Abstracts

Electric Arc Furnace Technology in the 21st century is confronted by an extreme challenge. New developments in electric steel making, published by this article, show options to reduce consumption values and increase productivity of Electric Arc Furnaces. The gain in efficiency not only helps to reduce the costs, however, helps to meet modern environmental issues set by the World Convention at Kobe. This paper concentrates on conventional EAF Technology, electric power input, recent developments in furnace design as well as modern oxygen technology.

Introduction

EAF Technology has gained increasing importance in steel industry within the last 10 years. The aims are not only to decrease consumption values, however to increase productivity, using more active electrical power or support melting by auxiliary media, i.e. oxygen, carbon and natural gas, with the demand of more accuracy and higher yields. In addition the main metallic charge materials are changing to less density. Due to the lack of scrap in quantity and specific quality, tendencies are observed, that more DRI, Hot Metal or other substitutes for scrap are charged to meet the demands with respect to final steel composition with low trace elements.

VAI FUCHS, founded in 1993 at Legelshurst, Germany, is active in the design and construction of equipment for steel mills since more than 35 years and was driven by this challenge. Worldwide more than 90 Electric Arc Furnaces [EAF] and more than 100 Ladle Furnaces [LF] were constructed or revamped according to most modern design criteria with excellent results. A number of our developments are showing high acceptance in steel industry. This paper shall concentrate on new equipment ideas and melt shop lay outs which seem to be of interest for steel industry in India.

Fig. 1: Energy Optimised Eccentric Bottom Tapping EAF [EOEBT]

Fig. 1 shows the latest design of the VAI FUCHS Electric Arc Furnace. This design can be adapted to Alternating Current [AC] or Direct Current [DC] technology. The furnace including the gantry is mounted on a tilting platform. Concentrating on the design of the vessel itself, the Furnace is equipped with Eccentric Bottom Tapping System [EBT], as close to the centre of the furnace as possible, thus it is called [EOEBT®]. The sidewall and roof are water cooled. The lower section of the side wall is fabricated from copper tube. The upper section of the sidewall is fabricated from steel tube. The panels are fixed to the sturdy cage construction of the upper shell, serving as water distribution and return. The roof, in self-supporting construction, does not need any roof supports above the vessel, which shows advantages concerning auxiliary arrangements and maintenance. Electrical energy is supplied via the transformer secondary bus bar system to the current conducting electrode arms, a development by VAI FUCHS explained later.
The liquid steel is tapped into a pre-heated ladle brought into position underneath the furnace by means of a ladle transport car. The slag, collected in a slag pot underneath the slag door, is exchanged by means of a manipulator. The Upper Shell of the furnace is completely water cooled and the height of the furnace is adapted to the type of scrap and its specific density, generally aiming for a two basket operation. There are tendencies to even aim for only one basket operation, reducing power-off time. The lower section of the water cooled panels are fabricated from copper tube to meet any requirements set by active power available (transformer rating above 0.8 MW/t steel) and heat during operation. All auxiliary equipment, i.e. burners, oxygen injectors and carbon powder injection for foamy slag are arranged in the lower section, as indicated in Figure 2.

The upper shell in sturdy cage construction, for easy access, serving as main water distribution and return, flanged to the lower shell. As clearly seen the diameter of the upper shell is larger than the bottom shell for reasons of security in case of small water leaks in the side wall panels. The vessel can be exchanged easily by overhead crane in total or separated in bottom and upper shell, to minimise time requirements for maintenance.

The Bottom is fabricated from heat resistant steel in loose plate construction. It is completely clad with refractory. In case sufficient oxygen is used during the process, porous plugs in the bottom of the EAF are no longer required for metallurgical reactions.

The Roof (Figure 3) in self supporting construction, is totally water cooled, except the centre around the electrodes, which is fabricated from refractories, minimising tendencies of arcing especially during first contact of the electrodes with the scrap. For reasons, water cooled rings around the centre are always a matter of highest wear, the inner water cooled ring is constructed as one water circuit, easy to be exchanged.

Since the roof is in self supporting construction, it can be lifted by means of one hydraulic cylinder, inserted into the eye, seen on the right hand side of Figure 3. In this case, the roof is easy to reach for any maintenance and exchange of the centre piece, since the electrode gantry can be swivelled into parking position without the roof.

Slag zone Panel
The slag zone is known as the most critical area in an EAF due to oxidic slag erosion and exothermic expansion of the refractories. VAI FUCHS thus found a solution with a slag zone panel, shown in Fig. 4, consisting of copper fins indirectly cooled from outside of the furnace shell. The gap between the fins is filled with ramming material, increasing the life cycle of this zone at least three fold, thus minimising hot repairs and increasing the service life of the bottom. The water cooling box outside the furnace vessel is arranged in safe position above steel level and easy to be mounted and maintained.
Current Conducting Electrode Arms [CCEA®]

The first current conducting electrode arms were developed and fabricated by VAI FUCHS in 1984 and are successfully in operation ever since. More than 300 such installations are in operation worldwide today for applications in AC or DC technology of up to 120 MW.

![Current Conducting Electrode Arms](image)

**Figure 5: Current conducting Electrode Arms [CCEA]®**

The following advantages can be derived by this development:
- Smallest pitch circle possible.
- The arm itself fabricated from copper cladded steel.
- The thickness of the copper cladding according to the current density.
- The arm totally water cooled.
- Only one insulation between stool and mast head, dust free pre-arranged in the shop.
- Clamping device with cup springs and hydraulic cylinder inside conductor.
- No magnetism inside conductor, insulation not necessary.
- High force to clamp electrodes, optimising availability and minimum maintenance.
- High regulation speeds with excellent active power input profiles.
- Power distribution equal on all three phases, adapted via secondary bus bar system.

RCB Injection Technology

The higher the furnace shell, the more pre-heating of the scrap is possible during melting and the more combustion reactions support the performance of the EAF. VAI FUCHS, therefore, concentrated on a combination of auxiliary burners in combination with new injection technologies, the so-called Refining Combined Burner [RCB] Modules, shown in Figure 6 with its possibilities. Starting on the left hand side, the RCB can be used as auxiliary burner, using natural gas or LPG during melt down. As soon as the scrap underneath the RCB is melted, supersonic oxygen lancing can be started via the same RCB automatic by remote control from the pulpit.

![RCB Injection Technology](image)

**Figure 6: RCB Injection Technology**
For this purpose the RCB is mounted by means of a back pack panel, shown in Fig. 7 into the sidewall. The RCB is inclined at a defined angle to the steel bath. The back pack panel, fabricated from copper, is cooled by means of high speed water. This back pack panel ensures, that scrap does not block the burner mouth, increasing the availability of the RCB.

The risk of back firing of the burner is minimised. By this method refractory erosion in the side wall is minimised. The burner mouth is protected from splashes of steel and slag by a low fire mode. A combined injection with carbon powder on the right hand side is possible. Since no oxygen manipulator is necessary anymore, the slag door can be kept close and false air ingress is minimised, reducing overall energy losses. Operation within multiple reaction areas around the furnace shell (shown in Figure 2) are possible with positive effects on heat distribution inside the furnace as well as decarburisation rates of more than 150 kg C/h/m² of bath surface. Oxygen thus is injected fully automated by remote control from the pulp and in reproducible process steps.

Trials were undertaken with a slightly modified RCB injecting Carbon into stainless steel with very good results. Similar, it is possible to inject any other fine grain material (i.e. Lime, FeSi, dust etc.) using condensed stream transportation methods.

First trials with a contact free measurement of the steel temperature via a RCB module show, that temperature in steel can be measured in an EAF contact free by means of remote control, minimising time losses and costs for the probes including more secure operations.

**Use of DRI and Hot Metal**

With increasing prices for scrap, especially with the demand on low trace elements in the final product, the use of Direct Reduced Iron (DRI) and Hot Metal is increasingly considered in Electric Steelmaking.

DRI needs more processing energy due to the final reduction of FeO as well as the amount of gangue. The carbon content in DRI has to be adapted to the degree of Metallization. In case of any surplus in carbon, oxygen can be injected very successfully. DRI preferentially is charged into the EAF via continuous feeding in rates adapted to power input for immediate melting, since the reduction of the FeO would create unexpected boiling reactions otherwise. More and more High Temp DRI directly from the DRI process is used, to minimise power-on time and thus reducing the overall energy requirements. This could be demonstrated at HYLSA, Monterrey, operating a Finger Shaft Furnace *.* As an indication the electrical energy consumption is reduced by 50 to 60 kWh/t steel by the use of High Temp DRI in case the temperature of the DRI is 400°C to 500°C. Definitely the DRI transportation systems have to be adapted respectively.

Hot Metal, to be charged into a EAF, needs specific charging technologies. Due to safety reasons hot metal shall not be charged via the open roof into an EAF equipped with water cooled side wall panels. Therefore, a Hot Metal Robot was developed by VAI FUCHS as shown in (Fig. 8). In this case the hot metal is charged form the tapping side via a special launder into the furnace at a rate of up to 5 t/min. Decarburisation thus can be started quite early during the process and oxygen flow rates of up to 150 Nm³/min with multiple point injection were applied successfully into the Finger Shaft Furnace with up to 40% hot metal.

![Fig. 8: Hot Metal Charging Robot (Anyang)](image-url)
Ultra High Power EAF

Conventional Arc Furnaces with a specific electrical power capacity of up to 1 MVA/t were designed and constructed by VAI FUCHS, showing a productivity of up to 120 t/h and excellent performance. One of the limiting factors in UHP Arc Furnace Technology is the heat transfer, supplied by the arcs to the charge material and liquid steel. It was found, that the specific power of 1000 kVA/t mainly depends on a scrap density of 0.70 t/m³ with a maximum deviation of ±0.05 t/m³.

At SWT ACELO, the 120 t DC EAF is successfully operated with a new fin type anode concept designed by VAI, reaching anode life cycles of more than 2000 heats.

Figure 9 shows the EAF, operated at HADEED, Saudi Arabia with a capacity of 150 t/heat and a transformer of 120 MVA charging normally 75% DRI per heat.

The 140 t EAF for the production of Stainless Steel at Outokumpu, Finland, shown in Figure 10, is equipped with a transformer of 140 MVA and an electrode diameter of 711 mm. In this special furnace without a slag door, the use of oxygen during melting and refining is minimized for reasons of Cr yield, charging stainless steel scrap. Lime powder injection via the roof in the hot spot areas helps to decrease refractory erosion.

It was taken into operation in December 2002 and operated successful ever since.

These examples for reference only.

In case of a comparison of these three furnaces with tap weights of 120 t to 150 t/heat including a Finger Shaft Furnace (FSF)* is allowed, the following Table shall give a general indication what kind of options today are viable in electric steel making (prices according to European standards).

<table>
<thead>
<tr>
<th>Furnace Type</th>
<th>EAF + DC</th>
<th>EAF - AC</th>
<th>EAF - AC</th>
<th>EAF - AC</th>
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<tr>
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</table>

Note: * DR (HE) with Metalization of 93%, Fe = 53%, C = 1.5%, Oxygen = 3.5%.
** Liquid metal: C = 0.2%, S = 0.05%, P = 0.10%, S = 0.002%, Temp. = 1300 °C.
*** DC: incl. Fingers plus Poles 5 t/m, Finger Shaft Furnace incl. Dependence of Shaft. plus Fins 3.0/Ends.
In each case of a new plant or investment in an existing plant it is strongly recommended to ask for a respective evaluation and pre-study.

Operations today depend on modern electrode regulation systems, one of which was developed by VAI FUCHS & Vatron, called ArCOS. Furthermore, the electric power supply asks for Flicker values created by the EAF below 1, which is reached by a dynamic compensation. The stability of the power supply can be improved by so-called reactors, which are integrated in the primary circuit or directly into the EAF transformer.

Summary

Electric Arc Furnace designs of the 21st century are challenged by highest thermal loads, created by an electric power input of =1 MW/t and an increase in oxygen injected into a furnace. The aim is to reach heat cycle times of less than 40 minutes, producing more than 40 heats per day. This only can be reached with equipment, which is capable to cope with this challenge and easy to be maintained. VAI FUCHS, Legelshurst, Germany, since 20 years in the construction of Electric Arc Furnaces and Ladle Furnaces, has not only developed furnace constructions but also new oxygen technologies with excellent performance issues reaching highest productivity. The RCB technology with its wide variability from burner mode to oxygen injection without consumable lances and operated by remote control from the pulpit is one of the leading issues in EAF steel making.

* References: