TECHNOLOGY TO REDUCE ENERGY DEMAND IN STEEL PLANTS

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Abstract:
Worldwide growth of economy and population has caused an immense increase in demand for energy. Furthermore, energy prices have always been volatile. These trends are expected to continue and even worsen in coming years. These trends create both pressure and opportunities in the steel industry to seek new technologies for conservation, substitution of fuels, and ultimately the development of new steelmaking processes which are environmentally friendly. Such measures are intended to reduce the steel industry's reliance on energy sources, as well as the volume of greenhouse gases it introduces to the environment. This paper discusses a technology to improve the energy efficiency of the Electric Arc Furnace (EAF) in the steelmaking process by utilizing the heat of the waste gases from the EAF to generate steam that can be used in other applications within the steel plant.

Introduction:
Currently steel industries are the largest energy consuming sector in the world, accounting for 15% of world's industrial energy consumption. Steel industries all across the globe are highly energy intensive. Of the total cost of producing steel, 20% is spent on energy. The increasing cost of energy and even its current and future availability shows the need to refocus attention on energy conservation in steel production.

India's Scenario
India is a developing country and thus has a very high future demand for steel. Different projections have been made regarding the proposed capacity by 2020.

Agency	Proposed capacity in million tons
• National steel policy (2005)	110
• Ministry of steel	200+
• Based on MOUs signed by the private producers with state government	293

In India, Steel is the second largest sector in greenhouse gas emissions, second only to the power sector. Energy accounts for 30-35% of total production cost of steel in India—worse than the global figure of 20%. A technology such as the one discussed in this paper should be deployed in steel plants of India to save energy and reduce CO_2 emissions. Development and installation of this system in newly constructed steel plants will not be very costly.

Energy & Steel Production:
The energy employed directly by the steel industry ultimately results in the production of final steel products, various by-products, and process losses in the form of heat (Figure 1).

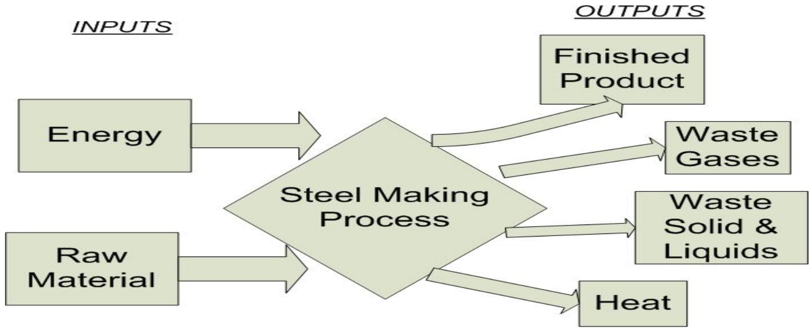

Figure 1. *Steel industry inputs and outputs.*

All the sources of energy used in steel production are factors in the generation of carbon dioxide to various degrees on account of:

- Electricity consumption
- Combustion of fossil fuels for energy (heat)
- Use of Coal and Lime as feedstock

We need approaches to lower energy use in steel production. Thus there is a need to develop:

- Technologies that can take advantage of the energy currently lost in existing processes.
- Recovering and applying wasted heat at high temperature.

There are significant energy savings opportunities in the steel production process which are yet untapped. Steel industries already produce fuels in the form of by-products like fume gases. Gas reforming technologies utilizing the sensible heat contained in steelmaking off-gases could yield substitute fuels for use in steel plants. A high potential for energy conservation lies in energy recovery.

Introduction to Steel Plant

Units of the steel plant that are relevant to the proposed technology are explained in detail below. For a flow diagram of the steel production process, the reader is referred to the following link http://tinyurl.com/yb5bpkb.

<u>Electric Arc Furnace</u>: Steel is an alloy, with iron as the base component. The other important elements are carbon, silicon, manganese, chromium, aluminium, phosphorus, molybdenum, and boron. Direct reduced iron (DRI) and sponge iron (SI) is sometimes used with scrap to help maintain desired chemistry of the steel. Pig iron is added to the above mixture (having 4% carbon), which finally forms the charge which is added to the electric arc furnace along with coke and flux (mixture of lime and dolomite). The furnace is heated for scrap melting at a temperature of 3000°C using graphite electrodes and pressurised oxygen. The slag formed is taken out; the flame is sucked out continuously using Fume extraction system (FES). The molten metal is then tapped to the ladle furnace.

<u>Ladle Refining Furnace:</u>

A ladle furnace is used for precision control of chemistry. The ferroalloys of elements such as manganese, silicon, chromium, nickel etc are added to the furnace and the ladle furnace is heated using graphite electrodes. Argon used as a purging gas and is purged to the ladle furnace from the bottom for proper mixing of the molten metal.

Vacuum Degassing Furnace:
The vacuum degassing system is used in the final refining step to remove hydrogen, oxygen, sulphur and/or carbon. These achieve low sulphur levels, remove carbon, and improve floatation of oxide inclusions, allowing them to be entrained in the slag. This results in the highest quality steel. A VD furnace pays for itself in 2 years, and VD systems are becoming popular in steel production. The vacuum in the furnace is mostly produced by an all-steam ejector pumping system, or a combination of steam ejectors and a mechanical pump system. For this reason, a steam boiler is installed near to the VD furnace.

Fume Extraction System (FES):
The FES is typically utilized in combination with the EAF & LRF to capture airborne particulate emissions and to exhaust certain flammable and hazardous gases that evolve during furnace operation. In particular, gases such as CO and H_2 are generated during the melting and refining process, and must be properly vented and treated by the FES. A negative pressure is generated within the FES, via an induced draft (ID) fan, to draw fumes from the EAF into the FES for treatment. (For an illustration, see reference 10, page 7.) The ID fan pulls fumes through a bag house including filters, and then exhausts the filtered gases into the atmosphere. Since the fumes exit the EAF at a temperature close to 1250°C, the fumes are typically cooled prior to entering the bag house at temperature of <130°C using a forced draft cooling system. In this cooling system, cold water from a cooling tower is pumped into ducts of the FES, which absorbs heat from the fumes. This hot water from the ducts is then pumped back to the cooling tower. This is done to bring down the temperature of the fumes before they are disposed off to atmosphere (Figure 2).

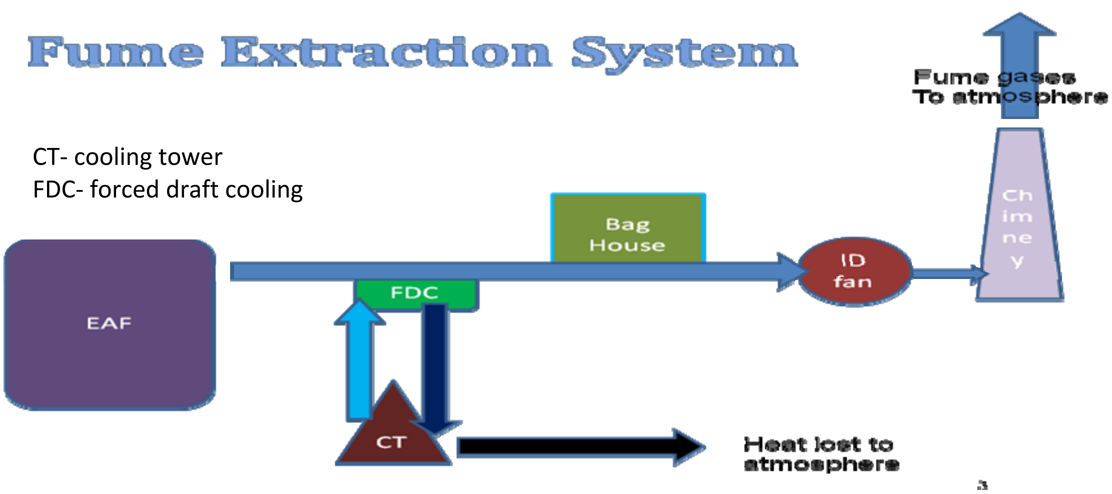

Figure 2. *In the fume extraction system, energy (heat) is lost to the atmosphere rather than recaptured and utilized.*

A large amount of energy is wasted in the form of fumes from the EAF and in the unavoidable heating of the furnace apparatus (Figure 3). Thus, it makes sense to extract and use heat from the fume gases of the FES and from the overheated furnace apparatus. The recovery of heat does not mean simply cooling the furnace to prevent overheating of structural parts or for other operational purposes, but rather, it means recovering the useful heat that would otherwise be lost.

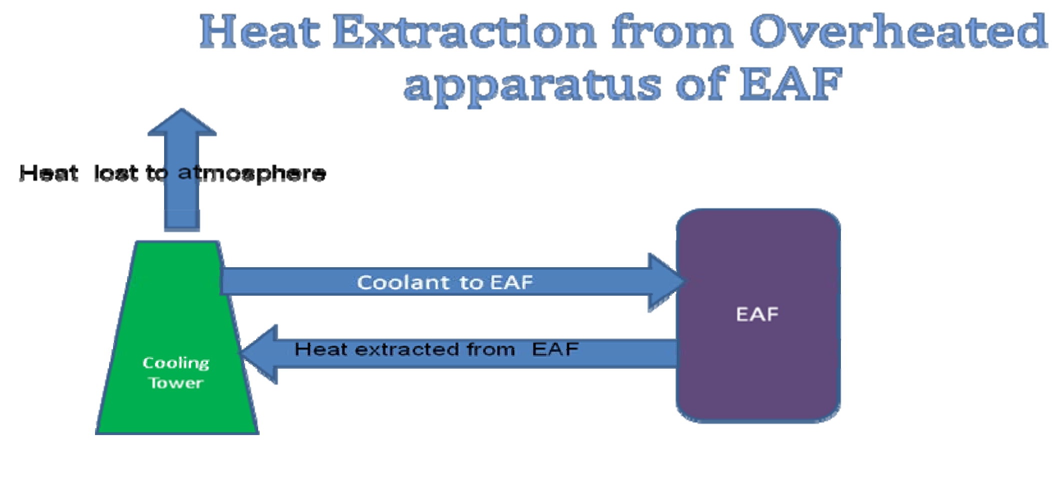

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Figure 3*. Heat loss also occurs in the EAF.*

Potential for Energy Conservation:

- For every ton of steel melted in EAF about **$4*10^5$ kJ** of energy is wasted, in the form of fumes and in heating up of the furnace & its apparatus.
- Vacuum degassing is done for high-level purification of stainless steel. This requires large quantity of superheated steam (230°C) in every cycle, for which a boiler is installed in the VD system.
- In the boiler of the VD system, for purifying one ton of stainless steel:
  Furnace oil consumption = 13 L.
  Amount of water converted into steam = 100 kg.
  Energy required to heat water from 20°C to steam at 230°C = energy required in boiler = **$3*10^5$ kJ**.

Background of the Technology

The proposed technology relates to a method and an apparatus for recovering waste heat from EAF whose exhaust gases have high dust content. The recovery of waste heat has been very difficult with conventional techniques. This paper improves and expands upon similar technology that has already been proposed and patented (see references 9 and 10.)

Various devices have been proposed for recovering waste heat from EAF. In these methods, the internal pressure of the recovery device is kept higher than atmospheric pressure in order to increase the quantity of useful heat recovered. But proper maintenance and management for safe operation is required. Another difficulty is that the dust contained in exhaust gases is generally very liable to adhere to the structure and because this dust has poor heat conductivity, the size of the heat recovery area must be enlarged, thereby resulting in increased size of the apparatus as a whole.

The present technology is free from the aforementioned disadvantages, and is capable of recovering useful heat without reducing the production capacity of the EAF itself.

Working of the System

Water is pumped through an ion exchanger where impurities are removed to prevent water hardening. This purified water is then stored in feed water tank.

The heat recovery system takes place in two parts:
1. Primary heat recovery section
2. Secondary heat recovery section, as shown.

The water from the feed water tank is fed into the primary heat recovery section by a pumping system and flow controller. Here the water cools the overheating apparatus of the electric arc furnace. The heat emanating from the EAF components is recovered by controlling the temperature of the cooling liquid circulating through the furnace apparatus in such a way that the maximum temperature of the coolant remains below its boiling point, under normal atmospheric pressure.

In the secondary heat recovery section, a stream of dust-laden gas leaves the EAF under the action of the induced draft fan. This stream of gas is passed through the internal tubes of the heat exchanger, which are made of heat-proof steel and have a circular shape so as to minimize adhesion of dust and to allow easy removal of dust if it does accumulate.

Simultaneously a stream of hot water is flowed by a pump, as a heat exchange medium, along the outer side (shell side) of the heat exchanger. The water is heated in the heat exchanger to a high temperature and is converted into steam. This steam is then collected in a steam drum. The stream of EAF discharge gas is lowered to a temperature level at which the filter can be operated effectively. The discharged fume gases are filtered and finally released to the atmosphere through the chimney, having less energy than before.

The steam from the steam drum and hot water from the feed water tank are accumulated in a steam accumulator. A **steam accumulator** is an insulated pressure tank containing hot water and steam under pressure. It is a type of energy storage device which is used to smooth out peaks and troughs in demand for steam.

This steam generated can be used for driving vacuum pumps at the VD plant, or for driving a single strand steam turbine to generate electricity (For an illustration, see reference 10, page 11.) Both ways a high saving of fossil fuel can be achieved and the carbon emission can be reduced significantly.

Calculations:
For every ton of steel produced-
120-150 kWh of heat that can be recovered from EAF.
Using the above mentioned heat recovery system, with a heat exchanger of efficiency close to 55%, 75 kWh can be utilized for steam generation.

<u>For Use in VD Boiler:</u>
Energy requirement at the vacuum degassing boiler is 85kWh.
Available energy recovered above = 90% of 75 kWh= 68 kWh
This is 80% of total energy requirement at the VD boiler.

<u>For Producing Electricity:</u>
Some steel plants use VD system full time, some of them use it sparingly and some don’t use it at all. Though it’s more efficient to use the generated steam in a VD boiler, it can also be used to run a steam turbine to produce electricity when a VD is not in use. The 75kWh of recovered energy could power a turbine and produce electricity with an overall efficiency of 50%, yielding approximately 40 kWh of electric energy.

Monetary Savings:
<u>VD Boiler:</u>
With an efficiency of 55% in VD boiler,
Calorific value of oil used- 10,000 Kcal/kg =12kWh/kg
For 68 kWh energy saved, the amount of fuel saved = 68kWh/(0.55*12kWh/kg)
= 10.5 kg

So, for every ton of steel produced 10.5 kg equivalent of furnace oil energy is saved. This otherwise would have cost Rs.350 ($7.6).

<u>Power Generation:</u>
For every ton of steel produced, 40 kWh of electrical energy will be produced. This otherwise would have cost Rs.240 ($5.2).

For a steel plant with an annual production capacity of 1 million tons, and which uses VD boiler 50% of the time, the total annual monetary saving will be:
{(350 +240)/2}* 1000,000 = Rs.30crore ($6.5 million).

In India the annual production capacity is expected to go above 200 million ton by 2020, thus incorporating such waste heat recovery in steel plants can save a lot of money.

Advantages
1. The dependency on fossil fuel will decline.
2. Overall carbon emission will be reduced.
3. Due to reduction in the combustion rate of the furnace of boiler, the boiler will be more efficient and actual fuel savings will be greater than that theoretically calculated.
4. The heat extraction and simultaneous utilization shows that both the cooling towers can be easily avoided as the heat diffused by them to the atmosphere is now being utilized as energy in the boiler.
5. By preventing the furnace from overheating, this process also improves the overall life of the furnace and its equipment.

Weaknesses
Even with the proposed recovery system, much energy is lost in the recovery process. Research should therefore focus on maximum recovery from these gases.

Conclusion
Changing the energy footprint of the steel industry is a daunting task, but the rewards could be large. Retrofitting the above discussed system in an already running plant can be difficult, and would impede the working of the plant during installation. But for a steel plant that is to be commissioned, this system can be installed with minimum difficulties and great advantages.

At this juncture, when demand for steel in India is growing rapidly to meet the domestic and global demand, energy efficiency is the only method to counteract the associated impacts. However, lack of financing capabilities as well as lack of incentives impedes the implementation of such systems.

Sectoral policies should be developed to promote such incentives, and policy strategy should be a mix of regulatory and price based incentives. There is an immense potential for energy recovery projects in the steel sector.

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