January/February 2011 – *Vol.35 No.1 – www.steeltimesint.com*

NEWS | FLAT PRODUCTS | PROCESS CONTROL | CONFERENCE REPORT

STEEL TIMES INTERNATIONAL

Heat recovery on an EAF at Georgsmarienhütte

Evaporative Cooling, already well established on oxygen converters and reheat furnaces, has been applied to EAF flue gas cooling at Georgsmarienhütte to generate steam for the VOD station thereby enabling closure of the boiler house. Consideration is being given to using excess steam for power generation via an ORC turbine.

By H Schliephake*, C Born, R Granderath**, F Memoli*** & J Simmons*****

THE target for any optimisation of an EAF or other industrial furnace is either to increase product quality or lower energy consumption. If we look at the different ongoing discussions the current focus is clearly on energy reduction. There has been much progress in minimising the input of primary energy through attention to such areas as slag management, optimised charging schemes or intelligent furnace control systems (eg EFSOP)[1].

How great this progress is and will be is still undetermined, however, a large amount of the energy supplied to the EAF will be lost in the off-gas and cooling water of the respective process.

When we view heat recovery, we should view it as a secondary option behind reducing the energy input. It is better to use one kWh less then to recover one kWh.

Fig 1 shows that the energy contained in the off-gas of an EAF amounts to at least 25% for furnaces with optimised use of chemical energy, or up to around 30% without optimisation, making the off-gas by far the greatest source for heat recovery. This does not apply to all types of mill equipment. For example, large walking beam reheating furnaces typically measure cooling water as the biggest energy loss.

Energy Savings vs Heat recovery

When viewed from an economical standpoint we must weigh up whether a project to reduce energy consumption is too costly when compared to achieving the same amount of overall energy savings by implementing heat recovery. If the EAF has been recently modernised it becomes more difficult and expensive to make even slight improvements in the operating efficiency. At this point the greatest potential for efficiency improvement in the EAF is by heat recovery from the off-gas.

Temperature as the determinant

A typical modern EAF has a water cooled waste gas duct that cools the off-gas to around 600°C while heating the cooling water from approximately 20°C to around 40°C, and sometimes from 70°C to 90°C. When off-gas temperatures are below 600°C a quench tower is typically used to cool the waste gas to approximately 200-250°C. The heated water is cooled and the energy is released into the atmosphere.

For cooling water at about 40°C, there is no low cost technology that can reverse the cycle and return the water to 20°C and recover the energy.

If the cooling water has a temperature of around 90°C it might be used for space heating purposes.

If the following two conditions are fulfilled then there is perfect use for waste gas energy:
– No other source of hot water in the plant;
– There is a demand for heating all year.

In many plants, there is more hot water than demand for it. The geographical location of a plant and seasonal demands can make the supply and demand gap even wider. **Fig 2** shows the typical hot water demand in a steel plant in Middle Europe during a year. There are examples of plants needing a constant supply of hot water for such uses as preheating feed water for a nearby power station, but these plants are the exception[3].

Steam by Evaporative Cooling

There are several reasons why steam production is the best method for flexible heat recovery. For example:
– Steam can be used for many purposes (eg process steam, heating, compressor operation and power generation);
– Wide temperature range (similar to off-gas temperatures – steam temperatures can be variable);
– Relatively easy to transport;
– Water is an inexpensive and non toxic media;
– Proven technology.

The technology used to turn waste gas energy into steam is called an Evaporative Cooling System (ECS). An ECS waste gas duct is a tube-tube-construction which looks very similar to a conventional cooling duct (**Fig 3**).

The main difference between an ECS and a conventional cooling system is that in ECS pressurised water at boiling point is fed through the piping. The chosen temperature-pressure combination is determined by the required steam parameters at the plant, typical values are between 13 bar at 192°C and 28 bar at 230°C. Higher pressures are used to run steam turbines.

The nearly boiling water absorbs the energy from the waste gas by evaporation. The physical process of evaporation consumes much more energy due to latent heat than heating water without boiling.

An ECS system is designed for partial evaporation of the water; typically no more than 5-12% will be evaporated under normal operation conditions, which means there is spare capacity in the cooling system.

Fig 4 demonstrates that an ECS with a steam weight content of 12.5% in the return stream requires approximately 35% less water than cold water cooling requires. This means smaller diameter piping and smaller pumps are possible.

ECS technology has been approved and applied to Basic Oxygen Furnaces (BOF) and walking beam reheating furnaces since the 1980s. The main factors for early use of the ECS technology on BOF vessels and large reheating furnaces was the presence of stable operating conditions due to:
– Constant temperature in the complete cool ing system (saturated steam has the same temperature as water);
– Fewer problems with corrosion and other chemical reactions due to a closed system using clean boiler water;
– Robust system at energy/temperature peaks;
– Robust at interruptions of water supply since it is a closed system with nearly no water losses unless steam is taken out.

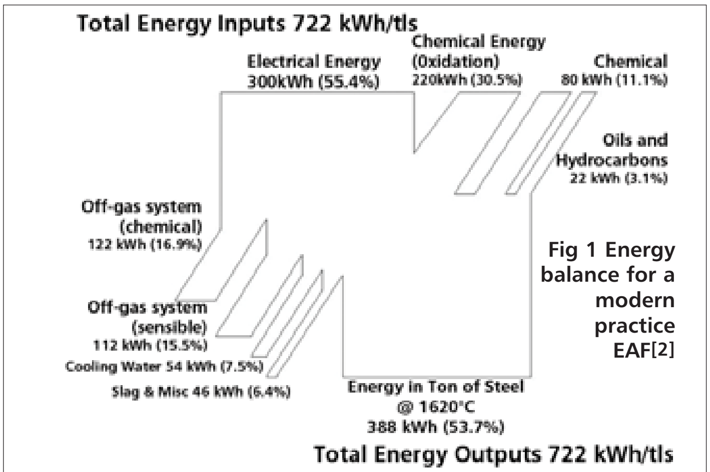

Fig 1 Energy balance for a modern practice EAF[2]

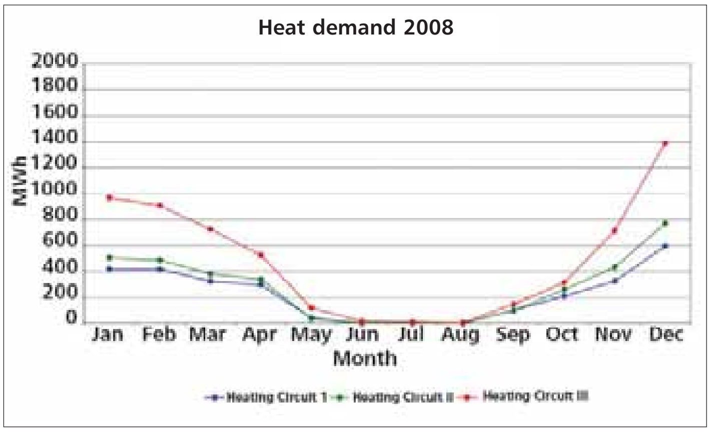

Fig 2 Typical demand for hot water in a European steel plant

*Georgsmarienhütte GmbH, Neue Hüttenstraße 1, 49124 Georgsmarienhütte (Germany) Tel +49 5401 39 0, e-mail info@gmh.de
**Tenova Re Energy GmbH, Graf-Adolf-Plats 6, 40213 Düsseldorf, Germany, Tel +49 211 540976 0, e-mail reenergy@de.tenovagroup.com
***Tenova Core Cherrington Corporate Center, 100 Corporate Center Drive Coraopolis, PA 15108-3185 Tel +1 412 262 2240, e- mail info@corefurnace.com

Fig 3 The Evaporative Cooling waste gas duct on the EAF at Georgsmarienhütte

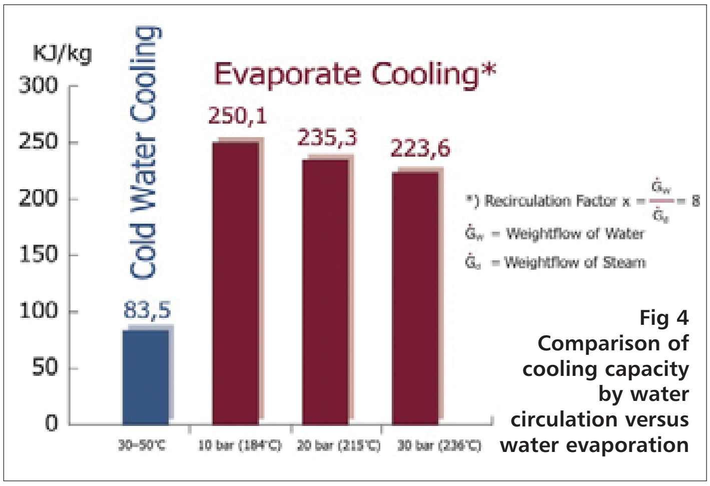

Fig 4 Comparison of cooling capacity by water circulation versus water evaporation

Table 1 Main Figures

Plant type	ECS waste gas duct for EAF 140 t/h
Project start	October 2007
Commissioning	January 2009
Maximum steam production	75t/h
Average steam production	20t/h
Steam parameters	Saturated steam, sliding pressure 13-20 bar
Steam buffer capacity	8t
Main steam consumer	VOD 7t/h

Heat recovery is the main driver behind today's growing interest in ECS for use on other types of furnaces such as electric arc furnaces (EAF). ECS benefits for the EAF other than heat recovery are viewed as secondary advantages.

ECS waste gas ducts work with radiation heat transfer which is efficient down to approximately 600°C. Below this temperature heat transfer by convection becomes more effective. Thus, a waste heat boiler must be used to recover the energy for temperatures between 600°C and an inlet temperature of 180-250°C. Due to the extremely high dust load in EAF waste gas the design of the waste heat boiler must be planned very carefully. Solutions for similar situations can be found at waste incinerators. **Fig 5** provides a schematic illustration of the two stages of EAF heat recovery.

Georgsmarienhütte Heat Recovery

Georgsmarienhütte (GMH) operates a 140t/h DC EAF and is located in Georgsmarienhütte, Germany. A unique feature of this EAF was the existing duct cooling system: When GMH switched from blast furnace – oxygen steelmaking (BOF) to EAF steel production in 1996 some of the main parts of the cooling system from the former BOF were kept in place and used for the new EAF. Since the former BOF was equipped with ECS the newly built EAF began operating using a used BOF ECS from the 1980s. Only the first section of the ECS duct had been upgraded in the 1990s to use conventional cold water cooling. However, the steam produced was not used due to the semi-continuous nature of production; a boiler house instead supplied steam to the vacuum degassing station and other minor steam consumers in the plant.

In 2007 GMH decided to replace the cooling system after almost 25 years of continuous operation – including the period when it was used for the BOF. The cooling system had deteriorated considerably and GMH also wanted to replace steam produced by the gas fired boiler house with steam generated in the new ECS.

One main challenge was to smooth out the steam output and efficiently handle the energy peaks. **Fig 6** shows a simplified time line for steam production during four EAF heats with a different melt type during the third cycle. The peaks of 75t/h are more than three times the average steam production of 20t/h. Normally, energy peaks in waste heat recovery process are reduced by releasing some energy. However, on an EAF, cooling of the flue gas is essential and each energy peak must be reliably transformed to steam to absorb the heat.

The normal EAF operating process creates gaps of 10-20 minutes power-off time when there is practically no steam production. The vacuum degassing station is the melt shop's main steam consumer and operates in its own batch mode asynchronous to the EAF. Additionally, vacuum degassing follows the EAF on a one cycle delay; when the EAF shuts down there is an EAF tapped ladle waiting for the vacuum degasser. GMH required a guarantee of enough steam for this situation.

This requirement was achieved by four design elements:

- The whole ECS was designed slightly bigger than required for cooling purposes, therefore the additional amount of water had an excess stored energy capacity.
- Two Ruth buffers were built into the system. Ruth buffers are large pressure vessels that store energy in hot water converting the water to steam when the pressure drops;
- Sliding pressure between 13 bar and 20 bar[4]. During the EAF power-on time the pressure rises with the effect, that a part of the absorbed energy heats the water that would evaporate at the lower temperature. During the power-off time the pressure will sink leading to steam production although no new energy is brought into the system.
- Variable temperature of feed water. The typical feed water temperature for boiler systems is 105°C. In the GMH system the temperature moves between 105°C and 159°C during the peaks of the power-on time. Energy is used to heat the feed water, thus leading to less energy required for evaporating the feed water in the steam drum during lower energy output of the EAF.

As a result of these actions 8t of steam is buffered at the end of each melt.

Table 1 presents an overview of the main data of the project

Future Power Generation

The boiler house at GMH has reduced consumption of natural gas for the vacuum degassing to almost zero resulting in the economical success of the project.

However, there is a large excess of steam; an average production of 20t/h compared to an average demand of 7t/h. Thus, about two-thirds of the energy recovered is eventually lost although it is initially recovered in the first step of the process. Although the project was economically profitable, the question remains as to how the system can make full use of its potential.

This is not an atypical situation. A VOD normally consumes only a third of the steam that can be won from the corresponding EAF. While some plants have steam networks to feed various other on-site steam consumers, other plants like GMH have no other plant demanding steam.

Power Generation

The other area to evaluate to use the excess steam is power generation. An average of 13t/h of steam may seem feasible for power generation, but a number of factors exist at GMH which are common for power generation from waste heat in steel plants in general:

- The amount of available steam fluctuates (as previously noted);
- The demand for process steam is the main priority; the use of steam as process steam is more economic than to use it for power generation and so have to use the boiler house to make process steam. This leads to a near unpredictable availability of the excess steam while steam turbines need constant operation to guarantee their efficiency.
- An EAF shuts down more frequently, compared to regular power stations, plants for petrochemical processes and waste incinerators. Standard power generation steam turbines require a lot of energy for starting and stopping.
- Another important point is that ECS steam can be buffered (as previously discussed) but superheated steam needed for efficient power generation cannot be buffered. Efficient power generation steam turbines require superheated steam; this means an external superheater would be necessary for

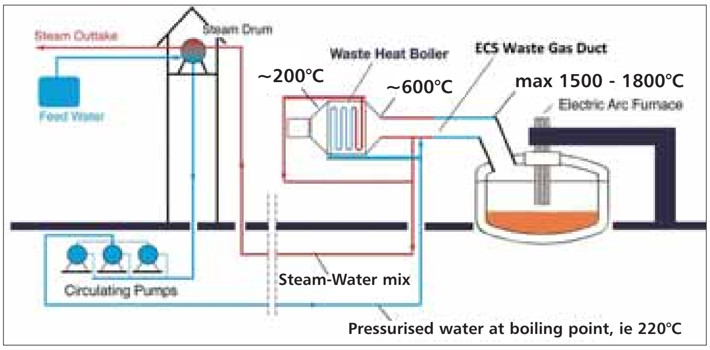

Fig 5 Scheme of 2-Stage Heat Recovery for an EAF

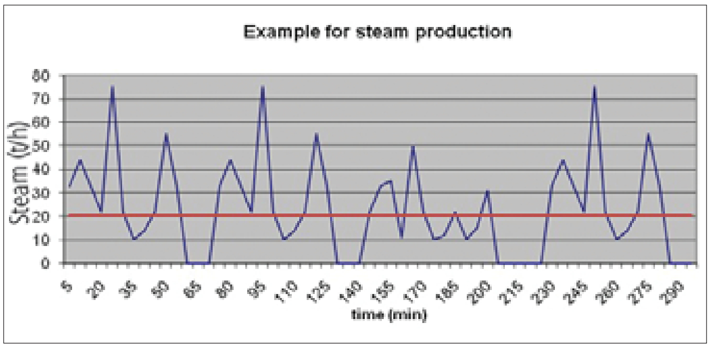

Fig 6 Simplified time-line for EAF steam production

EAF power-off periods. The superheater would have to be powered by gas, oil or coal, which is an additional cost.

When searching for a solution to these problems Organic Rankine Cycle (ORC) turbines offer an interesting alternative. The organic working fluid which flows through the turbine in a closed circuit has a low energy density and relatively large mass leading to a much lower rpm turbine value, enabling a relatively simple system design with an excellent partial load factor. The steam is not led through the turbine but transfers its energy to the ORC fluid via a heat exchanger; therefore no superheated steam is required.

The nominal efficiency of an ORC turbine is low compared with the nominal efficiency of a high temperature steam turbine of the same capacity. But, due to its ability to better cope at a partial load factor, the effective efficiency if employing an ORC turbine in an EAF steelshop would be at least equal to that of a steam turbine.

This combined with an automated start-stop-procedure and the near unmanned operation makes ORC turbines a highly interesting perspective for all scenarios with noteworthy amounts of excess waste heat. ■

References

1 Doug Suliani, Vittorio Scipolo, Carsten Born: Opportunities to Reduce Operating Costs, Increase Productivity and Lower GHG Emissions in Electric and Oxygen Steelmaking, stahl und eisen 129 (200)

2 Doug Suliani, Vittorio Scipolo, Joe Maiolo: Opportunities for Increasing Productivity and Lowering Operating Costs while Reducing GHG Emissions in Steelmaking, AISTech Conference, Pittsburg, 2010.

3 R Granderath: Intelligente Abwärmenutsung als Teil jedes Feuerungskonseptes, Gaswärme International 5-2009

4 In this special case the existing steam network did not allow to go above 20 bar. Generally speaking this is a low value

Contact

Tenova Re Energy GmbH, Graf-Adolf-Plats 6, 40213 Düsseldorf, Germany,

Tel +49 211 540976 0,

e-mail reenergy@de.tenovagroup.com