Journal of Applied and Advanced Research 2017, 2(1): 48–55
doi.: 10.21839/jaar.2017.v2i1.55
http://www.phoenixpub.org/journals/index.php/jaar
ISSN 2519-9412 / © 2017 Phoenix Research Publishers

Research Article – Chemistry

Solid waste management from steel melting shop

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Abstract

Production of steel in steel Industry is accomplice for the generation of solid waste materials like sludge, slag, dust etc. In recent days most part of wastes are generated from steelmaking process which is a focus point now-a-days. The solid waste generation, presently in Indian steel industry is in the range of 400-500 kg/t of crude steel and recycling rate varies between 40 - 70 % which lead to higher production costs, lower productivity and further environmental degradation. It is very essential not only for recycling of the waste valuable metals and mineral resources but also to protect the environment. I Solid waste management in steel industry is broadly classified in “4 R” i.e. reduce, reuse, recycle and restore the materials. The aim of the paper is to explore the various developments for total recycling of solid waste generated from steel industry, so that the vision for making “clean & green steel with zero waste” can be achieved for survival and growth of steel business in future.

Key words: Steel, Reuse, Recycle, Solid waste, Sustainable development.

Introduction

The production of steel in an integrated steel plant involves several operations starting from use of natural raw materials, like iron ore, coal and flux in production of hot metal and further processing of hot metal into steel and subsequently, rolling of steel into finished products in the rolling mills. Quantities of solid wastes generated in steel melt shops are a cause for concern as their nature is quite variable and diversified.

Steel is manufactured from iron ore mostly using blast furnace (BF) and basic oxygen furnace (BOF) and using electric arc furnace (EAF) in case of manufactured from scrap materials. Molten iron is produced in BF in presence of coke and molten steel is produced in BOF in presence of oxygen [2]. Smelting and refining process involves carbon reduction in BF to produce molten iron and decarburization of molten iron to produce molten steel. After BF and BOF process molten steel is controlled to a target composition and temperature for processing into continuous casting machine to produce slabs, billets etc. Finally the castings are rolled to the required dimensions in the rolling mill to get finished steel product [6]. The waste materials like slag, dust, sludge, etc. have a wide range of impact on the environment. Steel is a product of a large and technologically complex industry having strong forward and backward linkages in terms of material flows and income generation. Ingots are manufactured in the steel melting shop which is intermediate product, further used to manufacture TMT (Thermo Mechanically Treated) bars. Ingots are corrosive resistant to manufacture TMT bars and structural steel. Modern trend steel industries are focusing on eco-friendly technologies for making clean & green steel with zero waste to environment to make steel business a sustainable and successful venture.

The figure shows a flowchart of the integrated manufacturing process for iron and steel using the blast furnace and basic oxygen furnace (denoted BF and BOF hereinafter, respectively), which is presently the most commonly used method (51% of world

Received: 17-01-2017; Accepted 27-02-2017; Published Online 28-02-2017

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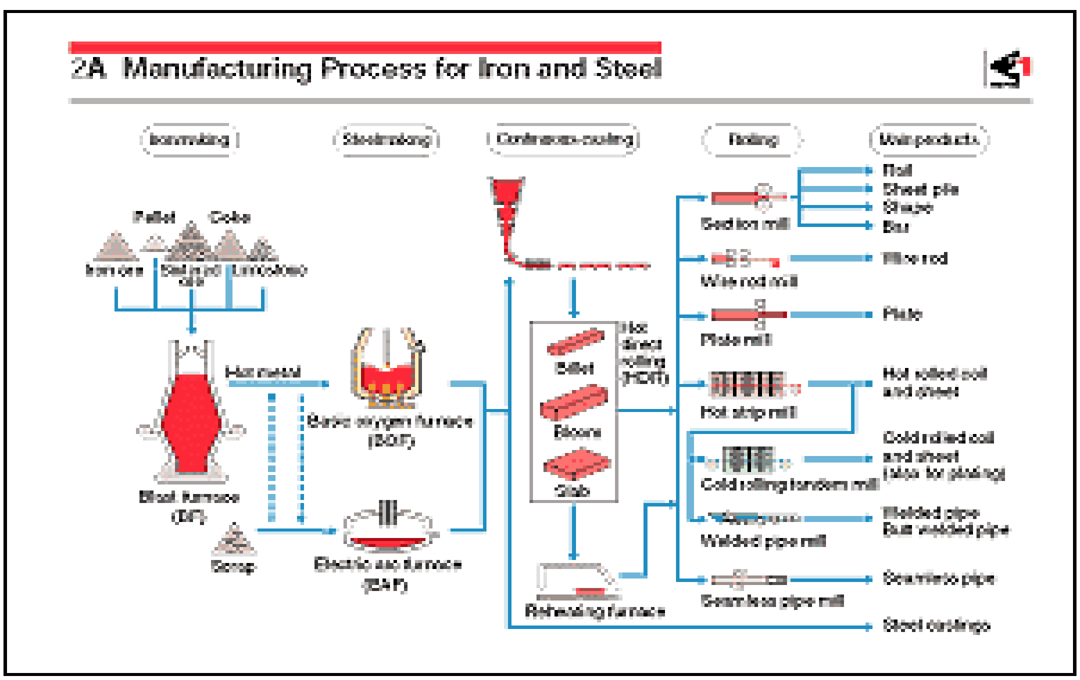
steel production). After the BF-BOF process, molten steel is controlled to a target composition and temperature and is then cast by continuous casting machine to produce slabs, blooms, and billets. These castings are rolled to the required dimensions by the rolling mill to produce steel products. The smelting and refining process for iron and steel in the BF-BOF process involves the carbon reduction of iron ore (Fe_2O_3) in the BF to make molten iron, and decarburization of molten iron in the BOF to make molten steel.

Major reducing agent in the BF is the carbon monoxide gas (CO) generated by the oxidation of the carbon (C) in coke. Consequently, carburization takes place at the same time as reduction, producing hot metal (molten iron) containing about 4% carbon. The hot metal is decarburized to the required carbon content in the BOF. The main reaction in this process is the oxidization of the carbon in the hot metal by both pure oxygen gas (O_2) and iron oxide (Fe_2O_3). The residual oxygen, after contributing to this decarburization reaction, remains in the molten steel. This oxygen is fixed and removed by deoxidation reagents such as silicon and aluminum as SiO_2 and Al_2O_3 or is removed as carbon monoxide gas in the subsequent vacuum degassing process.

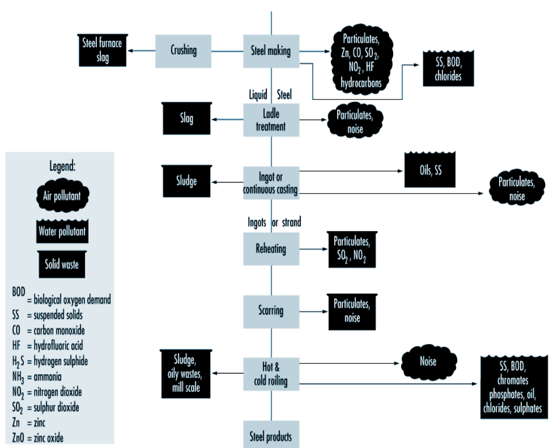
In addition to the BF-BOF process, there is another process which utilizes mainly scrap as an iron source, with some direct reduced iron whenever necessary. The direct reduced iron is produced by reducing iron ore with reformed natural gas, whose principal components are hydrogen, carbon monoxide, and methane. The scrap, along with direct reduced iron, is then melted in an electric arc furnace (denoted EAF hereinafter) to produce molten steel which is subsequently processed by the continuous casting machine, as mentioned above. The molten steel from the BOF and EAF is then deoxidized and alloying elements are added in the prescribed amounts. The molten steel is then held at the target temperature and continuously cast, and the castings obtained are cut to the prescribed length. After heating to the rolling temperature in a reheating furnace, these castings are hot-worked to the required products. Steel shapes, bars, and wire rods are worked on section and bar mills and wire-rod mills equipped with caliber rolls, plates are worked on reversing mills, and hot-rolled steel sheets are worked on hot strip mills. After pickling to remove scale from the surface, the hot-rolled steel sheets are worked to cold-rolled steel sheets on reversing mills or tandem rolling mills, and the cold-rolled steel sheets are tinned or galvanized as required to produce various surface-treated steel sheet products. Steel pipe is produced by forming and welding steel sheets or plates, or by piercing a billet and rolling to the final dimensions without a seam.



Development of steel industry has brought with it environmental degradation. Environmental conservation has become an increasingly more important aspect of our daily lives. With the rapid and extensive industrialisation and urbanisation in many parts of India, there is a dawning realisation that ultimate prerequisite for man's survival could well be the preservation of environment. We live under horns of dilemma. However, our expectations and our perceptions of what constitutes a minimum standard of living have put increasing pressure on both the public and private industrialists to ensure clean and healthy environment.

Environmental pollution in steel industry

Iron and steel industry which comprises, mining of ores, preparation of raw materials, agglomeration of fines in sinter plant, feeding of burden to blast furnace, manufacturing of coke in coke ovens, conversion of pig iron to steel, making and shaping of steel goods, granulation of slag for its use in cement plant, recovery of chemicals from Benzol and tar products etc. etc. All the above mentioned operations add to air, water, land and noise pollution. The environmental impact due to steel production is shown in following figure.



Source: UNEP 1986.

Types of wastes generation in steel plant complex in steel industry all three types of waste materials are generated, i.e., solid, liquid & gaseous wastes. The generation quantity of various types of waste materials differ from one steel plant to other depending upon the steelmaking processes adopted and pollution control equipments installed. The most common type of wastes generated in steel plant are as follows. Solid wastes like, hot metal pretreatment slag, dust, GCP sludge, mill scale, refractories, scrap, muck & debris, etc. Liquid wastes like industrial effluent, oil, grease, etc. Gaseous wastes like flue gases, fume extraction, etc.

Management of Air Pollution

Steel plant operations are vulnerable to air pollution. This can be visualised by the huge consumption of coal, iron ore, limestone, dolomite, sulphur etc. During the process large amounts of emission (stack and fugitive) consisting of dust, gaseous pollutants like SO_2, Noxetc. Are generated. To have an effective control over the pollutants first step for environmental management consists of conducting an emission inventory or pollution survey by visiting the plant at various locations such as blast furnace, coke oven, sinter plant, refractory plant, etc. to get a first hand information on the process and practices and also to carry out stacks and ambient air quality monitoring to establish the nature, quality and quantity of pollutants, emitted by the source, evaluate the performance of pollution control equipments if any, and also to compare it with emission standards so as to assess the necessity of controlling the emissions either at source by suitably altering the process parameters or by improving the efficiency of pollution control measures. Air pollution control equipment available in Indian steel plants are listed below : Raw material plant B. F. Boilers Sinter plant Stock house and cast house L.D Shop Bag houses Ventury scrubbers, Electro-state Precipitators (ESP) E.S.P. E.S.P. E.S.P. E.S.P.

Management of noise pollution

Noise is an unwanted sound. In steel plants noise is generated due to high speed rotating equipments like fans, blowers, exhauster; due to leakage of compressed air and steam, metal to metal contact, at rolling mills, forge shops, foundry etc. Though the effect of noise on the nearby township is minimal, its impact is very much felt in plants. In plant units (B.F., rolling mills, oxygen plant, power plant) noise survey is required to be carried out in well identified areas (sound level and frequency analysis) with the help of acoustic experts. Accousting absorbing system, use of bellow type tuyeres, etc. are being employed to contain noise pollution in steel plants.

Waste water management

Steel plant consumes huge quantities of water as high as 150-200 tonnes/ton of steel produced. Water pollution survey has to be conducted to determine the source, quality and quantity of pollutions viz. suspended solids, cynides, phenols, oils, greases, fluoride, ammonia, BOD, COD etc. Waste water treatment options consists of cooling the stream, separation and disposal of oil and suspended solids, biological oxidation of soluble organics, neutralisation with acids and crystallisation and removal of inorganic soluble salts. In steel plants in certain sections waste water is segregated and treated separately. Collective treatment by settling or coagulation is also practised. Recycling and reuse of water is adopted in various units. The cooling water is in continuous circulation through cooling and recirculating pond. If the waste water contains high pollutants the same is subjected to biological treatment, in trickling filters, by activated sludge treatment, etc.

Solid Waste Utilisation

Utilization of solid waste has been a difficult aspect but is of great concern in the steel industry. Experts have developed various means by a lot of trials and experiments for using the solid waste. However, R & D efforts are continued in this field to develop the common methods for use of solid waste of steel plants which can also add profit to steel industry. a) Steel Slag The phosphorus content of BOF slag is too high to be used in iron making & steelmaking process. In the process of iron making, complete phosphorus enters into the metal phase which increases the load of phosphorus in steelmaking process. R & D efforts are on to develop the ways to recycle the BOF slag in steelmaking & iron making process. However, in order to utilize steel slag, several experiments and developments have been tried and some of the successful means of utilization are described below.

i. Slag atomisation
ii. Rail ballast
iii. Road & pavement material
iv. Filling materials
v. Cement making
vi. Substitute for sinter flux
vii. Brick manufacturing
viii. Soil conditioners

(b) SMS Shop Dust: Dust collected from dedusting FES system of the SMS shop contains high % of (Fe>40%) and it is usable for reuse in sinter making plant.

c) Lime Dolomite plant Dust: Due to high content of CaO & MgO, these dust can be used for sinter making.

d) GCP Sludge: Sludge generated from BOF-GCP in rich in iron (> 40% Fe) and it dominantly constitutes Fe2O3 and therefore, it can be used for sinter making. The sludge generated from ETP plant is pumped to sludge dewatering plant having filter process. After dewatering dry filter cake is produced. These dry filter cakes are transported to raw material stock yard for feeding the same to sinter plant for sinter making. BOF sludge are also being tried for use for making of briquettes as a replacement to sized iron ore in BOF steel making. Industrial trials have been found successful in some steel plants and more trials are being conducted in this area.

e) Scrap: Scrap generated can be used as coolant material or re-melting in process of steel melting.

f) Refractories Waste refractories can be broadly used as follows:

Reusable portion of salvaged refractories are recycled.

Broken pieces are recycled/sold to outside parties.

Preparation of mortar etc.

g) Scale from continuous caster cooling Scales are generated during cooling of continuous cast product by direct spray. The dewatered scale from scale pit shall be transported to raw materials stock yard from where it will be conveyed to mill scale bunker of sinter plant for manufacture of sinter. Mill scale, caster scale, CRM dust and similar high iron containing waste are mixed and briquetted. Presently these scale briquettes are being used in both the steel making shops as secondary coolant-replacement of iron ore.

h) Muck & debris: Scrap removed from SMS slag is recycled back in the converter for cooling purpose. The wastes are being used and recycled in various ways in different industries depending on several local governing factors and provisions etc.

Waste Management in Steel Industry Waste management practice involves collection, transportation, processing, recycling or disposal of waste material, in properly defined ways with adequate efforts to reduce their effect on human health or local aesthetics or amenity. These practices shall be friendly with the natural world and the environment and to recover resources from them. Figure-2: Waste hierarchy The policy of waste management is to apply the waste hierarchy principle in steel industry successfully. The waste hierarchy refers to the "4 Rs" reduce, reuse and recycle, restore which classify waste management strategies according to their desirability in terms of waste minimization. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste. The waste hierarchy as shown in Figure-2 remains the cornerstone of most waste minimization strategies. In general by reducing or eliminating wastes an industry can:

- Solve the waste disposal problems created by land bans
- Reduce waste disposal costs
- Reduce costs for energy, water and raw materials
- Reduce operating costs
- Protect workers, the public and the environment
- Reduce risk of spills, accidents and emergencies
- Reduce vulnerability to lawsuits and improve its public image
- Generate income from wastes that can be sold.

In the present paper, emphasis has been given mainly on the various types of solid waste generated from “steel melting shop” of steel plant complex. The generation of solid wastes, their use and efforts for making complete use of all solid wastes have been elaborated. The principle of waste management basically depends on:

- Utilisation & recycling of waste generation
- Minimisation of waste generation

In present scenario, we have to aim for converting the waste management system into a profitable business and to achieve “zero waste concept”. The solid waste generated from steel plant needs various techniques and means with R &D efforts for its proper utilization & recycling in steel industry.

In steel industry for management of solid wastes, following are significant:

- Solid waste generation is controlled by efficient and optimum use of raw material.
- Solid wastes should be disposed properly through a proper disposal system.
- New technologies should be adopted for eco-friendly solid waste disposal.
- Transportation of solid waste from generation point to disposal point should be in a controlled and proper way.
- Displaying the area as solid waste disposal area.
- If possible, selling some of the solid wastes to be further used in some other ways converting waste into wealth.

Table 1. Measures for minimization of solid wastes generation in integrated steel plants

Shop	Type of waste	Waste minimization measures
BOF shop B	BOF dust/BOF sludge	Avoidance of over blown metal, minimization of fines in flux-mix, avoidance of late addition of fluxes, elimination of zinc-coated scrap in the burden, use of optimum top blowing rate, pressure and time in conjunction with bottom blowing rate and time, use of low Si hot metal, use of low SiO_2 lime.
	BOF slag	Use of low SiO_2, high reactivity and low LOI lime, use of low-silicon and low sulphur hot metal, if necessary, through hot metal pre-treatment, computerized charge balance or process control.

Shop	Type of waste	Waste minimization measures
EAF shop	EAF dust	Minimization of wastes at source through improvement in process, operation and maintenance such as, continuous charging (Con-steel process, Conti-arc process, Finger shaft furnace; it reportedly reduces the volume of dust discharged by as much as 40%).Lime addition as a part of the bucket charge contrary to addition by pneumatic injection. Adoption of foamy slag practice to the optimum extent. Minimization of carbon blowing by maintaining not so high carbon opening in the bath. Providing adjustable speed drives (ASD) bag house fan to reduce dust emission by 2 to 3% over the whole tap-to-tap cycle .Provision of computerized process control. Use of UHP in all solid charge operation to reduce tap to tap time.
	EAF slag	Improved charge-mix preparation, cost-effective optimization of charge-mix, maintaining minimum basicity by controlling low opening of „S" & „P" in the bath through optimized charge-mix, betterment of flux quality.
Continuous	Casting shop	Caster scale sludge Air mist cooling.

Table 2. Chemical composition of steel slags from different furnaces

Components	B.O.F (%)	E.A.F (For carbon steel)	E.A.F (For alloy stainless steel) (%)	Ladle (%)
SO2	8-20	9-20	24-32	2-35
Al2O3	1-6	2-9	3-7.5	5-35
FeO	10-35	15-30	1-6	0.1-15
CaO	30-55	35-60	39-45	30-60
MgO	5-15	5-15	8-15	1-10
MnO	2-8	3-8	0.4-2	0-5
TiO2	0.08-0.2	not available	not available	not available
S	0.06-0.15	0.08-0.2	0.1-0.3	0.1-1
P	0.2-2	0.01-0.25	0.01-0.07	0.1-0.4
Cr	0.1-0.5	0.1-1	0.1-20	0-0.5

General Modes of Solid Wastes Generation

The solid wastes generated in steel industry can be broadly divided into two categories i.e., ferruginous wastes and non ferruginous wastes. The ferruginous wastes, i.e. the iron bearing wastes are generated from steel making viz., mill scale, flue dust, sludges from Gas cleaning plants of Blast Furnaces and Steel Melting Shops, Blast furnace slag and SMS slag. The non ferruginous wastes are lime fines, broken refractory bricks, broken fire clay bricks, acetylene plant sludge etc. A list of solid wastes along with their source of generation is depicted in Table II. The chemical composition of various categories of solid wastes is also presented in above Table

Reuse Potential of Solid Waste

The major solid waste in steel industry i.e. blast furnace slags are used for the manufacture of cement, road base, railroad ballast, light weight concrete block, glass and artificial rock, high performance concrete admixtures. EAF steel making slag can be modified to use in cement making operations [1,5]. Basic oxygen furnace slag has high fluxing capacity and is being charged in the blast furnace due to easy melt and better utilization of calcium values. Suitable EAF slag generated at SMP can be effectively utilized for filling the low lying areas. Segregated refractories at the source of generation can be used as constituents in manufacture of new bricks/mortars [7,10-12,19]. Recycled iron and steel scrap is a vital raw material for the production of new steel products requiring much less energy than the production of iron or steel products from iron ore [8]. Blast furnace flue dust and electric arc furnace dust after extracting zinc and other metals can be used as a source of lime and phosphorous in fertilizers. Total scrap generated from rolling mills is either recycled or sold. High capacity Steel Plants can install captive cement plants for the utilization of BF Slag. The SMS Slag with particle size up to 5 mm is being charged into Sinter Plant replacing equal amount of flux .The roads are being repaired by the LD slag having 5-10 mm and 10 - 40 mm particle size. Besides, LD slag with 20-65 mm particle size is being spread in railway track replacing conventional stone ballast. The rejected refractory bricks are used for pavement making. Fly ash can be used in the cement plant for making PPC and for making fly ash bricks for building constructions [8,9].

Conclusion

Steel industry development is focusing on "Clean, green & sustainable technology" for its survival, development and growth. The sustainable technology development means development aims at improving the quality of life for everyone and generation to come. In order to achieve the above objective for steel industry, the waste management system has a vital role without which development & growth of steel making will be quite difficult . In this regard, we must adopt the methods and suitable technologies for 100% recycling and use of waste from steel plants. The enormous supports by way of R & D efforts in this field are required for making "waste management system" not only a successful venture but also as a profitable business. This concept will strengthen us to make commitment for success in steel industry for making "clean & green steel" for our sustenance and growth in to days highly competitive global steel market. References 1. http://eprints.nmlindi

Most economic management practices in steel industry of developing countries for minimizing the generation of solid wastes and maximizing the recycle of collected wastes can be opted in the following ways:

An advanced technology with economical feasibility options for minimizing wastage of resources to be evaluated.

- Should strive to make improvements in yield losses.
- To treat the waste as raw material of related industry on the base of avoiding secondary pollution.
- To build up series of integrated utilization programs, from the industry system technologies and products systems.
- To develop technology focused competitive products based on deep processing of wastes and by-products.

A zero waste approach should be considered viewing solid wastes as potential raw materials to be conserved or reused

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