Figure 1 / 'Climate transition of the world' Painting 2014

Ecology and economy in secondary steel production – or how to meet the goals of the energy and climate transition with profit.

At the end of June 2022, I had a lecture on the topic ' How can companies strive for net-zero targets and at the same time reduce costs? '. This was to initiate a discussion at the MMSteelClub conference in Barcelona.

Well, in the last two posts, we talked about the paradigm shift, the change from convection furnace to preheating furnace and how economically sensible and environmentally friendly scrap preheating works. We have seen the tremendous benefits that a simple change in gas flow can provide. We have also found that there are better ways to use the precious fossil energy than to heat cold spots that are avoidable. And we are also happy about lower electrode consumption and all the other savings and finally we have a clear, dependable, and controllable exhaust gas measurement, a 'must' to produce green steel. All together reason enough to switch to this innovative design.

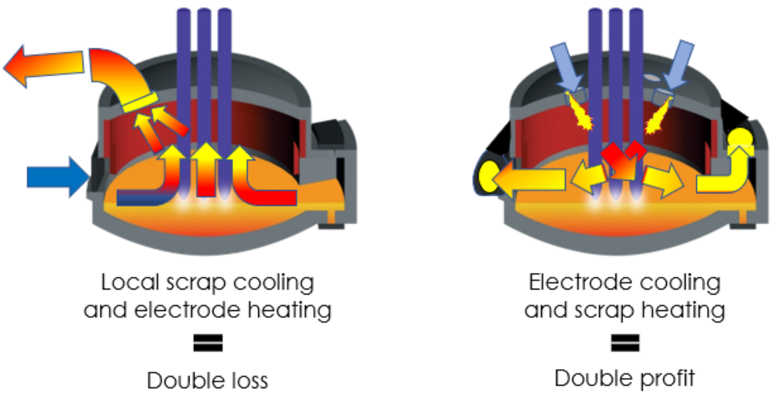

Figure 2 / Convection furnace vs. preheating furnace

We also talked about how a modern and optimized scrap preheating must be designed and what a separation of the melting area from the preheating area can entail. We have seen how much it is worthwhile to integrate the combustion of pollutants and how this heat can be used to preheat scrap. Finally, we found that the residual heat after preheating is still good enough and even better to generate steam or can be used for other applications due to its almost constant temperature.

The following discussion on how steel mills can achieve net-zero targets while reducing costs can be summarized with the following list of benefits:

- At the furnace:
    - Less chemical energy required
    - Supply of preheated burner air
    - Lower melting energy required
    - Lower electrode consumption
    - Lower refractory wear
    - Lower energy loss by less radiation
    - Better, dependable, unaltered, and continuous off-gas analyse and measurement to control the furnace atmosphere
- At the scrap preheating:
    - Full benefit of the post combustion of CO
    - Benefit of the combustion of pollutants
    - Integration of thermal energy to destroy combustion products
    - Benefit of slag builder preheating
    - Storage of preheated scrap
    - Separation of steel grades (no mixing with scrap grades of following heats)
    - Surface cooling by burner air preheating (furnace)
    - Scrap container designed as wear n' repair part
- After scrap preheating:
    - Off gas with extremely low dust content
    - Off gas flow at constant temperature
    - Off gas usable in all purpose heat exchanger
    - Three steps residual heat concept
- Over all benefits
    - High-temperature scrap preheating
    - Low energy melting procedure
    - Adaptable melting times (scrap density dependent)
    - Zero waste concept
    - Net-zero target approach with CO_2 feed back

Our last post ended with the note, that this effective preheating system is not only offering economical benefits, but it is also ecologically valuable and friendly because the process includes the elimination of the combustion products, the in-process use of the produced CO_2 and its zero-waste strategy, which means there is almost no waste heat. The energy loss, which is considered a waste of heat, is energy that could only be used with very extensive measures such as radiation panels, thermal slag treatment and extensive cable and conductor cooling. Here again the shown table with the energy and the environmental values.

Table 1 / Environmental figures in comparison

Steel making: environmental burden with or without scrap preheating

Scrap preheating system (CAA = Clean air act)	Line	Energy balance (kWh/t) ++)	Real energy input (kWh/t)	Real electric energy input (kWh/t)	# of compart. // Energy recuperation/ compartment (%)	Heat release to the environment (kWh/t) *)	Use & amount of residual heat (kWh/t)	Losses (kWh/t)	Reliable off – gas measurement and control **)	CO_2 Scope 1 (kg/t)	Method of elimination of toxic residuals
Column		1	2	3	4	5	6	7	8	9	10
Traditional EAF	1	680	680	430	0//0	~ 300	No/-	335	Not reliable	> 50	No elimination
Shaft based systems (CAA ☑)	2	680	590	310	1//32	203	No/-	333	Not feasible	> 50	Thermal treatment and reduction of toxic output
Eco-e tech (CORE and ECOFEEDER) (CAA ☑)	3	680	**463**	**231**	2//33 (66)	**55**	**Yes / 76**	**90**	**Included**	**<< 50 +)**	Thermal treatment and **incineration**

*) Without water-based cooling systems (low temperature cooling)
**) In traditional EAF there is no reliable Off-gas measurement possible (dust, changing aerodynamic conditions), in shaft-based systems and Consteel off-gas measurement is only possible after scrap preheating and therefor not reliable (CO post combustion, burning of combustibles, etc.).
+) With H_2-O_2 burner in burner chamber (CH_4 burner in EAF)
++) Normalized energy balance (without reactions and pollutions)

Now, the remaining topic of the lecture was the use of the off gas after the scrap preheating and the over-all benefits of the system.

But first let us discuss again the above table. The above table (figure 3) shows different values, all of them are quite important. Beside the energy balance of the furnace which of course does not include the preheated scrap and the pollution energy, the even more important values of the environmental burden of the production of steel.

First, column 5, the heat released to the environment. The green house gas (GHG) released by any combustion is one thing, the heat is another thing. Simply said, GHG form a protection shield around our planet which allows the radiation from the sun to reach and heat the surface of our planet and reduces the evacuation of the accumulated heat. The more GHG we produce the higher the heat isolation. All heats produced by any combustion is not included in the GHG equation. This heat adds to the heat generated by the sun. The production of steel requires approx. 680kWh/t energy, whereas 385kWh/t are the content of the molten steel (enthalpy) and about 300kwh/t are heat in form of off gas, slag, low temperature cooling water and radiation. A traditional scrap preheating transforms about 90kWh/t in scrap preheating and cooling water (shaft or tunnel), thus 203kWh/t are still released to the environment. Careful: the heat (enthalpy) of the molten steel is not included in this calculation as this heat is transformed in a separate process (casting machine or ingots). The ECOFEEDER releases just 55kWh/t, which is the radiation and the slag, both products which cannot transformed easily.

Next column, column 6, the use and amount of residual heat (off gas). At both, the furnace without scrap preheating as well as the furnace with scrap preheating, the off gas cannot be further used. It must be cooled down for filtering by merging ambient air to the hot off gas or by means of a cooling tower. The furnace with scrap preheating gets another issue, the harmful and even toxic output of the combustion products. These products must be treated, in the case of PCD (poly chlorinated dibenzo-compounds) they are reheated to crack the compounds and then shock cooled to inhibit reforming. An expensive treatment. Differently at the ECOFEEDER, here the combustion products are also reheated and then maintained for about two secs in this atmosphere which incinerates them. Incineration is definitive while inhibiting reformation is temporary.

Then, column 7. Losses. Obviously, the losses are higher than the heat released to the environment. Why? Because of the pollutions. The pollutions when burning produce heat and this heat is related to the filling of the furnace. At the traditional furnace, this heat burns off as loss. At the ‘traditional’ scrap preheating this energy burns off similarly to the furnace without scrap preheating without making any effect in the scrap. Furthermore, in scrap preheating the energy for reheating and fast cooling adds to the other losses. Unlike the ECOFEEDER, all losses that are summed up are limited to those discussed in column 6 and the low-temperature vessel cooling. The low-temperature container cooling, which in fact is not a loss, only its use is limited to a few applications, such as floor, wall and ceiling heating in buildings, industrial applications are not common, so we consider it a loss. However, less radiation towards the panels and roof helps to reduce this loss.

Column 8, a particularly valuable information. The knowledge of the actual composition of the off gas is important, upstream to coordinate the fuel-air burner, oxygen, and CO_2 addition, downstream to control the oxygen for post combustion. The maximum reduction of GHG production depends very much on a dependable, continuous, and truthful information on the exhaust gas from the furnace to the chimney.

Then Column 9. The information contained in this column is based on estimations as GHG scope 1 (direct emissions) include only the burning of fossil fuels, and not the back feed of CO_2. In any case the produced CO_2 e is lower with back feed than without.

Finally, column 10. This information is important as well. Whichever procedure is chosen, combustion products arise, whether in near distance to the furnace, at the stack, or in heater vessels. The ones falling out around the furnace are not treated (!), the ones measurable at the stack must be treated before going to the environment. This normally happens in heater vessels followed by a quenching tower. In this case the procedure is called ‘inhibiting the de-novo-syntheses.’ The third procedure is called incineration of the combustion products. This procedure is usually applied when producing cement. The reason this procedure cannot be applied in steel production is the high off-gas speed from furnace to the stack. Differently at the ECOFEEDER. Here, the various measures allow conditions which are favourable for the incineration of combustion products; first, the controllable air supply to the furnace, second, the inline reheating of the off gas loaded with combustion products and third, the channel length between burners and container entrance. The speed of the off gas in this duct is low and the quasi-stable temperature of the duct walls, which are made of materials with high thermal resistance enable a perfect atmosphere for the incineration.

Then, the lines. Line 1 shows the values for a traditional furnace. These values are the basepoints for the comparison. Most of European furnaces have no scrap preheating system. If they recuperate the energy contained in the off gas, then mainly to produce steam. Steam is often used to produce vacuum for the degassing tanks. This makes sense, even more as this is also possible with an appropriate scrap preheating system (see further down).

Line 2. The shaft-type scrap preheating. This scrap preheating system, used in countries where the clean air act (CAA) is not continuously controlled, or where it is controlled by specialists of the steel mill, which means that the published results are selected and therefore not very meaningful. However, the shaft scrap preheating plant and the continuous scrap conveyors only recuperate a limited amount of the available energy. The residual exhaust gas can also be used for steam generation, but with the same limitations as in the traditional furnace - dust agglomeration in the heat exchangers, interrupted energy flow, poor efficiency. The environmental values are not much better than at the traditional furnace. The real energy input is lower due to the scrap preheating, which corresponds to the reduced heat dissipation to the environment. The losses are equivalent due to the energy import for exhaust gas purification.

Line 3. The two-container preheating. The main difference between the previously described scrap preheating and the two-container scrap preheating system is the use of the energy inherent to the scrap, the pollutions, and the use of the reheating energy, the treatment of the VOC's. Thanks to the design of the two-container system, the zone between the burners and the off-gas outlet is far enough to actively burn the VOCs like those in the cement industry. There are no cooled vessel walls where dioxins and furans can reform, and the residence time in the CO free atmosphere is enough to burn the cracked compounds. The values speak for themselves. The real energy input is even lower with increasing preheating temperature. This is due to the control of the atmospheres in the furnace and in the container, a fact which is only possible with the paradigm change at the furnace. The control makes it possible to find the perfect moment to change the containers and continue to use the full off-gas energy. The right choice of the furnace values-in-use allows an almost stable off-gas temperature at the outlet and an almost dust-free off gas which contains enough energy to be used for further applications. The environmental values are now completely different. Due to the permanent control of the atmospheres a much higher use of the energy is possible, and the residual heat can be fully used. This results in a much lower release of heat to the environment. The losses are reduced to the heat of the slag, the radiation (furnace and container) and the heat produced by the electrical resistance. All other energies are recovered in one way or another.

In summary, and to answer the question raised 'how can companies strive towards net zero and reduce cost at the same time?' we can conclude that it is well possible to achieve net-zero by a two-step project which is timewise staggered, and which allows the verification of the benefits at any time. The two-step project consists of step one the furnace modification and step two the scrap preheating unit. This solution can be applied on almost any EAF (ask us for a study to evaluate your situation) and can save electrical energy, fossil fuels, and reduce the impact to the environment; it can even save the existence of the steel mill! Further, it can be said that the environmental advantages of the ECOFEEDER are convincing, the economic benefits are enormous, and the effort moderate, even low. There are no new buildings required nor any major modifications of the existing furnace, or in other words it is worthwhile to have a closer look at the ECOFEEDER, right?

And the last advantage, the almost constant temperature of the exhaust gas that leaves the ECOFEEDER, regardless of the furnace cycle. The furnace cycles are dampened by the preheating tanks. On the following figure a comparison of the off-gas temperatures prevailing in the individual procedures, green the recorded temperatures at the traditional furnace, red the measured temperature at the shaft furnace, and the blue line representing the calculated temperatures at the ECOFEEDER (two container solution). The superposition of the figures serves only for principally understanding. The shown temperatures cannot be taken to compare the procedures.

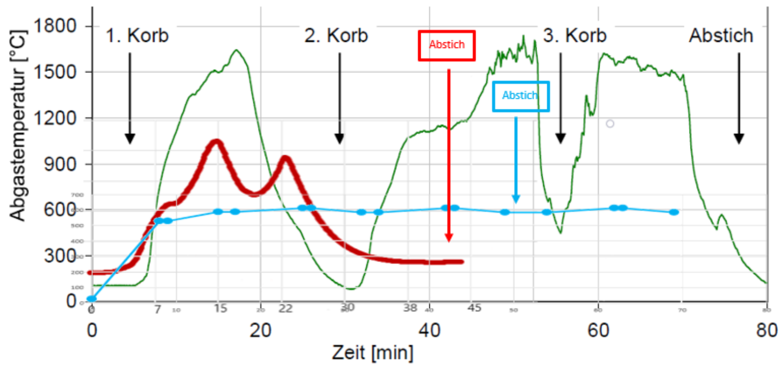

Figure 3 / Damping of off-gas outlet temperatures

Fact is, that with the ECOFEEDER it is possible to flatten the large temperature fluctuation of the electric arc melting. This opens a wide range of applications that require stable process temperatures, such as any direct use of thermal energy, e.g., DRI/HBI preheating, air heating and electrical energy generation. Storage tanks such as steam generators, saltwater energy storage tanks or hot water generation can of course also be operated with fluctuating temperatures, but the efficiency will then be lower. We propose DRI preheating followed by LT ORC to fully use the thermal energy.

Table 2 / Temperature range for energy recuperation

Installation \ Temperature range	1400 - 1000°C	1000 - 700°C	700 - 500°C	500 - 300°C	300 – 100°C	< 100°C
Raw material preheating						
Scrap						
DRI/HBI						
Air heater						
Gaz turbines without compressor						
Steam generator						
Steam turbines						
HT ORC						
Salt-water energy storage						
LT ORC						
Hot-water generator						

More about why we proposed DRI preheating followed by LT ORC and the ROI of the different steps will follow in the next contributions. Don't miss it.

The perfect moment for avoiding the climate change has gone – let us take the second best – and this is NOW!

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