SISCOL – ONE MILLION TONNES STEEL EXPANSION THROUGH ENERGY OPTIMIZING FURNACES[1]

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Abstract

Southern Iron and Steel Company Ltd (SISCOL) is a steel plant of the JINDAL Group, which operates twenty different steel facilities in India and abroad, based on different technological routes including COREX. SISCOL had a production capacity of 200,000 t per annum of carbon construction steel. Through technological upgrading the capacity of the existing production line is being increased to 400,000 t/year. SISCOL has taken up expansion plan for increasing the steel production to one million tons per annum of special steels through EOF route. A new production line is under implementation with a capacity of 600,000 t per annum. At the time of planning the second production line, various options for steel making were considered: LD Converter, Energy Optimizing Furnace and Electric Arc Furnace (EAF). Under Indian conditions, the Energy Optimizing Furnace was the most appropriate selection for the additional production, from the view point of capital investment and operating cost. Capital expenditure in Energy Optimizing Furnace is clearly lower than in LD converter and EAF. The cost of production in EOF, under Indian conditions, is lower than EAF and LD converter.

Key words: Energy; Optimizing; Furnace.

SISCOL – EXPANSÃO PARA UM MILHÃO DE TONELADAS DE AÇO VIA EOF – ENERGY OPTMIZING FURNACES

Resumo

A SISCOL – Southern Iron and Steel Company Ltd é uma usina siderúrgica do grupo JINDAL, que opera 20 unidades siderúrgicas na India e no exterior, baseadas em diferentes tecnologias, incluindo o processo COREX. A SISCOL tinha uma produção de 200.000 t/ano de aço ao carbono para construção. Através de atualizações tecnológicas a capacidade da atual linha de produção está sendo aumentada para 400.000 t/ano. A SISCOL está executando um plano de expansão visando expandir a produção de aço para atingir 1.000.000 t/ano de aços especiais através da rota EOF. Uma nova linha de produção está em implantação, com capacidade de 600.000 t/ano. Quando do planejamento dessa segunda linha, várias opções tecnológicas foram consideradas para a aciaria: Conversor LD, EOF (Energy Optimizing Furnace) e Forno Elétrico a Arco (FEA). Sob as condições indianas o EOF constituiu a opção mais acertada para a ampliação, do ponto de vista de investimento e custo operacional. O investimento em EOF é claramente menor que no conversor LD e que no FEA. O custo de produção do EOF, nas condições indianas, é menor que o do FEA e que o do conversor LD.

Palavras chave: Energia; Otimização; Alto-forno.

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1 INTRODUCTION

Southern Iron and Steel Company Limited (SISCOL), located at Salem, Tamil Nadu, India, is an integrated steel plant, originally having a capacity of 200,000 tpa of Carbon Steels. JINDAL group took over SISCOL in the year 2004. JINDAL is the fourth largest business house in the private sector in India, having annual sale of 3.44 billion US$. JINDAL group has long experience in steel and steel products and operates a number of steel companies in India and abroad. JINDAL group has good experience in different technological routes for steel making, including iron making through Corex. SISCOL took up an investment program to increase the plant capacity to one million tons per annum for producing Carbon and Low Alloy steels for automotive, engineering and construction applications.

1.1 Expansion of Existing Production Line

SISCOL had an existing production line consisting of Sinter Plant (20 m²), Blast Furnace (350 m³), Energy Optimizing Furnace (35 t), Ladle Furnace (35 t), two-strand Cont. Casting machine up to 130 mm², and a continuous rolling mill for coils and straight bars.
The existing production capacity at SISCOL, through technological upgrading, was increased from 200,000 t per annum to 400,000 t per annum along with increased production of special steels. The hot metal availability was improved through various actions in the Sinter Plant and Blast Furnace areas. The modifications were carried out in the main melting furnace (EOF), which has contributed for the doubling of the production capacity of the existing line. The important actions taken for the above are as under:

1.1.1 EOF capacity increase

Through modification of the inner refractory lining, the E.O.F. capacity was increased from 35 t to 45 t per heat without sacrificing the blowing time and safety of operation. The blowing time of 30 to 35 minutes was maintained even after increasing the furnace capacity by 30%. On monthly average basis, the billet weight at SISCOL is 46.5 t per heat.

1.2 Double Shell Practice

Originally EOF had two bottoms, rail-mounted on their respective trolleys, having a common shell, roof and scrap pre-heating system. In order to facilitate proper maintenance of the water cooled panels in the EOF shell and roof, and also to cut short the bottom changing time, double shell practice was adopted. The spare bottom was mounted with a shell and EOF roof along with roof upper piece. The stand-by shell was available for maintenance of the water cooled elements and also for refractory lining, while the other shell was used for production. This reduced the monthly shut-down timings and also improved EOF availability.

1.3 Modification of Scrap Charging and Pre-heating System

Under Indian conditions, liquid hot metal is the cheapest metallic input for EOF followed by coal based sponge iron and the most expensive commodity is scrap. 80% Hot metal and 20% solid charge was used in the EOF for melting. EOF was provided with a very elaborate scrap pre-heating system for pre-heating the solid charge to about 800° C for the subsequent heat. This pre-heating system had water cooled fingers which were quite maintenance prone. Pre-heating only 20% scrap did not give much benefit for either heat balance or reducing the blowing time. Moreover, long term strategy was to replace purchased scrap by adding sponge iron, which anyway cannot be pre-heated. Hence, to simplify the entire charging and pre-heating equipment, the fingers in the scrap pre-heating area were removed, which eliminated water leakage problems and also reduced the cooling water requirement.

One of the biggest advantages of this modification was that instead of two ID fans of 50,000 Nm^3/h gas flow, we could operate the EOF with the requisite negative pressure with only one ID fan. This has reduced the power consumption in the EOF by 10 kWh/t, which corresponds to an energy saving of 20%, which gave much higher benefits than what could have been accrued through pre-heating of 20% scrap. In the absence of scrap pre-heater fingers, scrap bucket was modified, such that the discharge of scrap from the scrap bucket was at the same level where scrap pre-heater fingers were located. This was done in order to avoid damage to the bottom refractory of the EOF during scrap charging.

1.4 Modification of Gas Cleaning Plant

In the absence of scrap pre-heating arrangement, the off-gases from the EOF were 1200°C and above. It was found that jamming in the exhaust system due to solidification of the fumes started taking place. In order to reduce the temperature on the GCP, air-water mist was added to bring down the gas temperature around 1000°C. Additional water spray was put on the down comer, in order to facilitate flow of the dust in the off-gases and also for further bringing down the gas temperature.

1.5 Modification of back up equipment

Necessary modifications were carried out in the hot metal ladle, hot metal ladle car, steel ladle and steel ladle cars to carry extra weight up to 45 t per heat.

In the downstream facilities, one ladle furnace and one vacuum degassing unit have been added in order to make higher percentage of special steels.

The Continuous Casting Machine (CCM) having 2 strands was converted to 3 strands for casting 160 mm^2 sections. The CCM was modernized for handling higher heat size ladles along with the modifications for producing quality steel billets viz., deep tundish practice, ladle to tundish ceramic shroud, closed casting practice, electro magnetic stirrer, hydraulic withdrawal straightener, synchronized secondary cooling and oscillation mechanism, solid dummy bar etc. This facilitated production of high quality steel billets and also increased the quantity to handle extra liquid steel produced in EOF and secondary refining plant.

1.6 Production Level

SISCOL has already started producing 30 heats of 46.5 t billet per heat of carbon and low alloy steels. This works out to a total steel production of over 400,000 t per annum. In addition a number of steps were taken for reducing the operating cost and improving the liquid metal yield.

2 PLANT EXPANSION

SISCOL has undertaken installation of second line of equipments for manufacturing of 600,000 t per annum within the same premises, having the following facilities:

1. One million metric tons per annum capacity Sinter Plant.
2. 550 m^3 high productivity Blast Furnace.
3. 65 t capacity Energy Optimizing Furnace.
4. 65 t Ladle Furnace.
5. 3-strand Bloom Caster for sections up to 340 x 400 mm
6. 390 t per day capacity Oxygen Plant.
7. 60 MW Captive Power Plant on off gases and coal.
8. 600,000 t per annum blooming mill for 60 mm to 200 mm rounds sections.
9. 300 tpd Lime Kiln.

The erection work for expansion at SISCOL is in advanced stages.

3 SELECTION OF PRIMARY MELTING UNIT IN STEEL MELT SHOP

Although the 45 t EOF was already operating at SISCOL, an in-depth study was undertaken for selection of a primary melting unit of 65 t capacity out of the following:

a) LD converter
b) Electric Arc Furnace using hot metal and scrap / DRI
c) Energy Optimizing Furnace.

More emphasis was given to Operating Cost while keeping in mind the total capital investment. For evaluating the operating cost, key operating parameters were collected from two steel plants having LD converters, and two steel plants having Electric Arc Furnaces using hot metal along with scrap / DRI. The key parameters of these plants were compared with the improved parameters of the EOF at SISCOL. Table 1 shows the data collected from the various plants and comparison of the same with SISCOL EOF. The metallic cost for any plant is location specific and also dependent on availability of captive mines. The other operating costs are common to all the plants and the cost structure primarily depends upon the consumption level.

Table1 - Key operating Parameters.

	KEY OPERATING PARAMETERS - EOF, LD AND EAF					
Sl No	**DESCRIPTION**	**SISCOL** (EOF)	**Plant-I** (LD)	**Plant-II** (LD)	**Plant-III** (EAF)	**Plant-IV** (EAF)
1	Capacity (t)	45	130	25	100	35
2	Metallic Charge/Heat	53	146	27	115	44
	a) Scrap (t)	11	8	4	5	9
	b) DRI (t)	2	2	--	50	16
	c) Hot Metal (t)	40	136	23	60	19
3	Liquid Steel (t/heat)	47,45	130	23	100	37,5
4	Billet Production (t/heat)	46,5	128	22	98	36,75
5	O_2 consumption (Nm^3/t)	65	58	62	40	48
6	Power consumption (kWh/t)	50	56	250	340	266
6a	Electrode Consumption (kg/t)		--		2,1	2,6
7	Lime consumption (kg/t)	55	74	90	85	55
7a	Coke consumption (kg/t)				15	20
8	Blow duration (min/heat)	32 - 35	16	32 - 35		--
9	Refractory Life (heats)	900	8233	1200	700	750
	a) Brick (kg/t)	2,5	6,5	2,7	0,8	1,3
	b) Gunning Mass (kg/t)	5,5		4,5	8,0	0,85
	c) Dry ramming mass / fettling (kg/t)				2,8	4,15
10	Charge to tap time (min/heat) / Power on to tap time (min/heat)	35	35	45	35	45
11	Tap to tap time (min/heat)	50	48	47 - 60	65	57

Source: Siscol

Hence, the cost structure has been analyzed for the key operating parameters other than metallics on common purchase price basis. The operating cost at SISCOL compared to the other four plants is as stated on Table 2.

Table 2 - Operating Costs of different Steel Plants.

Plant	Op. Cost (US$/t)
SISCOL EOF	16.07
Plant – I (LD)	18.76
Plant – II (LD)	28.84
Plant – III (EAF)	39.39
Plant – IV (EAF)	32.93

Source: Siscol

From the above data, it is very clear that for a heat size of 45 t to 65 t, which was conceived by SISCOL for expansion, Energy Optimizing Furnace would be more suitable for achieving the minimum conversion cost.
From literature, it is quite clear that for a 65 per heat unit, the LD converter with its back up facilities would be at least two times more expensive than EOF. The Electric Arc Furnace using 60% hot metal and balance scrap/DRI will be similar to the Energy Optimizing Furnace with regard to capital investment, as far as the furnace is concerned. However, if we include the additional cost of electrics in the EAF as well as in the power sub-station, the cost of electric arc based steel melt shop is also more than EOF. In order to contain the cost of EOF itself, SISCOL did a lot of scouting around the world to find the possibility of second hand equipment in good condition. Ultimately, one EOF of 65 t capacity was located with one of the plants in Europe, which was in good condition. The total EOF with back up equipment was purchased at economical price. The total cost of the 65 t EOF plant at SISCOL would be completed within the cost structure of US$ 22 per t per annum installed capacity.

4 DEVELOPMENTAL WORK

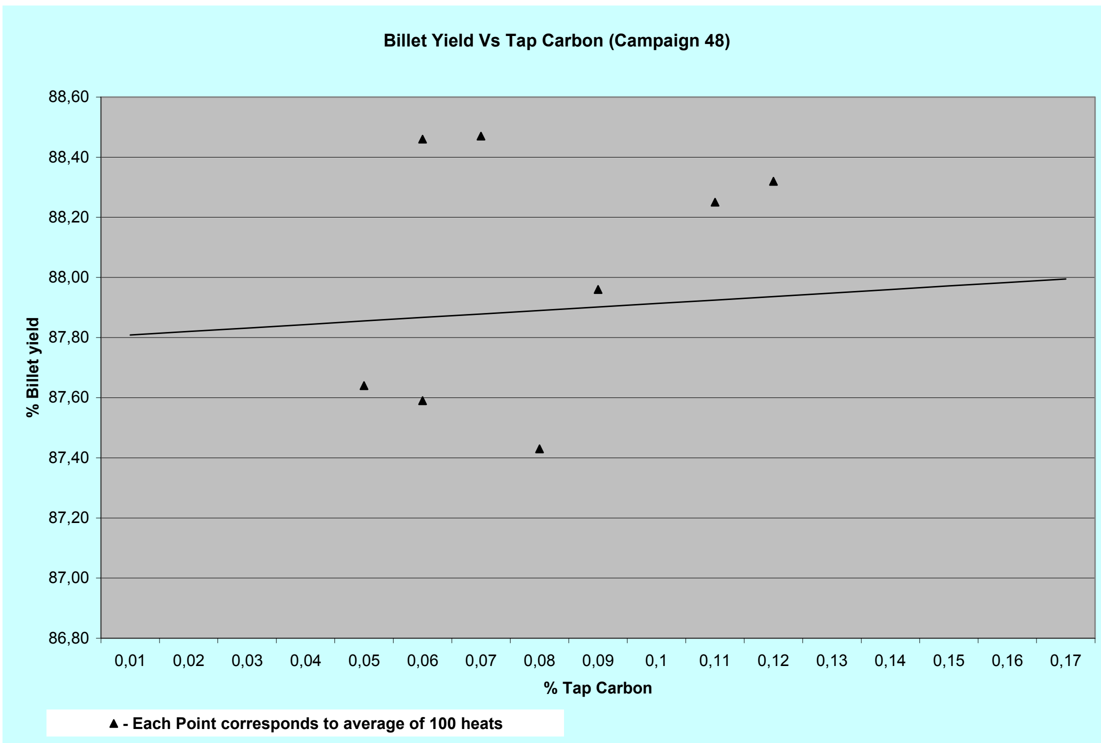
With the help of Government College of Engineering, Salem, India and M/s MINITEC Minitecnologias Ltda, Brazil, SISCOL has taken up the following developmental work for increasing the productivity and reducing the cost structure in the EOF.

1. Reducing the Blowing time in the EOF from 30/35 minutes to 20/25 minutes.
2. Improving the Charge-Billet yield to above 89%,
3. Improving the refractory life to above 1000 heats per campaign and refractory consumption to below 6 kg/t.
4. Using 6 t sponge iron per heat, to replace the costly purchased scrap.

<u>Reducing the Blowing time in the EOF from 30/35 minutes to 20/25 minutes</u>
The reduction in the blowing time will be achieved through the incorporation of the second supersonic lance, more precise control over catch carbon process, modification of the blowing profile itself, improving the lime quality, and reduction of hot metal silicon.

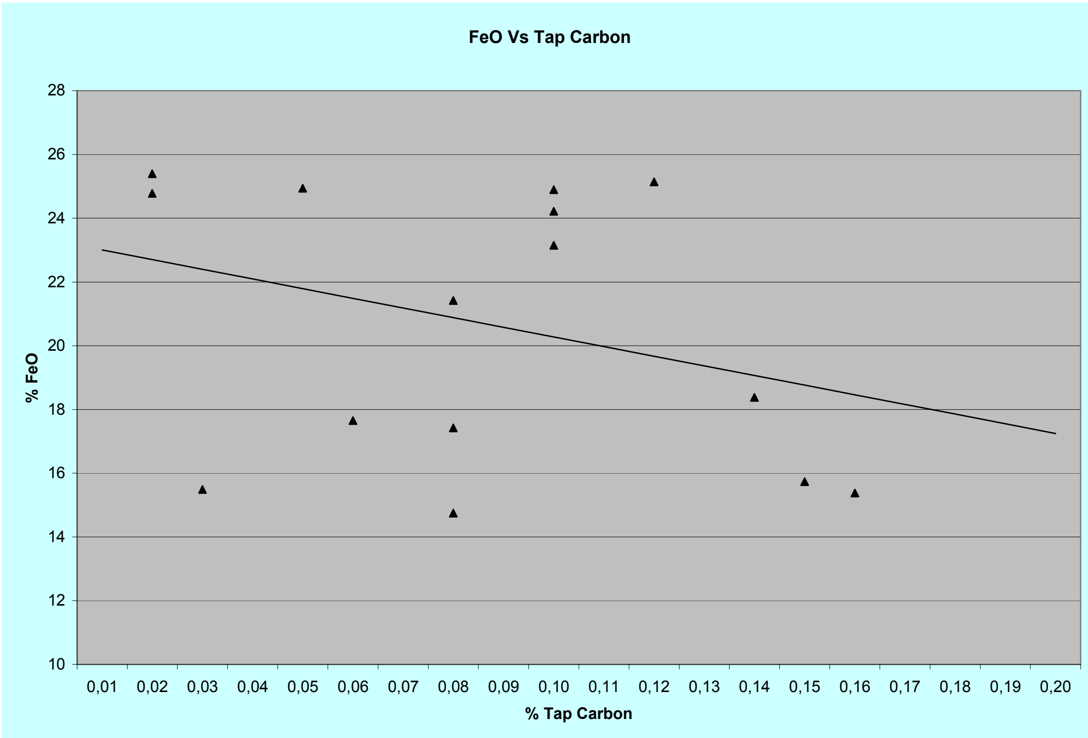
Improving the Charge-Billet yield to above 89%

The Charge-Billet yield will be improved by controlling the tap carbon above 0.10% from EOF, controlling the FeO in the EOF slag to 20% approximately. Control will also be exercised on hot metal silicon and hot metal temperature before pouring into EOF. Various experiments are under the way and it is established that there is an increase in the Charge-Billet yield for the low carbon steel grade (0.20% carbon) as the tap carbon increases and reduction in FeO content in the slag. The data is taken from Campaign no. 48 of the EOF, out of the sample of 917 heats. The present data are shown in Fig. 1 and 2, where the yield up to 88.3% has been achieved. Further experiments have been designed to increase the yield to above 89%.



Source: Siscol

Figure 1 - Billet Yield vs. Tap Carbon

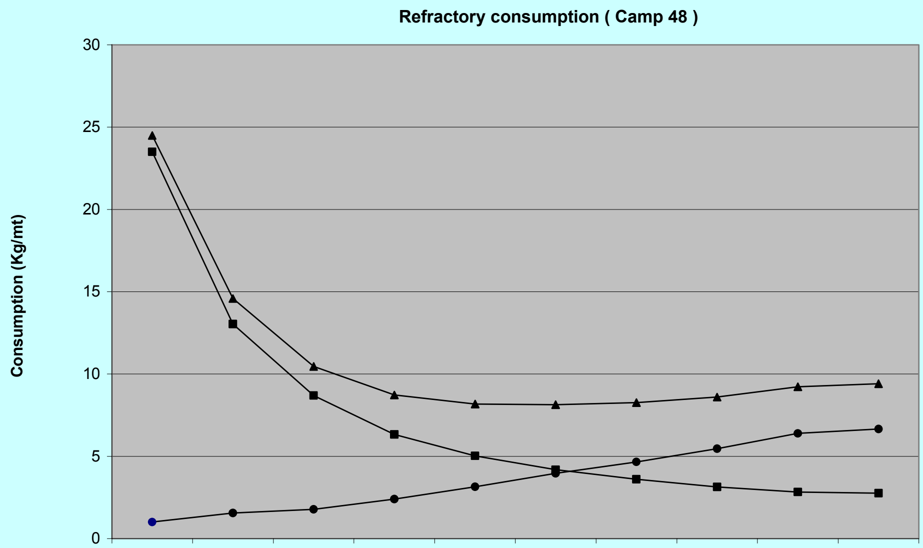


Source: Siscol

Figure 2 - FeO vs. Tap Carbon

Improving the refractory life to above 1000 heats per campaign and refractory consumption to below 6 kg/t.

The increase in refractory life and reduction of consumption of refractory brick and gunning material will be achieved through controlling the hot metal chemistry and temperature, EOF slag composition, control over tapping temperature in EOF, use of slag splasher in EOF and use of ceramic submerged tuyere. We are enclosing the data achieved so far for the 48th Campaign in the EOF where the brick consumption is 2.76 kg/t and gunning material consumption is 6.65 kg/t, (total 9.41 kg/t) in the campaign life of 917 heats, shown in Fig. 3. Various experiments are under the way to achieve the brick life beyond 1000 heats per campaign with a total refractory consumption below 6 kg/t.



Gunning Mass(Kg/mt)	1	1,55	1,77	2,4	3,15	3,96	4,66	5,46	6,39	6,65
Refractory Bricks(Kg/mt)	23,5	13,04	8,69	6,33	5,03	4,178	3,6	3,14	2,83	2,76
total (Kg/mt)	24,5	14,59	10,46	8,73	8,18	8,138	8,26	8,6	9,22	9,41

Camp.Life

Source: Siscol

Figure 3 - Refractory Consumption

<u>Using 6 t of sponge iron per heat to replace the costly input scrap</u>

The EOF process practice in SISCOL is autogenous, where the tapping temperature is achieved through oxidation of carbon through chemical reactions. External energy source is not given for increasing the temperature. Sponge iron, having higher percentage of gangue, consumes more energy for melting. Up to now 3 to 4 t/heat maximum sponge iron has been consumed at SISCOL. Various trials are in progress to increase addition of the sponge iron up to 6 t/heat through continuous feeding system without sacrificing the tapping temperature.

5 CONCLUSION

SISCOL has found a very cost effective solution with two Energy Optimizing Furnaces to enhance capacity of the existing integrated steel plant from 200,000 t to 1,000,000 t per annum. Due to the low operational cost of conversion in EOF, using the locally available low cost DRI, SISCOL will be a very competitive steel maker. Above all, EOF is a proven route for making special steels for most demanding end applications. At 1,000,000 t per annum production, SISCOL will be the largest special steel facility in India based on Energy Optimizing Furnace route.