Recycling of Waste Plastics in Coke Ovens

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Abstract

Economic growth and changing lifestyle patterns are resulting in rapid increase in generation of waste plastics in the world. Effective disposal of waste plastic is an area being seriously explored as a part of environmental initiatives. An attempt is made to assess the impact of waste plastics in coal blend on the coke properties at pilot scale studies. The present study explores addition of waste plastic in the coal blend. Experimental trials were conducted in a 120kg pilot-scale coke oven. The coal maximum fluidity at 1% plastic addition was found to be in line with the base composition. Results show that up to 1% plastics can be effectively recycled in the coal blend without any detrimental effect on coke quality. Addition of higher percentages of plastics resulted in deterioration in coke properties e.g. Coke Strength after Reaction (CSR) and Coke Reactivity Index (CRI) and coke yield. The waste plastic utilisation at coke ovens aims at a cleaner and greener environment around us. Based on the pilot-scale results, plastic shredding system was installed at JSW Steel Ltd., Vijayanagar Works. During the period Jan'21 to Aug'22, ~150 tonnes of waste plastic has been consumed in Coke Oven-3. The addition of waste plastics to coal blend in coke making can be attributed as one of the effective ways of waste plastic recycling.

1. INTRODUCTION

Coke is one of the major fuels for Blast Furnace (BF) and coke quality is one of the important factors affecting BF performance with respect to the production of hot metal and coke rate. Consistency of coke quality is also required for higher productivity and smooth functioning of BF. Coke Strength after Reaction (CSR) test is performed before hand to check the high temperature property of coke. CSR value specification limit varies from furnace to furnace based upon BF height, working volume and operating methodology. Metallurgical coal is used for producing coke, which is used as a reducing agent for iron oxide reduction in BF. Utilisation of plastic waste in the industrial sector is required to take initiatives. Coal carbonization with other carbon sources like biomass, wood, polyethylene and paper is gaining significance. As disposal of plastics is a serious global problem, various routes for recycling waste plastics needs to be investigated. Coke making found to be effective route for disposal of plastics.

Tata steel used 0.003 - 0.008% of waste plastics in the coal blend at plant scale for six months in two stamp charged batteries nos. 8 and 9 [1]. Based on their lab scale studies, they have concluded that maximum 0.5% plastic addition is safe to use without affecting the coke properties. Utilization of recycled plastics in coking processes was introduced at Nippon Steel, Japan in 2006, focused on utilization of waste plastics for decreasing energy consumption with the aim of obtaining 10% energy reduction [2, 3]. Kenji Kato et al established up to 1% plastic addition to coal blend and found no deterioration of coke properties and resulted in 1.5% energy consumption [4]. Kenji Kato et al studied the effect of chlorine containing plastics during coal carbonization [5]. Chlorine is converted into ammonia liquor by thermal decomposition treatment.

Veena et al Investigated alternate dissolution of carbon from coke/HDPE blends and compared to that from metallurgical coke alone [6]. The blend of coke and plastics resulted in the difference in physical and chemical properties, because of the individual characteristics of each polymeric material [7]. Sidorov et al studied the laboratory carbonization of coal blend with plastics at 850°C in order to determine the benzo-pyrene emissions [8]. In carbonization, the exhaust gases from all the polymers contain benzo-pyrene in levels far exceeding workplace air standards.

In JSW R&D, we have added waste plastic granules, together with the coal blend, charged into a 120 kg pilot coke oven, in which they are carbonized in an oxygen- free reducing atmosphere at about 1100 °C. As a result, the waste plastic and coal blend is thermally decomposed into coke and coke oven gas. These products obtained by the carbonization of waste plastic have their own uses.

2. PILOT SCALE TRIALS

Waste plastics experiments were conducted in 120kg pilot coke oven (Fig. 1) in R&D unit, Vijayanagar Works, Karnataka with different percentages of plastics (0 to 2%). Specification of pilot coke oven given in Table-1. Initially 120kg of coal blend is taken with no plastics added to it, it was considered as base blend experiment. Plastic granules taken were of 1- 3mm in size. Typical properties of plastics were shown in Table-2.

Fig. 1: Pilot coke oven in R&D unit, Vijayanagar Works, Karnataka

Table I: Specification of pilot coke oven

Parameter	Equipment details
Capacity	120 Kg
Heating	Electrical heating
Wall	Refractory brick
Temperature	1100 °C

Table II: Properties of waste plastics

Parameter	Value
Volatile Matter, %	99.53
Ash, %	0.45
Fixed Carbon, %	0.02
Total Carbon, %	85.06
Sulphur, %	0.12
Hydrogen, %	13.68
Nitrogen, %	0.69
GCV, KCal/kg	11,019

Bulk density was maintained in the range of 1.05 t/m³. Coal cake moisture is targeted in the range of 10%. With increase in plastics addition in the blend, blend volatile matter content increases from 27.02 % to 28.65% in 2% waste plastic addition in the combination. Coal Sulphur is within the range for all the cases. Coal ash is also in the acceptable range. The blend fluidity varies between 398 - 421 ddpm. This shows that the waste plastic addition does not hamper coal rheological property. Table-3 shows the coal blend properties and cake moisture.

Table III: Coal blend properties with waste plastic addition

	% of waste plastics addition								
	0.0	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0
Moisture (%)	9.87	9.78	9.93	9.78	9.85	9.85	9.88	9.88	9.92
Sulphur (%)	0.53	0.61	0.53	0.52	0.52	0.52	0.53	0.54	0.54
Ash, dry basis (%)	8.19	9.08	8.08	8.07	8.05	8.05	8.04	8.14	8.16
V.M., dry basis (%)	27.02	27.47	27.56	27.64	27.72	27.76	27.84	28.28	28.65
Fluidity (ddpm)	413	421	418	398	410	410	406	400	405

2.1. Effect of plastic addition on CSR :

Coke with higher Coke Strength after Reaction (CSR) breaks down more slowly than low CSR coke and thus in a blast furnace, the permeability of gas and liquid is better and the productivity is increased and the specific coke consumption of the blast furnace is decreased. Standard Blast furnace coke corresponds to CSR >= 66.5%. The CSR value decreases with increase in waste plastic addition in coal blend (Fig. 2). Fig.4 indicates that the average CSR is found to be 66.82% up to 1% plastic addition. At 1.5 & 2.0% plastics addition, CSR found to be 66% & 65.5% respectively.

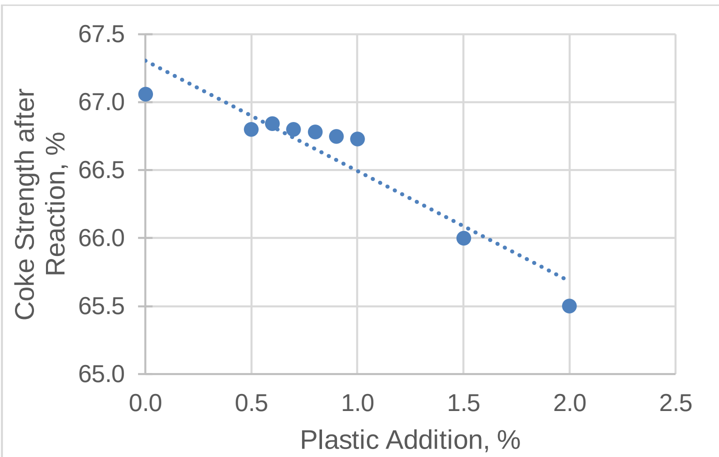

Fig. 2: Relation between plastic addition & coke strength after reaction

Based upon these pilot-scale trial results, up to 1% plastics can be effectively recycled in the coal blend without any detrimental effect on coke quality. Addition of higher percentages of plastics resulted in deterioration in coke properties e.g. Coke Strength after Reaction (CSR) and Coke Reactivity Index (CRI) and coke yield.

3. PLANT SCALE IMPLEMENTATION

Plastic shredding system was installed in Nov'2020 at JSW Steel Ltd., Vijayanagar Works to utilise all waste plastics generated inside plant. During the period Jan'21 to Aug'22, ~150 tonnes of waste plastic has been consumed in Coke Oven-3.

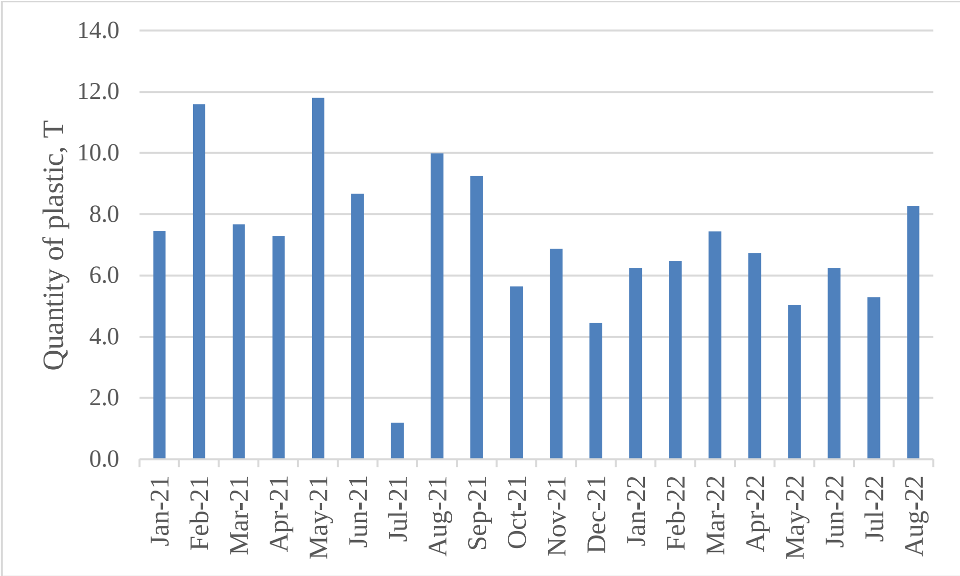

Fig. 3: Waste plastic consumption in Coke Oven-3 (month-wise)

Waste plastic generation inside plant is decreasing now-a-days (Fig. 3). A next level plan is being prepared to collect plastic from the townships and nearby villages. This method of recycling plastics by charging into Coke Ovens has huge potential to get consumed in large steel plants without affecting environment. The waste plastic utilisation at coke ovens aims at a cleaner and greener environment around us.

4. CONCLUSION

Disposal of plastic is the main environment concern. Conventional waste disposal options for plastic 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. With the increasing use of plastics, its sustainable re-use and recycling has become a serious environmental challenge. Thus, there is an urgent need for developing novel, cost-effective and environmentally sustainable polymer recycling techniques. The addition of waste plastics to coal blend in coke making can be attributed as one of the effective ways of waste plastic recycling. Pilot-scale results show that up to 1% plastics can be effectively recycled in the coal blend without any detrimental effect on coke quality. During the period Jan'21 to Aug'22, ~150 tonnes of waste plastic has been consumed in Coke Oven-3.

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