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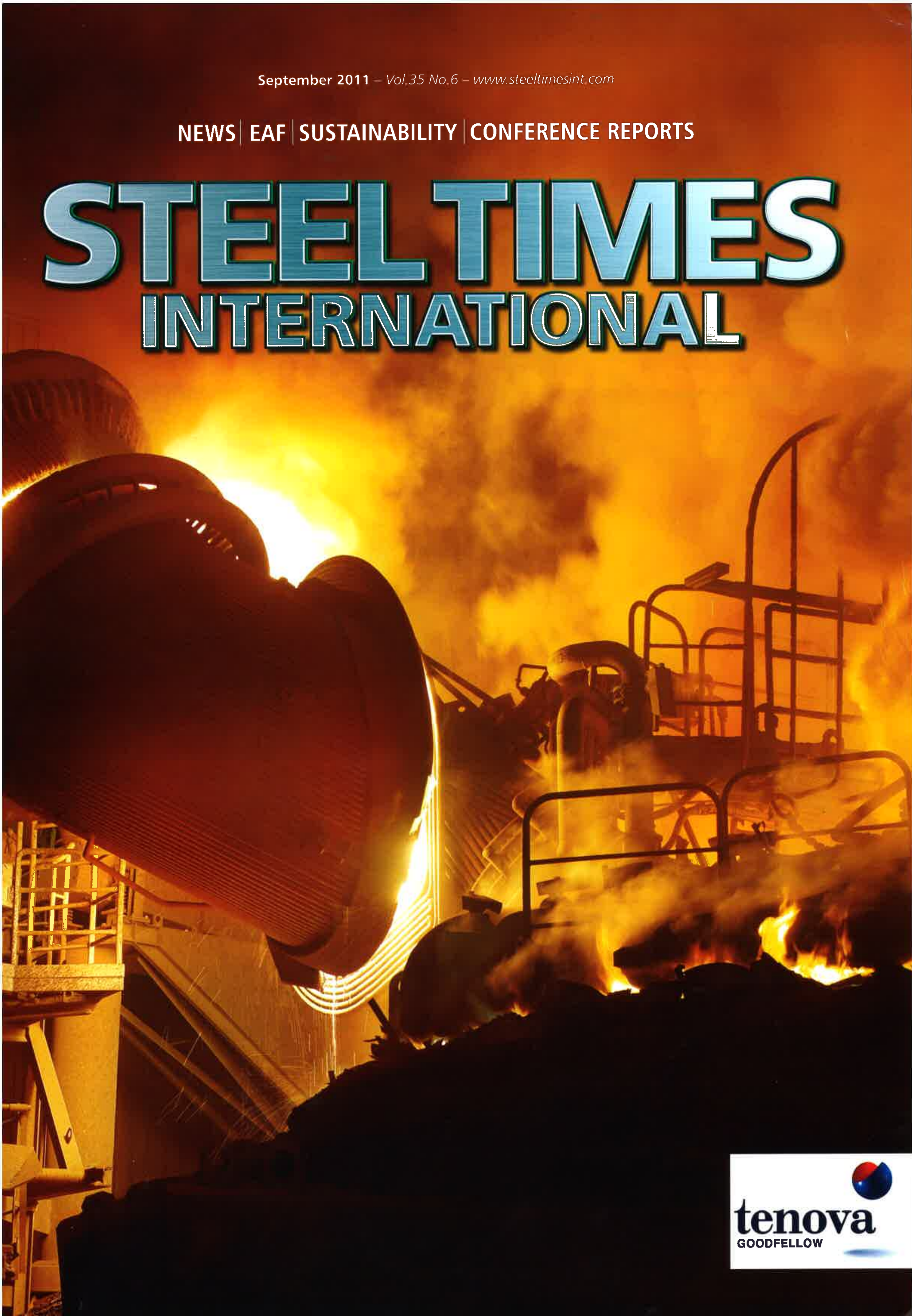

A new generation in pre-heating technology for EAF steelmaking

Fig 1 The EPC scrap pre-heater mounted on wheeled bogies moves to mate with the off-gas and wall charging port of the EAF

A scrap preheating shaft independent of the EAF has been devised which maintains an airtight seal during all stages of charging thus preventing emissions to the atmosphere. EAF operation and productivity are improved through continuously feeding scrap at up to 800°C to the furnace thereby maintaining flat bed operations with its associated reduced noise and power flicker throughout melting.

By K Rummler*, A Tunaboylu & D Ertas*****

EVER increasing electrical costs, stricter rules on CO_2 emissions and tighter environmental regulations mean steelmakers have to decrease energy consumption and to recycle waste materials.

Scrap preheating has been used for more than 30 years to offset electrical energy demand during melting. Conventionally it involved the use of the hot off-gas from the EAF to pre-heat scrap in the charge bucket. The source of the hot gas can either be solely the off-gas from the EAF and/or gas from supplementary burner(s).

The primary energy demand for the EAF is to heat the scrap charge to its melting point. Thus, energy can be saved if scrap is charged to the furnace hot. Preheating the scrap also eliminates the possibility of charging wet scrap into the furnace with the possible result of an explosion should wet scrap fall deep into the liquid steel. Thus, preheating the scrap also improves plant safety and reduces the occurrence of equipment damage.

As well as reducing energy demand and improving safety, preheating scrap increases melt shop productivity by shortening the tap to tap time.

The early scrap preheaters using independent heat sources heating the scrap in the charge bucket reported EAF power savings from this type of preheating as high as 30kWh/t as well as a reduction in electrode and refractory consumption due to reduced tap-to-tap times.

As fourth hole off-gas systems were developed in the EAF roof, attempts were made to use the off-gas for scrap preheating. A side benefit reported was that the amount of baghouse dust decreased because some dust was sticking to the scrap during preheating.

Scrap preheating in the charge bucket with furnace off-gas is difficult to control due to the variation in off-gas temperature throughout the heat cycle. In addition, a temperature gradient forms within the scrap being preheated. Temperatures must be controlled to prevent damage to the scrap bucket and to prevent burning or sticking of fine scrap within the bucket. Depending on the preheat temperature, charge buckets may have to be refractory lined.

Scrap temperatures can reach 315–450°C, (600–850°F), by this method, but this will only occur where the off-gas first enters the preheater. Energy savings in the EAF are typically only in the neighbourhood of 18–23kWh/t. In addition, as operations become more efficient and tap-to-tap times are decreased, scrap preheating operations become increasingly difficult to maintain. Eventually, hot scrap handling actually starts to reduce productivity and increases maintenance costs.

Some of the benefits attributed to scrap preheating are increasing productivity by 10–20%, reducing electrical consumption, removing moisture from the scrap, and reducing electrode and refractory consumption per unit of production. Some drawbacks to scrap preheating are that hazardous volatiles are evolved from the scrap, odours created and it necessitates a post-combustion chamber downstream to eliminate these. Spray quenching following post-combustion is also necessary to prevent recombination of toxic dioxins and furans.

EPC system

Environmental Pre-heating and Continuous Charging (EPC) has many advantages:

- *Minimum Dust Emission:* During charging the system is always in closed and airtight containment which results in minimum pollution in the meltshop.
- *Energy Saving:* The EPC reduces electric energy consumption by approximately 100kWh/t compared to the conventional EAF.
- *Independent Scrap Charging:* Charging of the scrap basket is carried out while the EAF power is on and independent of the furnace operation. This improves the operation and reduces the power-off time. Also, this eliminates the need for opening the EAF roof so substantially reducing heat loss from the furnace.
- *Low Downtime/Maintenance & Less Heat Loss from water cooled panels:* There are no critical water cooled mechanical parts such as fingers, there is no need for conveyors and no additional water cooled parts are present which may result in unforeseen stoppages, require intensive maintenance and lead to high heat loss to the cooling water.
- *Higher Productivity:* Due to shorter power-on and power-off times, the productivity of the furnace can be increased 20% compared to a conventional EAF.
- *Longer EAF Roof & Roof Delta Lives:* As there is no need to open or close the furnace roof for charging the power arc is always away from the roof causing less arc damage to the water cooled panels (WCP) and minimising thermal shock which additionally helps in extending the roof delta life.
- *Higher Return on Investment:* The EPC features lower conversion cost due to the preheating effect. Furthermore, higher productivity through shorter power-on and power-off times are assured. Depending on the scrap quality, some yield gain can also be expected.
- *Less Flicker:* Related to the flat bath EAF operation, preheated scrap and the constant energy input, flicker and harmonics are reduced on the power supply grid. This also leads to lower arc noise.
- *Savings on Scrap Treatment:* Approximately €10/t liquid steel are saved through not requiring special scrap treatments.

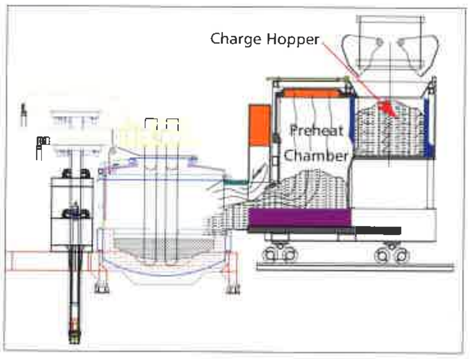

Fig 2 The EPC continuously charging scrap from the preheater chamber to the EAF with the second bucket charged to the charge hopper

EPC description

An important concept of the EPC charge system is to be able to charge the scrap independent of the electric arc furnace operation so reducing the environmental impact of operation.

EPC is a shaft type preheat furnace, based on AC technology in the EAF. The furnace will maintain a large hot heel (nearly 40%), so that uniform operating conditions can be maintained. Scrap is continuously charged through the side wall so preventing heat loss when removing the roof as necessary with bucket charging.

The EPC is mounted on wheeled bogies so the complete unit can be moved to the EAF upper shell to mate with the off-gas duct and side charging port of the furnace (**Fig 1**) but it can be drawn back during maintenance. The EPC remains in the same position during tilting to deslag and tap the furnace as there is a 20mm gap between the EAF and EPC.

The scrap charging system consists of two chambers, the preheat chamber adjacent to the furnace and a charging hopper which accepts scrap from the bucket above it (**Fig 2**).

The exhaust gas from the furnace flows through the preheat chamber preheating the scrap. Scrap temperatures as high as 800°C can be achieved. The exit temperature of the off-gas from the chamber is around 200°C. The off-gas leaves from the top of the preheat chamber and flows to a bag filter. Part of the gas can be recycled to the furnace to regulate the inlet gas temperature to the preheater.

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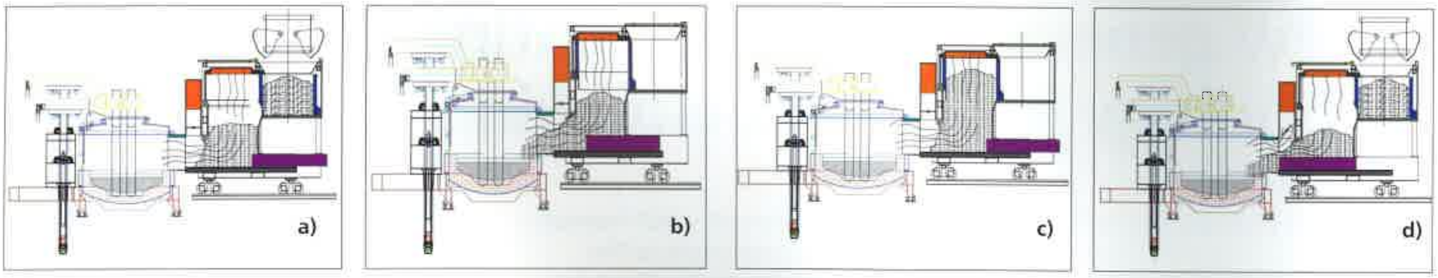

Fig 3 a) Charging 2nd bucket to charge hopper while heating charge from 1st bucket. b) Normal operation continuously charging pre-heated scrap to EAF. c) Preheating full charge of scrap. d) Charging 2nd bucket to charge hopper while continuously discharging heated scrap to EAF while off-gas is diverted

At the base of the preheat chamber, there are two screw type pushers. These operate in two stages allowing scrap to be fed into the furnace at a constant rate.

Operational modes of EPC

- Preheating next heat for EAF (**Fig 3a**)
- Preheating of 1st bucket of next heat in pre-heating chamber
- Second bucket charged to hopper.
- Preheating inside EPC (**Fig 3b**)
- Start feeding preheated scrap into EAF after tapping
- Pre-heating chamber half empty charge hop per can move to waiting/charging position
- Charging Preheating Chamber (**Fig 3c**)
- Move scrap from charge hopper into pre-heating chamber
- Preheat 2nd bucket of next heat in pre-heating chamber
- Off gas flap closed.
- Preheating inside EPC
- Scrap bucket in waiting position
- Continuous feeding of scrap to EAF during power on.
- Charging to Upper Charge hopper (**Fig 3d**)
- Start feeding of preheated scrap
- Opening of sliding gate on top of EPC
- Charging of next bucket into charging hopper
- Off gas flap open to divert gas

Scrap is fed continuously to the furnace until the desired bath weight is achieved. This is followed by a short refining and super heating period followed by tapping of the heat. The furnace de-slagging and tapped takes place in the same way as a conventional EAF.

Power input is expected to be almost uniform throughout the heat. Most furnace operations are fully automated. The rate of transfer of the scrap into the preheater chamber from the charge hopper is fully automated based on the scrap height in the preheat chamber as well as the temperature of the off-gas. In turn, the feeding rate of heated scrap to the EAF is related to this and to the actual power input.

Carbon and oxygen injections are controlled based on the depth of foamy slag in the EAF.

The EPC can be retrofitted to an existing EAF with the necessary modifications to the lower shell and upper shell and roof for charging through the side wall and diverting the off-gas through the scrap preheater. An important consideration, however, is that there is sufficient space and height in the meltshop to accommodate the EPC.

Discussion

Several technologies have attempted to maximise the use of chemical energy in the EAF flue-gas through post combustion of the remaining combustible components. These processes are dependent on achieving pseudo equilibrium where oxygen has completely reacted with these fuel components (carbon, CO, natural gas, etc) to give the maximum achievable energy input to the process.

Other processes have attempted to maximise the use of the energy that is input to the furnace by recovering heat energy from the off-gases (eg Fuchs shaft furnace, Consteel, EOF, IHI Shaft). These processes are dependent on good heat transfer from the off-gas to the scrap. This requires that the scrap and the off-gas contact each other in an optimal way.

Each of these processes have been able to demonstrate some benefits. The key is to develop a process that will show process and environmental benefits without having a high degree of complexity and without reducing productivity.

There is no perfect solution that will meet the needs of all steelmaking operations. Rather, steelmakers must prioritise their objectives and then match these to the attributes of various furnace designs. It is important to maintain focus on the following criteria:

- To provide process flexibility.
- To increase productivity while improving energy efficiency.
- To improve the quality of the finished product.
- To meet environmental requirements at a minimum cost.

With these factors in mind, the following conclusions are drawn:

The correct furnace selection will be one that meets the specific requirements of the individual facility. Factors entering into the decision will likely include availability of raw materials, availability and cost of energy sources, desired product mix, level of post furnace treatment/refining available, capital cost and availability of a trained workforce.

Various forms of energy input should be balanced to provide the maximum amount of flexibility. This will help to minimise energy costs in the long run, ie the capability of running with high electrical input and low oxygen injection or the converse.

Energy input into the furnace needs to be well distributed to minimise the total energy requirements. Good mixing of the bath will help to achieve this goal.

Oxygen injection should be distributed evenly throughout the tap-to-tap cycle to minimise fluctuations in off-gas temperature and composition. Thus, post combustion operations can be optimised and the size of the off-gas system can be reduced. In addition, fume generation will be minimised and the slag/bath approach to equilibrium will be greater.

Injection of solids into the bath and into the slag layer should be distributed across the bath surface to maximise the efficiency of slag foaming operations. This will also enable the slag and bath to move closer to equilibrium. This in turn will help to minimise lime flux requirements and will improve the quality of the steel.

The melting vessel should be air-tight to reduce the amount of air infiltration. This will lower the volume of off-gas exiting the furnace leading to smaller fume system requirements.

Scrap preheating provides the most favourable option for heat recovery from the off-gas. For processes using a high degree of chemical energy in the furnace, this becomes even more important, as more energy is contained in the off-gas for scrap preheating. To maximise recovery of chemical energy contained in the off-gas, it is necessary to achieve post-combustion. Ensuring high post-combustion efficiencies throughout the heat will be difficult. Staged post-combustion in scrap preheat operations could optimise heat recovery further.

Operations which desire maximum flexibility at minimum cost will result in more hybrid furnace designs. These designs will take into account flexibility in feed materials and will continue to aim for high energy efficiency coupled with high productivity. For example, operations with high solids injection, iron carbide or DRI fines, may choose designs which would increase the flat bath period in order to spread out the solids injection cycle. Alternatively, a deeper bath may be used so that higher injection rates can be used without risk of blow through.

Operating practices will continue to evolve and will not only seek to optimise energy efficiency in the EAF but will seek to discover the overall optimum for the whole steelmaking facility. Universally, the most important factor is to optimise operating costs for the entire facility and not necessarily one operation in the process chain. Along with added process flexibility comes greater process complexity. This in turn will require greater understanding of the process so that it may be better controlled. Consequently, much more thought must enter into the selection of electric furnace designs and it can be expected that many new designs will result in the years ahead. As long as there is electric furnace steelmaking, the optimal design will always be strived for.

By considering the above items, CVS Technology and KR Tec have developed the new patented solution EPC for pre-heating scrap. ■

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