Injection of Plastics in Electric Arc Furnace

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Abstract

With the increasing use of plastics, its sustainable re-use and recycling have become a serious environmental challenge. At JSW steel a new technology to inject plastics in an electric arc furnace (EAF) as a foaming agent has been developed and implemented. EAF utilizes coal /coke fines to increase the foaming behaviour of its slag for stable arcing and reduced arcing time. In the present work, the in-house generated plastics were shredded to < 5mm size and pneumatically injected into the EAF slag as a replacement for coke fines. For handling these finely shredded plastics, a unique pneumatic conveying system for has been developed which is first of its kind where different types of plastic particles are fully suspended in the conveying air and transported at controlled low pressure and high velocity into the furnace without choking from a single unit. The controlled burning inside the furnace takes advantage of the generated gases. This method of recycling plastics has huge potential to get consumed in large steel-making furnaces. India's first EAF plastic injection system has been commissioned at SMS-3 in JSW Vijayanagar works and is injecting 70 -100 kgs in every heat. The use of plastics has reduced the equivalent coke fines consumption and shown improvements in slag foaming and furnace efficiency along with overall CO_2 emission reduction.

Keywords: Recycling, Plastic, EAF, Injection.

1. INTRODUCTION

The demand for plastics has grown significantly over the past several decades and will continue to expand with the rising income levels in emerging economies. A global material balance study shows that 79 % of plastic produced in the world ended up as waste. Only 9% of plastic produced in the world has been recycled [1]. In India, the Plastic Waste Management Rules were mandated in 2016, which were amended in 2018 and 2021, to manage waste at the city level. The Central Pollution Control Board (CPCB) is collecting data on waste plastics from all the states which shows that 34, 69,780 Tonnes (3.46 million tonnes) of plastic waste was generated in the year 2019-20 [2]. Another study shows that India is producing 9.46 million tons of plastic waste annually and 40 % of it remains uncollected and 43 % cent is used for packaging, most of which is single-use [3]. India is the fifth largest generator of plastic waste. The utility and relatively short lifespan of plastics have resulted in a massive waste problem. Conventional waste disposal options for these polymeric products, burial in landfill, or incineration, are highly unattractive, due to their resistance to biodegradation, and the formation of pollutant polycyclic aromatic hydrocarbons upon combustion at incineration temperatures. Thus, there is an urgent need for developing novel, cost-effective and environmentally sustainable polymer recycling techniques. According to the Intergovernmental Panel on Climate Change (IPCC), the steel industry accounts for between 3– 4% of total world greenhouse gas emissions. On average, 1.7 tonnes of carbon dioxide are emitted for every tonne of steel produced. In plastic, carbon and hydrogen are the main constituents and have highly volatile matter with generally low ash content [4]. So, waste plastics have the potential to be a cheap and easily available source of carbon. It can partially replace the coke in steelmaking. Hence, any attempt made in popularizing the use of plastic waste by the steel industry shall help in minimizing dependency on imported coal and improve resource efficiency. Coke fines are also used in electric arc furnace as slag foaming enhancer by directly injecting them during the refining process and normally varies between 6 - 10 kg per ton of steel produced. Coke consumption in EAF needs to be reduced further. A significant decrease in utilization of coke in EAF could be obtained by injecting alternate carbonaceous materials like waste plastic into EAF. The high processing temperature of steelmaking gives an opportunity for a large-scale recycling of waste plastics without creating any changes in existing processes. Few researchers have reported the use of polymeric materials in EAF steelmaking. Sahajwalla et al. [5] investigated the recycling of waste plastics in EAF steelmaking. Carbon/slag interactions for different blends of coke and HDPE has been studied at 1550°C using a sessile drop arrangement and the best blend was implemented in the industry. Industrial results showed good accordance with lab scale results. Effect on the volume of FeO-containing slag by the interaction of FeO-containing slag with plastic/coke or rubber/coke blends as a carbonaceous material by using the sessile drop technique was investigated [6,7]. Dankwah et al. [8] studied the reduction of FeO in EAF steelmaking slags by the blend of coke, HDPOE and rubber tires as carbonaceous material. Results show that the hydrogen and fixed carbon contents lead faster reduction rates and carburisation. Asanuma et al. [9] investigated the effect of waste plastic injection as waste plastic/Coal blend in a blast furnace. The aim of this investigation is to develop and implement a new technology to recycle plastics in an electric arc furnace (EAF) as a foaming agent as a partial replacement of coke fines. EAF utilizes coal /coke fines to increase the foaming behaviour of its slag for stable arcing and reduced arcing time.

2. EXPERIMENTS

2.1 Waste Plastic for Injection

The majority of plastic is generated at JSW includes met wrap, polyethylene bags, waste plastic from households, HDPE (high-density polyethylene) Fabric, VCI Paper, Filament Tape, Polypropylene pipes, PPH Pipes, Old RO membrane, UF membrane. Generated plastics are in a variety of shapes, sizes, densities and physical characteristics. They were also mixed with wood, metal and other impurities. These collected plastics were first cleaned and segregated from other materials in a solid waste treatment unit. These plastics were then shredded to less than 5 mm size for making them suitable for injection through a pipeline. However, being a mixture of different characteristics of plastics, its followability is not uniform and requires a customized injection unit.

2.2 New Pneumatic Conveying System

Dense and heavy materials are usually conveyed pneumatically using a combination of silos and dispensers with high-pressure line. Lightweight (< 300 kgs/m3) or low density shredded or powdered material (< 10 mm) such as in this case are difficult to convey through such systems and pipelines. Existing pressurized dispensers do not go well for conveying shredded plastic into Electric Arc Furnace as low-density materials such as shredded plastics, paper etc tend to adhere and form chunks or generate disperse motion inside the holding vessel, resulting in slowing down or stopping material discharge into the conveying line. The airflow passes through the material without moving it, forming a rat hole in the holding vessel. To overcome the difficulties faced during conveying and injecting shredded waste plastic, a new pneumatic conveying system for low-density shredded and powdered materials has been developed without the use of large silos and dispensers as shown in figure 1.

Figure 1: New developed pneumatic injection system.

The conveying materials are fed in a pneumatic system through manhole feeding point. Pressurised air is uniformly distributed across the cross-section of the pneumatic conveying system by air shower blowing box. The cylindrical barrel has eccentric cones at the exit side for unrestricted flow materials. The pneumatic conveying system has fixed fluidisation points in the barrel and cone area to avoid any dead zone accumulations. The pneumatic conveying system has conveying line to control the output materials flow from conveying system. This unique design has no moving or rotating devices such as valves which makes it maintenance-free. In this system, the shredded material particles are fully suspended in the conveying air and transported at controlled low pressure and high velocity. It can be connected to long pipes and material can be conveyed into liquids, heated chambers and furnaces. This simple and movable system can be placed on any flat platform and can be applied to continuous and stable conveying of shredded plastic, shredded rubber, wood, lime fines, coal fines and any other similar materials.

2.3 Waste Plastic Injection in EAF

A new developed pneumatic conveying system has been commissioned on the shop floor at SMS-3 in JSW Vijayanagar works to convey and inject shredded plastic into Electric Arc Furnace. Figure 2(a) shows the experimental setup of shredded waste plastics injection. Injection of shredded waste plastic along with coke fines didn't require any modification of existing electric arc furnace infrastructure or operational procedures. Shredded waste plastic of size is less than 5 mm which can directly inject into EAF.

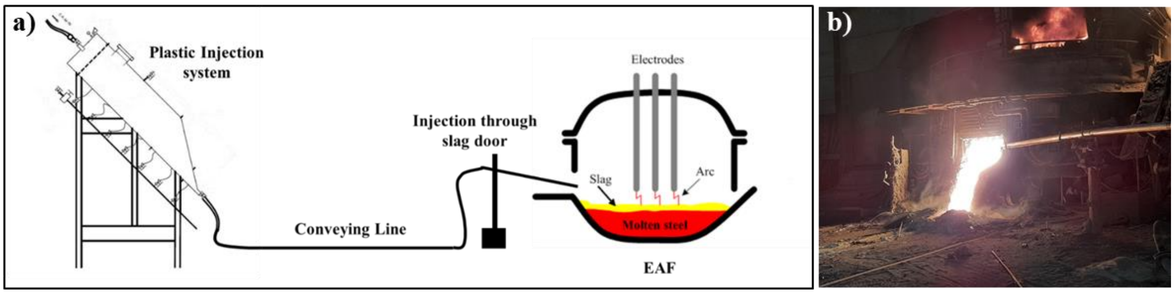

Figure 2 :(a) Experimental setup and (b) Waste plastic injection into EAF through slag door.

At JSW, Fe-bearing raw materials are Hot Metal, Scrap and DRI. Initially, Scrap is added in EAF followed by Hot Metal. At the end of pouring Hot Metal, arcing starts to give energy to EAF for further refining. After one minute of power on, all additions start to EAF and continue for the whole melting duration. In EAF, generally, injection of coke fines starts after 8 to 10 minutes of arcing. Coke fines are injected only when boiling tendency comes during 3/4th of arcing time. For the last quarter of arcing time, coke fines were injected continuously into EAF to increase the slag foaminess. Shredded waste plastic is injected in EAF through slag door along with coke fines into the slag bath as shown in figures 2(b). A new pneumatic conveying system has been injecting shredded plastic into an electric arc furnace through slag door successfully since it was commissioned. Approx. 10% of coke fines are replaced by shredded plastic for injection into EAF. To know the effect of plastic injection on slag foaminess of EAF slag, Slag samples were collected before and after of plastic injection and analysed for chemical composition.

3. RESULTS AND DISCUSSION

A new pneumatic conveying system for low-density shredded and powdered materials has been successfully developed without using large silos and dispensers and is the first of its kind in India. It has been successfully conveying and injecting shredded waste plastic into the EAF without choking. Shredded plastic is used as a replacement for coke fines as a foaming agent in the electric arc furnace. It is well established that full combustion of plastics takes place at temperatures prevailing in EAF and burn like oil. The particles shrank to a droplet and burned completely during the pyrolysis stage, leaving no char. It is expected to generate higher tar than core fines, but the percentage replacement is very low to make any impact on the gas system. The combustion study performed by Mitera and Michal [10] in a flaming chamber showed that, on combustion, plastics releases many products, which further gets converted to CO2 because of the oxidation atmosphere. In the EAF steelmaking process, Slag Foaming means the increase in the volume of molten EAF slag by entrapping CO bubbles which evolves from the chemical reactions occurring at the slag/ carbonaceous material interface and slag-metal interface during EAF steel-making process [11]. Hence, the slag foaming phenomena is mainly affected by two factors:1) rate of gas evolution by the reduction reaction occurring during EAF steel-making process and 2) the stability of the foamy layer in the molten EAF slag layer. The second factor is dependent on the bubble size of gas evolved from the reduction reaction and lamellae stability. The physicochemical properties of the slag have a major impact on the formation and stability of a foamy slag [12]. Apart from the entrapment of gases in the slag layer, another important reaction responsible for the increase in slag foaminess is the reduction of iron oxide of slag by carbon, when carbon is directly reacting with the molten slag during the steelmaking process in EAF [13]. Coke fines are injected to increase the slag foaminess of slag by reacting coke fines with slag. Here, coke fines are partially (10%) replaced by shredded waste plastic. Shredded waste plastic is successfully injected into EAF along with coke fines during EAF steel-making process. The data and sampling have been done in those heats which have normal tap-to-tap time. The enhanced performance of the plastic/coke fines blend is good in accordance with the laboratory results. Equivalent amount of coke fines addition has been decreased. In the final slag FeO % decreased marginally from 26.8 % to 26.1 % in the experimental heats. Decrease in 0.7% of FeO in slag is significant for EAF steel making of 160 T capacity furnace. It results to increase of EAF Yield by 0.2%. There is potential improvement in steel yield with increased addition. The reason for improved slag foaming is increased gas formation. The residue of shredded waste plastic/coke fines blend is mixed in the slag. This EAF slag is subsequently used as construction aggregates. Shredded waste plastic injection into EAF also gives environmental benefits by decreasing the disposal of waste plastic in the environment. This method of recycling plastics by injecting into Electric Arc Furnace has huge potential to utilise large amounts of plastic in large steel making furnaces benefitting the environment. We expect to recycle 340 T of plastic per annum giving a net savings of 600-700 tons of CO2 annually. The reduction in usage of carbon-bearing materials has been one of the key-takeaways from the project. Through plastic injection into Electric Arc Furnace has resulted in annual cost saving of INR 1.97 million with a Capex of INR 1.2 million. Additionally, one may also consider the savings from reduced plastic disposal expense as an add-on benefit of the intervention.

4. CONCLUSIONS

- A new pneumatic conveying system for low-density shredded and powdered materials has been developed without the use of large silos and dispensers. It is the first of its kind.
- Shredded waste plastic was successfully conveyed and injected into EAF through slag door along with coke fine by a newly developed pneumatic conveying system.
- Results show that lower FeO % in Slag in which waste plastic is injected along with coke fine resulting in improved slag foaminess.
- Improved slag foaming results in decreased energy consumption and therefore lower greenhouse gas emissions produced by coal-fired power stations.
- Lower coke fines consumption has been obtained which leads to the better environmental sustainability of EAF steelmaking.
- Environmental friendly plastic disposable technique
- This newly developed technology benefits both EAF steelmaking and the environment.

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