GREENSTEEL

No way without reliable off-gas measurement

ABSTRACT

A reliable off-gas control is sine qua non to produce low emission steel (GreenSteel). Low emission steel stands for low energy consumption, low CO2 emission, and low heat dissipation. Here, a way to obtain reliable information of the furnace atmosphere at real time.

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GREENSTEEL – NO WAY WITHOUT RELIABLE OFF-GAS MEASUREMENT

Summary

GreenSteel is not only an exact target composition of steel, but it also includes low emissions and as little energy input as possible to achieve the target composition. Therefore, it needs precise knowledge of off gas, the production of the off gas and its optimization. This requires measuring points that provide reliable, reproducible data and an algorithm that can process the data and quickly adjust the variables.

It is known that in the traditional furnace and in the well-known shaft furnace concepts, it is difficult, if not impossible, to obtain information close to the furnace and if so, then the data is influenced by many, constantly changing conditions and therefore does not provide any data that can be used for control.

A furnace concept is therefore needed in which the exhaust gas can be detected close to the furnace and influenced by controlling the media flowing into the melting area of the furnace. This exhaust gas measurement must not be falsified. Like efficient heating systems, the supply air is one of the control variables. Here, **a lot of energy can be saved** with an efficient control system.

The exhaust gas utilization system from **eco-e tech** – the **CORE** furnace concept and the ECOFEEDER two-chamber scrap preheating system – is the logical answer to the demand for **Net Zero** or '**GreenSteel**', because only with the three prerequisites: clear demarcation of the furnace atmosphere, measuring points, which provide reliable data and a fast and reliable control of the energies and the supply air, the goal is achievable. The burners are application-optimized, even with fossil fuels, the goal of climate neutrality can be achieved cost-effectively in the short term. The effect: active scrap preheating in the furnace (hot gas flows through the scrap and not along the electrodes), shorter melting times, less dust in the off gas and optimized off gas utilization in the ECOFEEDER thanks to an **off-gas measurement that provides reliable data** (no external influences, little dust, and no flow changes). Thanks to the almost constant temperature, the pollutant-free and low-dust residual gas is available for wide use (such e.g., steam generation, DRI preheating, heat exchanger, etc.).

The unique **eco-e tech** off-gas utilization system enables the production of **GreenSteel** and brings **massive cost savings**.

Conclusion: **Off-gas control = less energy (massive production cost reduction) = less CO_2 (low environmental costs) = climate neutrality = GreenSteel**

We will be happy to advise you.

April 2022, Roland V. Müller, eco-e AG

Automation – The information lies in the off gas

Climate neutrality or even better the 0%C emission 'Net Zero' does not come automatically and by itself – it takes a lot to trim electric steel production to 0% CO_2 emissions – but it needs sources of information and a functioning information system. Carbon (C) and iron (Fe) live in symbiosis, which can be seen in a variety of ways. The interaction between iron, carbon and oxygen is important for the steel and where is the steel produced – yes, in the furnace, so it is important that the furnace atmosphere is right, because without carbon and oxygen there is no carbon monoxide (CO), no slag foam and no bath movement. To detect and control this efficiently in real time, information about this very atmosphere is needed.

There are three prerequisites for successful control of the furnace atmosphere:

1. Clear demarcation of the furnace atmosphere
2. Measuring points that provide reliable and reproducible data
3. Fast and reliable control of gaseous and solid media flowing into the furnace (supply air, oxygen, fuel (hydrogen, hydrocarbon compounds, coal)) and energy

Clear demarcation of the furnace atmosphere.

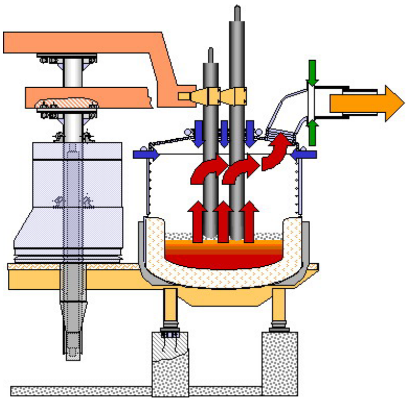

Figure 1 / Convection in the furnace

Where coal burns, CO_2 is produced. If we want to release as little CO_2 as possible, then we need to reduce the unwanted CO_2 sources - and how wonderful, we can also save a lot of money with it. An unwanted CO_2 source is the electrode burn-off. The hot gas that flows along the electrodes (Convection (picture 1)), heat them up additionally and the oxygen in the hot gases burns the carbon at the periphery of the electrodes. As a result, not only the carbon is burnt off (see picture 2), which is cost-driving, but also the oxygen, which was intended for the foam slag. Thus, the oxygen is missing to form CO with the injected carbon and the melt absorbs the carbon. Later during refining the carbon is again burned off. So double CO_2 production instead of reduction!
The airflow shown in Figure 1 is therefore not very 'clever'.

Figure 2 / Lateral burning of the electrodes

I would like to present a ‘clever' airflow (figure 3).

The 'Core' furnace forms a clear demarcation of the furnace atmosphere. The airflow is led away from the electrodes and flows above the slag to the off-gas canal. Thereby the scrap is additional heated which shortens the melting time. The interaction between preheating and melting time can be controlled with the supply air. The exhaust gas is produced without CO_2 of the electrode burn-off and measured without the influence of false air.

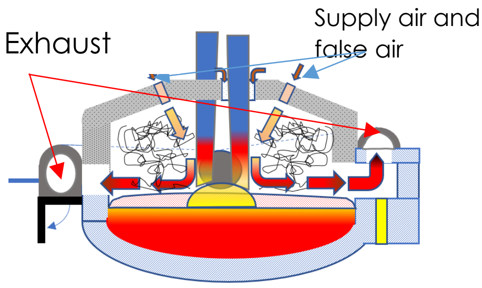

Figure 3 / Core furnace

Conclusion: In the traditional furnace with fourth hole or single-chamber scrap preheating, there is no clear demarcation of the furnace atmosphere (false air from all directions). **In the CORE furnace there is a clear demarcation of the furnace atmosphere (controllable supply air and false air from above)**

Measuring points that provide data that is reliable and reproducible.

Figure 4 / Lindarc exhaust gas measurement

In the traditional radiation-convection furnace the measuring point is positioned directly after the transition into the exhaust system, i.e., where the exhaust gas is mixed with fresh air. Depending on the arrangement and the off-gas dynamics (turbulence, tear-off edges, positioning of the sleeve, disturbing the laser optics by dust, etc.) can make the measurements strongly vary, so they are not reliable and not reproducible. Although it is interesting to have certain information regarding CO, (CO_2 and O_2 in dependency) and H_2 but evaluable control information for the supply air is not to be obtained in this way.

But one thing at a time. The melting down of scrap makes in electric arc furnace (EAF) lots of noise. This noise, like the thunder in a thunderstorm, is the product of the explosive volume increase of the air surrounding the arc. By the shockwave, the surrounding environment is shaken, and a lot of dust gets whirled-up. Due to the prevailing convection (air flow due to the thermals) (Image 2)) these dust particles are transported towards the secondary dedusting system. Figure 5 shows the amount of dust in the cold bore phase. At the beginning of the melting phase the arc and the associated hot zone lies well above the slag door, which is why the dust particles are not sucked-off by the primary dedusting (furnace off-gas extraction). The false air flow goes partially from the slag door directly into the shaft resp. to the fourth hole (see figure 6).

Figure 5 / Cold drilling phase

In the electric arc furnace, the electrical energy is converted into thermal energy, which is transmitted as radiation. This will heat-up the surrounding material that strong that even a sublimation of the iron can take place. The high energy density forms a plasma in which the scrap melts. Due to the high heat, 'cold' air is sucked in and heated-up. This creates convection, e.g., the hot off gas flows along the electrodes. Together with the radiation of hot scrap the electrodes burn-off laterally.

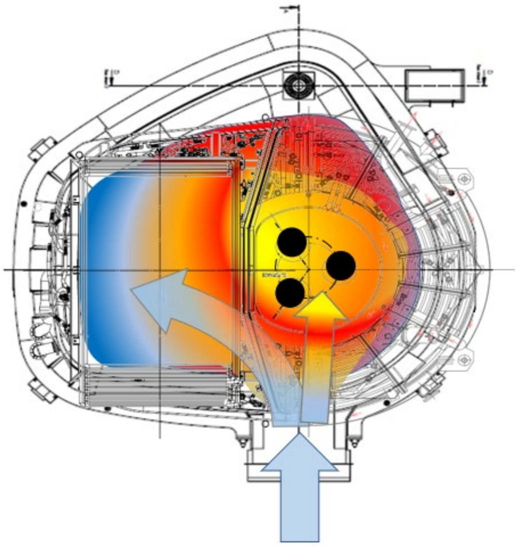

Figure 6 / Air flow in the shaft furnace with open, or leaking slag door

In the heated furnace, the air flow does not change significantly, with an open or partially open slag door, part of the ambient air is sucked into the furnace extraction system and the other part flows to the plasma, which neither promotes the melting process nor is useful for scrap preheating. The hot gas flows along the electrodes towards the furnace roof, heats the cooling panels and finally escapes via the fourth hole or the shaft into the off-gas system (see Figure 7 on the left).

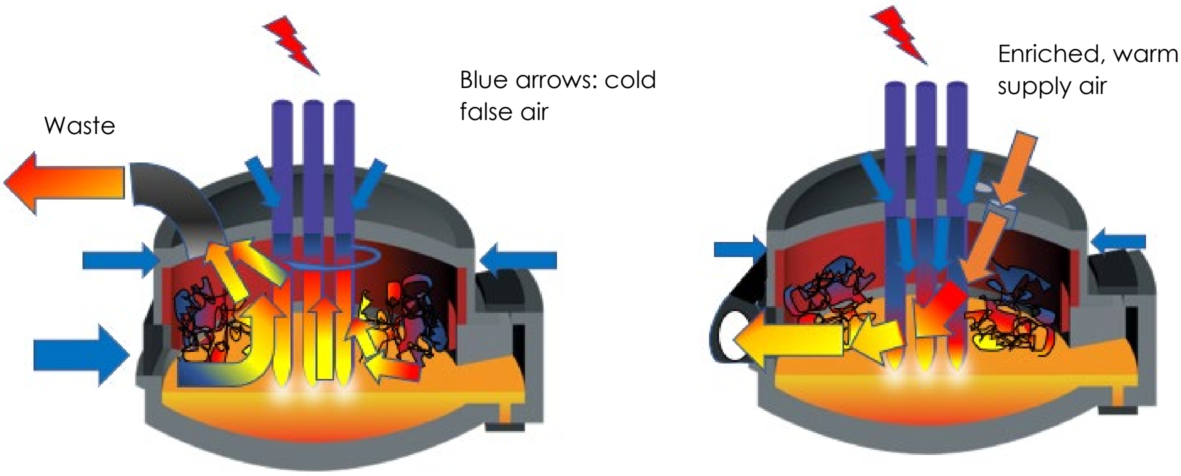

Figure 7 / Exhaust gas movement in the traditional furnace and in the CORE furnace

As already mentioned, in the traditional electric arc furnace (fourth hole) and in the conventional shaft furnace concepts, a near-furnace real-time measurement of the exhaust gas is impossible.

In the traditional furnace, the measurement is only possible after the fourth hole and only after mixing with ambient air, thus the result is influenced by constantly changing flow conditions.

In the shaft furnace, a measurement is only possible in the upper shaft area. However, since the post-combustion of CO in CO2 also takes place there, the result is neither reliable nor usable for control purposes.

This is all different in the CORE furnace: The air streaming-in from above is extracted through an opening in the torus of the CORE furnace. This prevents convection. The supply air ring is divided into several sectors, which are controlled in such a way that the air is not sucked directly into the torus, but that the shortest path leads over the hottest area in the furnace. The flow pulls the still 'cool' air through the 'borehole' along the electrodes to the arc (Fig. 8). The ambient air entering the upper part of the furnace (roof rim and electrode openings) is mixed with the supply air and flows towards the plasma. The exhaust gas, which is above 2000°C at this point, is pulled through the scrap lying over the slag and heats it up additionally or causes the scrap to melt. The dust mixture, which is whirled up in the plasma, settles on the doughy surface of the melting scrap. The burners or the burner lance combinations are switched on depending on their need and support the air flow. The heavier dust particles fall due to the turbulence that occurs in the scrap, settle on the slag, and melt there. In the flat bath phase, the foam slag covers the arc. Here, less dust is whirled up and the FeO produced in the plasma remains in the slag or can return to the melt as iron due to the reduction with the coal. At the CORE furnace the electrode burn-off is significantly smaller and is not of relevance to the off-gas measurement.

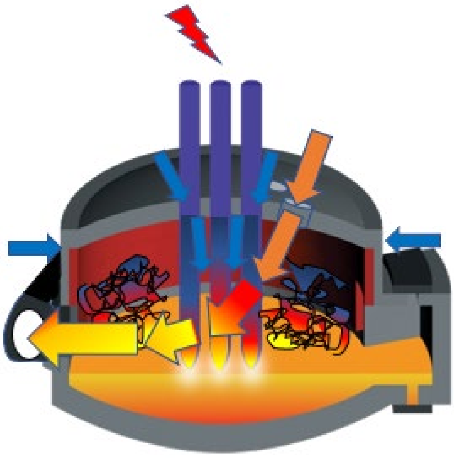

Figure 8 / Forced flow

Conclusion: The measuring points in the traditional furnace with fourth hole and in the shaft-based furnaces are not suitable for an active influence on the furnace atmosphere.
In the CORE furnace however, the first possible measuring point is at a well protected location in the off-gas duct, which is neither exposed to dust nor where the post-combustion happens. In addition, there are stable aerodynamic conditions. **For the minimization of emissions, or the production of climate-neutral steel or 'GreenSteel', however, a reliable and correct exhaust gas measurement is a prerequisite.**

In one of my previous articles 'Furnace off gas – gain or loss'[i] I showed the potential of the exhaust gas and showed how energy can be optimally extracted from the off gas. This optimization includes the conversion of the existing furnace to a CORE furnace, a cost-effective effort, the installation of an ECOFEEDER (two-chamber scrap preheating from eco-e) and a continuous DRI supply, as well as a comprehensive exhaust gas monitoring and supply air control. Unlike the single-chamber system, where the exhaust gas can neither be monitored chemically (composition) nor physically (temperature and pressure) close to the furnace and comprehensively, with the two-chamber system this monitoring is possible permanently and in clean areas.

Fast and reliable control of the energies and the gaseous and solid media flowing into the furnace.

The third condition, a fast and reliable control of the gaseous and solid media flowing into the furnace (supply air, oxygen, fuel (hydrogen, hydrocarbon compounds and coal) cannot be easily guaranteed in the traditional furnace. In case of well-closing slag door constructions, the supply air can be prevented but not controlled. So only the fuels and the oxygen remain. The control of the furnace atmosphere with fuel and oxygen only is complex, in addition, the ambient air entering the upper area of the furnace (rim edge and electrode openings), which is sucked-in directly into the fourth hole or the shaft, distorts the result. In convection, the hot off gas and the cold false air are mixed.

In contrast to the traditional furnace, the exhaust gas measurement of the CORE furnace is placed in a place where no external influence is possible, where there is no excessive dust, and the aerodynamic influences can be controlled. The exhaust gas measurement (quality and quantity of the exhaust gas) is reproducible and can therefore be used for the control of the supply air, the oxygen content in the supply air, the burner use, and the lance activity. **The CORE furnace is ideal for controlling the furnace atmosphere and thus CO_2 emissions. The CORE furnace is therefore the most suitable unit to produce 'GreenSteel'.**[ii]

Thanks to the information from the analyzers and the temperature and pressure probes, the algorithm calculates when and how much CO, CO2 and H2 is in the exhaust gas and which parameters need to be changed via the control system to optimize the off gas for minimum emissions and for optimal scrap preheating in the furnace and after the furnace. This information is accurate and reproducible.

Eco-e tech connects the CORE furnace with the two-chamber scrap preheater, the ECOFEEDER. In the ECOFEEDER, the exhaust gas flows again horizontally through the scrap, whereby a natural convection in the vessel occurs due to the massive volume increase (exhaust pipe to the scrap container). Before entering the burner chamber, the composition, temperature, and pressure in the exhaust gas are measured again. The post-combustion of CO and the combustion of impurities can be tracked and controlled. Depending on the condition and composition of the exhaust gas, the afterburners are used. In the subsequent preheating container, the energy is then passed on to the preheated scrap in accordance with the laws of heat transfer.

Conclusion: The traditional furnace and the well-known shaft furnace variants are not suitable for controlling the furnace atmosphere. Eco-e tech, the combination of CORE and ECOFEEDER allows a reliable measurement of the furnace off gas in the immediate vicinity of the furnace to the stack. This makes it possible to minimize emissions by means of control by adjusting the variables in the individual areas. The use of exhaust energy in and after the furnace is thus maximum and the pollution of the environment with waste heat and pollutants is minimal. The residual heat is fully available for further use. The residual gas has an almost constant temperature is pollutant-free and almost dust-free.

This means that the prerequisites for 'GreenSteel' are met.

Here is a compilation of the advantages of the eco-e tech concept (CORE & ECOFEEDER), divided into five groups:

1. **Direct energy-saving measures**
   a. High preheating temperature of the scrap up to approx. 750°C (-130kWh/t_{LS})
   b. Better exhaust gas flow in the furnace = scrap preheating in the furnace and better use of arc energy (-50kWh/t_{LS})
   c. Integrated combustion of pollutants (e.g., dioxin and furan) and use of post-combustion energy
   d. Integrated use of $CO \rightarrow CO_2$ post-combustion
   e. Integrated furnace air preheating (~300°C) (-15kWh/t_{LS})
   f. Usable residual gas with constant temperature (~600°C) (heat exchanger, ORC process, evaporator, DRI preheating, energy storage, etc.)
2. **Direct and indirect reduction of CO_2 emissions**
   a. Better burner utilization, thus fewer burners in use
   b. Enriched furnace air with preheating (~300°C), thus less NOx
   c. Optimal exhaust gas management through automation
   d. Lower material consumption (slag formers/lining)
3. **Metallurgical advantages**
   a. Utility value analysis and optimization (DRI / scrap)
   b. Continuous and discontinuous production possible
   c. Batch-neutral preheating (no mixing of scrap qualities)
   d. No scrap domes in the furnace, i.e., fewer bears
   e. Fewer electrode breaks
   f. DRI preheating and continuous DRI supply possible
4. **Maintenance advantages and flexibility gain**
   a. Hot storage of preheated scrap possible
   b. Better access on the furnace rim (DRI supply) and to the electrodes
   c. Production during maintenance / repair possible
   d. No wear parts at exposed positions
5. **Commercial Advantages**
   a. Shorter melting times
   b. Lower electrode consumption (less side burn-up)
   c. Less filter dust, as dust remains in the furnace or in the scrap
   d. Less mechanical wear during lining
   e. Smaller furnace cooling capacity (thanks to internal scrap preheating and better foam slag formation)

Less environmental impact (CO_2, pollutants, slag builder, furnace lining, NOx, etc.), **less costs** (energy, electrodes, fuels (NG, H_2, coal), maintenance) **and more flexible furnace management thanks to automation**.

April 2022, Roland V. Müller, eco-e AG

[i] 'Furnace exhaust gas – cost or savings potential?', www.eco-eag.com/English/Download, eco-e AG 2022
[ii] ‚GreenSteel – The Way to the Future.', www.eco-eag.com/English/Download, eco-e AG 2022