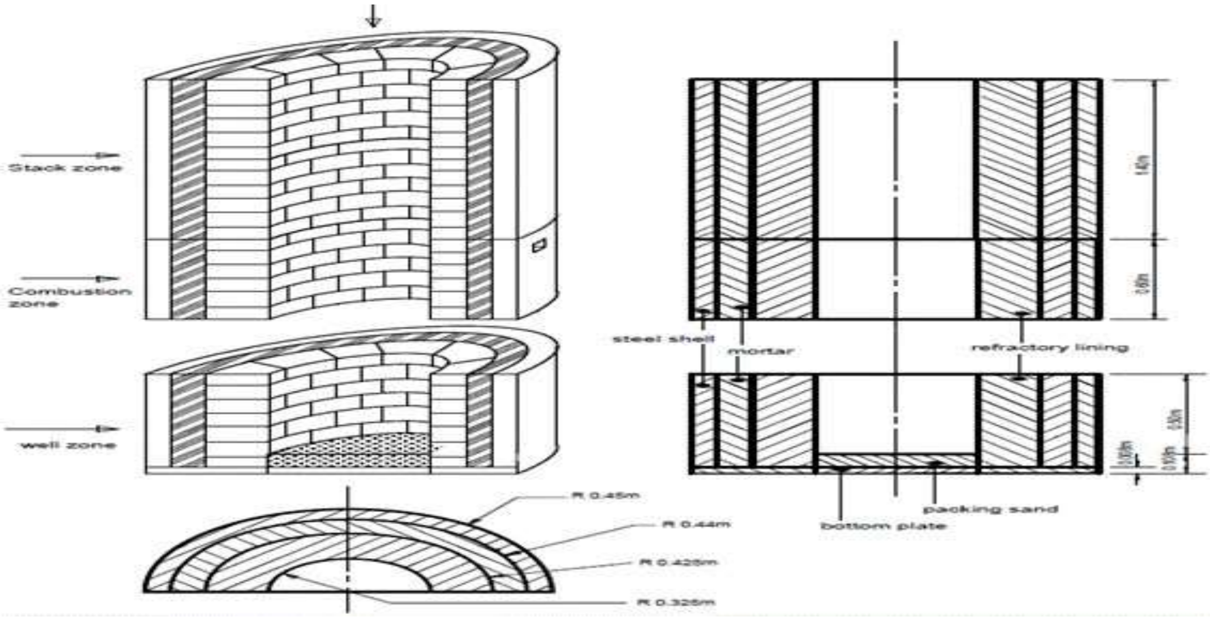

Figure 2. *Sectional views of the zones of the furnace[4]*

Table 1. *Chemical composition of metallurgical coke*

Composition	H2O (wet max.)	Ash max	S max.	P max.	Qd (calorific value) KJ/kg
% weight	1-1.5	10.80	0.58	0.037	27600-29500

Table 2. *Chemical composition of limestone ($CaCO_3$) [1-12]*

Composition	CaO	FeO	SiO_2	MgO	Al_2O_3	H_2O
% weight	52	1	0.6	1.2	1.5	0.6

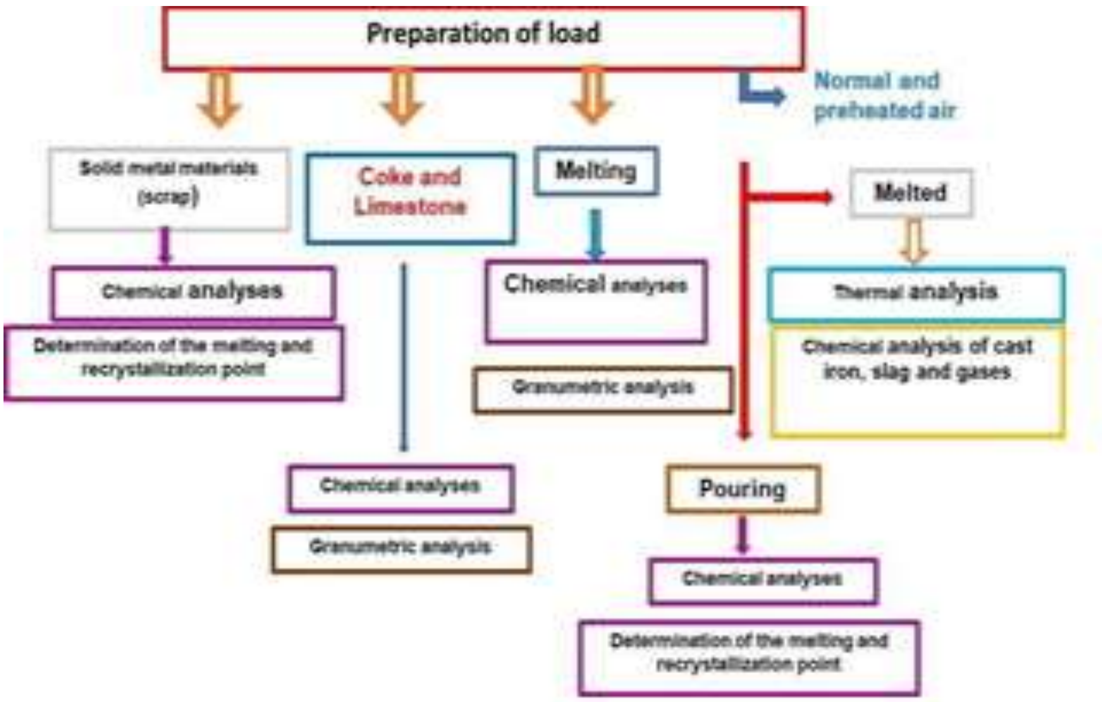

***Figure 3**. The methodology*

2. Material and Methods

The research of gas measurements in the E&E Foundry was carried out during the project research: Research of the impact of gas (CO) through fryers in the scrap melting area in the "E&E Foundry" in Gjakova [1]. The process of producing gray cast iron in the cupola furnace can release several gaseous pollutants, including CO_2, carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). These gases are known to contribute to the discharge effect of gases with a negative impact on air quality and environmental pollution [1]. In modern times, the cupola furnace technology has been replaced by other cleaner and more sustainable methods for the production of gray iron, such as the "gas cut method" (direct reduced iron - DRI) and the "pelletization method". The load of the cupola furnace at "Foundry E&E" in Gjakovë is the main factor determining the gases in the gray cast iron production process. The determination of the coke composition is shown in table 1. The coke used as a source of energy in the cupola furnace at the E&E Foundry in Gjakovë has a carbon content of 89.90% [11-12]. Figure 3 shows the methodology of study and figure 4 is the gas measurement apparatus and view of the gray cast iron production process. Table 2 is the chemical composition of limestone ($CaCO_3$) [1-12] and table 3 is cast iron composition at the E&E Foundry [1]. These methods have advantages in terms of pollution and impact on the environment, helping to reduce gas emissions and attract towards a cleaner production of gray cast iron. The fuel used in "E&E Foundry in Gjakova is coke with the composition of Table 1 [7]. We performed the measurements with the "Gassensing series 500" instrument [1]. The research of the amount of gases in the E&E Foundry in Gjakova was carried out in the working spaces of the Foundry and in the chimney of the cupola furnace. As a result of the gray cast iron production process at the E&E Foundry, we have this percentage of gases.

***Table 3.** Cast iron composition at the E&E Foundry [1].*

Elemente	Mean (%)
C	3.25
Si	1.03
Mn	0.61
P	0.14
S	0.07
Cr	0.54
Ni	<0.015
Cu	0.19
Co	>0.50
Fe	92.93

(a) (b)

Figure 4. *(a) The gas measurement apparatus (b) View of the gray cast iron production process*

According to the theoretical evaluations of the process, the ratio between CO and CO2 in the gas composition has not exceeded the highest level of 30% of CO and 70%. Due to the extremely low diameter of the furnace, as well as the unusual shape of the air stream (square shape of the blowers), the speed of movement of gases through the furnace areas has turned out to be very high, with which the level of development of indirect reactions was too low.

3. Results and Discussions

With the gas measurements carried out in the working space and in the chimney of the E&E Foundry in Gjakova, we reach these values in ppm. The process of producing gray cast iron in the cupola furnace can release a number of gaseous pollutants

- including CO_2
- carbon monoxide (CO),
- sulfur dioxide (SO_2)
- and nitrogen dioxide (NO_2).

These gases are known to contribute to the discharge effect of gases with a negative impact on air quality and environmental pollution. The temperatures of the gases in the chimney of the cupola furnace reach a temperature of 110-120°C. Table 4 shows demonstration of gas measurements inside working spaces at the E&E Foundry, Gjakova and table 5 is presentation of gas

Table 4. *Demonstration of gas measurements inside working spaces at the E&E Foundry, Gjakova*

Gases	Values	Unit
CO_2	525	ppm
NO_2	0.052	ppm
CO	19.88	ppm

Table 5. *Presentation of gas measurements at the E&E Foundry in Gjakova in the chimney of the cupola furnace*

Gases	Values	Unit
CO_2	2047	ppm
SO_2	58.34	ppm
CO	71.88	ppm

measurements at the E&E Foundry in Gjakova in the chimney of the cupola furnace.

4. Conclusions

Elevated carbon dioxide (CO_2) values, such as 2047 parts per million (ppm), in the chimney during the production of gray cast iron from scrap in a cupola furnace may indicate several factors contributing to increased emissions. Cupola furnaces are traditional melting devices used in the foundry industry [1]. Here are potential reasons for high CO_2 values.

In cupola furnaces, incomplete combustion of carbonaceous materials (such as coke or coal) can lead to higher CO_2 emissions. Insufficient air supply or improper air/fuel ratios can contribute to incomplete combustion [1].

The quality and composition of the fuel used, typically coke or coal, can impact combustion efficiency. Poor- quality fuel may contain impurities that affect combustion and increase CO_2 emissions.

The composition of the scrap metal being melted in the cupola can influence CO_2 emissions. Higher carbon content in the scrap may result in increased CO_2 production during the melting process.

Improper control of the air/fuel ratio in the cupola furnace can lead to suboptimal combustion conditions, affecting the efficiency of the process and contributing to elevated CO_2 emissions.

The design and condition of the cupola furnace play a role. Older or poorly maintained cupolas may have less efficient combustion, contributing to higher emissions. Regular maintenance and upgrades may be necessary [9].

Operating the cupola at excessively high temperatures can lead to increased CO_2 emissions. It's important to optimize the temperature for efficient combustion while minimizing emissions.

Alongside CO_2, cupola furnaces may produce particulate matter and other pollutants. Installing effective emission control devices, such as baghouses or electrostatic precipitators, can help reduce overall emissions [12].

Cupola furnaces traditionally have lower thermal efficiency. Implementing heat recovery systems can improve overall efficiency and potentially reduce CO_2 emissions as reported in similar works [12-15].

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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