

Preheating Technology Can Save Energy in the Tanzania Iron and Steel Industries

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Abstract

This paper is focused on means of reducing consumption of electricity in the Tanzania iron and steel industries so as to save energy through preheating Technology. The iron and steel industry is one of the largest energy consuming manufacturing sectors in Tanzania due to the fact that the technology used is old and inefficient. Furnaces used to melt iron scrap consume high electricity which is around 0.85 MWh/Ton. Electricity demand does not fulfill the country need since there is frequent unexpected power cut offs all over the country. The paper analyses maximum temperature of furnace and maximum temperature of hot gases so as to determine the energy lost through these flue gases and recovering them. However, the future outlook necessitates looking into ways of developing the backup systems for the country to utilization all other alternative sources to save energy. From the results the energy saved during preheating technology is 21.63% of the total energy used. This is the target recovered in this paper.

Keywords: Energy saving; Energy consumption; Iron and steel; Energy Resources

General Introduction

Steel even today is decidedly the vital component of a country's economy and is considered as the crux of modernisation. The iron and steel industry is one of the largest energy consuming manufacturing sectors in the world [1,2]. In 1990, its global energy consumption was estimated to be 18-19 exajoules (EJ), or 10-15% of the annual world industrial energy consumption. Iron and steel production consumes large quantities of energy, especially in developing countries and countries with economies in transition where outdated and inefficient technologies are still used to produce iron and steel [3]. These technologies can take advantage of the local low-quality resources and can be developed on a small scale, but they carry a heavy environmental burden. Increases in productivity through the adoption of more efficient and cleaner technologies in the manufacturing sector will be necessary in merging economic, environmental, and social development objectives. A historical examination of productivity growth in Tanzania industries embedded into a broader analysis of structural composition and policy changes will help identify potential future development strategies that lead towards a more sustainable development path. The Tanzania energy policy document shows that over 90% of Tanzania's primary energy consumption is accounted by biomass whereas petroleum and electricity accounts for 8% and 1.2%, respectively [4]. Coal, petroleum and hydropower are Tanzania's main sources of commercial energy. Dar es Salaam region has the greatest access to electricity, however less than 50% of all households in the region are connected. Only 18 districts out of 118 districts identified in Tanzania's 2002 population and house census have more than 20% of households with electricity access [5]. While rural dwellers depend on biomass as their source of energy, populations in urban areas depend on both electricity and biomass. Biomass, especially wood charcoal, continues to be the main source of energy for cooking purposes in urban area (about 80%) despite the high level of electricity access. The reason is that majority cannot affordable to pay for electricity due to low incomes and high tariffs. The annual, national consumption of charcoal is approximately 950,000 tonne [6]. Despite low electricity consumption, supply is still unable to meet demand. This shortfall is attributed to the country's dependence on hydropower which in turn is affected by climate variation and climate change.

In Tanzania the iron and steel industries uses scrap metal for making steel. Steel scrap has become the steel industry's single largest source of raw material because it is economically advantageous to recycle old steel into new steel. Steel scrap recycling has been identified as an effective means of conserving natural resources. Iron and steel industries in Tanzania use electric induction furnaces to melt the scrap. An electric induction furnace requires an electric coil to produce the charge which raises the temperature to 1800°C for melting the scrap. These furnaces consume a large amount of electricity. Electric induction furnaces do not use coal as a raw material, but are reliant on the grid electricity [7].

Tanzania's grid electricity supply does not meet current demand levels [5] and because iron and steel industries consume large amounts of electricity, there is a need to preheat the iron and steel to reduce electricity demand in order to consume low electricity in and accelerate the production by reducing tapping time. The specific objectives of this study were:

- i. To determine the existing energy consumption of the iron and steel industry
- ii. To find the means of reducing electricity consumption in the iron and steel industries using preheating methods.

Methodology

The research was conducted through a series of methods in order to get the information and data required, to analyze it and to arrive at the

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desired results and recommendations. This is described in this chapter. Information was obtained from different sources such as internet, journals, books, and reports on various industries which produce iron and steel in Tanzania.

Field Survey

Field search was done on the iron and steel industries located in Dar es Salaam. It involved questions on electricity used, technology used, tapping time, methods of charging scrap and temperature of the hot gases.

The questionnaire was distributed to different iron and steel industries and TANESCO. The questionnaire were intended to collect information on scrap input, energy consumed and power, tap weight, tapping time and technology used.

The industries covered were:

1. Steel Masters Ltd
2. M.M. Integrated Steel.
3. Metro Steel Mills Ltd
4. Kamal Steel Ltd
5. Quaim Steel Mills Ltd
6. A.M steel and Iron Mills Ltd
7. Dar Steel Mills.
8. Kinota Foundry Enterprises Ltd

Findings and Discussion

Data collection

Data was collected from the various industries through observation, interviewing and questionnaires is given in Table 1. Also other data concerning energy consumed and maximum temperature of the furnace were recorded and source of energy were recorded.

Other data such as furnace used, raw material, tapping time and

temperature of exhaust were collected from the same industries as shown in Table 2.

Data analysis

Collected electric induction furnace data were analysed using Microsoft office excel. The following steps was adopted in the calculation and analysis

1. The energy consumption was calculated and recorded to represent the energy consumption for that of the recycling process.
2. Energy consumed for one tonne of semi-finished steel produced was calculated

The energy consumption to produce one tonne of semi-finished steel from the scrap recycling process has been calculated using the formula (1) below.

Energy consumption

Energy is consumed from the melting stage or flow of production of steel rod to the end in all of the industries.

From the TANESCO charge of the intended industries the utility bills were analysed and given in Table 3. This table is derived from the energy consumption in kWh and power demand in kVA for month December 2011. The iron and steel is categorized in high voltage supply.

This is the amount paid to TANESCO as electricity service charge from iron and steel industries for December 2011. Figure 1 shows the distribution of levies paid to TANESCO by the iron and steel industries for December 2011. Iron and steel Ltd contributed the maximum percentage which was 19%.

Preheating technology

Since the electric induction furnace process can use up to 100% recycling scrap for the production of crude steel, it is the main process in which the technology of reducing electricity consumption can be employed. The electric induction process has four main outputs during melting the scrap as shown in Figure 2:

S/N	Name of the industry	Location	Furnace capacity per batch	Furnace temperature	Source of energy
1	M.M integrated steel mills (P.N.P steel mills)	Kijitonyama -Kinondoni district	5 tons	1600°C	Electricity
2	Steel Masters Ltd	Chang'ombe -Temeke district	5 tons	1750°C	Electricity
3	Metro steel mills Ltd	Vingunguti - Ilala district	8 tons	1800°C	Electricity
4	Kamal steel Ltd	Chang'ombe - Temeke district	5 tons	1700°C	Electricity
5	A.M steel and iron mills	Mbagala - Temeke district	5 tons	1700°C	Electricity
6	Quaim steel mills Ltd	Chang'ombe - Temeke district	5 tons	1650°C	Electricity
7	Dar steel mills	Mbagala - Temeke district	1 ton	Not yet applicable	Electricity
8	Kinota foundry Ltd	Mbagala - Temeke	0.5 ton	1809°C	Electricity

Table 1: Iron and steel industries located in Dar es Salaam.

S/N	Industry	Temperature of hot gases
1	M.M Integrated steel	600 – 750°C
2	Metro steel mills	650 – 800°C
3	Steel Masters	500 – 750°C
4	Kamal steel	570 – 700°C
5	A. M steel and iron	630 – 800°C
6	Quaim steel mills	500 – 700°C

Table 2: Furnace specifications.

- a) The liquid steel itself
- b) Cooling losses
- c) Slag
- d) Hot waste gases.

Relying on the data collected, the temperature of hot waste gases is round 500°C to 800°C and represents 15 to 20% of the every output which can be used to offset grid electricity consumption (Marwa, 2013).

Technology consideration

In this section three technologies are employed which are commonly used in preheating iron and steel scraps. These are:

- a) Conventional scrap bucket charge preheating system
- b) Consteel process
- c) Fuchs shaft furnace

Conventional scrap bucket charge preheating system: Conventional scrap preheating involves the use of hot gases to heat

S/N	Industry	Total Tshs
1	M.M Integrated steel	88,308,726
2	Metro steel mills	102,760,140
3	Steel Masters	97,928,766
4	Simba steel	111,008,340
5	Iron and steel	161,262,600
6	Kamal steel	96,876,234
7	A. M steel and iron	87,232,440
8	Quaim steel mills	95,768,088

Table 3: Monthly utility bills in iron and steel industries.

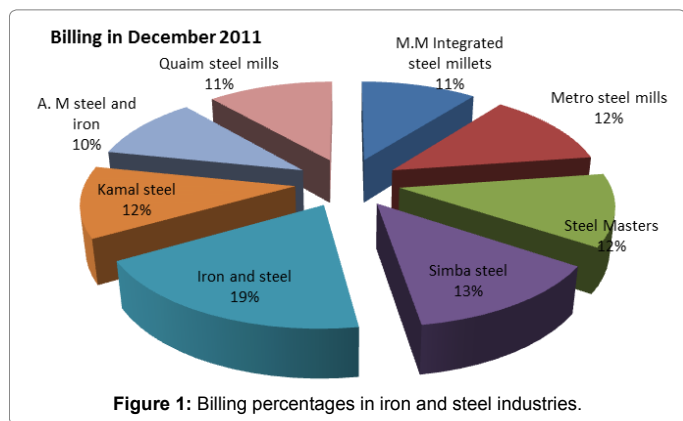


Figure 1: Billing percentages in iron and steel industries.

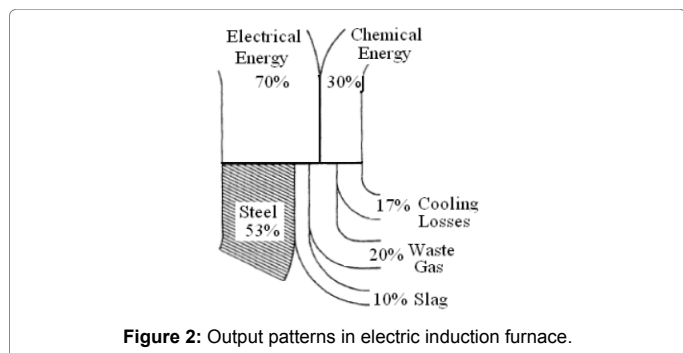


Figure 2: Output patterns in electric induction furnace.

scrap in the bucket prior to charging it into the furnace. The source of the hot gases can be either off- gases from the electric induction furnace or gases produced by burning natural gas as shown in Figure 3. Scrap preheating can be accomplished by delivering the hot furnace gases to the scrap-charging bucket by piping the off- gases from the fourth hole in the electric induction furnace to a special hood over the charging bucket. Typically the gases leave the electric induction furnace at about (1800°C), enter the bucket at (800°C), and leave at around (200°C).

Preheating scrap has several advantages:

- a) Reduced energy consumption
- b) Removal of moisture from the scrap

However, the method of scrap charging bucket preheating has some disadvantages limiting its use:

- a) Inconvenient to operate as the scrap sticks to the bucket
- b) Short bucket life
- c) Poor controllability of preheating

Consteel process: The Consteel process consists of a conveyor belt which carries the scrap through a tunnel, down to the electric induction furnace through a hot heel. Scrap is loaded onto conveyors by the scrap yard cranes and these conveyors move the scrap in an oscillating motion comprising a slow forward movement and rapid reverse motion which causes the scrap to move together with the conveyor during the forward stroke but to slide on the conveyor surface during the more rapid reverse stroke so producing a net forward travel of the scrap towards the furnace.

Some distance before reaching the furnace the scrap enters a preheating section consisting of a tunnel through which the hot gases exiting the furnace flow in a counter direction to the motion of the scrap. In the preheating section carbon monoxide in the exhaust gas is burnt by an automatically controlled injection of air, allowing more energy to be recovered to the scrap as shown in Figure 4. The conveyor belt continuously transports the scrap charge to the furnace, while the charge is preheated by off gases leaving the furnace through the preheat conveyor.

Fuchs shaft furnace: A shaft furnace is an advanced form of scrap preheating as shown in Figure 5. It is mounted on top of the furnace. Off-gases leaving the melt zone rise up the shaft and pass through the next scrap charge. In order for the furnace to be practical the heat size must be at least 45 tons and the furnace must be equipped with gas burners to generate sufficient off gas. The complexity of these technologies requires large capacity furnaces operated on a continuous basis to be technically and economically feasible. Therefore, these technologies are not applicable to typical foundry operations. The Fuchs-systems make almost 100% scrap preheating possible, leading to potential energy savings of 100-120 kWh/t [8]. The energy savings depend on the scrap used, and the degree of post-combustion (oxygen levels).

Recovering heat gases

The hot gases that come out from the furnace are used for preheating the scrap which is to be melted. Before the scrap is fed into the furnace, it is preheated using hot gases as shown in Figures 6 and 7.

Energy mass balance

Case I: Normal, no preheating

$$E_{Total} = m_{ms} \times C_{ms} \times \Delta T + m_{ms} \times L_{ms}$$

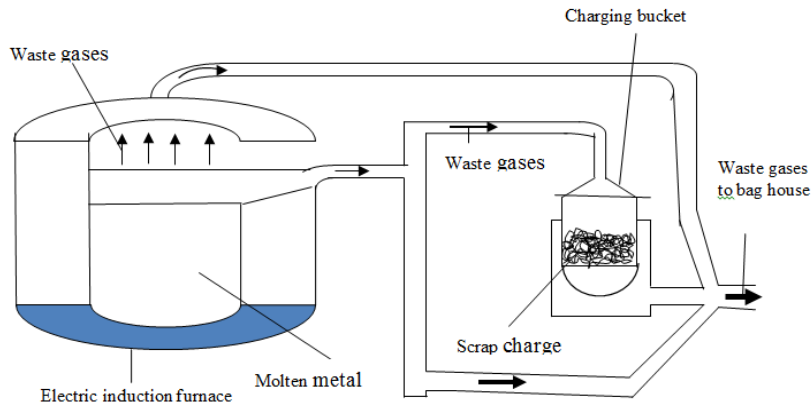


Figure 3: Schematic of a conventional scrap bucket charge preheating system.

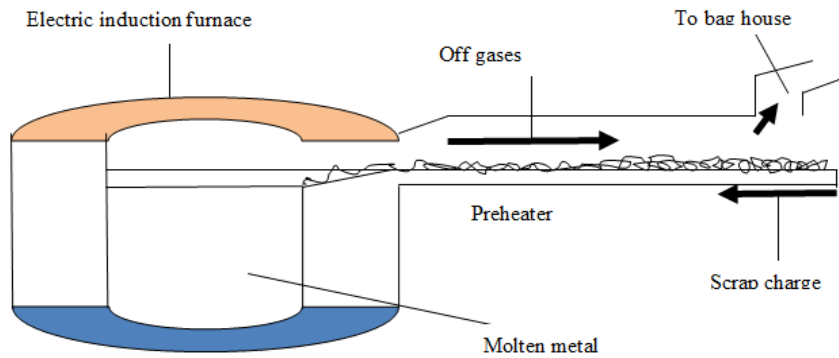


Figure 4: Schematic of a Consteel scrap preheating system.

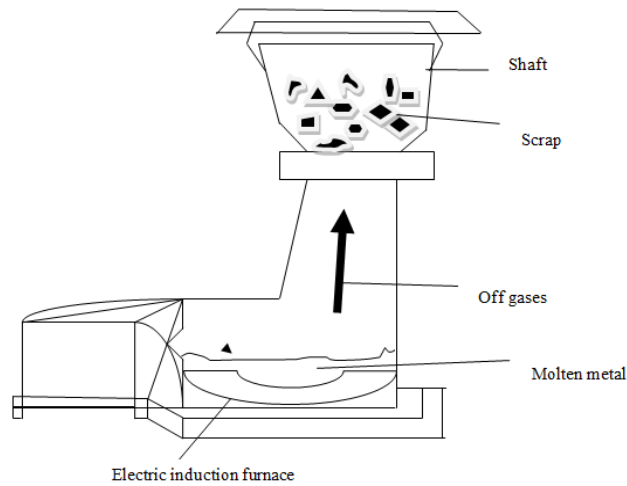


Figure 5: Schematic of a Fuchs shaft scrap preheating system.

$$\Delta T = 1800^{\circ}\text{C} - T_o$$

Case II: Energy lost due to flue gases

$$E_{Total2} = m_{fg} \times C_{fg} \times \Delta T_2$$

$$\Delta T_1 = T_{fg} - T_o$$

T_{fg} = maximum temperature of flue gases (800°C)

Case III: Energy due to flue for preheat

$$E_{Total3} = m_{ms} \times C_{ms} \times \Delta T_2$$

$$\Delta T_2 = T_{pmin} - T_o$$

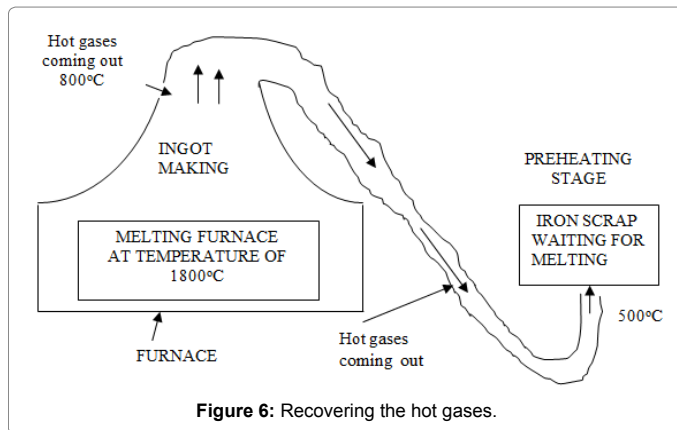


Figure 6: Recovering the hot gases.

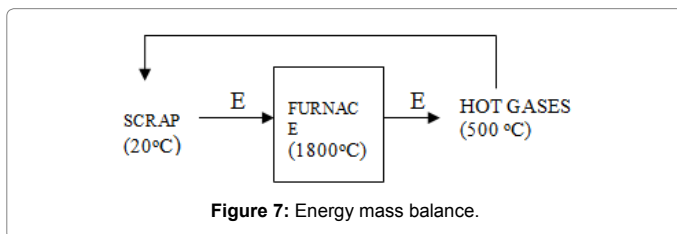


Figure 7: Energy mass balance.

T_{pmin} = minimum possible preheating temperature (500°C)

Energy lost is calculated from the change of total energy without preheating and total energy of flue gases.

$$\Delta E = E_{Total1} - E_{Total2}$$

$$\text{Saved Energy in percentage (\%)} = \frac{\Delta E}{\Delta E_{Total1}} \times 100\%$$

Where,

E_1 = Energy entering the furnace

E_2 = Energy leaving the furnace

m_{ms} = mass of iron scrap per day (45 tons)

$C_{p(ms)}$ = specific heat capacity of mild steel (620 J/kgK)

T° = Room Temperature 25°C

ΔT_1 = change of temperature of flue gas

ΔT_2 = change of temperature of melting scrap metal

T_{fg} = maximum temperature of flue gases

L = Latent heat of fusion of iron (272 kJ/kg)

m_{fg} = mass flow rate of flue gas (2100m³/h)

C_{fg} = Specific heat of flue gas (0.24 kcal/kg °C) or (1.0056 kJ/kg °C)

Therefore:

CASE I: Normal, no preheating

$$E_{Total1} = 45000 \times 0.62 \times (1800-20) + 45000 \times 272$$

$$E_{Total1} = 61,902 \text{ kJ}$$

CASE II: Energy lost due to flue gases

$$E_{Total2} = 2100 \times 1.0056 \times (800-20) \times 10$$

$$E_{Total2} = 16,471,728 \text{ kJ}$$

CASE III: Energy due to flue to preheat

$$E_{Total3} = 45000 \times 0.62 \times (500-20)$$

$$E_{Total3} = 13,392 \text{ kJ}$$

Energy lost is calculated from the change of total energy without preheating and total energy of flue gases.

$$\Delta E = E_{Total1} - E_{Total2}$$

$$\Delta E = 61,902 \text{ kJ} - 16,471,728 \text{ kJ} = 45,431 \text{ kJ}$$

$$\text{Energy lost in percentage (\%)} = \frac{45431}{61902} \times 100\% = 73.39\%$$

Energy which can be saved due to preheating method can be calculated as

$$\text{Energy saved in percentage (\%)} = \frac{13392}{61902} \times 100\% = 21.63\%$$

Conclusion and Recommendations

Conclusion

This paper work focused on how to use preheating using waste gases in order to reduce electricity consumption in the Tanzania iron and steel industries. The energy saving by application of preheating technology method has been shown to reduce electricity consumption by 21.63% of the total energy. So there many benefits on implementing preheating technology such as reducing tap to tap time and increase production in the industries.

Recommendations

The following are recommendations for further promotion of iron and steel industries. The role of the government in improving energy saving in the iron and steel industry is still limited. Several areas may be the subject of governmental policy:

1. Financial support for the development of energy-saving technologies
2. Encouraging iron and steel companies to implement most efficient technologies.

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