DIRECT SMELTING OF STAINLESS STEEL PLANT DUST

T.J. Goff and G.M. Denton

Pyrometallurgy Division, Mintek, Private Bag X3015, Randburg.
E-mail: trevorg@mintek.co.za and glend@mintek.co.za

ABSTRACT

Mintek has developed the Enviroplas™ process for the treatment of solid wastes from the metallurgical industry, especially steel plant dusts, without requiring agglomeration to produce inert slag and at the same time recover metal values such as nickel, chromium and zinc. The products that are generated in the plasma-arc process are usually a metal and a non-toxic slag, which are tapped from the furnace in liquid form. The metal is mainly composed of chromium, nickel and manganese.

During the production of stainless steel between 30 and 70 kg of dust and fine waste is generated per ton of steel. Mintek has successfully processed around 1000t of AOD/EAF dust on a toll treatment basis in order to recover the contained Cr and Ni. The metal produced contained 18.5 per cent Cr, and 5.5 per cent Ni. All slag samples tested conformed to US EPA regulations for disposal. The chromium and nickel recovery to metal was 90 and 98 per cent respectively, on a once through basis i.e. no baghouse dust recycle. Slag tapping temperatures varied between 1650℃ and 1750℃. The average actual energy requirement excluding furnace heatlosses of smelting steel plant dust with anthracite as reductant was 1.36MWh/ ton of dust. The total mass of feed reporting to the off-gas stream was 10 per cent. The average ZnO content of the fume was 35.5 per cent.

1. INTRODUCTION

The Enviroplas process[1] [2] [3] was developed at Mintek for the treatment of solid wastes from the metallurgical industry and is a DC arc process that can treat EAF dust, alloy-steel dust, or a mixture of both. The process is based on the reduction of selected metal oxides at high temperatures by means of a carbonaceous reducing agent, with the production of an innocuous slag. The main objectives of the Enviroplas process are to produce disposable slag and in the case where dust from a stainless-steel operation (e.g AOD dust) is smelted, another objective is to recover chromium and nickel into a crude ferroalloy.

2. DESCRIPTION OF PILOT PLANT

Schematic diagrams of the pilot plant and furnace are shown in Figure 1 and 2 respectively. The equipment consisted of a 5.6MVA d.c power supply, raw material feed system, a DC arc furnace, a gas cleaning system and instrumentation for data logging and control. The DC arc furnace comprised a refractory-lined cylindrical shell, a conical roof, a small flat roof positioned on top of the conical roof, and a central graphite electrode.

The furnace employed a single graphite electrode as the cathode and the molten bath as the anode. The arc forms the conducting path between the graphite electrode and the molten bath. The standard multiple-pin anode design utilized for testwork at Mintek, comprises of multiple steel rods embedded into the hearth refractories. The rods are connected to a steel plate installed in the hearth in contact with the molten bath by means of the pins. The steel plate is directly connected to the domed hearth of the furnace.

The furnace had an internal diameter of 2.5m and a shell diameter of 3m. The hearth of the furnace was lined with MgO rammable while the sidewall was lined with MgO bricks. Alumina castable was used for the roofs. The top section of the shell was equipped with forced watercooling while in the middle section spray cooling was used. Watercooled panels were used for the conical and flat roof. The flat roof contained the feed port and the off-gas was located in the conical roof. The feedsystem consisted of three hoppers, one each for reductant, flux and dust, mounted on loadcells and fitted with independently controlled beltfeeders. The dust feeder consisted of a $2m^3$ hopper equipped with two vibrators in its conical section.

The off-gas system comprised watercooled ducting, a gas cooler, a reverse pulse bag filter, a fan and a stack.

The furnace was controlled using a Distribution Control System (DCS), which provided a console for the configuration of operating parameters, recipe management, alarm communication and data logging. The furnace was operated at power levels of between 0.8 and 1.6MW on a 24-hour basis. Feed was supplied to the furnace at a constant rate. (Typically at between 0.5 to 1ton of dust per hour)

3. TREATMENT OF STEEL PLANT DUST

The suitability of the Enviroplas process for the smelting of zinc-bearing alloy-steel dust was first demonstrated at Mintek in 1990, during a 5-day continuous campaign on the 500kW scale of operation. In 1995 a 3-day campaign was carried out on the smelting of alloy-steel dust in Mintek's 5.6MVA DC arc facility. The results of this testwork are described elsewhere. [4][5]

This was followed by further testwork of which the most recent was a campaign involving the smelting of 1000t of Columbus Dust on Mintek's 5.6MVA DC arc furnace. Batches of 3t were continuously fed to the furnace and slag was tapped after every 2-3 hours. The anthracite-to-dust ratio in the feed was selected to reduce the iron, chromium, nickel, lead and zinc oxides in the dust to their respective metals. Metal was tapped after these batches, typically after 9t had been fed to the furnace. Combustion air is drawn in to burn the zinc, and lead through a slip gap and a mixed oxide of zinc, lead and entrained dust were recovered in the bagfilter.

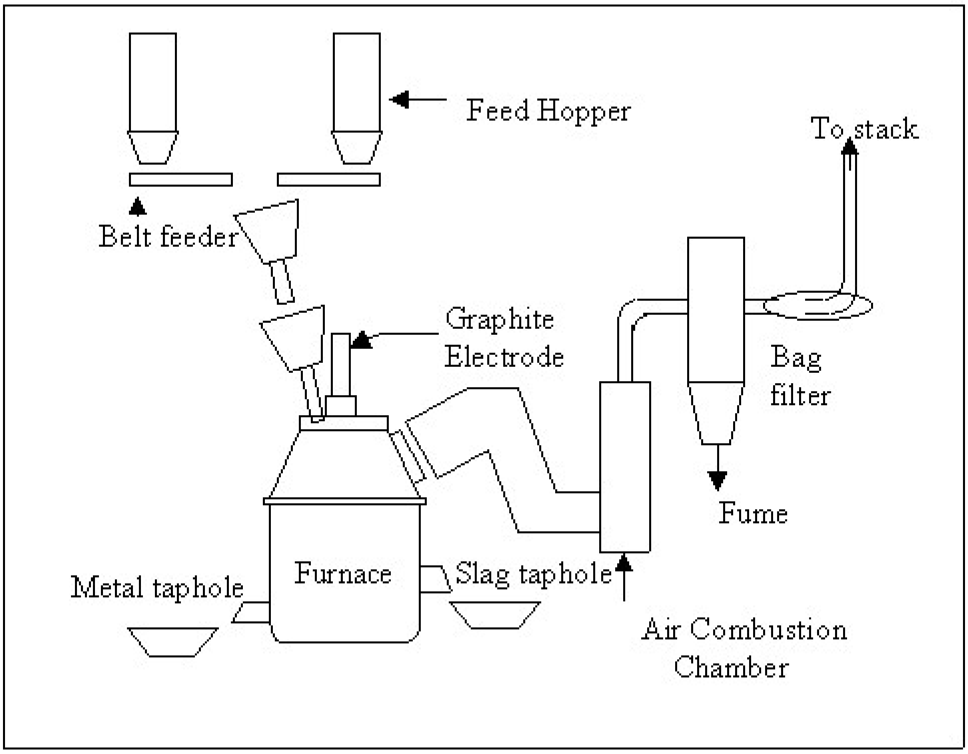

Figure 1. Schematic diagram of the pilot plant.

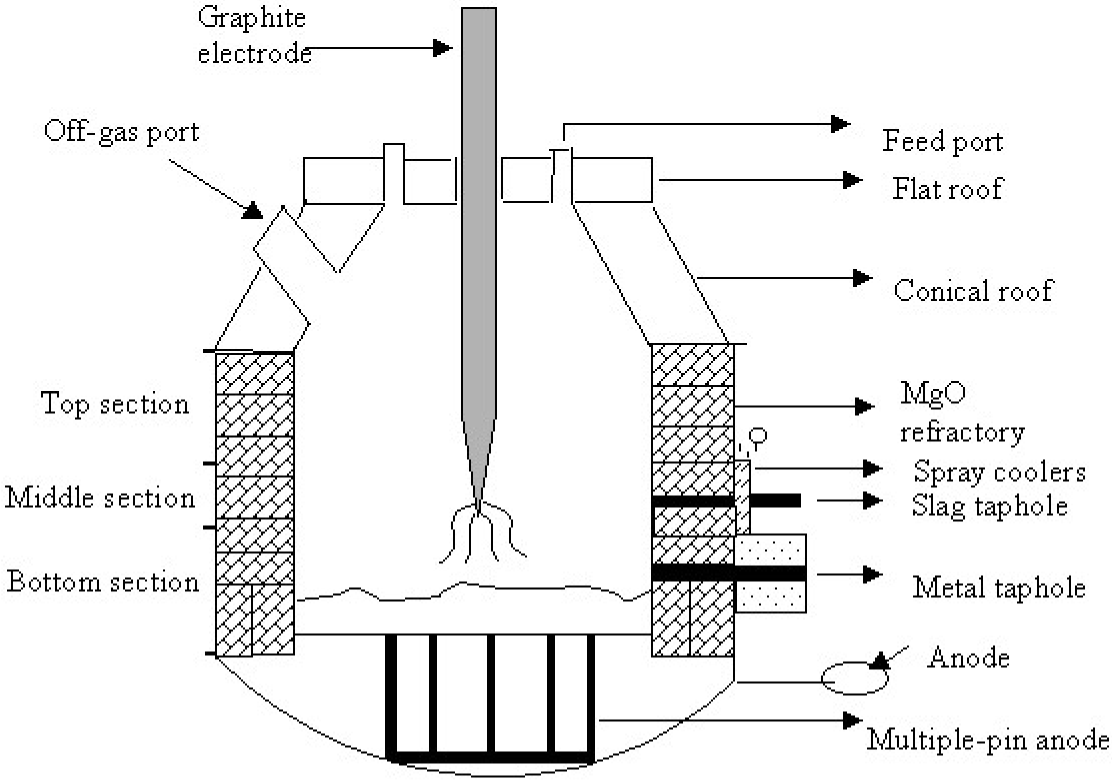

Figure 2. Diagram of the furnace.

3.1 Feed materials and Products

The chemical analysis of the Steel Plant Dust is shown in Table 1. The dust contained on average 14.63 per cent Cr2O3 and 3.48 per cent NiO. The reductant contained about 82 per cent fixed carbon, 14.1 per cent ash and 6.8 per cent volatiles. The magnesite had a MgO content of 91per cent and dolime a content of 39 per cent. The flux addition was about 2 per cent of the feed dust, to aid bank formation.

However, flux addition was added/ceased under following conditions:

- was ceased as soon as the banks were deemed to be satisfactory,
- added to the recipe if the energy flux through the furnace middle section area seen to increase.

Table 1. Average Chemical analyses of the Steel Plant Dust (all in mass%).

Cr2O3	FeO	ZnO	NiO	MnO	SiO2	CaO	MgO	Al2O3	PbO
14.63	42.62	4.13	3.48	4.39	5.16	13.04	4.62	0.49	0.38

The average analyses of the metal, slag and fume can be seen in Tables 2, 3 and 4 respectively.

Table 2. Average Chemical analyses of the Alloy (all in mass%).

Cr	Fe	Mn	Ni	C	Si
18.5	63.6	4.63	5.51	5.80	0.09

Carbon, phosphorous and sulphur, i.e important elements with regard to recycling, were analysed at 5.8, 0.035 and 0.001 per cent respectively. Because of the relatively small quantities involved, no problems are envisaged with regard to contamination when the ferro-alloy is recycled to steelmaking furnaces.

Table 3. Average Chemical analyses of the Slag (all in mass%).

Cr2O3	FeO	ZnO	NiO	MnO	SiO2	CaO	MgO	Al2O3	PbO
1.15	0.08	0.03	0.14	1.68	22.4	49.8	13.6	5.67	0.009

Table 4. Average Chemical analyses of the Fume (all in mass%).

Cr2O3	FeO	ZnO	NiO	MnO	SiO2	CaO	MgO	Al2O3	PbO
2.38	9.08	35.5	0.65	6.18	2.95	3.69	17.7	1.14	3.35

The fume was contaminated with 0.955 per cent Cl, 0.952 per cent F, 0.003 per cent As, 0.788 per cent Na and 1.109 per cent K.

Slag and fume samples were submitted for toxicity leaching tests and were found to conform to US EPA regulations for disposal. The average analyses of the TCLP tests for Steel Plant Dust, slag and fume are given in Table 5.

Table 5. TCLP tests for dust, slag and fume (all in ppm).

	Cr^{6+}	F	Cr	Mn	As	Cd	Hg	Pb
Feed Dust	6.25	1.84	5.7	0.04	<0.01	<0.01	<0.01	0.05
Slag	<0.02	1.85	<0.02	0.04	<0.02	<0.01	<0.01	0.05
Fume	0.48	1.89	0.47	21	0.01	2.6	0.01	0.13
TLCP MAX	2	-	5	3	5	1	0.2	5

3.2 Energy Balance and Electrode consumption

The energy consumption excluding energy losses was 1.07 MWh/ton of feed (1.36 MWh/ton dust). The overall energy consumption for the smelting of feed dust with anthracite was 2.07 MWh/ton dust. Taking the theoretical energy requirements into account, this would indicate thermal efficiency of the furnace of about 66 per cent. The rate of energy losses through the water-cooled parts of the furnace was measured and an extra 50kW was added as an estimate for the non-water cooled bottom of the furnace. Taking availability of the plant into account, the thermal efficiency was re-calculated to be 70 per cent. Expressed as a percentage of the power input the rate of energy loss is expected to decrease when the process is scaled up, as experienced during other processes tested at Mintek. It is envisaged that a 10MW industrial plant would have a thermal efficiency of about 85 per cent.

The slag temperature varied between 1660°C and 1750°C with an average temperature of 1730°C. For the metal, the temperature varied between 1350°C and 1600°C with an average temperature of 1495°C. Electrode consumption was calculated and varied between 3.15 to 3.51kg/MWh. During steady state operation an electrode section was added once per day.

3.3 Mass Balance and Recoveries

About 1000t of Steel Plant Dust, 240t of anthracite and 5t of flux were fed to the furnace. In total, about 485t of crude ferro-alloy, 240t of slag and 100t of baghouse fume were produced during the campaign. The deficit can mainly be attributed to the formation of CO gas during the reduction of the iron and chromium oxides.

Recoveries of chromium and nickel to the metal were calculated and amounted to 90 and 98 per cent respectively. A mass balance table for the recoveries of Cr and Ni can be seen in Table 6.

Table 6. Recoveries of Nickel and Chromium.

	Feed t	Metal t	slag/fume t	Recovery %
Cr	100.1	89.7	3.5	89.7
Ni	27.3	26.7	0.8	97.8

3.4 Equipment Performance

In general, the equipment performed very well under extreme conditions. The feed system had high availability with minor feed blockages being experienced occasionally. These blockages were typically caused by the malfunction of the pneumatic slidegate valve.

As mentioned previously, magnesite or dolime were used as flux to promote bank formation in the furnace, thereby protecting the furnace refractories. The flux addition was ceased as soon as the banks were deemed to be satisfactory and added to the recipe if the energy flux through the furnace middle section area started to increase.

Carbon blocks were tested in the metal taphole region seemed to perform well.

4. CONCLUSIONS AND RECOMMENDATIONS

The suitability of Mintek's 5.6MVA DC arc furnace for the smelting of alloy steel dust was demonstrated during the processing of 1000t of Steel Plant Dust.

Anthracite was used a reducing agent at a rate of 240kg/ton of dust. High recoveries of chromium (about 90 per cent) and nickel (about 98 per cent) to the metal were obtained. The overall energy consumption was 2.07 MWh/ton of dust and the thermal efficiency of the furnace was about 70 per cent. Overall availability was around 90%.

TCLP tests were carried out on the slags and fumes produced and these were found to be disposable according to EPA regulations.

Furnace refractories were protected by the formation of banks along the sidewalls brought about by the addition of flux containing MgO.

DC arc toll treatment of Steel Plant Dust on Mintek's furnace has led to the intended implementation of the technology at Mogale Alloys in Krugersdorp.

5. ACKNOWLEDGEMENTS

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