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Optimizations of the Degree of Steel Scraps Preheating Temperature for Use in Electrical Arc Furnaces

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Abstract: Study has been made on the optimization of the degree of steel scraps preheating temperature for use in an Electrical Arc Furnaces (EAF) using steelmaking based chemical thermodynamics mathematical models. The use of preheated scraps has a number of advantages over the use of cold scraps in EAF most especially in a country like Nigeria where quality electrical output is quiet scarce. From the mathematical modeling calculations of the process, it was discovered that the use of preheat scraps (550-1100°C) led to a cut down of electrical energy from 528-546 KWH/Ton of steel as against when cold scraps are used (650kwhr/ton of steel) when the furnace is equipped with 20 MVA transformer. The tap-to-tap time was found to range between 2.43-2.07 hrs as against 3.08 hrs when cold steel scraps was used. However, the furnace productivity was efficiently high.

Key words: Optimization, Electrical Arc Furnace, Mathematical modeling, Preheat scraps, Graphite Electrods

INTRODUCTION

The steel industry is the single largest industrial energy consumer, responsible for 4% of the world energy consumption, this fact is a reflection of the wide spread uses of steel in today's society (Heard R.A. and Roth, J.L., 1998). The energy consumption of the steel industry is more pronounced at the stage of liquid steel production.

The process design economics requires a careful analysis of the input variable most especially the condition of the steel scraps.

The use of preheated scraps for steel production is one of the many ways of cutting down on energy consumption in the steel industry.

In the past, during energy crises of the seventies this method of raising steel scraps temperature before charging into the furnace was quite popular. This popularity is being revived again due to several factors.

- Rising cost of fossil fuel
- Countries with abundant supply of fossil fuel and liquefied natural gas are moving towards the use of their endowed natural resources in achieving industrialization at a cheaper cost.
- Countries with poor quality of electrical energy supply are fast embracing this technology.

There are two methods for steel scraps preheating (International iron and steel institute committee on Technology, 1998).

- The use of steel scrap loading buckets of various capacities.
- Installation of gas burners into the electrical arc furnace (EAF).

Numerical Procedure:

Modelling of known physico-chemical processes of steelmaking, based on this, the following were carried out:

- Mass and heat balance calculation for various steels used were carried out.
- Using established chemical thermodynamic based models to determine heat (energy) consumption to melt a ton of steel scrap.

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- Choice of furnace type and capacity (50 ton).

Theoretical Basis:

The use of preheated scraps in Electric Arc Furnaces (EAF) has a number of advantages:

- Reduction of the total tap to tap time
- Reduction of electrical/electrode consumption in EAF.
- Reduction of unwanted impurities like oils, plastics scrap and water at the preheating stage.

The chemical thermodynamic models used are the following parameters for determining total heat energy spent on melting a ton of steel:

$\sum = Q_{Theori} + Q_{pre\ steel\ scrap}$ (Heard R.A. and Roth, J.L., 1998) (1)
n-10

Where:

- Q_{Theori} - This is the theoretical quantity of heat energy required to heat a ton of steel scrap to melt down temperature KWt.hr/T.
- $Q_{preh.\ steel\ scrap}$ - The quantity of heat energy required to heat the steel bath above the line of liquidus. i.e. $\frac{KWat.hr}{T}$

Where:

$Q_{Theor} = C_1\ (t_{melt} - to) + \lambda_M$ (Tulevskii, U.N. and Nichaev, E.V. 1987) (2)

- C_1 – Theoretical heat capacitance for steel.
- T_{melt} - Temperature at which liquid steel is formed, °C
- T_0 – Average temperature of the charge material which was varied from 500 - 1100°C
- λ_M – Latent heat content of the liquid metal 0.79 KWt.hr/T [1,7]

Mathematical model for determination of the heat required to heat the liquid steel bath above the line of liquidus.

$Q_{AB} = C_2\ (t_1 - t_{melt})$ (3)

- C_2 – Heat capacitance of molten steel, 0, 23 KWtt.

Model for determination of power on time calculations (Madugu, I.A. 1984; Madugu, I.A. 1987).

$$\Delta t_{melt} = \frac{\sum Q''}{Q_{Theor}} * t_{melt} \quad (4)$$

- Q'' - The heat content of the metallic scrap after heating in steel buckets.
- T_{melt} – duration of power on time without preheating of the scrap

Model for determination of electrical energy consumption (Madugu, I.A. 1984; Madugu, I.A. 1987).

Where:

- q_1^*, q_2^* – Furnace heat loss during stationary and reduction period
- t_1 - Power-on time for one melt, (min.)
- p_H^* - Transformer voltage, (20MVA)
- τ_{melt} - scraps melt down period, (min.)

- T_3 - Oxidation and reduction period, (min.)
- $Cos\mu^*$ - Power factor
- Q_3 - Endothermic heat consumption during the reduction period
- G - Tap weight, Tons.
- n_{elet} - Ultilization degree of active power during melting, (0.93)

Optimization Basis for the Use of Preheated Scraps:

To have a good correlated out put result the following basis were assumed.

- The bucket type steel container use assumed being used 50T type.
- Preheated scraps temperature were varied from 550 - 1100°C
- The use of 50 Ton electrical arc furnaces.
- 20000KVA transformers were assumed to be installed in the above furnace.

Results and Analysis:

Effect of the use of preheated scraps on furnace output parameters.

RESULTS AND DISCUSSION

The results obtained are based on calculations using models (Heard R.A. and Roth, J.L., 1998; International iron and steel institute committee on Technology, 1998; Tulevskii, U.N. and Nichaev, E.V. 1987; Paul Nilles, Reeves, R. 2000) which are all based on the theoretical output parameters for steel processing in electrical arc furnaces. The temperature variation was carried out from 550 - 1100°C and preheating ws assumed o be carried out in basket bucket of 50 tons.

Table 1:

Output Parameter	tc 20	550	600	650	700	750	800	850	950	1100
Melt down period hr.	1.32	0.67	0.64	0.60	0.57	0.54	0.50	0.46	0.41	0.31
Total Tap to Tap time	3.08	2.43	2.40	2.36	2.33	2.30	2.26	2.22	2.17	2.07
Electrical energy consumption KWH	650	546	542	541	539	539	538	523	528	522
Daily output	440	558	565	578	582	590	600	611	625	655

Table 2:

S/N	Optimal temperatures, t°C	T, min	Ton./day	W Kwhr/Ton	Electrode consumption Kg/Ton
1.	800	135	600	538	5.33
2.	850	133	611	523	5.29

From the result in table 1 it can be observed that when preheated scraps are used in an electrical arc furnace (3-graphite electrodes):

- There is a reduction in the scrap melting time i.e. when a liquid pool of metal is formed in the furnace which varies from 0.67-0.31 (550-1100°C) as against 1.32 hours for cold scraps (20°C).
- For each 1°C rise in scraps temperature, will lead to a cut down of melting period by 0.040 minutes. This in turn will adversely affect the consumption of electrical energy by reducing it. Since electrical energy consumption is reduces from 546 – 522 Kwt per ton of scraps as against 690Kwhr/ton of scraps. This means that the total reduction fall between 144 – 162Kwhr/Ton and electrode consumption fall between 1.82 – 2.04 Kg/ton of scraps within the temperature range of 550 - 1100°C as formulated in our models.

Conclusion:

- Preheating of steel scraps above 1100°C is not recommended because this will lead to over-oxidation of the liquid metal and the preheating time as a result, this could lead to a low metal yield (International iron and steel institute committee on Technology, 1998).
- The optimal preheating temperature for steel scraps was found to be 800°C. At this temperature we obtain a high technico-economical output parameters for the electrical are furnace.

Based on literature survey a higher temperature of more than 800°C could lead to fusing of the steel scraps among themselves (Heard R.A. and Roth, J.L., 1998)]

The obtained optimal Technico – economical output process parameters for the study (550 - 1100°C) are as stated in table 2 below.

- It was observed that the use of preheated scraps will lead to an increment of the furnace productivity by 26 – 48% .

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