ecology eco economy

ENERGY SAVINGS

EAF Off gas – gain or loss?

ABSTRACT

No evolution without a change – Change is often a paradigm shift – Paradigm shift is EVOLUTION and this time an ECOLUTION!

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The right use of exhaust gases is the best way for electric steel production towards climate neutrality

Even though electric steel production 'only' contributes 8% of CO_2 emissions to the total CO_2 emissions of steel production, it is still a lot! The production of electric steel is also required to reduce CO_2 emissions per ton of steel. Depending on the source, process and utility values, the electric steel industry produces 300-400kg CO_2/t liquid steel (t_{LS}).

Currently, about 30% of the world's steel production is produced in the electric steel mill, which is about 520 million tons of steel per year with an annual production of 1700 million tons of steel. According to the forecast, about 2500 million tons of steel will be needed in 2050 and the share of electric steel production will increase to about 50%. With a target of 200kg $_{CO2}$/tFS and a system-related CO2 emission of at least 400kg CO_2/t_{LS} of the converter line, 0kg CO_2/t_{LS} would result for electric steel production![i]

Well, to estimate whether this prediction will come true or not. is not the content of this article. This is more about showing how this goal can be achieved with consistent implementation of known and already proven measures.

It is generally accepted that the losses incurred in the e-furnace in the form of hot gas can be recovered 'easily'. But are they recovered efficiently and to the maximum?[ii]

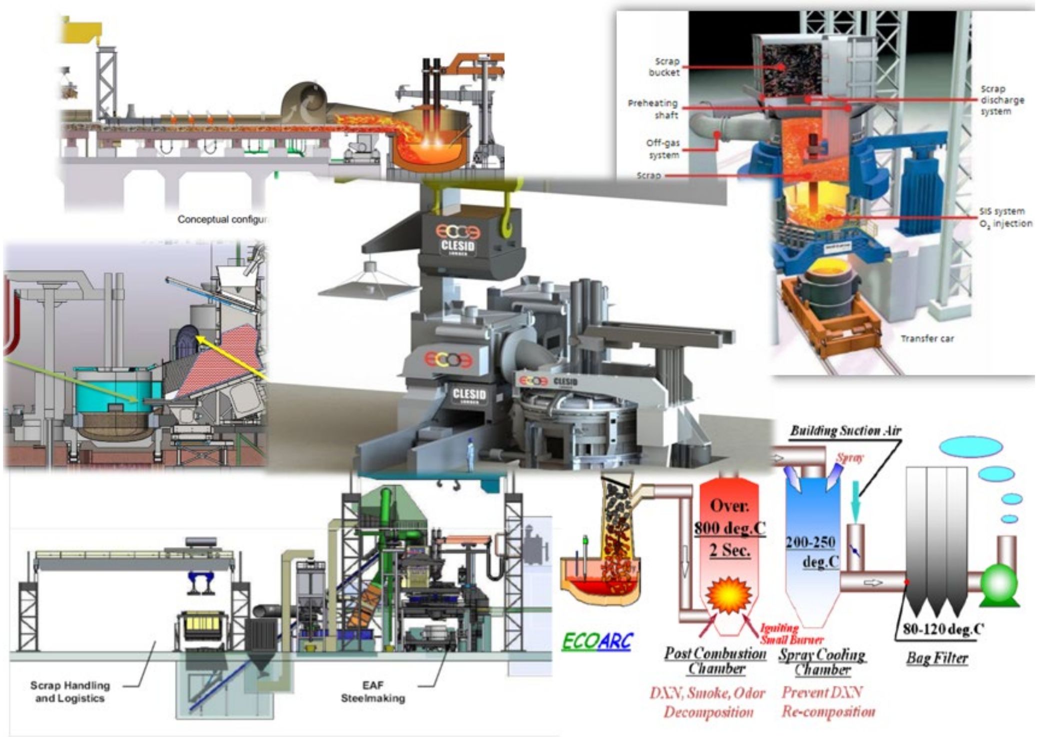

Figure 1 / Some modern scrap preheating systems (ECOFEEDER©, Consteel, Sharc, ECOArc, Quantum, Ismelt)

In one of our articles ('the energy (pr)icebreaker')[iii] we have shown that when the hot gas is passed through cold scrap once, only part of the energy contained in the hot gas is transferred to the scrap. It is common knowledge that heat transfer is, among other things, a function of contact time that remains with the two media to exchange. Furthermore, it is also known that the heat transfer is also a function of the differential temperature of the two media over the exchange distance. The contact time and the exchange distance are in turn a function of the speed at which the hot medium flows around and through the cold one.

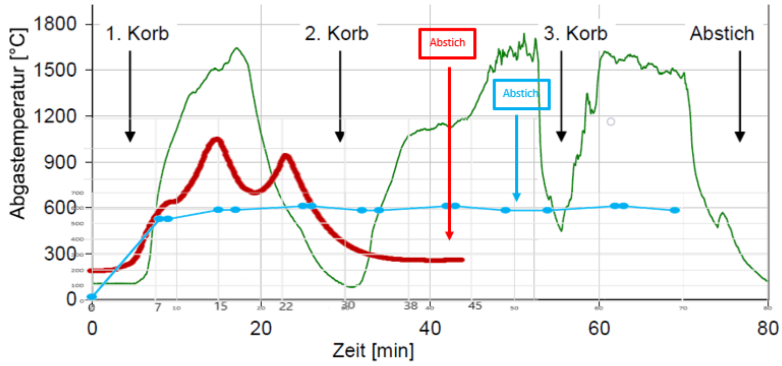

Figure 2 / Exhaust gas temperatures (EAF without scrap preheating (green), shaft furnace (red), ECOFEEDER© (blue))

Since the gas velocity prevailing in the case of exhaust gas use, i.e., the throughput time, cannot be selected arbitrarily, as it in turn depends on other factors, it is obvious that the throughput distance must be increased accordingly. This, in turn, is not possible without restriction due to the scrap volume (loading of the furnace). The solution: the two-chamber system. Due to the double run, the scrap final temperature is much higher than with the single-chamber systems and the external post-treatment of the combustion products becomes obsolete, i.e., unnecessary, since integrated, which has a very **cost-saving** effect. The residual gas, which is applied at a constant temperature (see blue line in Fig. 2), can also be used ideally, as it is almost dust-free.

The climate goal, the reduction of CO_2, the main proportion of greenhouse gases (CO_2, methane, and nitrogen oxides), is one thing, but it is also important to reduce the heat that is not generated by the combustion of carbon, but which is also released into the environment. You can imagine what happens in a greenhouse that is also heated from inside.

In another article ('The energy (pr)icebreaker (2)')[iv] we have shown that with simple considerations a thermally more efficient gas flow can be forced, which on the one hand reduces the burning of the electrodes – **very cost-effective,** and on the other hand preheats the scrap in the furnace before the actual melting (active scrap preheating in the furnace), which is **energy-saving**. This simple and <u>cost-effective</u> conversion would already be a first step in the right direction (towards the desired climate target) and towards an active scrap preheating, which can be implemented in a second conversion phase (addition of a two-chamber scrap preheater (ECOFEEDER©)).

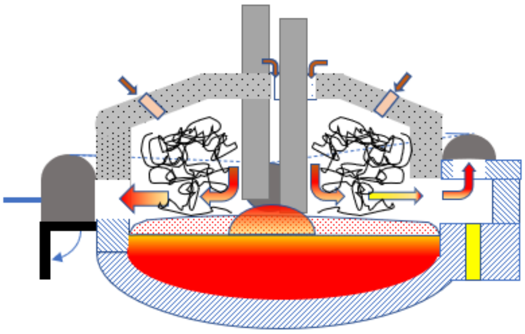

Figure 3 / Internal scrap preheating

The electrical energy introduced via the arc generates the thermal energy required for the melting process of the scrap. A high-temperature plasma is formed around the arc, which on the one hand melts the scrap and on the other hand forms iron oxide (FeO) together with the oxygen present in the ambient air. However, the plasma not only heats the scrap, but also the direct ambient air, which leads to an increase in volume (greatly simplified description). The exhaust system must ensure that on the one hand enough 'fresh' air is supplied and on the other hand the 'used' air is sucked out, the furnace must be able to live. The much-quoted closing of the slag door can possibly cause the melting process to be influenced in such a way that oxygen intended to produce the foam slag is suddenly missing and the foam does not develop. As described in the aforementioned article, oxygen must be supplied to the furnace. The oxygen can be introduced via the sucked in air (false air) or directly. The false air can be enriched with oxygen and, if possible, without effort, can be preheated (**saves energy in the furnace**), but it is important that the flow direction is correct. Suction via the open slag door cools the scrap in the place where it should melt, the slag door bears form there.

As described, the 4th hole in the traditional electric arc furnace (EAF) is thermally in the wrong place. Why? Because the EAF is mistakenly built as a convection furnace, even though it has a forced suction! The aim of the furnace is primarily to melt the scrap and not the production of hot exhaust gas. This also applies to all shaft furnace systems. Gerhard Fuchs' idea, which undoubtedly went in the right direction, has not been thought through to the end to this day. The exhaust gas must and can be used much more efficiently than in the well-known single-chamber systems (Quantum, Sharc, EcoARC, Consteel, etc.).

The single-chamber system <u>was</u> the first step towards energy- and environmentally conscious steel production.

The ECOFEEDER© is the next step. The ECOFEEDER© not only uses the heat of the exhaust gases after the furnace, but also in the furnace. As a result, a uniform and complete melting of the already preheated scrap is achieved. This is done without further energy supply, only through a thermally better use of the furnace air. An extremely important side effect is that the electrodes are cooled by the supply air flow, i.e., less side burning, both on the roof heart and in the scrap column. The burners used support the exhaust gas flow by being used via the automatics depending on the off-gas suction.

After that, the off gas in the ECOFEEDER© is passed horizontally and vertically through the scrap, resulting in a better 'wetting' of the scrap surface. The use of the exhaust heat is supported by the burning of the impurities in the chamber and the complete combustion of the CO to CO_2, the post-combustion. The sum of these energies causes a rapid increase in the scrap temperature. The residual gas with the combustion products is heated again to approx. 1000°C in the subsequent burner chamber and then fed into the second container.
Thanks to the large cross-sectional changes and the associated speed differences, we achieve optimal heat transfer and the dust carried along (FeO and slag dust) can sink into the containers.

The ECOFEEDER© is an exhaust gas utilization system supplied as an external attachment (instead of the post-combustion chamber) to an existing EAF (the only change to the furnace: the exhaust gas duct (blue taurus and brown supply air ring on the furnace roof (Figure 4))) or as a total solution (advantage: no opening of the furnace lid) with an asymmetrical furnace shape used exclusively to feed scrap into the furnace.

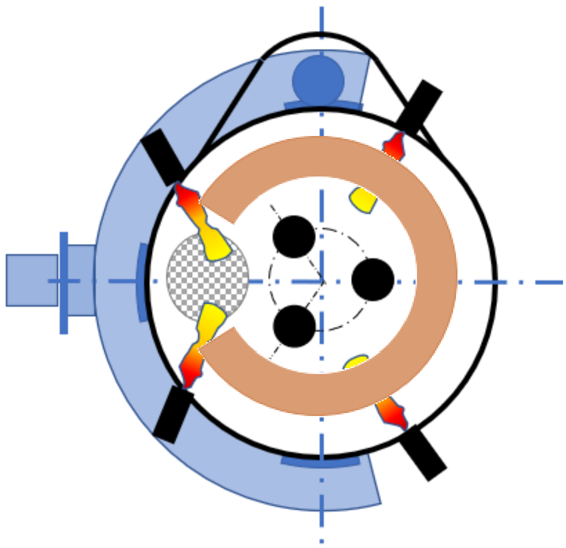

Figure 4 / Sketch: EBT-EAF with exhaust gas (blue) and supply air ring (brown) and DRI addition (ex 4th hole)

Due to the exhaust gas and burner control, the scrap is evenly preheated in the furnace. The scrap/liquid metal transition zone is more balanced and **fewer cold islands and scrap domes are formed**. As a result, the foam slag can also build up and distribute better.

The enriched (to reduce NOx values) and preheated air flows over the orange supply air ring over the roof, along the electrodes to the plasma and on to the respective exhaust gas openings.

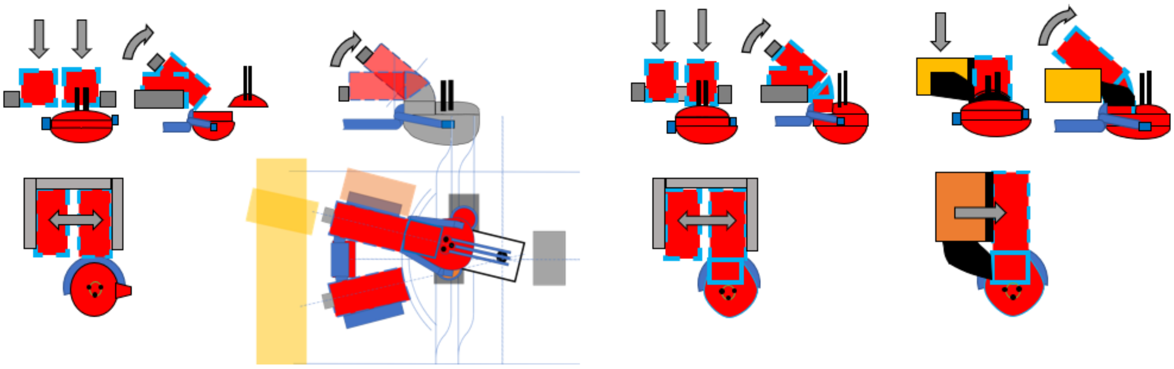

Figure 5 / The ECOFEEDER© versions with improved exhaust gas routing

The advantages of the ECOFEEDER© concept can be divided into 5 groups:

1. Direct energy-saving measures, i.e., lower costs
   a. Higher preheating temperature of the scrap up to approx. 750°C (-130kWh/t_{LS})
   b. Correct exhaust gas routing in the furnace → Better use of energy
   c. Integrated combustion and use of pollutants (-30kWh/t_{scrap})
   d. Integrated use of CO → CO_2 post-combustion
   e. Integrated use of the auxiliary burners (PCDD/F) (-60kWh/t_{LS})
   f. Integrated furnace air preheating (~300°C) (-15kWh/t_{LS})
   g. Constant residual gas temperature (~600°C)
2. Direct and indirect reduction of CO_2 emissions, i.e., lower costs, less environmental impact
   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, i.e., advantages that result qualitatively and quantitatively
   a. Value in Use analysis and optimization
   b. Batch-neutral preheating (no mixing)
   c. No mountains of scrap in the furnace
   d. Fewer electrode breaks
   e. DRI preheating and continuous DRI supply possible (C and slag)
4. Maintenance advantages and flexibility gain, i.e., lower costs
   a. Hot storage of preheated scrap possible
   b. Better access to the electrodes
   c. Production during maintenance / repair
   d. No wear parts at exposed positions
5. Commercial advantage, i.e., better return
   a. Lower electrode consumption (less burn-up)
   b. Dust remains in the scrap → less waste
   c. Less wear during lining
   d. Smaller furnace cooling capacity necessary (thanks to internal preheating and better formation of the foam slag)

These convincing advantages of the ECOFEEDER© family are supported by a simple realization of the system, e.g., a step-by-step conversion and construction is possible.

Realization of a plant

In a first step, the furnace can be converted from an inefficient convection furnace to a thermally more efficient furnace with just a few changes. This enables initial savings. After successful commissioning and initial experience, an ECOFEEDER© E can be attached to the modified furnace. This conversion consists of three parts, which are pre-assembled in the workshop. The conversions on the construction site can be realized in a few weeks. The increase in energy efficiency with the ECOFEEDER© E is large, but not yet optimal. To eliminate the energy loss when opening the roof, the ECOFEEDER© E can be converted into an ECOFEEDER© MC. Depending on the shape of the furnace, this is more complex. Adaptation of the lower and top furnace, possibly the platform and the furnace roof. Further the addition of the scaffolding with the 'filler neck'. The ECOFEEDER© E does not have to be significantly rebuilt for this. This modification can take several weeks to months, depending on the effort.

DRI as scrap additive/replacement

Optionally, a continuous DRI conveying can be installed on the ECOFEEDER© instead of the 4th hole.[v] Therefore, however, combination burners (burners & O-lance combinations) would have to be used instead of the pure oxy burners (O-H or O-CH4). The DRI can thus be optimally fired and melted down. The DRI enables optimal foam slag formation and thus an increase in the efficiency of the arc energy and a reduction in the cooling capacity of the panels.

Thanks to the VIU (value in use) analysis, an optimal operating model can be established in which the proportion of DRI/scrap can be ideally adjusted.

Result

The ECOFEEDER© concept allows the existing production facilities with poor exhaust gas utilization to be gradually converted into an efficient plant that can achieve the goal of 'climate neutrality' well before the deadline and is commercially profitable.

The concept also sets new standards for a green or brown field project in terms of efficient exhaust gas use and, accordingly, the lowest production costs.

Order a feasibility study or a tailor-made offer.

March 2022, Roland V. Müller, eco-e AG (www.eco-eag.com)

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[i] 'International Energy Authority G20 Hydrogen report, the future of hydrogen and assumptions', International Energy Authority IEA
[ii] 'CO_2 Verminderung in der Metallerzeugung', Forschungsgesellschaft für Energiewirtschaft mbH FfE, 2018
[iii] 'Energy price – The energy (pr)ice-breaker', www.eco-eag.com/English/Download, eco-e AG, 2022
[iv] 'Energy price – Warm air - window dressing or not?', www.eco.eag.com/English/Download, eco-e AG, 2022
[v] 'DRI – Future of the steel industry?', www.eco-eag.com/English/Download, eco-e AG, 2022