ecology eco economy

ENERGY PRICE

The energy (pr)ice-breaker

ABSTRACT

Scrap preheating is the most profitable way to save energy. Any scrap preheating? No – there are new findings on how to maximise profit by a booster solution which allows also to clean the off gas of dust and toxics.

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'The industry is paying more than it has in a decade! ' or 'the energy is putting more and more strain on the household! ' Such and similar headlines can be read more and more often.

It seems certain that energy prices will continue to rise – yes, energy will be worth using sparingly. Hand on heart, until recently energy had a symbolic price, considering how easy and cheap it is and was to quickly flip the switch and mindlessly let the light burn, whether you need it or not. Ok, the light is an alias. We are surrounded by energy-guzzling amenities, e.g., in the car there are countless engines that quickly fold in the mirror or open the rear door, things that we could just as well do manually, but comfort must be!

Well, in the steel mill the energy is used on a larger scale, but no less wasteful, it seems to me. How far does the price of energy have to rise until the pain threshold is reached, or does the threat of the closure of workplaces, which are a political issue even before the pain threshold, come about?

Pain threshold, what is the point and where is it? Well, the pain threshold seems to be close to the current energy price for many steel mills, or it has already been reached, because the voices that talk about plant closures are getting louder and louder. Is the steel industry in Europe, with its 8% of world steel production, threatened with extinction?

Well, that does not have to be the case, because we have a proposal on how to prevent the pain threshold and thus an imminent closure of the workplaces.

We agree that the total energy to produce liquid steel without energy recirculation is somewhere between 680 and 800kWh/t and the proportion of electrical energy is between 300 and 600kWh/t (see Table 1).

Table 1 / Total energy input [kWh/t_{LS}]

Raw material / Energy	Liquid iron / Scrap	Scrap (100%)	Pig iron / Scrap	DRI / HBI / Scrap
Electrical energy	180 -300	320 -520	325 - 400	470 -600
Chemical energy *)	200 - 320	280 – 480	350 - 420	200 - 330
Input **)	300	-	-	-
Total energy input	680 -800			

*) Fossil fuels (gas (LPG, NG), coal)
**) Enthalpy brought along

The values listed in Table 1 are range values that come from various sources.

I hope that you also agree that energy recirculation has a positive effect if it is used. By energy recirculation, we mean any type of device or plant that serves to transfer or convert some of the energy used but not remaining in the final product, so that this energy is available for the process or can be reused separately from the process. This includes raw material preheating, the use of hot gas in mechanical plants (gas turbines, ORC, etc.), the transfer of thermal energy to another medium (air heaters, steam generators, salt-water storage tanks, water heaters for district heating, etc.) and much more. Depending on the type of system and transmission, this energy recirculation has an efficiency of 10% to a maximum of 70%. Also, not all types of energy recirculation are applicable in every temperature range (see Table 2).

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						

In the case of an electric arc furnace, energy recirculation is conceivable in three areas: in the field of furnace exhaust gas, in the area of furnace cooling and in the area of slag. Due to the process, the furnace exhaust gas has a strongly fluctuating temperature in the range of 200-1800°C, the coolant of the furnace cooling is normally water, due to the steam formation, the temperature range between 45 and 60°C is maintained. The slag is basically liquid stone, the energy of the slag is not yet meaningfully traceable for several reasons.

1 RECIRCULATION OF FURNACE OFF GAS

The following picture shows the off-gas temperature of a normal electric arc furnace with a 3-basket strategy without energy recirculation. The exhaust gas temperatures vary from approx. 150°C to almost 1800°C from loading the first basket to tapping. The measurement was taken at the fourth hole before mixing with ambient air.

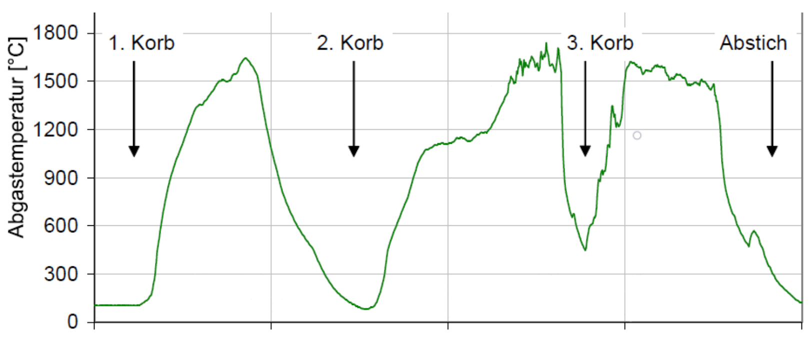

Illustration 1 / Off gas temperatures

The off-gas temperatures in a typical shaft furnace (single-chamber system) measured at the upper shaft outlet are more balanced, they probably start at the same level, rise less high (1050°C), fall to about 700°C when loading the shaft with cold scrap and rise again to about 1000°C. When refined, the exhaust gas temperatures then drop back to about the initial value.

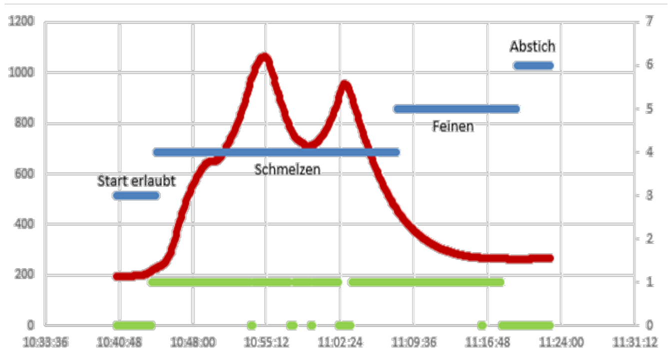

Illustration 2 / Off-gas temperatures shaft furnace

Stored on top of each other, it looks like this: The off-gas temperatures and the melting times are aligned. Now it is noticeable that with similar scrap use per basket (40t scrap) in the shaft furnace energy from the exhaust gas was transferred to the scrap. This is not a new insight, but it leads us to the next step.

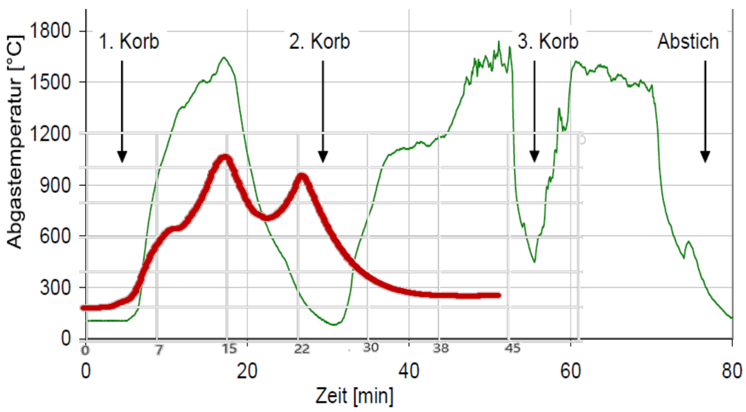

Illustration 3 / Overlay of the exhaust gas curves (gradient: green = 2K/sec | red = 1.5K/sec)

Assuming that the integral under the off-gas curve is equivalent to the off-gas energy from the moment the temperature curve rises to the maximum, then about half of the off-gas energy in the shaft furnace would have passed into the scrap. The off-gas with the residual energy is then released into the environment or must then be treated.

In the two-chamber system, the residual energy is fed together with the supplied energy for the combustion of the hydrocarbons from the broken chlorine compounds into the second chamber and is used again, albeit to a lesser extent, for scrap preheating.

The off-gas temperature that leaves the furnace without energy recirculation has a temperature of about 1500°C, the off-gas temperature after scrap preheating in the single-chamber system is about 1000°C, and the exhaust gas temperature in the two-chamber system is about 600°C. As a result, the total energy can also be concluded directly, namely 680kWh/t_{LS} for the furnace without energy recirculation, approx. 600 kWh/t_{LS} for the single-chamber system (all types of shaft furnaces) <u>without</u> off-gas cleaning (post-treatment) and approx. 550kWh/t_{LS} for the eco-e two-chamber system <u>including</u> off-gas cleaning (post-treatment).

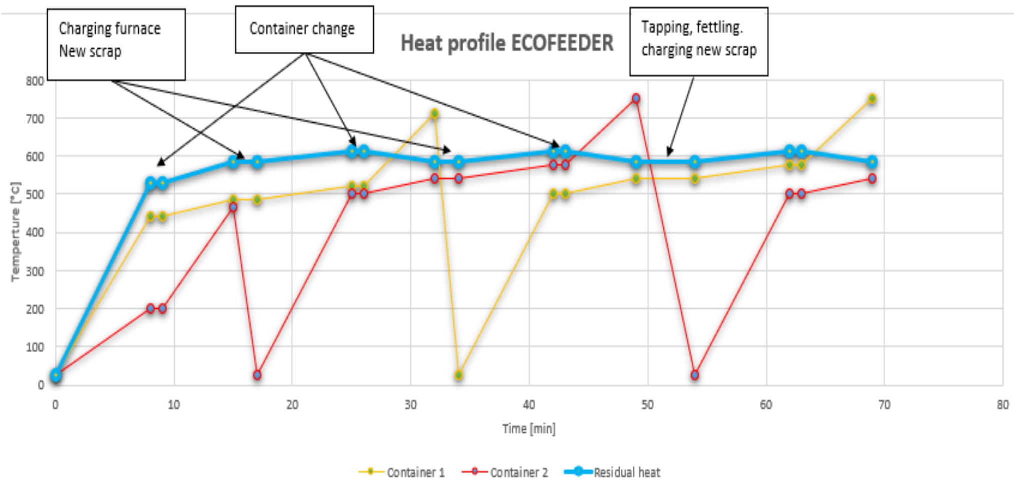

Illustration 4 / Temperature profile ECOFEEDER

If we now look at the temperature segment, we see that the residual off gas in the two-chamber system has an ideal temperature for further use, namely about 600°C. So, there are several ways open, e.g., the way via the DRI/HBI preheating followed by a high-temperature ORC system, or the steam generation for steam turbines and hot water generation for district heating systems, etc.

The superposition of the off-gas temperatures (EAF 4th hole, EAF with shaft furnace and EAF with a two-chamber system) impressively shows that energy can be saved efficiently with scrap preheating. After scrap preheating by off gas, the residual heat that is available for further use is by nature still at an important level. This residual heat can be ideally used thanks to a constant temperature profile.

Furthermore, it is noticeable that the residual heat in the off gas does not show any strong fluctuations coming from the loading of the furnace or the containers thanks to the calming of the two containers. This is because the residual off gas only ever leaves a container with the already heated scrap.

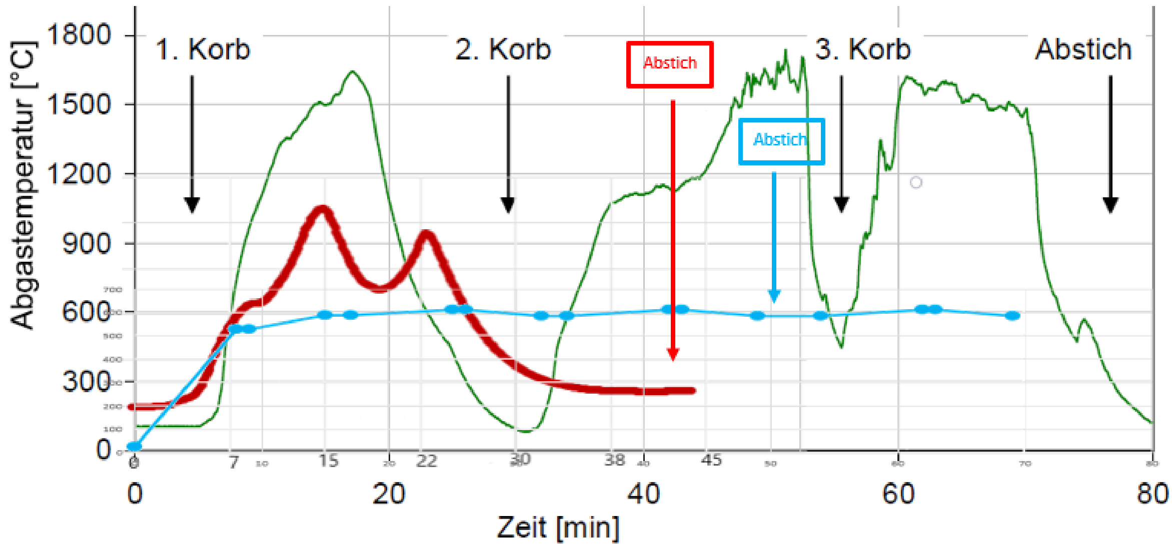

Illustration 5 / Superposition of the 3 processes

The calculation of the residual heat and the associated temperatures are based on known models.

The scrap preheating temperature is approx. 750°C. The clean residual off gas leaves the container at about 550 to 650°C. This results in a residual heat energy of approx. 80kWh/t, which is partly used for the warming of the (wrong) furnace air and for the generation of electrical energy via an ORC turbine. The remaining residual heat can still be used to heat the building.

The fossil energy used in form of natural gas (NG) can be replaced by hydrogen (H_2) if the burners are adapted accordingly, so that the production of CO_2 in this area is eliminated.

1.1 Summary Recirculation of Furnace Off Gas

The use of the furnace off gas has physical limits, so a meaningful use will only be possible up to a certain temperature. The two-chamber system uses the off-gas energy analogously to the single-chamber system and includes the post-treatment of the off gas, which has been enriched with the products of the combustion of the impurities in the preheating process. In the following chamber, the additional energy introduced is partially transferred to the already preheated scrap. The second chamber creates a balancing area that compensates for the process-related fluctuations in the off gas.

However, the use of residual gas requires that it be as dust-free as possible and free of environmental pollutants. The furnace off gas has a high proportion of fine and coarse dust, which is produced during the melt. The two-chamber system is a natural dust trap with its large gas velocity changes (cross-sectional changes), and the lying scrap is an aerodynamic filter for the gas flow with an infinite number of turbulences. The coarse dust settles in the first container after the furnace and is conveyed back to the furnace after the preheating phase. The particulate matter settles in the second container, which can be regarded as a calming line.

2 Return of vascular cooling

The vessel cooling includes, depending on the design of the furnace, not only the top furnace (panels) and the furnace roof, but also the connecting piece furnace roof to the post combustion chamber, or the shaft and the downstream cooled ducts. Depending on the process status, these components dissipate energy in the cooling medium. The energy transfer usually takes place via radiation, be it from the arc or from the slag blanket or melt in the shallow bath phase. The transfer of energy through contact is the exception. The remaining energy transfer takes place through convection, i.e., the contact of the heat sinks with the exhaust gas. The intensities vary, so the thermal load on the panels in the case of unprotected arc and that of the fingers in the single-chamber system is fairly high. The transmission coefficient is significantly higher for radiation than for convection. By appropriate guidance of the supply air, the local load can be strongly influenced (see article 'All warm air?!') which, i.e., can lead to a strong reduction in electrode burning and make the melting of the scrap more uniform, which in turn leads to a smaller local load on the panels. The construction of a foaming slag is particularly important in this respect and must go hand in hand with the melting process. The common cooling medium is water. However, water poses certain hazards, so the boiling point must never be reached, as there is a risk of explosion due to the associated volume increase. Therefore, water is not suitable for efficient energy recirculation. To efficiently restore the energy of vascular cooling, an incombustible cooling medium with a higher boiling point must be used. As a result, the flow and volume could be reduced, and electrical energy could be obtained by means of the ORC process. The associated effort hardly justifies a conversion. In the case of a new building, however, this alternative must be discussed and possibly considered.

The two-chamber system is based on swap bodies. Liquid cooling and the associated feeders are complex and less suitable. The two-chamber system is therefore equipped with cooling fins for air cooling (i.e., by the furnace air) of the container surfaces. Here, up to 10kWh/t can possibly be saved.

2.1 Summary Return Vascular Cooling

With proper fresh air flow, ideally preheated, and a more suitable cooling medium, considerable savings can be achieved.

3 Result

With appropriate measures, the specter of energy prices can be banished or at least kept at a distance. Measures such as bringing the right air flow into the furnace, even if not preheated, already bring considerable savings.

We should talk about it.

February 2022, Roland V. Müller