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RECENT TRENDS IN ELECTRIC ARC FURNACE PRACTICE

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ABSTRACT

Ferro alloys, Calcium Carbide, Aluminium and Calcium-silicon alloys, Iron and Steel are some of the important metallurgical products of electric arc furnaces (EAF). Processing of ilmenite in EAF for producing synthetic rutile and pig iron seems to be the future trend in titanium dioxide pigment industries as this process ensures a cleaner technology. EAFs are also being employed to vitrify a variety of wastes from mineral and metallurgical industries, as such a practice helps in recovery of metal values and makes disposal problems easier.

Electrothermal processes are highly energy intensive and hence recent studies in this area pertain mainly to lowering the manufacturing cost with the development of ultra high furnaces and also D.C and plasma arc furnaces.

1. INTRODUCTION

The manufacture of many electro metallurgical and electrothermal products by the application of arc furnaces was initiated as early as 1800. The development gained momentum only towards the end of the 19th century. Contributions of Hall in U.S.A. and Heroult in France opened up new chapters in the field of electrothermics. The first arc furnce designed by Heroult was installed in the year 1900 for the production of steel. Since then the application of direct and indirect arc furnaces accelerated the growth of electrothermal products such as calcium carbide and ferroalloys in huge quantities. The growth of iron and steel industry depends very much on the production of ferro alloys as they are used for deoxidation, nucleation, grain refinement, control of hardening and for the development of special properties in steels and other engineering alloys.

Single or three phase furnaces are used for the poduction high carbon Fe-Mn, Fe-Cr and Fe-Si. They are simpler in design and resemble furnaces used for smelting of pig iron and calcium carbide. Refining furnaces are used in the production of high grade ferro alloys.

Closed top furnaces are increasingly used to recover and utilise the furnace gases which are mostly carbon monoxide. The roof of the furnace is provided with safety valves as a precaution against excessive gas pressure.

The furnaces may be of tilting or stationary type. Rotating hearth is also used because of high power factor, greater gas permeability avoidance of crust formation and prolonged furnace lining since the high temperature zone moves constantly with respect to the hearth and sides of the furnace.

The furnaces are also equipped with flue and dust precipitating systems. The use of hollow electrodes with continuous feeding of the charge in the region of the arc is also becoming common. In recent times there is a growing inclination to use coated graphite electrodes as they have longer life leading to reduced electrode consumption.[1]

2. RECENT IMPROVEMENTS IN ARC FURNACE TECHNOLOGY.

2.1 Energy Conservation

Electrothermal industries are highly energy intensive and the energy component alone of the cost of production in many cases varies between 30 - 40 %.

Table 1 gives the energy needed for the production of different electrothermal products.[2]

TABLE 1. ENERGY REQUIREMENTS FOR VARIOUS ARC FURNACE PRODUCTS

Sl. No.	Products	Energy Kwh / T
1.	Calcium Carbide	4000 - 4500
2.	Ferromanganese (H.C)	2300 - 3000
3.	Ferrochrome (H. C)	4000 - 5000
4.	Ferrochrome (L. C)	5100 - 5200
5.	Ferrosilcon	8500 - 9200
6.	Silico manganese	4200 - 5500

From table 1, it is evident that the viability of the EAF industry requires keeping the cost of power at lowest rate possible. Hence any savings in energy requirements would be reflected in the cost of production of electrothermal products.

The biggest change in the arc furnace technology has been the use of ultra high power inputs. These ultra high power furnaces permit improved heating and melting efficiencies with minimum thermal and electrical losses. However choice and control of current and voltages are necessary as otherwise higher refractory wear will take place. Recent developments[3] indicating the use of siliconised graphite and corrundum - zirconia refractory bricks for the lining of the furnace have resulted in giving the longest service with good thermal shock and chemical resistance thereby assisting energy savings.

The application of hollow electrodes makes it possible to increase the power input and yield with decreased electrode and power consumption[4]. If upto 25% of fines are to be employed in the charges fed into the arc furnace, hollow electrode is recommended[5].

Production of electrothermal products is always accompanied by the release of huge quantities of carbon monoxide which carries as much as 10 - 15% energy supplied into the furnace. Table 2 gives an idea about the potential utilization of the off gases from an arc furnace. The energy rejected in the waste heat gases of an electric arc furnace producing 180 T steel is approximately 200 Kwh[6]. The heat value of dusts and fumes in a CaC_2 furnace is equivalent to 1.02×10^6 K. Cals per ton[7]

TABLE 2. DATA ON GASES GIVEN OUT BY VARIOUS TYPES OF ELECTRIC FURNACES

Furnace Type	Gas Vol. M^3/T	Gas Analysis (Vol. %) CO	CO_2	H_2O	N_2	CH_4	Temp. of gas at outlet °C
Iron	650-700	72	15	8	2	2	350
Fe-Mn	800-950	72	11	6	10	1	350
Fe-Cr (HC)	900-1050	72	11	6	10	1	350
Fe-Si (75 Si)	1700-1800	90	-	6	-	-	1000
CaC_2	350-400	90	1	2	0.37	1	500
Phosphorous	850-950	98	-	-	-	-	400

Due to its chemical composition and calorific value, the off gases from the electric furnaces may be utilised in many ways. As a fuel, or as a raw product in chemical processes or in the production of electricity. Used as a fuel or a raw product,it will give the best revenue.

The waste heat of the furnace gas has been effectively used in a waste heat boiler for generation of steam at 1.7 M Pa and 250°C[8]. The potential heat content of the out going gases has been amply demonstrated by a ferro silicon plant in France which has been able to recover 19 % energy by employing a turbo generator, the enhanced capital investment being more than offset by the generation of power[9]. Irrespective of the recovery of the sensible heat of the outgoing gases, use of closed or semiclosed arc furnaces leads to some energy savings as evident from Table 3 given for Calcium Carbide production[10]

TABLE 3. COMPARATIVE DATA ON OPEN AND CLOSED TOP FURNACES

Inputs	Open	Closed
Lime/ton Carbide	0.940 T	0.921 T
Carbonaceous material	0.610 T	0.583 T
Electric power	3243 KWh/T	3000 KWh
Electrode consumption	0.025 T	0.025 T
Mandays/Ton	0.97	0.24
Carbide Quality	0.3 M^3/Kg	0.3M^3/Kg

Utilisation of the sensible heat of the molten ferro alloys and other products of the EAF can also contribute to energy savings. A 11% energy savings is claimed by adding lime - coke mixture in 1 : 3 mole-ratio (109 Kg lime and 76 Kg Coke per ton of carbide) to the tapped Calcium Carbide when it is cooled from 2000°C to 1600°C[11]. Heat from solidified CaC_2 melt is also recovered by transporting the filled wagons successively through a tunnel heat exchanger[12]

In yet another power saving process heavy oil and oxygen are injected through specially designed nozzles into layers of calcines in the electric furnace to increase the melting speed in order to more quickly and efficiently melt the charges in place of using electric power[13]

Use of power operated voltage taps and electrode clamps[14], application of micro processor control of power and thyristor control of elecrodes have been found to be necessary for the efficient operation of arc furnaces with an attendant savings in energy consumption[15]

Very recently Dan arc, Italy have combined high impedence technology with bottom tuyers for oxygen and carbon injection. The idea is to secure efficient system for the supply of both electrical and alternative energy. The Dan arc technology uses specific amounts of oxygen and carbon as substitute for the electrical energy[16].

2.2 Application of D.C. Arc Furnaces

Although the concept of DC elecric arc furnace was as old as the AC EAF itself, a beginning for its industrial application started only in the late seventies when the semi conductor technologies were developed[17]. Today the DC EAF competes well with the AC EAF because of the availability of highly efficient thyristor controlled rectifiers.

DC EAFs are particularly useful and employed in the production of steel and also for the smelting of ferro alloys such as ferrochrome[18] with the following advantages.

Over current surges are quite common due to short circuit between the electrode and the molten charge in AC EAF. Due to thyristor control of current no such defect can happen in DC EAF. High current densities could be employed in D.C in which the flickering effect is only 50% compared to 100 % in A.C.

In DC EAF longer arc gap is achieved so that the arc erosion is minimum and this is responsible for a saving of more than 50 % on the consumption of graphite electrode [19]. A 92 % efficiency as against about 85 % with A.C system has been claimed with a d.c arc furnace having top electrode and a bottom hearth electrode [20].

D.C. technology in the production of steel has been able to reduce the tap to tap time and the energy consumption has fallen from 630 Kwh/T to less than 400 Kwh/ and the electrode consumption[21] from 6.5 to 1.5 Kg/T.

Additionally Argon injection through hollow electrodes in DC EAFs lead to extended arc melting with the result the melting period and power consumption are further lowered[22]

Reduced specific consumption of refractories has also been observed with DC furnaces [23]. Very importantly the noise level is very much less in D.C. systems.

However, investments on DC EAF installation cost approximately 30 % higher. Apart from the components already known for 3 phase A.C arc furnaces i.e., a step down transformer and furnace transformer, a thyristor rectifier is additionally provided in D.C furnaces. However the capital cost could be paid back within five years of operation due to the low operating costs. The viability of DC EAF is evident from the fact that about 70- 75 % of the new electric arc furnaces under construction for steel making are of the D.C type [24].

In India ESSAR Steels have already commissioned the DC EAF for steel production with technology from Clecim, France. Today it appears that the DC EAF technology seems to be the only solution for weak power supply net work.

Though the DC EAFs could be used for ore smelting, their application in smelting of CaC_2 and similar products have not been pursued as steel, probably due to the former's low quantity production compared to the very huge needs of steel.

2.3 Plasma Arc Furnace

In the recent years a new branch of arc furnace technology of pyrometallurgical products is fastly emerging viz., Plasma arc furnace[25-29]. The principal attraction of plasma furnace is the potential of producing very high temperatures. Such a high temperature source permits the design of reactor with high processing rates per unit volume. Other advantages include utilisation of fines and low electrode and power consumption.

In most applications of plasma technology in extractive metallurgy, plasma is generated with graphite electrodes or in plasma torches with the electrodes directly in contact with plasma[30]. The plasma arc can be either ejected from the torch or ejected to an external electrode which may be the molten bath. There are two different ways of running a plasma system which are termed as non transferred arc and transferred arc modes respectively.

Plasma furnaces have been widely employed for the production of a variety of products such as ferro alloys, iron and steel calcium carbide and even in the smelting of steel plant waste.

It has been reported that for an alloy steel melting furnace with a capacity of 1 Ton the melting time was one hour, Argon consumption 5 - 5.4 m^3/hour, voltage 177 V, current 990 - 2500 Amps and the energy consumption 1225 Kwh. Calcium Carbide of 93 % purity was achieved in a plasma reactor with argon gas [31].

The electrical consumption for an integrated ore treatment and plasma smelting process in the ferro manganese manufacture is approxomately 2100 Kwh while the value for the submerged arc furnace using similar ore is 3200 Kwh/T, the reduction in power consumption being 33 % [32]

The reduction of ilmenite to yield a high grade titania slag and pig iron by product in a d.c. transferred plasma arc furnace was also reported [33]

Considerable quantities of metal fines are produced during the crushing of ferro alloys and the recycling of the same in the submerged arc furnace presents problems due to their high conductivity which will reduce the power available to the furnace and lower the productivity. Plasma arc remelting offers solution. High carbon Fe-Mn metallic fines were successfully melted in a 3 MVA plasma furnace at power inputs upto 696 KWh which approached the predicted value of 410 KWh/T of the Fe - Mn fines [34]. Steel plant dust could also be processed using coal or coke as reducing agent in a plasma furnace.

In the recent years even large scale plants have come up using plasma technology[35] due to its versatility of melting, compactness, reduced pollution hazards and above all low energy consumption due to efficient level of energy recovery from the furnace waste gases.

2.4. Electric Arc Furnace as a Waste Melter

According to a recent survey in U.S.A, the minerals industry alone generate approximately 2 billion metric tonnes of waste per year. Others include 453 million tonnes of hazardous waste, 178 million tonnes of municipal waste, in addition to 250 million tonnesof solid waste generated by other industries [36].

Land fills are under extreme pressure due to stringent environmental regulations. Further, transportation costs are escalating leading to the ultimate objective of zero land filling. Additionally the ash from the minicipal incinerators contain heavy metals and other non bio degradable materials that can pollute ground water. Detoxification methods include immobilization, chemical additives and thermal treatment. The latter offers environmental assurance over the other and the thermal treatment involves techniques using electric arc furnace.

The Vitrified products find potential uses as aggregate in portland cement or asphaltic concreates, for Walkway or garden tiles and construction fills. Vitrification of arc furnace bag house dust has resulted in a glass frit for use in ceramic roofing granules and sand blasting abrasive grit[37].

In EAF steel production about 1 - 2 % of the furnace charge is converted into fine dust and fumes. This dust contains upto 30% Zn, 5 % Pb and a potentially hazardous waste because of the leachablity of the contained lead, cadmium and hexavalent chromium ions in ground water. The smelting of the dust to recover the metals and to produce an inert slag is an alternative to an increasingly expensive disposal problem. The Plasma arc furnace offers very good scope in processing steel plant dust using coal and coke breeze as the reducing agent to produce an enriched product containing 75 % ZnO, 7 % Pb_3O_4 and a Zn and Pb free alloy[34].

In the years to come under increasing pressure from the Environmental protection agencies, the role of the electric arc furnace for waste disposal is bound to increase as it is economically and environmentally acceptable.

3. CONCLUSION

Electrothermics is an expanding area with the introduction of a new class of materials viz., refractory hard metals which comprise the carbides, borides, silicides and nitrides of the transition metals for applications where high temperature strength, stability and oxidation resistance are required. Many important hard metals such as carbides of titanium, Tungsten, Boron etc. and also the borides Ti, Zr and Ca etc have been produced in electric arc furnaces.

Recently ultra fine, ultra pure ceramic oxide powders have been produced by employing what is known as reactive electrode submerged arc technique (RESA) which uses two submerged metal electrodes in a dielectric fluid which react with the metals at normal line voltages. By this technique gamma Aluminium oxide, a variety of titanias, Zirconias, Oxides of Tungsten and Iron in 10 to 1000 nm size have been produced[38].

Zirconia-Alumina and similar super refractory materials from the electric arc furnace offer very good scope for heavy duty applications. It is, therefore, likely that the requirements of high temperature materials will increase in future due to the increase in newer technological application.

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