Alternate charge materials - problems and prospects of utilizing in electric arc and induction furnaces

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Abstract

Electric Arc and Induction furnaces are classifiable with the preferential charges they use. Arc furnace is versatile because refining operations can be done in it for compositional adjustments. Induction furnace is basically a melting and alloying unit. During the last forty years the quality of steel has undergone gradual modification. In earlier days P&S levels of 0.05% in steel compositions were good enough for most of the uses but today one requires P&S < 0.025 in most cases and in particular usages the same is to be kept < 0.015. These gradually changing stringent requirements on the quality of steels coupled with economy of production has compelled the manufacturers not only to look for alternative charges but also for the alternative processes. Paper discusses these aspects in the light of present day requirements.

Introduction

In early days of electric arc furnace steel making in this country there were only a few furnaces making steel mostly for the purpose of castings and sundry requirements of merchant bars. The bulk requirement of steel and in finished shapes were coming from the integrated steel plants. Towards the fag end of sixties there was a spurt in the number of these units when several mini steel plants came up all over the country. These plants melted steel in Arc furnaces and made pencil ingots which were finally rolled into merchant sections in rolling mills. This spurt of Arc furnaces and mini steel faded very soon because the power available for making steel was extremely inadequate and irregular. Charge material in all cases was return scrap from the unit itself along with scrap sheet cuttings pressed into the form of bails. Steel made was C, Si $\leq$0.1 and S, P $\leq$ 0.05. With the increase of these furnaces power supply was not the only problem but the charge materials was a bigger problem. The manufacturers could not keep quite after having made huge expenditure and therefore several steps were taken to augment the facilities to sustain the activities. There were several advances in the steel making technology following this period, which on one hand relaxed a bit on the charge material but steel grades started becoming stringent. All this needed to look for alternate charges.

Scrap

In late sixties when the boom of mini steel plants was there, the estimated requirement of scrap for charging into electric furnaces was put at 2.5 million tons whereas barring the integrated steel plants the availability of the scrap in the late sixties and seventy was restricted to 0.75 - 1.1 million ton only. This availability was from degrading material and was mostly substandard in use. However, industry had no option. It had to survive in scrap as well as power shortage and restrictions. Both the problems were complementing each other. If you do not have power you do not need scrap and vice versa. Steel making in this period was restricted to the usual double slag process making oxidising and reducing slags in turn to bring down C, P, S and to adjust the final composition ferro alloys were used.

In late seventies and thereafter there had been marked changes in the steel melting technology. VAD and ladle furnaces had become common addition to the steel melting shops along with the arc furnaces. Our government also allowed to import the shredded scrap from abroad which was cheaper and better than the scrap available in the country. With VAD and ladle furnaces in operation the other important addition to the mini steel plants were the continuous casters for the billets. These casters initially had been vertical and the inconvenience of teaming due to excessive height was inhibitory factor in their popularity. Very soon horizontal continuous casters came into operation and the castings of pencil ingots practically became extinct. With these attributes (VAD, Ladle furnace and the continuous casters) the quality of steel being made in these shops were also grossly upgraded. In ordinary merchant steels, the S, P requirement was designated at 0.05 whereas continuous cast billets are being manufactured for wire rods, rails, I, H beams, skelp and so many other sections. S&P level was brought down slowly to below 0.025. Designers were particular in choosing specialised qualities of steel for which compositional constraints were in narrow ranges. With diversity in melting accessories (secondary steel making) it no longer required a double slag process. Sulphur is removed in ladle furnaces whereas phosphorus is taken care in the main arc furnace. This has cut down the dwell time of the metal in the furnace resulting in the increase of the productivity. With the inclusion of VAD the production of special grades, more particularly, stainless steel became conveniently possible and there was a sudden rise in the production of alloy steels. Inspite of these facilities being conducive to the production of steels in arc furnaces the scrap and the metallic charge alloy with additions (mostly in the form of ferro alloys) were the limiting factors. The main constraint was posed by the scrap. It was desired by our planners that in the production of steel the contribution from sources other than the integrated steel plants be at least 30% and on present day level of production it comes to about 4 million tons for which the scrap requirement is also of the same order. Availability is much below it. This has compelled the electric steel makers to look for alternate charge materials than the usual scrap available indigenously or through imports. It has already been commented that the scrap and powerare output limiting inputs in electric steel making. In competitive market one has to keep quality and quantity in optimum level for maximum turnover and profits. The effort by secondary steel makers has been to counter the problems connected with these two major inputs. In recent years the attention has shifted to arrange alternate charge to supplement the shortage of the scrap. Many organisations are now going for sponge iron and the hot metal from the mini blast furnaces as alternative.

Sponge Iron

This has been an important alternative to metallic scrap as a part replacement. Many methods have been developed now a days to produce sponge iron with low S and P maintaining carbon in range from 0.01 to 2%. Most of the middle size organisations like Sun Flag and Nippon Dendro in Nagpur and Essar Steel in Gujarat have planned to base their melting operations substantially on sponge iron produced by them. It serves two purposes. They do not starve for the shortage of scrap to match their capacity and the steel produced can be low in S, P. This is particularly true for the gas based sponge iron. Result of this alternative has been that the extreme low S, P levels can be achieved in the final composition without much of working. In the production of stainless steel or DD or EDD steels these carbon levels to the extent of 0.05% or below are to be achieved along with S, P as $< 0.015\%$. While making these steel with indigenous raw materials there is no alternative than to use a good percentage of sponge iron to bring down S and P. Carbon does not pose much problem because it can be taken care of in VAD.

Hot Metal from the Mini Blast Furnace

This has been taken up after the so called success of Chinese and Brazilian experiences. A few organisations have put up mini blast furnaces and are transferring the hot metal directly to the electric arc furnaces. It has cut down their scrap requirement considerably and can keep the furnaces fed to their capacity. The greatest problem which may have to be faced by them in times to come will be ecological and environmental imbalance created by them which by legislation and by social obligation point of view may be objectionable.

Induction Furnace Charges

So far discussions were centered around the arc furnaces only. Induction furnaces are basically the melting and alloying units. Refining operation are not done in these furnaces. We get induction furnaces in three frequency ranges e.g. (i) High frequency, (ii) Medium frequency, and (iii) the mains frequency. Heating is done by induction whereby eddy currents are induced in the charge. Heating and melting takes place by the heat effect of induced eddy currents. It is a common knowledge that the penetration of induction is inversely proportional to the square root of the frequency and hence lower the frequency greater the penetration. Thus where charges are very small high frequency induction furnaces are used. For medium size charge medium frequencies are used and for bulky charge we use mains frequency. Generally places where machined chips or turning and other small charges are there we use high frequency induction furnace and the frequency is lower in case of increasing size of charges. For main frequency furnaces one has to start with a large size (comparable to the diameter of the furnace) starting block and once a pool of metal is formed it can take any type of charge. More often in practice main charge is melted else where and these furnaces are used for alloying and holding till pouring. Alloying is convenient in induction furnaces because recoveries are almost total. Thus the problem of charge in induction furnaces is indirect for most of it.

Allied Problems

Allied problems with arc and induction furnaces are (apart from the charge) appropriate grades of ferro-alloys, refractories and electrodes suited to the new developments in melting. Since specifications on S, P are continuously going lower and lower the ferro alloys have to match their quality to maintain S & P. For very low S&P the raw materials for making the ferro alloys need enrichment. Fe-Mn suffers with the perennial problem of high phosphorus. The beneficiation processes have to develop to make these ferro alloys of the quality requirement of the present days.

In refractories development have taken place. Superior refractories have been evolved and need further work. NML itself has developed sintered Alumina, Tabular Alumina, Sintered Mullite and a few very useful fly ash based ceramics, refractory mortars and castables help eason the situation commercially and technically. NML has evolved the process of beneficiation of indigenously available magnesites to bring them to a stage where brick making is possible. Our magnesites contain up to 86% $MgCO_3$ with acid insolubles more than 7%. To make them worthy of use the processes have been developed to make $MgCO_3$ in indigenous deposits more than 92% and acid insoluble less than 2%. This makes it suitable for brick making. Similar thing has been done for the beneficiation of graphite make it suitable for electrode making.

Conclusion

Problems in electrical steel making are basically circumstantial and have to be tackled on national level. Charge and power are crux of it and to a great extent they are beyond the purview of steel makers in one way or theother. A concerted effect from all concerned is the need of the hour.