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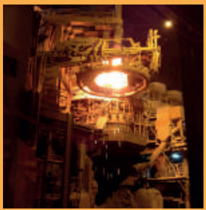
ENERGY EFFICIENT TECHNOLOGY PACKAGES FOR ELECTRIC ARC FURNACE



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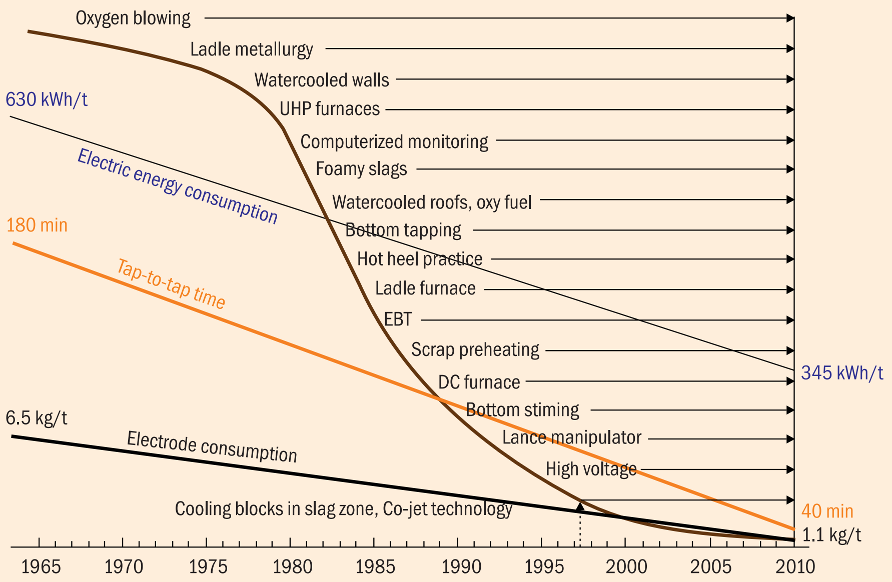
Energy Efficient Technology Packages

The secondary steel Electric Arc Furnace (EAF) sector plays an important role in the overall steel production in India. An electric arc furnace uses steel scrap or mix of steel scrap and sponge iron (DRI) as charge material, producing billets and bars.

The major energy forms used in an EAF include electricity and chemical energy. Wide variations in SEC levels were observed in EAF operation. There is a significant scope for energy savings and corresponding greenhouse gas (GHG) reduction in the sector through adoption of 'energy efficient' (EE) technologies and practices.

The key performance indicators (KPIs) of Indian EAFs shows, that the specific energy consumption, levels are significantly higher than international benchmark offering significant potential for improvement. The other KPIs, such as TTT and electrode consumption are also showing a higher trend which calls for further improvements. The improvements in performance at the international level have been achieved through constant innovation and upgradation in technology and practices.

The United Nations Development Programme (UNDP) is facilitating the diffusion of energy efficient low carbon technologies in EAF sector in India with a focus to bring down end-use energy level, reduce GHG emissions, improve productivity and



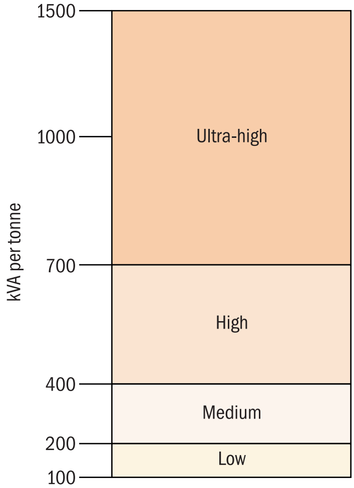
Technology development in international EAF sector enhance cost competitiveness. With this background, UNDP had entrusted TERI to undertake a comprehensive energy audit study of select EAF furnaces in India and develop a technology compendium and a ready-reckoner booklet that can provide as a guide to EAF units in the country.

This booklet is a ready reference on the energy efficient technologies and practices relevant for the Indian EAF units. It provides an overview of technology options applicable for the sector. For more details, the user may refer to the technology compendium on "*Energy Efficient Technology Packages on Electric Arc Furnace*".

1 Ultra High Power Transformer

Background

The power ratings of the transformers used in Indian EAFs are limited to a maximum of 500 kVA per tonne resulting in longer tap-to-tap time and higher SEC Levels. The overall energy loss due to use of low power rating transformer can be as high as 7%.



EE Technology

The inefficient transformers can be replaced with Ultra High Power transformers (UHP), having rating of 700 kVA per tonne or above. A transformer with an input power of above 700 kVA per tonne is defined as a UHP transformer. Although UHPs are typically available in the range 700–1500 kVA, transformers above 1000 kVA per tonne capacity are commonly used in developed countries. The major benefit of UHP transformers include (i) substantial increase in productivity, (ii) reduction in electrode consumption, and (iii) energy saving.

Savings, Investments and GHG Reduction

The average energy savings with UHP transformers is estimated to be about 5%. Typically for a 50 tonne furnace, the investment requirement is about ₹400 lakh with simple payback period of about 2 years. The greenhouse gas (GHG) emission reduction potential is about 3,690 tonne of CO_2 per year.

UHP transformers – Case study		
Parameter	**Unit**	**Value**
Existing transformer rating	MVA	50
Old transformer	kVA/t	500
New transformer	kVA/t	1000
Productivity enhancement	%	8.0
Reduction in electrode consumption	%	10.0
Reduction in energy consumption	%	5.5
Investment	₹ lakh	400
Simple payback period	Years	1 -2

2 High Impedance System

Background

The EAFs, which earlier were using shorter arcs and high currents, switched over to long arc operations with use of foamy slag practices. Although EAFs were using lower operational currents and lower impedances that helped in minimizing electrode consumption, it had led to higher flickers and harmonics, particularly during bore down period leading to unstable operation. It further resulted in higher stress on mechanical components due to increased vibrations.

EE Technology

High impedance operation helps in more stable and smooth operation of EAFs. With low current and long arc operation, appropriate power factor and system reactance are selected for stable operation. High impedance system helps operating the furnace close to maximum power point of a given tap and lowers the sensitivity of power changes versus current changes through a series reactor on primary circuit and raising the voltage taps on secondary side. The major advantages of the high impedance system include (i) reduction in electrode tip consumption and breakage, (ii) less flickers, lower harmonics and more stable arc operation, (iii) less mechanical forces on electrodes and electrode arms, and (iv) potential to use lower electrode diameter to reduce oxidation losses.

Savings, Investments and GHG Reduction

The average energy savings with high impedance operation is estimated to be about 1%–2%. Typically for a 50 tonne furnace, the investment requirement is about ₹170 lakh with simple payback period of about 3 years. The GHG emission reduction potential is about 740 tonne of CO_2 per year.

Particular	Unit	Case 1	Case 2	Case 3
Secondary voltage	V	800	1025	1100
System reactance	m Ω	3.3	6.1	7.1
Electrode current	kA	65.3	50.4	50.4
Active power	MW	73.7	71.5	71.4
Arc power	MW	67.8	67.7	67.6
Power factor		0.84	0.83	0.78
Arc voltage	V	363	461	460
Electrode saving	%	-	15	15
Energy saving	%	-	1.5	1.5

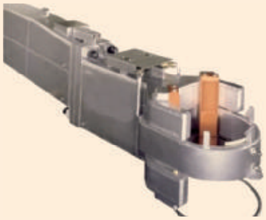
3 Aluminium Electrode Arm

Background

A mild steel support with water cooled copper cables is the standard material used in EAFs. A copper clad i.e. steel arm with copper bus tubes is also being used by a few units. Though copper system (Cu-system) offers high strength and conductivity, electromagnetic forces around copper bus and electrode clamping heads affect the system performance. This increases system resistance, leading to drop in power fed to the furnace.

EE Technology

The aluminium system (Al-system) is lighter and non-magnetic. The Al-system comprises aluminium current-conducting electrode arms and columns with guide roll assemblies. The major advantages of aluminium electrode arm include (i) high arc power, (ii) increased productivity, (iii) reduction in maintenance downtime, and (iv) low mechanical vibrations.



Aluminium electrode arm

Savings, Investments and GHG Reduction

The energy savings with aluminium electrode arm is about 0.7%. Typically for a 50 tonne furnace, the additional investment requirement is about ₹70 lakh with a simple payback period of 1.5 years. The GHG emission reduction potential is about 520 tonne of CO_2 per year. A case study of an EAF unit located in USA which replaced copper arm with aluminium electrode arm in a 100 tonne, 85 MVA furnace is reproduced in following table.

Particular	Unit	Cu-system	Al-system	Change
Reactance (short circuit)	mΩ	3.02	2.88	- 4.6%
Reactance (foamy slag)	mΩ	3.31	2.93	- 11.5%
Power foamy slag	MW	82.1	82.6	+ 0.6%
Power normal	MW	76.6	77.3	+ 0.9%
Power melt down	MW	75.5	75.9	+ 0.7%
Power ON time	Min	41	39.7	- 3.2%

4 Improved Regulation Control

Background

The degree of transformation of electrical power into thermal energy is important in an EAF and depends on regulation of the transformer. The major issues with analog-based electro-hydraulic regulation system include (i) high switching time and (ii) excessive wear and tear.

EE Technology

The shortcomings in conventional regulation systems can be addressed with "high pressure hydraulic digital regulation" system. The digital system allows minimum delays for switching from one melting stage to another. This system can be linked with "Level-2 or 3" automation for dynamic production control. The main advantages of digital based regulation system include (i) reduction in tap-to-tap time, (ii) increase in productivity, and (iii) enhanced operational reliability.

Savings, Investments and GHG Reduction

The average energy savings with improved electrode regulation is about 3%. Typically for a 50 tonne furnace, the investment requirement is about ₹75 lakh for hardware & software and associated hydraulic systems. The simple payback period is about 6 months. The GHG emission reduction potential is about 2,210 tonne of CO_2 per year.

The case study, as depicted in below table, of a 40 tonne, 36 MVA EAF illustrates effects of using state-of-the-art electrode regulation system. The units wherein digital regulation system is already in use can achieve additional energy saving with fine-tuning of the software with reference to their respective scrap quality.

Particular	Unit	Base case	EE Technology
Furnace capacity	t	40	40
Transformer rating	MVA	36	36
SEC	kWh/t	426	412
Power ON time	min	49.7	48.9
Electrode consumption	kg/t	3.51	3.40
Monetary benefit	₹/t	-	81
Investment cost	₹ lakh	-	250
Simple payback period	Years	-	0.52

5 Oxy-Fuel Burner

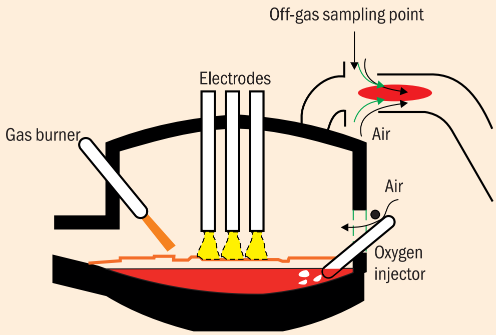
Background

During EAF operation, cold spots form between electrodes on the peripheral areas of furnace bottom. These cold spots within the EAF would lead to increase in tap-to-tap time thereby increasing the specific energy consumption. It is therefore, important to eliminate cold spots from the furnace.

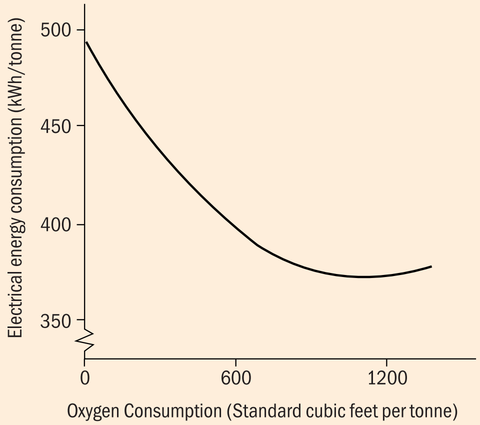
EE Technology

The state-of-the-art EAFs are equipped with oxy-fuel burners which use fuels, such as natural gas, and LPG, and provide chemical energy to cold spots, thereby ensuring more uniform melting and homogeneity of temperature of the molten metal bath.

Modern EAFs widely use stationary wall-mounted oxy-fuel burners and combination lance-burners, which operate in a burner mode during the initial part of the melting period. The important advantages of oxy fuel burner include (i) low electricity consumption, (ii) reduced tap-to-tap time, and (iii) enhanced yield.



Oxy–fuel burner



Savings, Investments and GHG Reduction

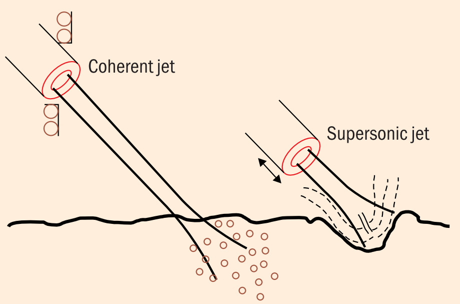
The average energy savings with use of oxy-fuel burners is about 3%. Typically for a 50 tonne furnace, the investment requirement is about ₹400 lakh with a simple payback period of about 2 years. The GHG emission reduction potential is about 2,210 tonne of CO_2 per year.

6 Coherent Jet

Background

The oxygen injection system in traditional EAFs uses supersonic jet-based burners. However, the traditional method generates splash and leads to formation of cavity in liquid metal. The penetration of oxygen is not very effective in a conventional system and leads to high refractory consumption.

EE Technology



Coherent jet vs. supersonic jet

The shortcomings in supersonic jet are overcome with the use of coherent jet technology (CoJet). The CoJet injectors are mounted on furnace side walls. The performance of Co-Jet system can be enhanced further using programmable logic controllers. The major advantages of using CoJet system include (i) better penetration of liquid metal bath, (ii) use of precise amount of oxygen, (iii) less splash and cavity formation, (iv) lower refractory consumption, (v) improved slag foaming with less carbon, and (vi) decreased air infiltration.

Savings, Investments and GHG Reduction

The average energy savings with use of CoJet injectors is about 2%. Typically for a 50 tonne furnace, the investment requirement is about ₹300 lakh with a simple payback period of about 2.5 years. The GHG emission reduction potential is about 1,480 tonne of CO_2 per year. The case study of a 50 tonne 40 MVA EAF unit using CoJet injectors is shown in the following table. The benefits include energy saving (6.4%), reduced electrode consumption (9.4%), and decreased tap-to-tap time (10.6%).

Particular	Unit	Conventional	CoJet
Capacity	tph	27.1	28.8
Tap-to-tap time	min	114	102
SEC	kWh/t	485	454
Electrode consumption	kg/t	3.2	2.9
Investment	₹ lakh	-	100

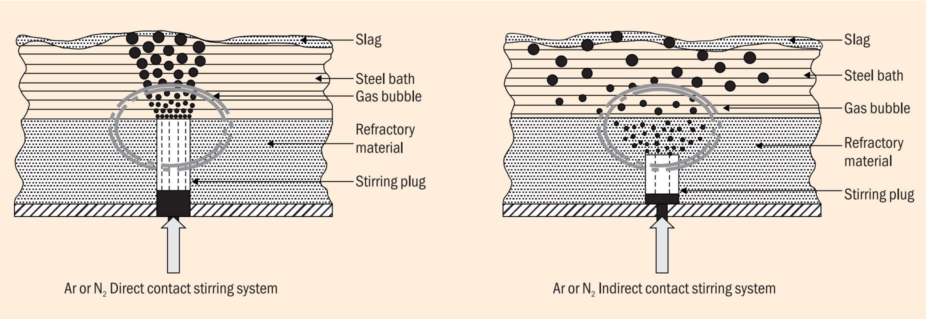
7 Bottom Stirring – Inert Gas Purging

Background

The molten metal in EAFs may not be of homogenous mass or uniform quality across the cross-section and depth of the furnace resulting in increased tap-to-tap time and specific energy consumption. Moreover, it can also lead to high rejection level.

EE Technology

The inert gas injection is the most commonly used practice in EAFs for achieving homogeneity of the liquid bath. It is done using inert gases, such as argon or nitrogen. Direct/indirect purging options are available for bottom stirring. Bottom stirring using inert gases are more suitable for smaller furnaces since it accelerates chemical reactions between steel and scrap. The advantages of inert gas-based bottom stirring include (i) improved control of the temperature and chemical composition of liquid metal, (ii) lower consumption of refractory and electrodes, and (iii) shorter-tap- to tap times. However, the use of inert gas will require significant maintenance after every heat.



Savings, Investments and GHG Reduction

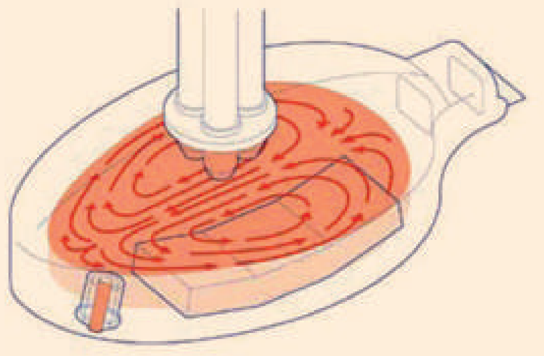
The average energy savings with inert gas-based bottom stirring is estimated to be about 3%. Typically for a 50 tonne furnace, the investment requirement is about ₹10 lakh and the payback is immediate. The GHG emission reduction potential is about 2,210 tonne of CO_2 per year.

8 Bottom Stirring–Electromagnetic System

Background

The molten metal in EAFs may not be of homogenous mass or of uniform quality across the cross section and depth of the furnace which results in increased tap-to-tap time and specific energy consumption. Moreover, it can lead to high rejection level.

EE Technology



Electromagnetic stirrer

Bottom stirring of liquid bath in EAF is a potential solution for better homogenization and to ensure uniform quality. The electro-magnetic stirrer (EMS) is a new generation stirrer arrangement for EAF. It has a stronger stirring ability and enables to reduce tap-to-tap time in liquid steel production.

The EMS enhances melting of large scraps and reduces stratification as a result of forced convection. It leads to increased melt velocity which is almost 10 times higher as compared to natural convection and results in less power ON time. Some of the special features of EMS system include (i) low stirring cost, less than 2 kWh per tonne, (ii) low maintenance, and (iii) fully integrated and automated control system. The advantages of EMS system include (i) high yield, (ii) less power on time, and (iii) lower consumption of refractory and electrodes.

Savings, Investments and GHG Reduction

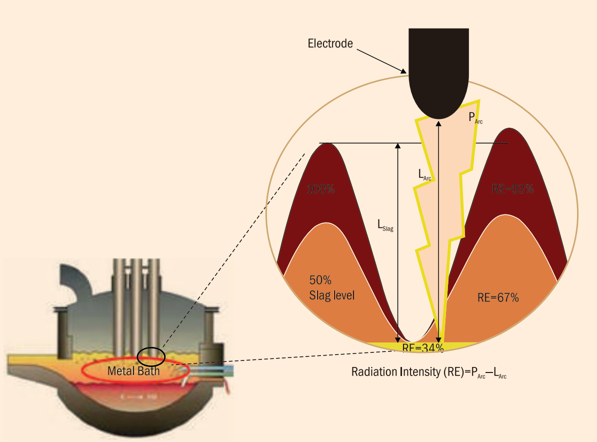
The average energy savings with electro-magnetic based bottom stirring is estimated to be about 5%. Typically for a 50 tonne furnace, the investment requirement is about ₹400 lakh with a simple payback period of about 2 years. The GHG emission reduction potential is about 3,690 tonne of CO_2 per year.

9 Foamy Slag Practice

Background

The radiation loss from electric arc to the side walls of the EAF is negligible in the beginning, as the electrodes are surrounded by scrap at low temperatures. During melt-down, the temperature inside rises quite high and more heat is radiated to side walls. The increased heat transfer to side walls leads to increased surface heat losses and refractory consumption.

EE Technology



Heat losses to side walls with foamy slag

In EAFs, the slag thickness is typically about 4 inches, and with proper foaming practice, it can be increased up to 12 inches. It is important that the 'foaming slag' needs to be maintained throughout refining period to minimize energy losses to side walls. The formation of deep foamy slag has the potential to increase the arc voltage significantly, which allows higher power inputs. Slag viscosity plays an important role in maintaining proper foamy slag, as it would determine the retention time of the CO_2 bubbles in foam. Dololime addition would help in enhancing the formation as well as retaining foamy slag.

The major benefits by maintaining foamy slag in molten metal bath include (i) enhance heat transfer to molten bath, (ii) reduce thermal load radiated to the furnace lining, (iii) decrease electrode and refractory consumption, (iv) better electric arc stability during long arc operations, and (v) minimize arc noise.

Savings, Investments and GHG Reduction

The average energy savings with enhanced foamy slag practice is about 1.5%. This requires marginal investment with immediate payback. The GHG emission reduction potential is about 1,100 tonne of CO_2 per year.

10 Use of Chemical Energy

Background

The chemical reactions form part of EAF operation which generate significant quantity of heat during various phases. However, the heat generated is not utilized to its optimum potential by a majority of EAF units resulting in significant heat losses.

EE Technology

The methods for utilizing the chemical energy available from the EAF include post combustion, oxidation reaction, and carbon injections.

Typically there is insufficient oxygen (O_2) inside the EAF for complete combustion of carbon monoxide (CO). Post combustion is a process of utilizing chemical energy present in CO and hydrogen (H_2) evolving off the steel bath to heat the steel in the EAF ladle or preheat scrap to (300–800°C). The main advantages of post-combustion are (i) savings in electricity consumption (ii) reduces bag–house emissions.

There is a need to control and manage oxygen injection to keep oxidation of iron to a minimum. For carbon level in liquid bath above 0.3%, all oxygen present reacts with carbon to produce CO. If the level is below 0.3%, the efficiency of carbon oxidation to form CO drops and more and more iron oxide (FeO) is generated in the slag. For scrap carbon levels below 0.1%, FeO levels in the slag can become quite high which is unavoidable yield loss. Carbon injection needs enhancement to control slag FeO levels and prevent excessive refractory losses. Carbon injection is beneficial where 100% scrap practice is being conducted or carbon content of the bath is insufficient to produce CO for slag foaming.

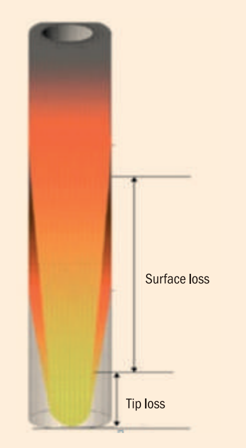
Savings, Investments and GHG Reduction

The average energy savings with proper utilization of chemical energy is estimated to be about 1%. The investment requirement is marginal and payback is immediate. The GHG emission reduction potential is about 740 tonne of CO_2 per year.

11 Mist Cooling for Electrodes

Background

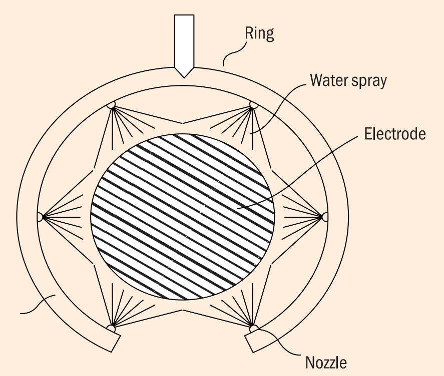
The electric arc is generated between the tip of the electrodes producing heat to melt the charge material. The side surface of the electrodes is oxidized and consumed due to the high temperature. During the operation, the shape of electrodes changes considerably and at the tip it decreases to as low as 70% of the original electrode diameter.



Electrode consumption	Value (%)
Due to arcing	40
Side surface oxidation	50
Tip falls down due to thermal shock	10
Electrode consumption	kg/t
Investment	₹ lakh

EE Technology

The oxidation loss of the side surface of the electrodes in the EAF can be reduced by coating the outer surface or by reducing the outer surface temperature of the electrodes. For this purpose, a jacket of water mist is created over the outer surface of the electrodes thereby reducing the temperature of the side surface.



Mist cooling arrangement

Savings, Investments and GHG Reduction

When the flow rate of the cooling water is kept optimum depending on electrode diameters, the electrode consumption reduces by 10–15%. The corresponding reduction in energy consumption is about 1%. The GHG emission reduction potential is about 740 tonne of CO_2 per year.

12 Water Cooled Cables

Background

The cables providing electrical power supply to the furnace from transformer are water cooled. The resistance of cables increases with usage and life, which almost doubles in about two years. The EAF units generally replace cables once in 3–5 years leading to energy losses.

EE Technology

The EAF units should carry out periodical measurements of resistance of the water cooled cables, at least twice in a year as a regular maintenance practice. As soon as the resistance of the cables increases to about 1.5 times of the design value, the older cables must be replaced with new cables which offer lower electrical resistance.

Water cooled cables

Savings, Investments and GHG Reduction

The average energy savings by replacing old high-resistance water cooled cables with new cables is estimated to be about 0.15%. Typically for a 50 tonne furnace, the investment requirement is about ₹20 lakh with a simple payback period of about 2 years. The GHG emission reduction potential is about 110 tonne of CO_2 per year.

An EAF unit in India has adopted regular maintenance practices of its facilities as in depicted in the following table. During regular maintenance, it was found that the resistance of the water cooled cables has increased to about 3.5 times than the design value. The unit replaced the old, high resistance cables with new cables having a resistance of about 90 mΩ. This had resulted in an estimated energy saving of 0.6 kWh per tonne of liquid metal.

Particular	Unit	Old cable	New cable
Furnace capacity	t	40	40
Cable resistance	mΩ	310	90
Energy saving	kWh/t	-	0.6
Investment	₹ lakh	-	10
Simple payback period	Year	-	0.4

13 Copper-based Water Cooled Panels

Background

The water cooled panels typically used in the electric arc furnaces are made of mild steel. These mild steel-based water cooled panels normally have low life. Over a period of use, the effectiveness of heat transfer reduces significantly, resulting in higher refractory consumption.

EE Technology

The mild steel-based water cooled panels can be replaced with copper-based water cooled panels. The advantages of copper-based water cooled panels include (i) increase in life of panels (up to 6 times), (ii) decrease in number of panel failures, and (iii) reduction in refractory consumption.

Copper water cooled panel

14 Improved Refractories

Background

The quality of refractory materials used in the furnace is important for the overall performance. The consumption rate of refractories in smaller capacity EAFs is about 20–35 kg per tonne of liquid steel. For furnaces with water cooling system, the refractory consumption is considerably low at about 5–10 kg per tonne of liquid metal. High refractory consumption in an EAF leads to high downtime resulting in lower productivity and higher production costs.

EE Technology

The furnace bottom is generally prepared with magnesite ramming mass or dead burnt magnesite peas or ready mix and formed as a monolithic layer. The use of type of magnesite is dependent on the grade of steel to be manufactured. For example, for manufacturing of high alloy steel or special steel, high purity magnesia ramming mass is preferred. For side walls, the modern practice includes use of "mag-carb" bricks that are highly resistant to corrosion. Carbon addition in the bricks leads to high thermal shock resistance. At high temperatures, the porosity of refractories is reduced which brings down the potential for penetration by slag or molten metal.

The use of improved refractories, such as castable alumina and Mag-carb refractories, helps in improving the overall life of the furnace, for example the life of side walls with use of Mag-carb refractory is about 200 heats without any repair in case of continuously operated furnaces. This reduces the furnace downtime and enhances productivity.

Savings, Investments and GHG Reduction

The average energy savings with use of improved refractories for furnace bottom, side walls, and roof is estimated to be about 0.2%. The GHG emission reduction potential is about 150 tonne of CO_2 per year.

15 Nitrogen as Carrier in Al-Mix Injector

Background

In stainless steel production from EAFs, typically aluminium mix is injected in the furnace, which acts as a reducing agent. This reduces the yield of liquid metal from the furnace.

EE Technology

In the aluminium mix injector, nitrogen (N_2) can be used as carrier gas in the production of stainless steel. The main advantages of the N_2 -based Al-mix system are (i) reduction in Chromium Oxide (Cr_2O_3) in the slag, (ii) yield improvement, and (iii) reduction in energy consumption.

Savings, Investments and GHG Reduction

The average energy savings with nitrogen as carrier in Al-mix injector is estimated to be about 0.2%. The investment requirements are marginal with immediate payback. The GHG emission reduction potential is about 150 tonne of CO_2 per year.

16 WHR for Boiler Feedwater

Background

The average temperature of melt inside the EAF is about 1650 °C. The off-gases from the furnace leave at about 900° –1200 °C, which is quite high. In most of the EAF plants in India, at present the off-gases are forced to cool down using industrial cooling water so that the gases can be passed through bag filters which have temperature limitations. The waste heat available in off-gases, which is about 15–20% of total heat input can be effectively recovered and reused. Although, the best option for utilizing off-gas heat is preheating of scrap material, there may be constraints in existing layout of the plant for installing scrap preheating system.

EE Technology

The EAF unit typically uses steam for applications, such as vacuum pump operation, in Vacuum Oxygen Decarburization (VOD). The steam requirements are presently met through fossil fuel fired boilers. The feedwater required for steam generation is usually drawn at ambient temperatures. The industrial cooling water is used for reducing the temperature of off-gases in fumes extraction system to meet the temperature requirements of bag filter. This water can be replaced by circulating boiler feedwater. The sensible heat in off-gases will help in preheating of feedwater, which would result in fuel saving in boiler.

Savings, Investments and GHG Reduction

The energy savings for waste heat recovery (WHR) system for preheating boiler feedwater include reduction in fuel consumption. Additional electrical energy will be required for pumping of feedwater in WHR circuit. Typical investment required for WHR system is about ₹10 lakh with a simple payback period of about 3 months. The investment would depend on the physical distance between the EAF and the boiler. The GHG emission reduction potential is about 1,510 tonne of CO_2 per year.

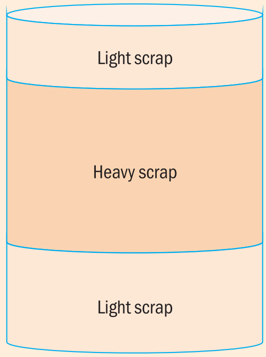
17 Scrap Processing

Background

Scrap is an important charge material in EAF. The bulk density of scrap varies largely and affects the duration of melting. The EAF units use both heavy and light scraps. The scrap constitutes for almost 40%–50% of charge material, about 25%–30% being heavy scrap and about 15%–20% light scrap. A large number of EAF units do not follow proper procedure for scrap management. Scrap processing and management is one of the key parameters that influence the overall performance of the furnace.

EE Technology

Pre-processing of scrap is required to accommodate for variations in bulk density of scrap used by the plant. Scrap processing comprises shredding, cutting, and bailing operations. Any foreign material from the scrap is removed and the bulk density is enhanced by compacting and homogenization. Preparation of charge bucket is important to ensure proper melt-in chemistry, good melting conditions, and for protection of the refractory lining. The bottom of the charging bucket must be filled with light scrap followed by heavy scrap in the middle. The light scrap will be charged again at the top to enable faster melting.



Procedure for scrap charging in bucket

Savings, Investments and GHG Reduction

The average energy savings with scrap processing is about 5%–9%. Typically for a 50 tonne furnace, the investment requirement is about ₹350 lakh with a simple payback period of about 1 year. The GHG emission reduction potential is about 5,170 tonne of CO_2 per year.

Scrap processing in EAF

Parameters	Unit	Values
SEC - without scrap processing	kWh/t	475
Reduction in power on-time	min	6.9
SEC with scrap processing	kWh/t	434
Annual monetary benefits	₹ lakh	225
Investment	₹ lakh	350
Simple payback period	Year	1.6

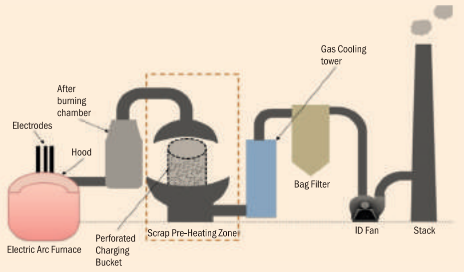
18 Scrap Preheating – Bucket System

Background

Electric arc furnace involves high temperature melting operation. The average temperature of melt inside the furnace is about 1650 °C. The off-gases from the furnace leave at about 900 °C–1200 °C, carrying about 20% of input energy. This waste heat available in off-gases can be effectively recovered and reused which would help in reducing the overall energy consumption of the furnace.

EE Technology

One of the major options for waste heat recovery from off-gases is preheating of input scrap material. In the bucket preheating system, hot off-gases from the furnace are directed into the scrap charging bucket with a piping and special hood arrangement. The off-gases enter the bucket at about 800 °C, and leave at around 200 °C, after imparting sensible heat to the scrap. The scrap can be preheated to about 400 °C. The key advantages include (i) increase in productivity, (ii) removal of moisture from scrap, and (iii) reduction in electrode and refractory consumption.



Bucket type scrap preheater in EAF

Savings, Investments and GHG Reduction

The average energy savings with scrap preheating using bucket arrangement is estimated to be about 8%. Typically for a 50 tonne furnace, the investment requirement for bucket arrangement is about ₹200 lakh with a simple payback period of about 0.5 years. The GHG emission reduction potential is about 5,900 tonne of CO_2 per year.

Bucket scrap preheating system		
Parameters	**Unit**	**Value**
Temperature of off-gases	°C	800
Temperature gain by scrap	°C	300
SEC reduction with preheating	kWh/t	41
Annual monetary benefits	₹ lakh	268.0
Investments	₹ lakh	200
Payback period	Year	0.7

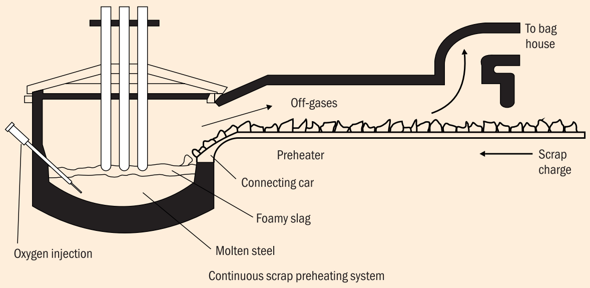
19 Scrap Preheating–Continuous System

Background

Electric arc furnace involves high temperature melting operation. The average temperature of melt inside the furnace is about 1650 °C. The off-gases from the furnace leave at about 900 °C–1200 °C, carrying about 20% of input energy. This waste heat available in off-gases can be effectively recovered and reused which would help in reducing the overall energy consumption of the furnace.

EE Technology

One of the major options for waste heat recovery from off-gases is preheating of input scrap material. In a continuous scrap preheating system, the scrap is placed on a conveyor and passed through the preheating section. The off-gases from the EAF are routed through the preheater in a counter flow direction. The preheated scrap fed to the furnace is transferred through the conveyor car.



Continuous scrap preheating system

The key advantages of the continuous scrap preheating system include (i) increase in productivity, (ii) removal of moisture from scrap, (iii) reduced electrode and refractory consumption, and (iv) reduction in dust generation.

Savings, Investments and GHG Reduction

The average energy savings with scrap preheating using continuous type arrangement is estimated to be about 12%. Typically for a 50 tonne furnace, the investment requirement is about ₹400 lakh with a simple payback period of about 1 year. The GHG emission reduction potential is about 8,860 tonne of CO_2 per year.

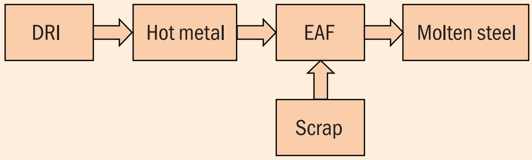
20 Hot Metal Charging

Background

A majority of the EAFs in India use charge materials at ambient temperatures. The units equipped with DRI process along with EAF can charge the hot DRI directly in the furnaces. The major reason for not using hot metal is improper layout to handle hot charge to feed in the furnace.

EE Technology

There is a great potential to charge hot direct reduced iron (DRI)/hot briquetted iron (HBI) directly into arc furnaces at a temperature of about 600 °C. The hot metal can be charged in a controlled manner to take care of carbon content in liquid metal bath. Further, hot metal is free of foreign non-metallic materials which would have been removed as slag during iron making process. Depending on the existing layout of the unit, one of the following systems can be adopted for hot DRI charging in EAFs: (i) pneumatic transfer, (ii) electro-mechanical conveyor system, (iii) gravity feed, and (iv) transport in insulated bottles. The major benefits associated with hot metal charging in EAF include (i) enhancement of productivity, (ii) improvement in slag foaming, and (iii) increase in carbon content in the charge.



Hot metal charging in EAF

Savings, Investments and GHG Reduction

The energy savings for hot DRI charging depends largely on the share of DRI in input feed. Typically in furnaces with 50% DRI charging, the energy saving potential is about 150 kWh per tonne of liquid metal, considering a hot DRI temperature of 600 ^{0}C. The GHG emission reduction potential is about 22,140 tonne of CO_2 per year.

21 Shaft Furnace

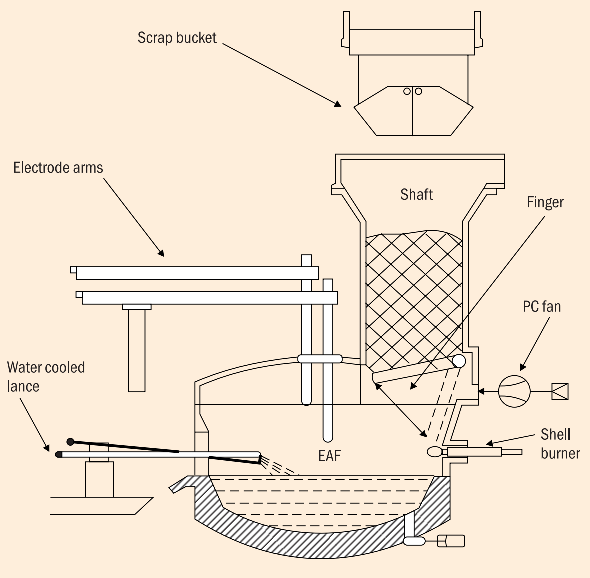
Background

Scrap preheating is an important technology for improving the energy performance of the EAFs. Typically, scrap preheating is either not in use or a bucket preheating arrangement is adopted. With this arrangement the improvement is energy efficiency is limited.

EE Technology

Shaft furnace is an advanced scrap preheating system. In a shaft furnace, the preheating arrangement is mounted over the arc furnace itself. The different types of shaft furnaces used in EAFs are (i) single shaft, (ii) double shaft, and (iii) finger shaft. In a single shaft furnace, about 50% of the scrap can be preheated. A double shaft furnace is an improvement to the single shaft furnace, which consists of two identical shaft furnaces, having twin shell arrangement and positioned next to one another.

The most efficient shaft-furnace design is the "finger shaft furnace". The scrap is charged into the furnace through the shaft. Off-gases pass through the shaft and heat the scrap. The finger shaft is water cooled to ensure smooth operation. The advantages of finger shaft furnace are (i) high energy saving and (ii) increase in productivity by about 20%.



Finger shaft furnace

Savings, Investments and GHG Reduction

The average energy savings with finger shaft furnace is estimated to be about 15%–20%. Typically for a furnace of 50 tonne capacity, the investment requirement is about ₹2,500 lakh with simple payback period of about 3–4 years. The GHG emission reduction potential is about 11,070 tonne of CO_2 per year.

22 DC Arc Furnace

Background

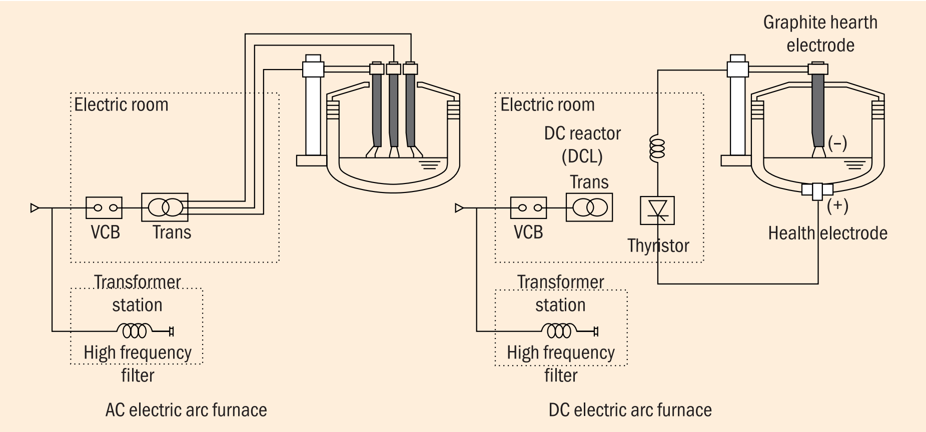
The EAF units in India use AC electric arc furnace. In an AC EAF, the electric arc forms between the three electrodes and the melt. The major issues associated with AC EAFs include frequent electrode tip breakage and higher radiation loss to side walls. The electrode consumption of AC-arc furnaces in India varies between 3–4 kg per tonne of liquid melt.

EE Technology

DC arc furnace is an alternative to the AC-based EAF. The output of the UHP transformer is converted to DC using a power rectifier usually bridge-connected thyristors. DC-EAF has only one electrode which acts as a cathode whereas a return electrode known as anode is at bottom of the furnace. The major advantages of DC-EAF are (i) high current density and power usage, (ii) low electrode and refractory consumption, and (iii) less flickers.

AC-EAF vs DC-EAF

Parameter	Unit	AC-EAF	DC-EAF
Electrical losses	%	4.0	5.5
Electrode use			
Tip	kg/t	0.721	0.845
Side	kg/t	0.919	0.398



Savings, Investments and GHG Reduction

The average energy savings with DC arc furnace is about 5%. Typically for a furnace of 50 tonne capacity, the investment requirement is about ₹2,500 lakh. The monetary benefits from reduction in consumption of electrodes will be substantial. The simple payback period will be about 2 years. The GHG emission reduction potential is about 3,690 tonne of CO_2 per year.

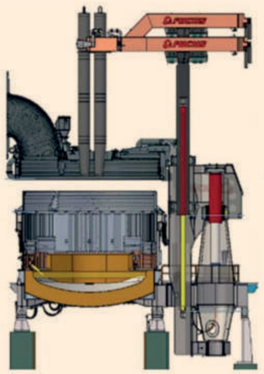
23 Single Bucket Charging System

Background

In conventional EAFs, a minimum charge density must be maintained which otherwise would lead to increase in number of bucket charges. This would lead to interruptions in melting process resulting in loss in productivity and poor energy performance. Typically, in Indian EAFs, roughly 10%–15% time is lost in every heat due to multiple bucket charging.

EE Technology

In an EAF with telescopic roof enclosure system, a single bucket system with low charge density can be used without increasing shell diameter and height. The telescopic system allows flexible shell charging volume and the electrode length can be significantly shorter. With the start of scrap melting, the roof along with electrode columns is lowered to follow the reducing height of charge volume. The roof is gradually slid down to completely closed position which leads to overlapping between roof and part of upper shell. The lifting system for roof and electrodes are independent which allows electrodes to continuously track falling height of charge pile.



Telescopic roof EAF

The major advantages of single bucket charging system with telescopic arrangement include (i) ability to handle low charge density i.e. 0.55 tonne per m^3 (ii) less tap-to-tap time, (iii) low power-OFF time, and (iv) low electrode consumption and breakage.

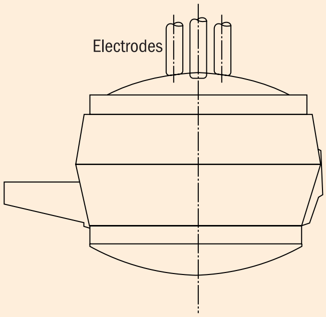
Savings, Investments and GHG Reduction

The average energy savings with telescopic roof-based single bucket charging system is estimated to be about 10%–15%. This type of furnace is presently available for capacity in excess of 100 tonnes. The investment requirement is about ₹3,000 lakh with simple payback period of about 5 years. The GHG emission reduction potential is about 7,380 tonne of CO_2 per year.

24 Tapered Shell Furnace

Background

The EAFs have uniform cross-section along the height of the furnace. This would result in hot spots close to side walls leading to reduced lining life of the furnace. It would further increase heat losses to side walls thereby reducing the efficiency of the furnace system.



Tapered shell furnace

EE Technology

One of the solutions for reducing the hot spots and heat losses to side walls is use of tapered shell design for the furnace. In this design, the furnace volume is increased without increasing the shell height. This is achieved by increasing the shell diameter only midway between sill-line and the top bezel ring. The bezel ring helps in maintaining the shape of the top of the furnace shell. This arrangement is more useful for large capacity furnaces.

The associated benefits of tapered shell furnace include (i) longer life of side wall lining due to larger diameter of the shell at the hot spots and (ii) lower heat losses, and (iii) better heating of the charge material.

25 Neural Network for Process Control

Background

The present control systems for EAF operation through modelling of the dynamic parameters have not yielded optimum results. The existing process control for electrode regulation systems provide energy saving of about 3%. However there is a further scope for more efficient operation based on state-of-the-art process control.

EE Technology

Recent advancements have led to the use of artificial intelligence-based electrode controllers. Intelligent data processing with neural networks offers a better solution for electrode regulation system. These intelligent systems integrate real-time monitoring of process variables, such as liquid metal temperature, carbon percentages, and oxygen lancing practices.

Savings, Investments and GHG Reduction

The average energy savings with neural networks based electric arc furnace electrode regulation system is estimated to be about 3%–5%. Typically for a furnace of 50 tonne capacity, the investment requirement is about ₹150 lakh with a simple payback period of about 6 months. The GHG emission reduction potential is about 2,950 tonne of CO_2 per year.

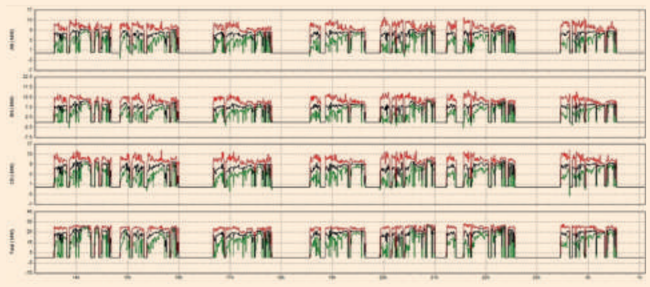
Neural network for process control		
Parameter	**Unit**	**Value**
Energy saving	kWh/t	30
Electrode saving	kg/t	0.5
Productivity improvement	%	10
Monetary benefit	₹/t	50
Investment	₹ lakh	150
Simple payback period	Years	3

26 Variable Frequency Drives in ID Fans

Background

The off-gases generated from various reactions inside EAF are removed using fumes extraction system, which is typically equipped with an ID fan. The load on ID fan is maximum during 'power-ON' period (i.e. arcing) and minimum during 'power-OFF' period which is about 20%–30% of overall batch duration.

EE Technology



A sample of loading pattern of EAF

During the power-OFF period, the speed of ID fan can be reduced using variable frequency drive (VFD). Upon sensing the power conditions of the furnace, the VFD would change the speed (high or low) of the ID fan based on pre-set parameters. With VFD application, the ID fan is operated at full speed during power-ON and about 15-30% of design rated speed during power-OFF.

Savings, Investments and GHG Reduction

The typical energy savings with VFD application on ID fan of primary fumes extraction system is estimated to be about 10%. Typically for a 50 tonne furnace, the investment requirement is about ₹7.5 lakh with simple payback period of about one year. The GHG emission reduction potential is about 120 tonne of CO_2 per year.

VFD application in ID fan: Case study			
Parameter	**Unit**	**Fixed speed**	**VFD**
Consumption during power ON	kW	196	196
Consumption during power-OFF	kW	196	68
Duration of power-OFF	min	17	17
Power consumption per heat	kWh/t	9.15	8.11
Annual monetary benefits	₹ lakh	-	7.5
Investment	₹ lakh	-	7.5
Simple payback period	Years	-	1

27 Intelligent Control for Off-Gas Cleaning

Background

Off-gas cleaning is an integral part of EAF operation which however remains as a neglected auxiliary system. It is often less efficient and offers significant potential for improvement. The gas cleaning is an important aspect in terms of complying with environmental performance standards as applicable.

EE Technology

A gas cleaning system comprises a number of extraction points from where the off-gases are sucked. In a gas cleaning with intelligent control, the cleaning system is mapped in mathematical model and loaded into the control unit. The mathematical model evaluates required flap settings and flow rates in individual network segments in real time and controls dynamically. The monitoring arrangement at an extraction point will ensure that the flow rate of off-gases do not fall below a certain minimum level, independent of flow rates required at other extraction points. The monitoring function of the control system ensures reliability in long-term planning for operation and servicing of the fumes extraction system.

Savings, Investments and GHG Reduction

The typical energy savings with adoption of intelligent control for off-gas cooling is estimated to be about 20% of the fumes extraction system. Typically for a 50 tonne furnace, the saving is in tune of 1–1.5 kWh per tonne of liquid metal. The GHG emission reduction potential is about 210 tonne of CO_2 per year.

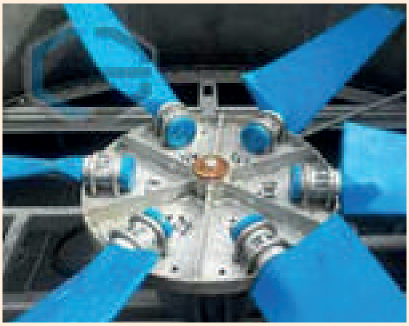
28 FRP Blades for Cooling Tower Fans

Background

The sidewalls, roof, and electrodes of the EAF are water cooled to protect the furnace system. Cooling towers are used to meet the cooling demand. Metal blades (aluminium) are commonly used in cooling tower fans. The metal blades increase the overall weight of the cooling system leading to additional power consumption.

EE Technology

The metal blades in cooling tower fan can be replaced with 'fibre reinforced plastic' (FRP) blades, which are lighter. Use of FRP blades would reduce the power consumption of cooling tower system. It further increases the possibility of de-rating or re-sizing the motor capacity of cooling tower fan to a lower sized motor. The other advantages of FRP blade include high reliability and better performance due to lower failure rate.



FRP fan blades for cooling towers

Savings, Investments and GHG Reduction

The typical energy savings with use of FRP fan blades in cooling towers is about 15–25%. Typically for a cooling tower of 1.5 lakh kCal capacity, the energy saving is in tune of 0.2 kWh per tonne of liquid metal. The GHG emission reduction potential is about 40 tonne of CO_2 per year.

FRP blades for cooling tower fan			
Parameters	**Unit**	**Metal blade**	**FRP blade**
Rated capacity	kW	37.0	22.4
Input power	kW	26.3	19.7
Annual monetary saving	₹ lakh	–	2.0
Investment	₹ lakh	–	1.6
Simple payback period	Year	–	0.8

29 Thermostatic Controller for Cooling Tower

Background

The main function of a cooling tower is to reduce the temperature of incoming water based on wet bulb temperature and relative humidity of ambient conditions. A majority of the cooling towers are not equipped with automatic controls to regulate fan operation. A few units control the cooling tower operations manually based on outlet temperatures of cooling water.

EE Technology

The seasonal variations in ambient temperatures and relative humidity show that the cooling tower requires continuous monitoring of temperatures for effective operation. The maximum possible drop in temperature of cooling water is limited to the wet bulb temperature of the ambient conditions. Automatic controls are preferred over manual operation for cooling tower fans. The most common system used in cooling towers is thermostatic controller. The controller switches- on or off the cooling tower fans automatically based on prevailing level of cooling water temperature.

Savings, Investments and GHG Reduction

The typical energy savings with installation of thermostatic controllers in cooling water circuit is about 5%–10% depending on geographical location. Typically for a cooling tower of 1.5 lakh kCal capacity, the energy saving is in tune of 0.1 kWh per tonne of liquid metal. The GHG emission reduction potential is about 20 tonne of CO_2 per year.

30 Energy Efficient Centrifugal Pump

Background

The cooling water system for an EAF requires pumping to reject the heat gained. Pumps are also used in jacket cooling in fumes extraction system. Typically the efficiency of the pumps used in cooling water circuit is lower, in range of 40%–60%. Improvements in energy efficiency of the pumps would help in reducing the overall energy consumption in auxiliary systems.

EE Technology

The design of an efficient pumping system depends on the relationships between fluid flow rate, piping layout, control techniques, and pump selection. Centrifugal pumps can handle high flow rates, provide smooth, non-pulsating delivery, and regulate flow rate over a wide range at higher efficiency levels. Selection of an energy efficient pump is based on performance curves. By keeping the operation close to the 'best efficiency point' (BEP), a pump can be operated efficiently while meeting the process requirements, such as flow rate and head, for a particular type of pump and impeller size. To minimize energy consumption, the pump should be selected in such a manner that the system curve intersects the pump curve within 20% of its BEP.

Savings, Investments and GHG Reduction

The energy savings with use of EE pumps in cooling water system is about 15%–25%. Typically for a 100 hp pump, circulating cooling water to a 50 tonne EAF, the energy saving potential is about 0.5–1 kWh per tonne of liquid metal. The investment requirement is about ₹5 lakhs with a simple payback period of 6 months. The GHG emission reduction potential is about 90 tonne of CO_2 per year.

Energy efficient pump			
Parameter	**Unit**	**Existing pump**	**EE pump**
Flow rate	m^3/h	338	340
Head	m	45	45
Input power	kW	76	56
Pump efficiency	%	54	75
Annual monetary saving	₹ lakh	-	8
Investment	₹ lakh	-	5
Simple payback period	Year	-	0.6

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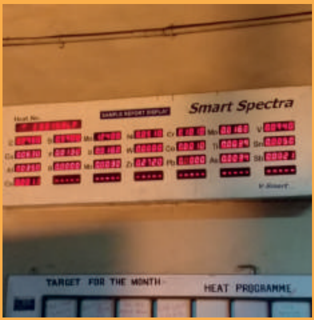
Smart Spectra
TARGET FOR THE MONTH
HEAT PROGRAMME