technical note

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Using Scrap Tires in EAFs as a Substitute for Carbon

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Abstract

EAF plants normally consume coal and coke as reactants, alloying elements, or fuel. The price of these materials varies from € 0.20-0.35/kg. This is while nearly 10 million pieces of tires are annually discarded in Iran. The present study shows that scrap tires can be used as a substitute for coal and coke in EAF plants. Thirteen grades of steel including low, medium, and high carbon steels as well as low and high alloys were produced during 73 heats in a 6t EAF. Coke consumption reduced from 18.00 to 0.00 kg/ton of steel produced and power consumption decreased from 448 to 388 kWh/t. Stack gas analysis and measurements were performed to find that the gaseous pollutants released such as CO, NO_x, and SO_2 were far less than the permitted standard limits. More than 200 heats have so far been carried out using waste tires in Esfahan Steel Co. (ESCo) where experiments were conducted in this study. Industrial tests were replicated in Iran Alloy Steel Company (IASCo) where 20 heats were made in a 40t EAF, which resulted in coke consumption to reduced from 15 to 0 kg/ts and power consumption to reduce by 10%. Similar results were obtained in the EAF Unit of Malayer Alloy Steel Company operating a 25-ton heat capacity EAF. The results of this study show that the process is reliable, economical, and eco-friendly leading to a production cost reduction of 5 €/t.

Keywords: Scrap tire, EAF, Carbon, Steelmaking.

Introduction

Iran produced a total quantity of 10.1 mmt of crude steel in 2007. Figure 1 shows the steel production trend via EAF route in Iran indicating its share to be 78.5%. Carbon is one of the most utilized compounds in EAF steelmaking and plays a significant role in the process along the following lines:

- As a source of energy in the steel bath via reaction with oxygen:

$$2C+O_2 \rightarrow 2CO \qquad (1)$$

- As a source of energy above the bath via post-combustion with oxygen:

$$CO+1/2O_2 \rightarrow CO_2 \qquad (2)$$

- For recovery of iron from slag via the reaction

$$FeO + C \rightarrow Fe + CO \qquad (3)$$

- As slag foaming materials and the fundamental alloying element

The amount of charge carbon used depends on several factors including carbon content of scrap charge, desired tapping carbon, projected oxygen gas consumption, and the economics of iron yields versus carbon cost [1]. Carbon-bearing materials normally used for EAF steelmaking are metallurgical coke, anthracite coal, calcined petroleum coke, fluid coke, and artificial graphite.

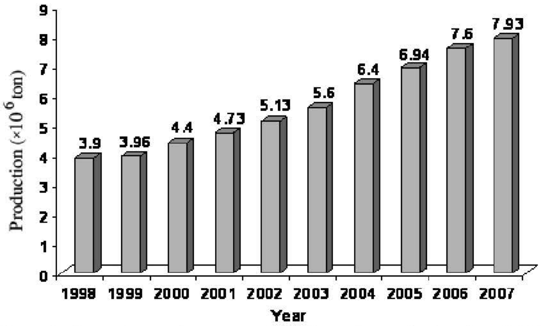

Fig. 1. Iranian steel production trend via the EAF route.

Iranian EAF plants mainly use coke or coal as their carbon-bearing materials which are mostly imported from abroad. The price of coke varies from 200-230$/t. On the other hand, about 10 million passenger car and truck tires scrapped each year are usually left as garbage in the environment. ESCo decided to consider the recycling of scrap tires instead of burying them in landfills not only to save the environment but also to reduce steelmaking costs by using the scrap tires as a carbon source. The original idea dates back to 2004 when ESCo first used waste tires partially as steel scrap and partially as replacement for coke in the EAF unit. While the use of tires in EAFs is new to Iranian steelmaking

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industry, it has been the standard practice in U.S and France since 2000 and since 1998 in Japan where presently some 15% of all used tires is consumed in EAFs. In the U.S., 1.34 million (18,880 tons) waste tires were consumed in EAF steelmaking in 2005 [2].

Scrap tires and the environment

In 2006, more than 1.3 billion scrap tires were discarded worldwide. U.S, Japan, Russia, and Iran, respectively, discarded 300, 130, 50, and 10 million truck and passenger car tires [2]. Disposal of scrap tires in tire piles is not an acceptable waste management practice because of their fire risks and their potential health hazards by providing habitats for disease vectors such as mosquitoes [3]. Scrap tires pose a significant environmental problem worldwide and their disposal into the environment presents environmental and safety hazards including fires, overflowing landfills, and pollution of the atmosphere.

Tire stockpiles host snakes and small mammals such as rats, opossum, skunks, and raccoons. The greatest risk associated with scrap tire stockpiles is their possible ignition. Once ignited, stockpile fires tend to spread rapidly generating massive quantities of smoke oil and contaminated water that cause environmental damage. Seven scrap tire stockpiles recently went ablaze in Iran. It is reported that in 1983 a 7-million tire fire in Rhinehart Virginia issued a plum of smoke with air pollution deposited in three states. In 1999, a lightning strike ignited tire fire in Westley, California [4].

Taking their environmental responsibilities very seriously, ESCo has put a lot of efforts into resolving environmental problems while also taking advantage of the economic benefits from using scrap tires. For this purpose, ESCo began to use scrap tires in its EAF process.

According to the information released by the Rubber Manufacturing Association, tires contain nearly undetectable levels of chlorine and do not form dioxin during high temperature processes such as EAF steelmaking. Dioxin formation peaks at 200°C and decreases unsymmetrically with increasing temperature Figure 2 [5]. Selection and sorting to prevent addition of materials contaminated with organic matter or precursors can reduce the potential for dioxin formation. Meanwhile, oxygen injected into the upper part of the furnace ensures complete combustion of furnace gases. The temperature of the gas entering the bag house has strong effects on dioxin content discharged into the atmosphere. When the temperature is kept below 80°C, a dioxin content of less than 1 ngTEQ/Nm^3 (Nanogram-Toxicity Equivalent Quotitent/ Normal Cubic Meter) can be achieved [7].

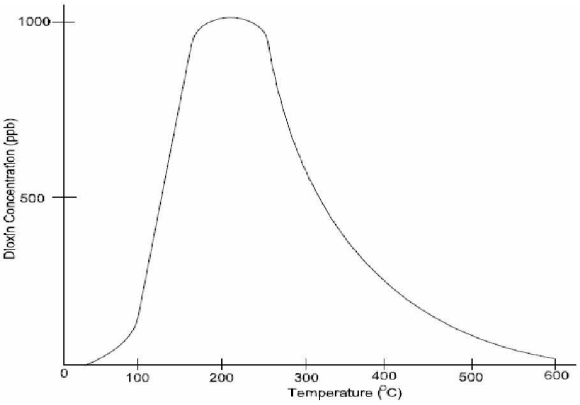

Fig. 2. Dioxin concentration versus temperature[5].

There are various applications for used tires including tire-derived fuels and road construction rubber products. Prior to using worn-out tires in the EAF process, a survey was carried out of the results obtained from other industrial applications. Discarded tires have been used in cement kilns, boilers, pulp and paper mills. Except for cement kilns, old tires are not readily usable as energy sources [6]. Size and steel belts and beads of tires can be problematic for some scrap tire uses, but belts and beats are valuable raw materials for steel mills using the EAF process. For the purposes of the present study, ESCo's scrap tire storage was visited to determine their counts, types, and weights. There were 12,715 tires with weights varying from 5 to as high as 1000 kg. To obtain steel bead weight, seven pieces of passenger car tires were randomly selected and completely burned to find that scrap tires typically contain around 10% bead. The steel grade of the bead was determined to be C67. The heating value of the scrap tire was 8,334 kCal/kg (10.2 kWh) [8].

Experiments in 6-ton EAF Units

The primary experiments were performed in the melting shop involving a 6t EAF unit which produces casting parts. The EAF is powered by a 2.8 MVA transformer. All scraps and fluxes are delivered via a single basket. So far, more than 200 heats have been made with 13 grades of steel including carbon (low, medium, high), heat, wear resistance, and tools steels. The steel grades produced are presented in Table 1. The details of heat parameters are presented in Table 2. As shown in Table 2, approximately 16 kg of scrap tire is consumed for each ton of steel produced. The sulfur content of the steels was below the standard limits. The coke charge as a source of carbon was eliminated. Power consumption reduced by 10% and 12% percent for nominal and actual rates, respectively. As shown in Figure 3, actual power consumption decreased from 448 to 388 kWh per ton of steel produced. Carburizing of steel (up to 1% carbon) is accomplished by scrap tires. Production cost reduced by €5 per ton of steel. Environmental emissions were measured using the Testo 350XL. The CO, NO_x, and SO_2 contents present in the flue gas were below the permitted ranges.

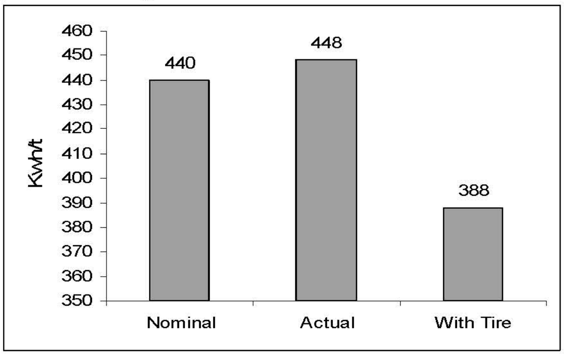

Fig. 3. Effect of using scrap tire on power consumption.

Table 3 shows a comparison of the flue gas analysis against standard ranges. The heat results of EAF (6t) did not show any significant differences in carbon outputs from coke, coal, pig iron, or from whole scrap tires. More than 300 tons of casting parts were manufactured in this stage for which a total amount of 4.5 tons of scrap tire was consumed, making an average of two passenger car tires for each ton of steel charged. Scrap tires were charged in whole to the scrap bucket near the bottom of the metallic charge. Steel scrap was added on top of the tires to compress them and, thereby, to decrease their volume. Figure 4 shows the charging of scrap tires into the scrap bucket. It should be noted that introducing scrap tires into molten steel is not recommended due to flotation problems.

Fig. 4. Charging of scrap tires in the scrap basket.

Table 1. Steel grades produced by charging scrap tire.

Grade	C	Mn	Si	P ≤	S ≤	Cr	Ni	Mo
20GL	0.15-0.25	1.20-1.50	0.20-0.42	0.040	0.040	≤0.30	≤0.30	
GS-45	0.20-0.25	0.60-1.00	0.35-0.60	0.030	0.030	≤0.40	≤0.40	
25L	0.22-0.30	0.30-0.75	0-20-0.42	0.040	0.045	≤0.30	≤0.30	
30L	0.27-0.34	0.30-0.75	0.20-0.42	0.040	0.040	≤0.30	≤0.30	
35L	0.32-0.40	0.40-0.90	0.20-0.42	0.040	0.045	≤0.30	≤0.30	
45L	0.42-0.50	0.40-0.90	0.20-0.42	0.040	0.045	≤0.30	≤0.30	
WS-140	0.67-0.75	0.72-0.78	0.47-0.53	0.030	0.030	2.22-2.28	≤0.30	0.30-0.40
WS-170	0.80-0.90	0.70-1.20	0.30-0.60	0.045	0.045	2.00-2.40	≤0.50	0.30-0.45
38KhGN	0.35-0.43	0.8-1.10	0.20-0.42	0.040	0.040	0.50-0.80	0.70-1.00	
30KhN2M	0.27-0.34	0.30-0.60	0.17-0.37	0.020	0.020	0.60-0.90	1.30-1.70	0.20-0.30
30Kh	0.65-0.75	0.40-0.90	0.20-0.42	0.035	0.035	0.80-1.10	≤0.40	
GS-20Mn5	0.17-0.23	1.00-1.50	≤0.60	0.020	0.015	≤0.30	≤0.40	≤0.15
6KhGNM2	0.50-0.60	1.00-1.20	.040-060	0.040	0.040	2.40-2.60	0.70-0.90	0.40-0.60

Table 2. Details of certain heat parameters.

Final (%C)	%C	En.Con. (KWh/t)	Scrap Tire (kg)	Final (S%)	Grade	Heat #
0.37	0.32-0.40	387.6	59	0.022	35 L	20748
0.66	0.65-0.75	387	76	0.026	WS-140	20751
0.72	0.65-0.75	333.5	125	0.015	WS-140	20760
0.37	0.32-0.40	389.9	90	0.027	35 L	20762
0.70	0.65-0.75	416.8	125	0.010	WS-140	20763
0.31	0.27-0.34	312.8	80	0.022	30 L	20765
0.30	0.32-0.40	457	100	0.022	35 L	20766
0.49	0.42-0.50	345.9	100	0.027	45 L	20767
0.69	0.65-0.75	407.6	135	0.015	WS-140	20768
0.83	0.75-0.85	384	150	0.011	WS-170	20771
0.66	0.65-0.75	467.7	150	0.015	WS-140	20773
0.29	0.27-0.34	404.7	110	0.018	30 L	20774
0.73	0.65-0.75	390.2	160	0.020	WS140	20789
0.28	0.27-0.34	374.4	100	0.020	30 L	20790
0.45	0.42-0.50	420.7	130	0.026	45 L	20791
0.37	0.35-0.42	353.6	120	0.025	38 KhGN	20792
0.45	0.42-0.50	360	130	0.015	45 L	20793
0.43	0.42-0.50	317.5	130	0.022	45 L	20795
0.71	0.65-0.75	381.8	160	0.015	WS140	20796
0.36	0.32-0.40	397.8	110	0.020	35 L	20798
0.36	0.32-0.40	322.6	100	0.021	35 L	20806
0.27	0.22-0.30	341.7	70	0.024	25 L	20809
0.36	0.32-0.40	360	100	0.026	35 L	20812
0.40	0.42-0.50	338.5	120	0.021	45 L	20813
0.22	0.20-0.25	453.6	150	0.025	GS-45	20815
0.04	0.42-0.50	391.4	100	0.029	45 L	20817
0.36	0.32-0.40	346	100	0.021	35 L	20829

Table 3. CO, NO_x and SO_2 content of the flue gas.

Gas	Unit	Allowed Range	Heat # 20738	Heat # 20774	Heat # 20796	Heat # 20815	Heat # 20817	Heat # 20844	Heat # 20921	Heat # 20922	Heat # 20929	Heat # 20930
CO	PPM	435	128	129	114	144	110	435	180	178	297	87
NO_x	PPM	350	126	128	158	36	0.5	84	87	72	42	11.79
SO_2	PPM	800	19	19	11	15	0	56	6.8	25	9.5	16.7

Performance of used tires in a 40t AC EAF

Once satisfactory results had been obtained from using scrap tires in a 6-ton EAF, the experiment was repeated using a higher capacity EAF operating in IASCo. This plant has two 40t EAFs, two ladle-stir stations, and a 4-strand billet CCM.The EAFs are powered by two 30 MVA transformers and a cojet slag door burner device equipped with post-combustion oxygen port making between 14-15 heats per day. Twenty heats are made with 11571 and 00601 steel grades. Metallic materials are charged by 2 or 3 baskets into EAF. The amounts of scarp tires charged reduced from the first to the third basket. For safety purposes, 40-50% of the required lime was charged on the bottom of EAF after each tapping. Scrap tires were put in the middle of each basket. Once the steel scrap charge got molten, pure oxygen was injected by lance to create decarburization and post-combustion of the excess carbon content of the scrap tires added with the iron bearing charge, thus producing additional energy by exothermic reactions [6].

Decarburizing:

$$C + 1/2\ O_2 \rightarrow CO + 1.35\ KWh/KgC \qquad (4)$$

Post-combustion:

$$CO + 1/2\ O_2 \rightarrow CO_2 + 6.0\ KWh/KgC \qquad (5)$$

Total:

$$C + O_2 \rightarrow CO_2 + 7.35\ KWh/KgC \qquad (6)$$

An increase in oxygen (up to 50 Nm^3/t) and carbon injections is a general trend observed for EAF processes. This increase yielded the following results in IAS:

Coke was totally replaced by scrap tires so that coke consumption was completely eliminated from the process. Average scrap tire consumption was 14.1 kg/ts. Power consumption decreased by 10% (from 580 to 530 kWh/t) and production cost reduced by 5€/t. CO, SO_2, and NO_x contents of stack gas were below standard limits. Similar results were obtained in Malayer Alloy Steel Company using a 25- t EAF.

Conclusion

Using scrap tires in the EAF process can lead to total elimination of the coke and coal charge from the EAF steelmaking process. Oxygen gas is injected into EAFs while the scrap tires are burning so that complete and pollution-free combustion is accomplished. Moreover, bead wires become part of the steel charge. Since steel and other materials of the scrap tires are usefully consumed, there remains no ash or other waste. Scrap tires are put to useful applications as a carbon source for a variety of steels including low, medium, and high carbon steels as well as heat and wear resisting steels in EAF. Consumption of scrap tires in EAF can provide a net decrease in electrical and chemical energy consumption. The stack gas analysis showed the content of CO, NO_x, and SO_2 gases to be far lower than the permitted range. The sulfur content of steel products was also lower than 0.026%. The final cost of steel decreased by 5 euros per ton of steel produced. Mechanical, physical, and chemical properties as well as gas content and absence of casting failures of the steels produced met the standards of the QC Department. In this study, whole tires (without shredding) were charged into the EAF. In this respect, a whole loader tire weighing 250 kg could be charged into a 40-t EAF. Iran is expected to be producing 40 million tons of crude steel as mandated by its 4th National Development Plan. This means that 50 million passenger car tires can be potentially used in the EAF steel making process.

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References

[1] J. A. T. Jones, "Carbon Utilization In the EAF", 1998 Electric Furnace Conference proceeding", P. 599.

[2] Rubber Manufacturing Association, "Scrap tire markets in the U.S. 2005 Edition", 1400 K Street, N W Washington DC, 20005, November 2006.

[3] EPA. Management of Scrap Tires- Tire Derived Fuel, 2005, Code "EPA 530-F-05-006".

[4] EPA. Management of Scrap tires- Tire fires, 2006, Code "EPA- 905-B-06-001".

[5] EPA-454/R-97-003" Locating and Estimating Air Emissions from Sources of Dioxins and Furans" U. S. Environment Protection Agency. Research Triangle Park, North Carolina 27711 (1997), 172.

[6] Leroy Stebbing, P. E., "Using scrap tires as a Chemical fuel source in the EAF", http://www.acceleratedtech.com/tire-info. html.

[7] H. Yamakawa, K. Isakari, H. Sasamoto, T. Okazaki, S. Matsuoka, "Study on dioxin reduction & behavior of it in EAF", La Revue de Metallurgie, (2002), 23.

[8] C. Clauzade Aliapur, "End of life tyres in electric arc furnaces: An industrial success story", http://www.aliapur.fr/media/files/recherche/Acierie-GB.pdf.