Conservation of energy by utilisation of waste heat/ direct power reduction in ferro alloy industry

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ABSTRACT

Ferro Alloy Industry is a power intensive industry. Ferro alloys, such as Ferro Manganese, Ferro Silicon, Silico Manganese are manufactured in electric smelting furnace. Due to thermodynamic considerations, production of these Ferro alloys consume large amount of power.

With the development of steel industry, requirement of Ferro Alloys as well as power is increasing day-by-day. Hence due consideration can be given in minimising electric power.

The object of this paper is to give various directions in which work can be done to achieve saving in power. The paper deals with various factors affecting power consumption & work areas for improving technology to reduce energy consumption.

Introduction

The ferro alloy industry is a power intensive industry. Ferro alloys such as ferro-manganese, ferro silicon, silico manganese, ferro chrome, calcium carbide etc. are manufactured in electric smelting furnace, carbon electrodes which carry electric current are submerged in the charge in these furnaces. Due to thermodynamic considerations production of these ferro alloys consume large amount of power.

Ferro alloys are essential raw material for production of alloy steels and final deoxidation of mild steel. With the development of steel industry, requirement of these ferro alloys is increasing. Hence requirement of electrical energy for production of these ferro alloys is also increasing. In order to meet increasing demond for power one of the measure to be adopted is by minimising electric power requirement for production of these alloys. Electric power requirement can be minimised by utilising the heat which is being wasted in the process or minimising the loss of heat. Energy requirement can also be reduced by improving process technology so as to reduce power consumption per tonne of alloy produced.

Minimisation/Utilisation & Waste heat

During the production of ferro alloys in electric smelting furnace lot of heat energy is wasted through flue gases which is being discharged to atmosphere at a temperature as high as 500-900°C. Gas evolved in the operation

is 700 to 1000 NM³/Tonne of alloy. The figure varies with the type of alloy produced. Temperatue of flue gas and volume of gas evolved in case of FeSi is much higher. Hence rich fuel gas with a calorific value of 2000-2500 KCal/M³ is evolved from a ferro alloy furnace which is being wased to atmosphere. If heat evolved is utilised economically for drying of wet charge, steam generation or pre-reduction energy saving can be achieved.

Energy saving by improving furnace process parameters/direct power reduction

In this paper various methods are discussed for improving furnace process parameters to achieve saving in power.

Various improvement in the process such as use of beneficiated raw material, use of raw material with a lower gangue material, maintaining close size tolerance of charge, use of agglomerated fines and various other process are suggested for reduction in power consumption.

The object of the paper is to give various directions in which work can be done for saving in power. The paper deals with various factors affecting power consumption and work areas for improving the same with specific reference to ferro manganese production in electric smelting furnace.

Theoretical considerations

The basic theory for production of FeMn is well known. The higher oxides of manganese which are present in Mangauese ore such as MnO_2, Mn_2O_3 & Mn_3O_4 are unstable at higher temperature and decompose in presence of carbon and carbon monoxide. MnO_2 dissociates to Mn_2O_3 at temperature of 430°C (according to following equation)

$2MnO_2 = Mn_2O_3 + 1/2\ O_2$ and this Mn_2O_3 in turn dissociates at 950°C to give Mn_3O_4.

$3\ Mn_2O_3 = 2\ Mn_3O_4 + 1/2\ O_2$

The dissociated oxygen combines with CO comming up through the charge and thus adds heat to the charge. The reduction of Mn_2O_3 to Mn_3O_4 and subsquently to MnO occurs only if retention time and temperature of charge is sufficient.

Mn_3O_4 is reduced by carbon monoxide to MnO by the following reaction.

$Mn_3O_4 + 2\ C = 3\ Mn + CO_2$
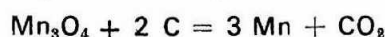
The reduction of MnO by carbon proceeds as per following reaction :

$2\ MnO + 2\ C = 2\ Mn + CO$
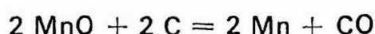
Reduction of higher oxides of Mn to lower oxides is exothermic. So efforts have to be made to utilise the sensible heat of gas effectively for pre-reduction and preheating of charge.

The heat is transferred upward in the furnace by the flue gas. The sensible heat of gas is to be transferred to the charge. So condition has to be created for pre-reduction of the charge and transfer of heat. With this in view indirect reduction is important.

Heat balance

Calculation of heat balance for production of one tonne of 75% Mn High Carbon Ferro-Manganese with flux process is as follows :—

Heat Input :	In Kwh	%age
Heat evolved due to combustion of fixed Carbon	758.3	18.0
Heat of formation of slag	106.2	2.5
Heat evolved due to carbide formation	140.5	3.4
Electrical Energy	3210.0	76.1
	4215.0	100·0

Heat Output :		
Heat required for Chemical reactions :	In Kwh	%age
Heat required for reduction of oxides	1513.6	35.9
Heat required for decomposition of flux	193.5	4.6
Sensible heat of metal (FeMn)	363.0	8.6
Sensible heat of slag	333.4	7.9
Sensible heat of dust	41.1	0.3
Sensible heat of gas	159.2	3.8
Moisture content of charge	54.7	1.3
Heat loss due to circulating water	941.8	22.3
Other heat losses (radiation electrical etc.)	641.7	15.3
	4215.0	100.0

Heat balance calculation will assist in indentifying the process where heat losses occur. From the above heat balance we find that metal, slag and gas carry lot of heat energy. Moreover heat taken away by circulating water is as high as 22% of total energy input. Efforts should be made so that heat losses are reduced or heat wasted is utilised.

The factors affecting the power consumption where efforts can be made to reduce power consumption are as follows :

Preparation of raw material

Most of the raw materials are brittle and during handling generate fines. Fines are detrimental for electric smelting furnace. These fines reduce the porosity of charge. They also carry higher quantity of gangue material. Coke fines being lighter are easily carried away by the gases They affect the permeability of charge to a greater degree than that of manganese ore fines.

Apart from fines over size fraction of charge also is to be controlled closely. Ideal size of Mn ore feed for furnace is 3 mm to 70 mm with + 5 to—10 mm and + 50 to —70 mm size fraction not to exceed 15%.

Similarly, size of coke should also be controlled. Different fraction of coke not only affect the porosity of charge but also affect the position of electrode inside the charge, resistance of charge and resultant heat distribution inside the furnace. Breeze coke (5 mm to 10 mm) and nut coke (10 mm to 25 mm size) proportion in coke should be properly controlled so as to promote favourable furnace condition. Hence proper screening of ores before charging is of paramount importance. This will improve furnace performance.

Apart from percent fines in the charge some fines are generated inside the furnace at certain temperatue due to decrepitation characteristic of manganese ore. Some quantity of manganse ore containing MnO_2 has decrepitation tendency ane crumbles to fines inside the furnace. Hence before charging manganese ore its decrepitation characteristic should be taken into consideration.

It is well known that fines in charge affect permeability of charge. It tends to block the passage of the gas, leading to, non uniform distribution of gas and heat. Transfer of sensible heat of gas is also not uniform, which leads to slag boil and bringing of charge erruption & gas blows. If moisture content is more, control of fines become still more important, so as to avoid unsteady condition of furnace. Hence charge should be properly screened and sized before charging in furnace.

Apart from sizing, uniformity of chemical composition of charge is also important Proper control of composition of slag and thereby the furnace temperature depends upon Manganese to carbon ratio in the charge. If compositions of charge vary to a greater degree it will be difficult to control furnace burden, which will affect the position of electrode inside the furnace & thereby the condition of furnace and power consumption for smelting will be affected. In order that Mn Ore composition is uniform ore should be stacked layer by layer and should be charged in a uniform way.

Beneficiation of Manganese Ore & Coke

The silica and alumina present in the manganese ore form slag which carry considerable amount of sensible heat. So these unwanted impurities should be removed by beneficiation before charging the ore inside furnace. Similarly ore should be so chosen that burden contain minimum of gangue material. On an average 1 kg. increase in slag volume increases power by 1 Kwh. Hence beneficiated ore with lower silica & alumina should be used as burden. For similar reason preference should be given for coke with lower ash content.

Slag Composition

Composition of slag affects the melting point as well as viscosity of slag. For better slag metal seperation viscosity of slag should be minimum, to avoid loss of metal in it.

In order to control composition of slag, chemical composition of charge as well as proportion of Mn Ore to Coke in burden should be controlled.

Melting point of slag is determined by its composition and basicity. The melting point of slag should be controlled between 1350°C to 1500°C. Electrical conductivity should be as low as possible to encourage high operating resistance. With this nature of slag composition is necessary between low viscosity & low electrical conductivity.

If melting point of slag increases there will be high volatilisation loss of Mn. Slag with higher basicity has higher melting point than acid slag. In flux technique with basicity of slag more than 1.0, Mno % in slag is very low & more Si passes in metal thereby increasing power consuming reactions. Moreover, in such operation less variation in slag basicity is tolerated. If slag basicity is less than 0.5, more % MnO goes in slag and reduction of MnO from slag bacomes difficult. Hence from partical experience it is observed that 25/30% MnO in slag with 0.70 to 0.8 basicity promotes stable operation & less susceptible to changes in viscosity due to changes in slag composition. Hence power copsumption is also kept down by choosing proper % MnO in slag as well as basicity of slag.

Use of agglomerated Fines

Sintering is the most widely used as a method of agglomeration of fines for charging in furnace.

There are some advantages of use of sinter as part of burden for smelting furnace. Use of sinter increases permeability of bed thereby uniform distribution of flue gas. Mn Ore fines can be beneficiated before agglomeration hence SiO_2 content can be reduced, but since coke is added in production of sinter which adds to impurities.

During sintering higher oxides of manganese i.e. MnO_2 is reduced to lower oxides. Reduction of MnO_2 to lower oxide is an exothermic reaction. So by use of sinter the exothermic reaction which would have taken place by use of lumpy ore is absent. Hence electric arc sinter practice consume more power than when the burden is composed of lumpy ore only. But in actual practice increase in porosity of charge affects increased power and ultimately there is reduction in specific power consumption. Use of sinter to the extent of 30-35% of the charge is recommended for optimum power consumption.

Effect of Moisture

Moisture content in charge affects furnace condition very adversely. Increased moisture content in charge not only takes more power for evaporation of moisture but also increases power due to poor furnace operating condition. With increase in moisture screenability of charge is reduced, due to blockage of screen opening. Hence fines pass through alongwith charges in the furnace without being screened. These fines carry more moisture than lumpy ore. Hence porosity of charge reduces, resulting in crust & bridge formation inside the furnace. This affects uniform descend of the charge, uniform passage of flue gas & heat distribution inside the furnace.

The moisture content in coke varies widely. Hence carbon balance in the burden is disturbed, If burden is disturbed it effects the slag composition thereby the melting point. Hence due to variation in moisture furnace operation is also affected.

Increase in 1 kg. of moisture increases power by 1 Kwh approx. Further there is increase in power due to dissociation of water in presence of carbon leading to endothermic reaction. There will be further increase in power consumption due to adverse furnace condition. Hence moisture content in the charge should be

controlled. Coke absorbs around 15% max. moisture. If the same is dried before charging in furnace not only the moisture content in furnace is reduced but the burden control can be properly exercised. Apart from water content in charge water due to leakage inside the furance should also be checked in order to control increase in power consumption. Hence all precautions should be taken to avoid water leakage inside furnace.

Preheating & Prereduction process

At some of the Ferro-alloy plants in Japan preheating & pre-reduction of charge is being practiced.

Flue gas temperature of closed electric smelting furnace for production of FeMn is around 500°C. For 9 MVA Furnance about 35,000 NM³/day of gas passes to the atmosphere. Hence lot of heat energy is wasted to the atmosphere. Calorific value of the gas is around 1900 KCal/M³.

Attempt has been made for utilisation of flue gas for preheating of charge by increasing pressure under furnace cover and flue gas is allowed to pass through shaft carrying the charge. In shaft preheating is done by counter current heating of the charge by combustion of clean furnace gas.

As in the case of FeMn production preheating and pre-reduction takes place at the upper layer of smelting furnace charge, less benefit is derived.

Most losses can also be reduced by reducing flue gas temperature by increasing the charge height. In such case flue gas has to pass through greater column of charge which will transfer sensible heat to the charge. For achieving this furnace design has to be modified suitably.

Furnace operation parameter

In order to obtain lower power consumption correct operating schedule has to be followed :

For production of FeMn flux or semiflux technique of production is followed. Whatever may be the technique for particular MnO in slag, proper basicity should be chosen for which slag composition should be closely controlled.

Movement and position of electrode in the charge affect furnace operation. Movement of electrode depends upon resistivity of charge which in turn depends upon metallic & non metallic content of the charge. For good operating schedule & less heat loss deep electrode penetration in the charge should be practiced.

Furnace should be run on a lower secondary voltage. This will keep the electrodes down, reduce heat loss & avoid excessive heating & thereby volatilisation loss of Mn. leading to reduction in specific power consumption.

Frequent taphole opening & closing should be avoided. So number of tappings should be reduced by taking tappings at higher power consumption. This will avoid wastage of heat.

Heat loss due to circulating water can be reduced by reducing flue gas temperature, which can be reduced by proper control of furnace charge, use of beneficiated charge with lower fines content, increasing height of charge & by constantly covering the electrode with the charge.

Discussions

G. Rangarajan, Maharashtra Electrosmelt Ltd., Chandrapur

Q. The suggestions in the paper are good. We would like to know the experience of the authors in the following :

1) Recovery of heat from flue gases and circulating water.

2) Can author tell something about CO percentage in flue gas.

A. 1) For gas cleaning plant and recovery of heat from flue gases proposals from

various parties are under consideration at our plant.

Heat loss in circulating water can be reduced by reduction of flue gas temperature which in turn can be reduced by proper control of furnace charge, increasing height of charge etc. which is enumerated in the paper.

2) CO presentage in flue gas at our plant is 60-70%.

R. Y. Sane, Paramount Sinters Pvt. Ltd.

Q. What is the calorific value of gas let out at KFA and quantity of gas ?

A. Calorific value of gas - 1900 KCal/M^3 let out at KFA plant. Quantity of gas evolved - 35000 NM^3/day.

Q. What is the average moisture content of Mn-ore and coke at KFA ?

A. In rainy season moisture content in Mn-ore is 3-5% and in Coke - 14-15%.

Q. Have you tried any pre-heating or pre-reduction of Mn-ore with your gas ?

A. Pre-heating and pre-reduction has not been tried by us. But we have run our furnace under positive pressure by throttling buttertly value to have partial preheating.

Q. Whether any simple beneficiation techniques are followed at KFA to increase Mn content and reduce SiO_2 & Al_2O_3 content. If so to what extent ?

A. Trials of washing Mn-ore has been tried on experimental scale and there is a reduction of 1-2% SiO_2 in the ore. No conclusive data have been arrived at.