JSW STEEL LTD (SISCOL) - ACHIEVED ONE MILLION TONNE STEEL MAKING CAPACITY WITH THE COMMISSIONING OF THE WORLD'S LARGEST ENERGY OPTIMIZING FURNACE [1]

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Abstract

The new 65 t Energy Optimizing Furnace (EOF) of Southern Iron And Steel Company Limited (SISCOL), a steel plant of the JINDAL Group, was commissioned, as part of the expansion plan for increasing the steel production to one million ton per annum of special steels. After having considered various options for steel making, the EOF route was selected for this expansion. Since commissioning, the new EOF has been operating continuously, confirming that the option was the right one. This paper presents the plant configuration upstream and downstream of the EOF, and the statistical data on the performance of the furnace. Easiness of EOF operation and predictability of timing are the basis of the high productivity already achieved. Process standardization of Steel Making through EOF has been implemented at SISCOL. Efficient dephosphorization and the reliable catch carbon technique account for steel quality and cost effectiveness, as expected when the option for EOF was adopted.

Key works: EOF; Submerged oxygen blow.

JSW STEEL LTD (SISCOL) - ALCANÇA CAPACIDADE ANUAL DE UM MILHÃO DE TONELADAS DE AÇO, AO DAR PARTIDA AO MAIOR EOF DO MUNDO

Resumo

O novo forno EOF de 65t da SISCOL, uma aciaria do Grupo JINDAL, entrou em operação, como parte de um plano de expansão da produção de aço para um milhão de toneladas por ano de aços especiais. Após terem sido consideradas varias opções de aciaria, a rota EOF foi selecionada. Desde a posta em marcha, o novo EOF tem operado continuamente, confirmando que foi a opção correta. Este trabalho apresenta a configuração da usina a montante e a jusante do EOF, e dados estatísticos do desempenho do forno. A facilidade de operação e previsibilidade do EOF são as bases para a alta produtividade já alcançada. O processo de padronização da produção de aço via EOF tem sido implementado na SISCOL. A eficiente desfosforação e a confiável descarburação respondem pela qualidade do aço e baixo custo, o que era esperado quando a opção pelo EOF foi adotada.

Palavras-chave: EOF; Sopro submerso de oxigênio

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Introduction

SISCOL commissioned the world's largest 65 t EOF on 18th October 2007 with the successful tapping in the very first attempt. SISCOL already had experience of operating 35/45 t capacity EOF for over nine years before commissioning the 65 t EOF. From the ground breaking to commissioning, it took total eighteen months for project completion.

Apart from the EOF shell itself, the other important equipments of the 65 t EOF are: stand-by shell, water system, hydraulic systems, valve stand for oxygen/nitrogen/argon gases, lime and ferroalloy feeding system, gas cleaning system, electrical, instrumentation, automation and control system. The EOF main shell, stand-by shell including ladles and other equipments were purchased from M/s A.F.Servola, Trieste, Italy. All other parts of EOF were fabricated and procured in India.

Figure 1. 65 t EOF - Tapping of Steel

In the very first campaign of 65 t EOF, campaign life of 603 heats was achieved, in which 37.344 t billets were produced. During this campaign the steel qualities manufactured were carbon construction steel, carbon and low alloy special steels for forging and automotive applications, free cutting steels, cold heading quality steels and drawing quality carbon steels. The key operating parameters during the 1st campaign are shown in Table 2 hereunder.

The main features of 65 T EOF are shown in Table 1.

Table 1 - Main Features of 65 t EOF

1	Technology	MINITEC – Brazil
2	Capacity per annum	0.6 million t
3	Steel grades	Carbon and Low Alloy Special Steels
4	Shell diameter	6500 mm
5	Hot Metal Input per Heat	60 t (81%)
6	Scrap Input per Heat	14 t (19%)
7	Oxygen blowing	Top & bottom combined blowing
8	Blowing time	30 min
9	Tap to Tap time	45 min
10	Number of heats per day	32 heats
11	Total Refractory consumption	8 kg / t
12	GCP system	Wet type
13	Exhaust Gas volume at Peak of blow	85000 Nm^3/h
14	Clean-ness of Exhaust gas	<50 mg/Nm^3
15	Spare bottom with shell	Faster bottom changing
16	Bottom Tilting	Slag flushing & slag free tapping
17	B.T. type Steel Launder	Slag free tapping.

Table 2 - 65 t EOF - First Campaign Operating Data

	Key Operating Parameter	Parameter achieved
1	Hot metal in charge	80.11%
2	Solid scrap charge	19.89%
3	Average heat size	61.93 t (billets) (*)
4	Charge to liquid Metal	90.1%
5	Charge to billet yield	87.1%
6	Blowing time	38 min
7	Oxygen consumption	66 m^3/t
8	Average power consumption	65 kWh/t
9	Average lime consumption	58 kg/t
10	Refractory consumption	6.5 kg/t
11	Gunning material consumption	4.16 kg/t

(*) Heat size during part of first campaign was limited to 62 t, due to unavailability of new bloom caster.

As expected, the operation and consumption norms were not the very best in the first campaign. Action plan has been drawn to improve upon the operational parameters in the subsequent campaigns, to the desired levels, namely 60 Nm^3/t oxygen consumption and 40 kWh/t power. It needs to be mentioned that the steel produced in the first campaign was meeting the specifications with regard to phosphorous levels, slag free tapping, control over opening carbon etc. In the first campaign, full attention was given on achieving safe operation of the 65 t EOF.
The capital expenditure for the installation of 65 t EOF was US $ 4,25 million for a capacity increase of 600,000 t per annum.

COMMISSIONING OF 3-STRAND BLOOM CASTER

SISCOL commissioned 3-strand Bloom Caster on 21st December 2007.
The main features of the Bloom Caster are shown hereunder in Table 3.

Table 3 - Special Features of Bloom Caster

1	No. of strands	3
2	Machine radius	12 m
3	Sections	Rounds - 160, 200, 220, 310 mm Ø Square 250 and 340 x 400 mm
4	Steel Quality	Carbon and low alloy special steels
5	Casting speed	0 - 4 m/min
6	Turret	H-Type Liftable Ladle Turret
7	Tundish Car	Gantry Type
8	Tundish capacity	18 t (deep tundish)
9	Automatic Mould Level control	Electro mechanically operated automatic stopper control system
10	Electro Magnetic Stirrer	Mould EMS
11	Oscillation	Hydraulic
12	Secondary cooling	Air mist cooling
13	Withdrawal Straightner	4 Nos – hydraulic
14	Unbending	3 Points bending - 12 / 16.5 / 30m
15	Cutting	Automatic cutting torches
16	Cutting length	3,5 to 7,0 m for square section 7,0 to 11,0 m for round section
17	Cooling bed	Sq. Section: Pusher type Collecting bed Round Section – Walking beam cooling bed

The production capacity of the bloom caster is 650,000 t per annum of Carbon and Low alloy special steels.

SISCOL - 1 MILLION TONNE

With the commissioning of 65 t EOF and the bloom caster, the as-cast billet/bloom production capacity of SISCOL has increased to one million tonne per annum.

TOTAL 'AS CAST' STEEL CAPACITY 1,000,000 t / annum

	65 t EOF	45 t EOF
Bloom/Billet production per annum	600,000 t	400,000 t
Liquid metal production per annum	625,000 t	420,000 t
No. of working days	335	335
Production per day	1.865 t	1.255 t
Heat size	65 t	45 t
No. of heats per day	29	28

Note: Table above shows average production/annum for carbon and low alloy steels. The maximum heats per day for individual EOF would go up to 32 heats per day, which is quite practical to achieve.

MAIN FACILITIES AT SISCOL:

Presently, the main facilities at SISCOL are as under:

1 67.5 MW capacity power generation (30 MW coal based and balance waste gas base)

2 0.4 million tonne heat recovery Coke Oven Plant.

3 0.2 million tonne, 20 m^2 Sinter Plant
4 1.1 million tonne, 90 m^2 Sinter Plant
5 402 m^3 Blast Furnace capacity - 0.4 million tonne of hot metal per annum
6 550 m^3 Blast Furnace capacity –0.6 million tonne of hot metal per annum
7 Pulverized Coal Injection system common for both the Blast Furnaces
8 150 tpd Oxygen plant - 1 no. Oxygen, Nitrogen and Argon gases
9 390 tpd Oxygen plant - 1 no. Oxygen, Nitrogen and Argon gases
10 45 t EOF - 1 no.
11 65 t EOF - 1 no.
12. 45 t Ladle Furnace - 1 no.
13 65 t Ladle Furnace - 2 nos.
14 65 t Vacuum Degassing unit - 1 no.
15 9 / 16 m radius, 3-strand 130/160 sq.mm billet caster - 1 no.
16 12 M radius, 3 strand Bloom caster for rounds and squares - 1 no.
17 Bar & Rod Mill - having 18 stands H/V mill and 10 stands No Twist Block

Wire Rod coils	5,5 to 16 mm dia
Garret coils	17 to 32 mm dia
Straight lengths	16 to 60 mm dia.

PROJECTS UNDER IMPLEMENTATION

The following projects are under implementation at SISCOL, with their scheduled dates of commissioning:

1. Addition of 24 coke ovens for producing 100,000 t of metallurgical coke. - March 2008
2. 300 tpd Lime Kiln for captive consumption - Sept. 2008
3. 1 no. Ladle Furnace for 45 / 65 t ladles - May 2008
4. 1 no. Vacuum Degassing station for 45 / 65 t ladles - Aug 2008
5. Blooming Mill project for rolling 60 mm to 200 mm in RCS and Rounds. - Dec. 2008

PROCESS STANDARDIZATION OF EOF

EOF is a very high productivity equipment for converting the combination of hot metal and solid scrap to crude steel suitable for secondary refining. Due to combined blowing, the rate of decarburization and dephosphorization is very fast, in order to achieve low blowing times to 25 / 30 minutes. The productivity in the EOF is much faster than in EAF using up to 60% hot metal. The productivity in EOF is similar to that of LD converter, which usually have 20 to 25 minutes blowing period. Since continuous flushing of high silica slag is possible in the EOF, we are able to achieve over 80% of the heats below 0.015% phosphorous even at slag basicity of 2.8 to 3.2. At SISCOL, we are working on process improvement in order to achieve the following:

(a) Charge to Liquid metal yield - 92 %
(b) Blowing time - 20 to 25 min
(c) Total refractory consumption - 6,5 kg/t

Through detailed data analysis it is established that, if percentage of carbon during tapping from EOF could be controlled above 0,10%, the achievement of the above objectives becomes much easier. Practicing catch carbon consistently is easier in EOF as compared to the LD converters since there is a facility to draw samples in EOF during the process through the slag door.
Percentage carbon *versus* Oxygen ppm for EOF processing was established after taking bath samples along the heat. Figure 2 shows the variation of oxygen ppm with carbon percentage in 45 t EOF.

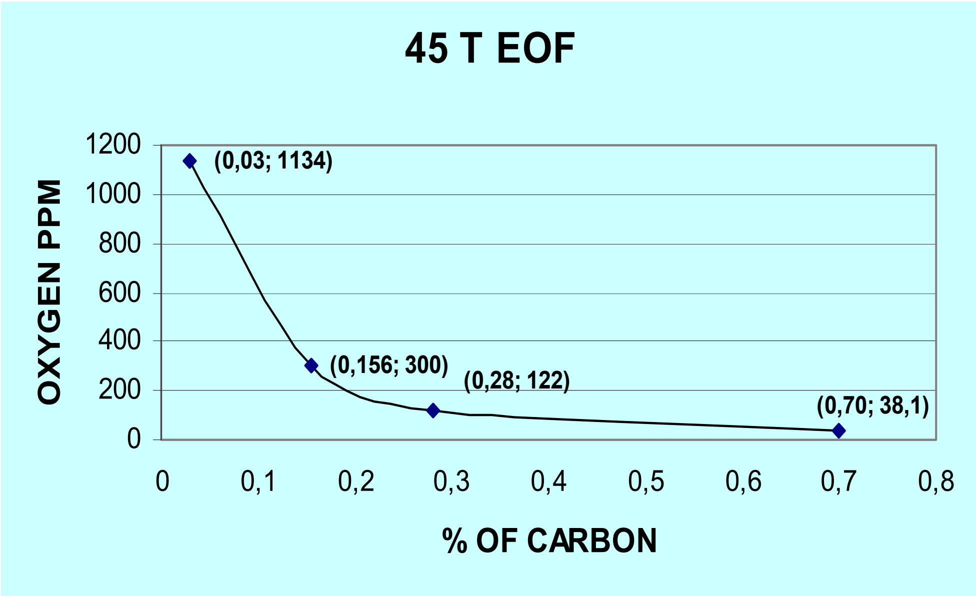

Figure 2 - Carbon vs Oxygen Variation in EOF

Data was collected from a number of heats and correlation was established for the following parameters:

(a) Carbon percentage drop in the steel bath with the quantity of oxygen blown through tuyeres.

(b) Carbon percentage drop in the steel bath with the quantity of oxygen injected through the injectors and SS lances.

(c) Carbon percentage drop in the steel bath with total oxygen blown in the EOF.

Good correlation was established in the cases of (a), (b) and (c), i.e., drop of carbon percentage with oxygen blown through tuyeres, atmospheric injector and total oxygen. 'R' - (Pearson Co-efficient Rank) was 0,92 for Oxygen blown through tuyeres, 0,89 for oxygen blown through atmospheric injectors and 0,90 for total oxygen flow. The drop of carbon percentage with m³ of oxygen blown through tuyeres, injectors and total oxygen is shown in Figures 3, 4 and 5.

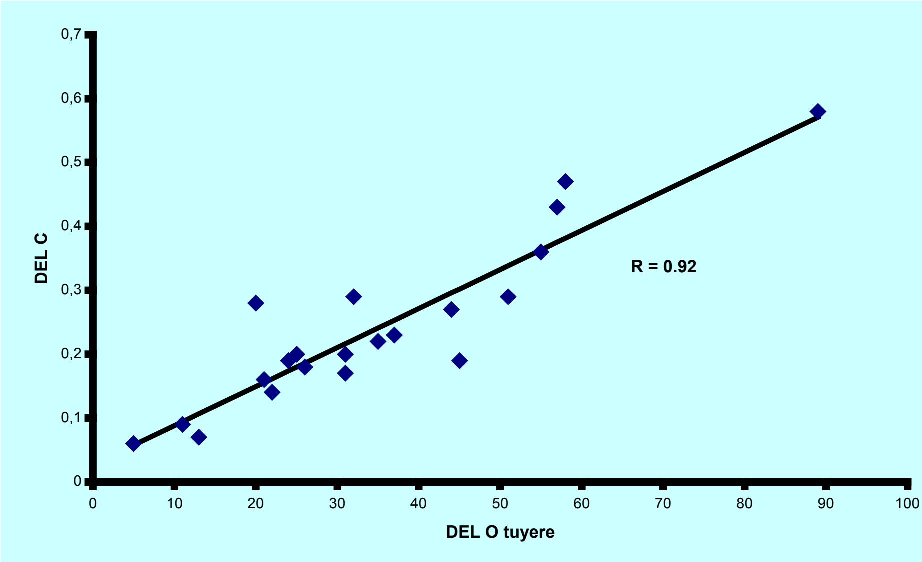

Figure 3 - Variation of Carbon with Oxygen Blowing through Tuyere

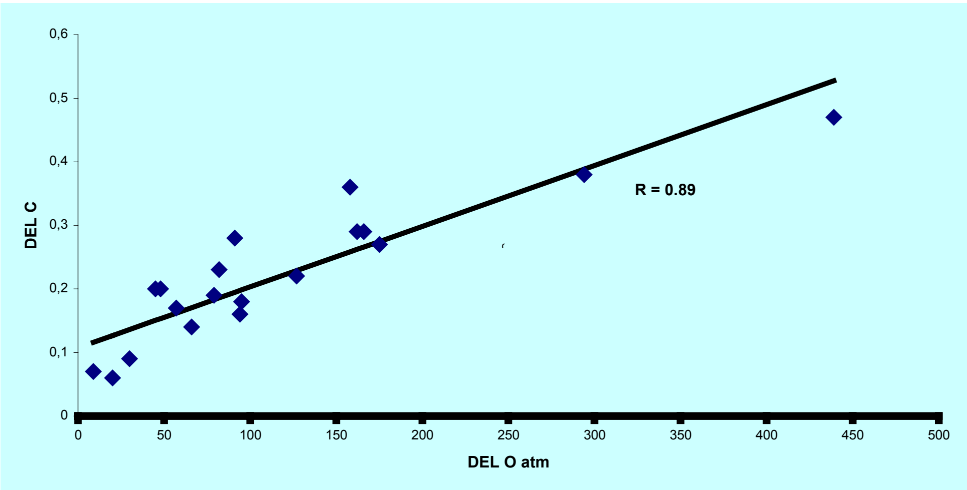

Figure 4 - Variation of Carbon with Oxygen Blowing through Injectors

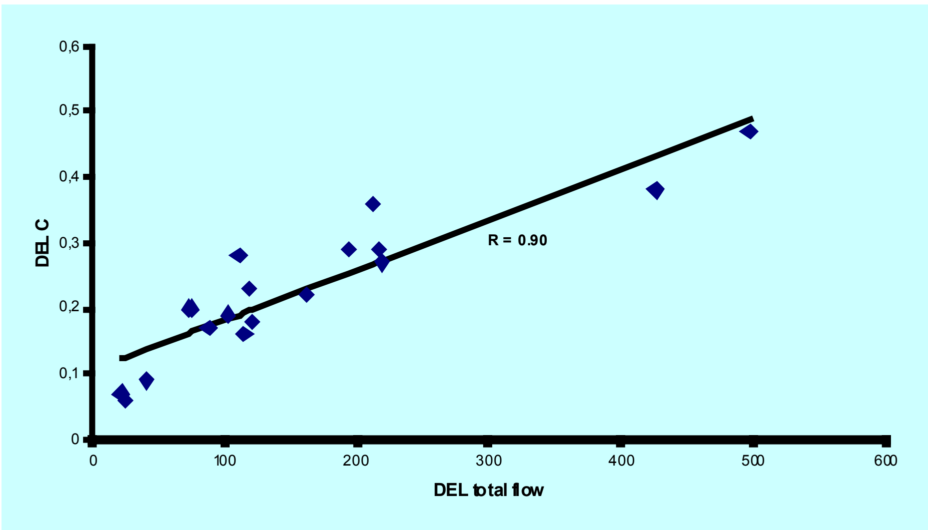

Figure 5 - Variation of Carbon with Total Oxygen

Through the above studies, a pattern was established for percentage carbon drop with total oxygen consumed between the two bath samples. Earlier the practice was to take 3 samples in the EOF bath per heat. The decision for tapping the steel was taken on the basis of the 3rd sample, which was only 1 or 2 minutes before opening the tap hole and as a result, most of the casts were having carbon percentage below 0,10 in the ladle after tapping.

Through the above analysis carried out at SISCOL, the decision-making was shifted to the second sample, which was taken at least 5 to 7 minutes before tapping.

Table 4 – Catch Carbon Result for low Carbon Steels

34146	**TMT**	**0,08**	**0,15**	**0,5**	**0,03**	**33**
34147	**TMT**	**0,19**	**0,16**	**0,54**	**0,028**	**34**
34148	**TMT**	**0,24**	**0,14**	**0,45**	**0,046**	**38**
34149	**TMT**	**0,13**	**0,14**	**0,51**	**0,05**	**30**
34150	**TMT**	**0,2**	**0,14**	**0,5**	**0,033**	**35**
34151	**TMT**	**0,14**	**0,18**	**0,54**	**0,014**	**32**
AVERAGE		**0,16**	**0,15**	**0,52**	**0,030**	**33**
			TWO SUPERSONIC LANCE			
				LPI		**BLOW TIME**
HEAT NO:	**GRADE**	**C**	**Si**	**Mn**	**P**	**in Min**
34248	**TMT**	**0,13**	**0,15**	**0,48**	**0,026**	**25**
34249	**TMT**	**0,1**	**0,13**	**0,49**	**0,023**	**34**
34250	**TMT**	**0,14**	**0,13**	**0,4**	**0,026**	**25**
34251	**TMT**	**0,15**	**0,12**	**0,4**	**0,025**	**31**
AVERAGE		**0,14**	**0,14**	**0,46**	**0,026**	**29,65**

Through this technique, opening carbon from the steel bath was improved above 0.10% in over 80% of the heats. The representative results of proper catch carbon process are shown in Tables 4 and 5.

Table 5 - Catch Carbon Results for Medium Carbon Steels

				LPI		**BLOW TIME**
HEAT NO:	**GRADE**	**C**	**Si**	**Mn**	**P**	**in Min**
33916	**Sup-9**	**0,28**	**0,1**	**0,38**	**0,009**	**28**
33917	**Sup-9**	**0,26**	**0,14**	**0,49**	**0,014**	**32**
33918	**Sup-9**	**0,25**	**0,14**	**0,51**	**0,013**	**31**
33919	**Sup-9**	**0,26**	**0,13**	**0,47**	**0,014**	**34**
33920	**Sup-9**	**0,35**	**0,13**	**0,46**	**0,013**	**32**
AVERAGE		**0,28**	**0,128**	**0,462**	**0,0126**	**31,4**
				LPI		**BLOW TIME**
HEAT NO:	**GRADE**	**C**	**Si**	**Mn**	**P**	**in Min**
33996	**C45 E**	**0,16**	**0,11**	**0,51**	**0,011**	**32**
33997	**S43 C**	**0,33**	**0,11**	**0,53**	**0,01**	**44**
33998	**S43 C**	**0,14**	**0,1**	**0,49**	**0,012**	**33**
33999	**C45 E**	**0,1**	**0,09**	**0,41**	**0,011**	**34**
34000	**C45 E**	**0,19**	**0,11**	**0,49**	**0,013**	**37**
AVERAGE		**0,184**	**0,104**	**0,486**	**0,0114**	**36**

The catch carbon process helped in the improvement of the following:
(a) Charge to Liquid metal yield
(b) Blowing time reduction
(c) Recovery of Silicon and Aluminium
(d) Improvements in furnace life and gunning mass consumption.
The improvement in the recovery of Silicon is shown in Figure 6.

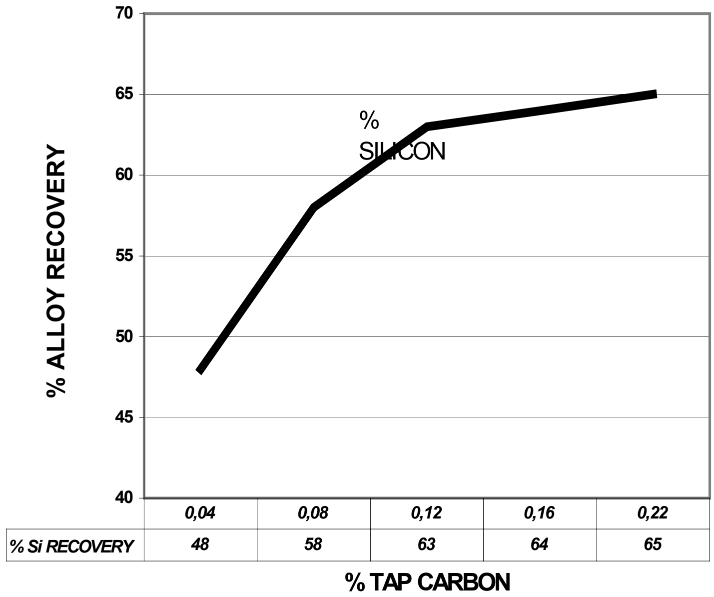

Figure 6 – Silicon Recovery Variation with Opening Carbon

The improvement in the recovery of Ferro alloys and liquid metal yield is shown in Table 6 hereunder.

Table 6. The improvement in the recovery of Ferro alloys and liquid metal yield

	Ferro Alloy	Saving in kg/t	Value in US$/t
(i)	**FeSi**	**0,93**	**1,00**
(ii)	**SiMn**	**0,79**	**0,72**
(iii)	**Graphite Fines**	**1,92**	**1,29**
	Al Ingots	**0,05**	**0,18**
	Fe-Al	**1,19**	**2,30**
	Ca-Si Wire	**0,018**	**0,06**
Savings to recovery of ferro alloys			**5,55**
Savings due to liquid metal yield			**2,10**
Total savings US$/t			**7,65**

At SISCOL, we are carrying out developmental work in the area of EOF in collaboration with Government College of Engineering, Salem, Tamil Nadu, India and M/s MINITEC Minitecnologias Ltda., Divinopolis, Brazil for further improvement of productivity, improvements in the quality of liquid steel and cost reduction through EOF route.

CONCLUDING REMARKS:

SISCOL is the only steel plant in the world producing one million tonne per annum through EOF route. It has been well established that the EOF process is of very high productivity and a safe operation for mass production of steel. EOF is exceptionally good tool for producing special steels. The capital investment is quite low amongst the various options and the operating costs are very economical. Moreover, the EOF has still a lot of scope for further improvements and developmental work.

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