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Use of spent potlining from the aluminium electrolytic cell as an additive to arc furnace steel melting and cupola iron melting in steel industries

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ABSTRACT

Use of arc furnace steel melting is increasing very fast due to certain advantages offered by it. It is carried out with industrial coke (nut coke and petro coke) as an additive for composition adjustment and carbon pick up by the steel, while in cupola iron melting this coke is used mainly as fuel. Low quality coke can also be used for these purposes. The cost of production increases to a considerable extent due to use of the industrial coke. Efforts are going on to replace the same without affecting the properties of the product. Spent potlinings or SPL (waste cathode lining material from aluminium smelters) may be one of such material. It has 45-50% of carbon in addition to other impurities as calcium oxide (CaO), iron oxide (FeO), silica (SiO_2), alumina (Al_2O_3), sodium fluoride (NaF), sodium cyanide (NaCN) etc. The toxic nature of spent potlining due to presence of cyanide and fluoride requires safe disposal. One way of disposing this is to use it in arc furnace steel melting and cupola iron melting in iron and steel industries. Western countries use this material in arc furnace steel melting for composition adjustment and as supplementary fuel in cupola iron melting, thus reduce the pollution hazards which may occur due to the storage of this material. Quality wise it resembles the low grade coke used in steel industries for different purposes. Financially it is found much cheaper as compared with conventionally used coke. There is an urgent need to assess the same material under Indian context. The requirements of the iron and steel making process and the characteristics of the SPL material are considered in this paper with a view to explore the possibility of its use in the steel industries.

Keywords : Aluminium electrolytic cell, Aluminium smelters, Recycle of spent potlining.

INTRODUCTION

The extraction of pig iron from ore and its conversion to mainly steel, constitutes the largest use of metallurgical extraction and refining processes. This derives from the conversion of abundant mineral supply, relatively low processing costs and the wide range of useful forms and mechanical properties exhibited by the products. These extend from the cast products containing over 1.8% carbon to the heavily worked packaging sheet in which the carbon content is below 0.05%.

Steel Making Processes

The production of steel from pig iron is essentially an oxidising process in which carbon, silicon, manganese and phosphorus are removed by oxidation. There are two types of steel making processes which can be distinguished by the type of slag used, either acid or basic. The acid process can only be used to make steel from blast furnace iron low in phosphrous and sulphur, since these elements are not removed by the slag during the refining process. The slag is essentially an iron-manganese silicate and the refractories in the smelting furnace must be high grade silica. If the blast furnace iron contains more then about 0.4% sulphur and phosphorus, it is necessary to use a basic slag in which there is a high proportion of CaO and the furnace refractories are of dolomite and mangnesite. The two types of refining processes may be distinguished by the mode of transfer of oxygen to the metal bath.

In the open hearth and electric arc processes oxygen is transferred to a shallow metal bath, of large surface area, from the atmosphere and from added iron oxide by contact with slag floating on the surface. However in order to reduce the time of refining, processes derived from the hearth, such as Ajex, Dual and Tandem utilise oxygen blow in to the molten pig iron by lance passing through the roof. In the same way, oxidation in the electric arc furnace is accelerated by the use of oxygen lances or refining can be carried out in the ladle.

Arc Furnace Steel Melting

The basic Arc furnace steel making process grew leaps and bounds from a specialised tool for making alloy steels or steel for casting on an integrated cycle, to a large scale steel production unit for ingots or continuous casting machines. The reasons for the increased popularity of this process are as follows:

- Independence from hot metal, the natural charge for the basic electric arc process is scrap with coke or cast iron scrap as recarburiser. Hot metal or direct reduced iron (DRI) may also be used.

- ❑ High productivity (20 to 100 tph): Two furnaces can keep a continuous caster going in long strings of heat, without interruption. If it takes one hour and 20 minutes to cast a heat, two furnaces, each tapping every 2 hour and 40 minutes will keep one caster going without interruption. Only changing of laddle is required.
- ❑ The above facility coupled with the relatively low capital cost of basic arc furnaces made it possible to operate arc furnaces even by small industries.
- ❑ The furnaces are always of the tilting type allowing for easy removal of the slag.
- ❑ The heat is well concentrated as radiation from the arc and charge resistance. As a result, control of temperature is easy and precise and the thermal efficiency is high. This is because there is no combustion air passing through the furnace and the arc is being limited only by the refractory wear.
- ❑ Because of absence of air, it is possible to obtain non-oxidising, actually reducing conditions, thus making possible highly efficient desulfurisation, especially at high temperatures.
- ❑ Because of the absence of high volume of excess air and combustion gases, dust cleaning installation is relatively compact but is necessary. A fair amount of dust is generated especially from poor quality scraps.

In arc furnace steel making, heat is generated through electrical power supply. Graphite electrodes are used as medium for supply of electricity. Coke containing carbon as major part, is used for composition adjustment, so low grade cokes can also be used. By use of spent potlining in place of coke may result in about 60% reduction in coke consumption in EAF. For a normal process, coke consumption is about 350-400 kg/ton of pig iron used. Quality wise this coke need not be of the same quality as it is in the case of blast furnace. Almost up to 50% of coke breeze or coke of low quality can also be used here. In arc furnace, all raw materials are charged from top. The produced steel and slag forms two separate layers. The volume of gases is only about 15% of that obtained in ordinary blast furnace, but its calorific value is considerably high. Hence, it can be reused after cleaning as a preheating media in soaking pits or in holding furnaces in an integrated steel plant.

Spent Potlining as Coke Substitute

Used potlinings are recovered from aluminium reduction cell after its useful life, the usual generation of potlining being 40-50 kg/ton of metal produced. It is proportional to the metal produced by any individual pot during its full life time and vary with operating rates. Average life of a pot ranges from 4-10 years.

A cell lining consists of an inner lining made up of carbonaceous materials, and an outer fire brick or alumina (backup) refractory linings. The linings contained in a steel box, becomes impregnated with sufficient levels of fluorine and other elements in various compound form. Usually SPL can be subdivided into two groups as:

i) Consisting of mainly carbonaceous materials

ii) Consisting of mainly refractory materials

Specific separation between the two layers is not possible in the plant site during digging of the material due to intermixing of the two. Average composition of SPL that can be used in arc furnaces and cupola furnaces is given below:

Constituents	Composition (in %)
C	40-55
S	1% max.
F	12-20
Na_2O	15-20
CaO	0.2-1.0
Fe_2O_3	0.5-1.0
Cyandies	0.008-0.056
Alumina (Al_2O_3)	5-8
Cryolite/Bath	10-12
Others	15-20

As reported by United States Department of the Interior (Bureau of Mines), U.S.A., the use of SPL can very well be done for cupola iron melting, basic open hearth furnace and arc furnace steel melting. It can replace the reducer/fluorspar without any harm. At present CIS countries (erstwhile USSR) are using this material successfully. The benefits shown by them is the reduction of coke/flux/ fuel, required quality of product, no harmful effect on furnace lining and above all economically feasible process.

Use of SPL in Arc Furnaces

If used, spent potlining material may give following benefits for the users:

1. Owing to low coke/SPL consumption, less flux is required and less amount

of slag is produced.

2. It can produce low sulphur grade iron, as SPL has maximum of 1% sulphur.
3. High power consumption makes the electric arc furnace dependent on the price of electricity. By using this cheap alternative carburiser, the cost will come down to a great extent.
4. In cupola iron melting, the chemistry of the slag is controlled within wide limits by the addition of limestone or lime, respectively, as sources of calcium oxide. This primary flux also provides some control over a rheological property usually called the fluidity. An auxiliary flux such as fluorspar imparts additional fluidity to the slag. In most cases, fluorspar also increases the rate at which an existing slag can assimilate the primary flux. By the use of SPL, amount of fluorspar can be reduced to almost nil. As it can be seen from the analysis of SPL, requirement of flux to give fluidity to slag can be fulfilled by the CaO and this is already present in SPL.

Expected reactions due to the use of SPL are as follows:

$FeS + CaO = FeO + CaS$

$FeO + C = Fe + CO\uparrow$

$FeO + CO = Fe + CO_2\uparrow$

$FeO + SiO_2 = FeO.SiO_2\downarrow$ (partly)

$Na_2O + SiO_2 = Na_2O.SiO_2\downarrow$ (partly)

$CaO + SiO_2 = CaO.SiO_2\downarrow$ (partly)

$C + SiO_2 = Si + CO\uparrow$ (above 1500°C))

$2NaAlO_2 + SiO_2 = Na_2O.SiO_2\downarrow + Al_2O_3$

$Al_2O_3 + SiO_2 = Al_2O_3.SiO_2\downarrow$

$Na + C = 1/2\ Na_2C_2\downarrow$

$4Na + S_2 = 2Na_2S\downarrow$

CUPOLA IRON MELTING

In iron melting, the quality of the metallic product is influenced by the chemical and rheological properties of the slag, which is an integral part of the operation.

Slag formation in the cupola helps remove silicon and aluminium oxides in coke ash, together with other oxides present in the charge. Fluxes lower the liquidus temperature and viscosity of the slag, thereby improving operation by removing ash from the coke surface. This improves combustion and carbon pickup from the coke by the metal. Other benefits include lower sulphur and phosphorus in the iron produced.

In cupola iron melting, raw material is charged from top in a particular sequence so that each of the material is well heated up till it reaches hearth. Here BP/Beehive coke is mainly used as fuel. It also helps in keeping the fluidity of the slag sufficient for separation from metal and easy removal from the slag notch. If SPL is used, it can also serve the purpose.

PROSPECTS FOR USE OF SPENT POTLININGS IN INDIAN STEEL INDUSTRIES

Taking all these points into consideration, use of SPL (Spent Potlinings), was critically analysed. Safe storage of this material costs too much and commercial use of it is not well justified due to its hazardous constituents. India being a high rain fall area, long term storage of such material is dangerous.

In India, average yearly generation of SPL at present is around 20,000 tons, out of which carbon part is around 9,000-10,000 MT. In addition thousands of tons of this material is lying in the plant storage for anticipated used. If used in a systematic manner, it may last for next 8-10 years without any trouble. Even after that, as generation of this material is of continuous nature, regular supply of it can be assured to the user industries. Aluminium industries are in search of such a process which can not only will use this hazardous material but also can free the land area required for its storage. In India, this will be a new process to be adopted.

During discussions with various small and large iron and steel industries, NML and R&D Centre for Iron & Steel (RDCIS), Ranchi, it was observed that all were keen to know the details of the possible affects of using this material, but were of the view that pilot plant trials must be conducted in India prior to its commercial use. Efforts for the same are also going on.

For an experimental study of the process at pilot plant level costs would be around 0.72 lakh per day (detailed breakup is given in the Annexure I) including all the equipment and the manpower requirements. Out of it 0.25 lakh/day will be returned in the form of metal produced. Such trials are very much required for assessment of this alternative fuel.

CONCLUSION

After going through the above details, it can be concluded that spent potlinings of aluminium smelters can be tried in arc furnaces and cupola iron melting furnaces without any harm. In Western countries this practice is found to be successful in reducing the consumption of costly additives without any deterioration of the quality of metal produced.

Jawaharlal Nehru Aluminium Research Development & Design Centre, Nagpur, would like to do the trials in a systematic manner if the users take interest. If found successful, it will open a new avenue for the co-operation between aluminium and steel industries of the country. Initial efforts are on in this direction.

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ANNEXURE - I

Material Balance for Pilot Plant Experiments of
SPL when used in Arc Furnace Steel Melting

Sl. No.	Charge Material	Quantity	Cost*/ Unit (Rs.)	Total Amount (Rs.)
1.	Iron Ore (Fe>60%)	150.0 Mt	2,000/-	3,00,000/-
2.	Limestone (CaO>54%)	40.00 Mt	500/-	20,000/-
3.	Quartzite (SiO_2>98%)	25.0 Mt	250/-	6,500/-
4.	Nut Coke (F.C.~70%)	15.0 Mt	1,100/-	16,500/-
5.	Petro coke (F.C.~97%)	10.0 Mt	12,500/-	1,25,000/-
6.	Electrodes (8" round and 6' long)	5.0 Mt	90,000/-	4,50,000/-
7.	Carbon Paste (50% petro coke and 50% anthacite)	1.5 Mt	25,000/-	37,500/-
8.	Power	2,500 kWH	1.8 per ton iron	45,00,000/-
9.	SPL material after crushing and transporation at plant site	30.0 Mt	2,800/-	78,000/-
10.	JNARDDC Personnel (tours & travels)	30 days for 2 scientists	2,000/- per day	60,000/-
11.	Conslutancy charges for JNARDDC	3 month total time	1,00,000 per month	3,00,000/-
	Total			58,93,500/-
	10% Administrative overheads			5,89,350/-
	Grand Total			64,82,850/- say 65,00,000/-

*All these costs are temperory and subject to variation of (±) 10%.