CHANGING REQUIREMENTS OF FERROALLOYS FOR FLAT PRODUCTS – USER'S PERSPECTIVE

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ABSTRACT

Ferroalloys are integral part of steel melting process. The purpose of using ferroalloys is three fold e.g. killing of steel, modifying the slag composition and steel alloying. Amount of ferroalloys used for alloying is subject to requirements of steel properties e.g. yield strength, ductility, formability etc. Variety of ferroalloys (sometimes pure metal) is used by steel industries depending upon their techno-economic feasibility. Size, chemistry and modes of addition of ferroalloys are suitably engineered to bring in operational consistency and cost benefits.

Of late, Tata Steel has tried out a few ferroalloys for the first time with interesting results to meet the specific requirements of high strength interstitial free (IF) and micro-alloyed steels. Some of these ferroalloys have been put into regular use with complete or partial replacement of ferroalloys used earlier. Size of one of the ferroalloys has also been modified without any other adverse effects. This paper summarizes requirements of ferroalloys for the steel industry with special emphasis on recent trials.

1. INTRODUCTION

Steel plants are constantly innovating to increase productivity and quality of its products. Concurrently, there are requirements to produce special grades of steels e.g. high tensile, interstitial free (IF) etc. More often than not, these special grades require new operating regime and therefore pose a new challenges to steelmakers. Ferroalloys play an important role in overcoming such challenges. Besides, the existing steelmaking process can be made more efficient by selection of suitable kinds of ferroalloys. Higher grades of steel (w.r.t alloying elements) requires higher amount of ferroalloys addition. Use of high grades of ferroalloys or pure metals bring down amount of alloying, as a result steel temperature drop can be minimized to a large extent. Lower temperature drop facilitates higher productivity owing to

- lower steel tapping temperature at LD/BOF which impacts favourably to prolong life of refractories and therefore campaign life of LD/BOF vessel
- reduction in cycle time at LF to compensate for temperature drop (for same tapping temperature)

Higher amount of alloying also brings in residuals e.g. P, C, S, N etc., which are considered to be detrimental to the properties of steel products. Therefore, ferroalloys should contain less of these elements as far as practicable.

Yet another important aspect associated with ferroalloys is the recovery of alloying element into the steel. Recovery is defined as the ratio of amount of alloying element present to total amount added into the steel. Apart from steelmaking parameters, recovery is dependent of consistency in the quality (chemistry and size) and addition practice of ferroalloys. Steelmaker's are confronted with two issues related to recovery e.g.

- Consistency in recovery (inconsistent recovery produces off specification steel – increases cost of production)
- Higher recovery (lower recovery adds to cost of production)

Recovery is closely associated with the melting and dissolution characteristics of ferroalloy [1]. The mechanism of melting and dissolution into the steel bath is a complex process. As ferroalloys are added into the steel bath, a solid steel shell freezes around it. Then, melting and dissolution of the ferroalloy follows following mechanism:

1. first melting of core and then melting of shell
2. first melting of steel shell and gradual melting of exposed core
3. repeated melting and formation of steel shell till full melting takes place

To address the issues mentioned above, trials on few ferroalloys are discussed in detail as follows:

2. MANGANESE (Mn) FERROALLOYS

Mn is the most common alloying element for the steel plant. Mn is added through a few Mn ferroalloys e.g. High Carbon Fe-Mn, Medium Carbon Fe-Mn, Silico-Mn and Mn metal. Mn metal is the purest variety which contains over 95% of Mn. Other elements e.g. P, C, S, N etc. is also on the lower side. Table 1 gives comparison between Mn metal and Medium Carbon Fe-Mn.

Mn metal [2] was tried in place of Medium Carbon Fe-Mn to enhance process capability of the existing process in terms of

- Higher steel Mn
- Lower residuals
- Higher & consistent Mn recovery

Table 1: Chemical composition of Mn Metal & Med. Carbon Fe-Mn

Parameters	*Mn Metal*	*Med. Carbon Fe-Mn*
% Mn	95	70
% C	0.04	1.5
% S	0.04	0.02
% P	0.03-0.05	0.4

Mn metal has higher Manganese, therefore steel Mn can be raised with bulk of addition remaining same (as compared to medium carbon Fe-Mn). Mn metal has higher bulk density and this gives better consistency in terms of Mn recovery in steel. Sulphur in Mn metal is a bit higher, however, calculations shows very little impact on the rise of steel sulphur (2 tons of Mn metal addition for heat size of 138 tons will give 1 ppm ~ 0.0001% rise in steel sulphur). Residuals such as carbon & phosphorus being lower with Mn metal, there is no rise in steel carbon or phosphorus in case of higher level of additions (>1.5 tons) i.e. there is no pick up of carbon or phosphorus in steel. This helps in achieving higher steel Mn (≥0.8%) with no rise in phosphorus (with medium carbon Fe-Mn, there was 0.003-0.005% rise in steel phosphorus).

The trial result with Mn metal in RH also shows favourable impact on treatment time and steel carbon at the end of RH treatment. Table 2 shows trial results with Mn metal (as against medium carbon Fe-Mn) for RH heats.

Table 2: Operational result with Mn-metal at RH

Parameters	*Result*
Recovery*	100 kg Mn-metal : 0.06% Mn in steel 100 kg MC Fe-Mn: 0.04% Mn in steel
De-C time	Lower by 2 min.
Steel C after RH	Lower by 2 points (0.0002%)
Slag MnO	Lower by 6-8% in High Strength IF

(*Recovery, % = (amount of Mn in steel) / (amount of Mn added)* 100. Based on the trial results, recovery for Mn metal and MC Fe-Mn is calculated to be 87% and 81% respectively)

For same level of Mn in steel, addition of Mn metal being less (33% lower), resulting into lower drop in steel temperature. Lower drop in steel temperature can have following advantages (to the extent of drop):

1. reheating in LF can be avoided (affects cycle time)
2. tap temperature can be reduced (affects refractory and steel oxidation level)

3. VANADIUM (V) FERROALLOY

Vanadium (V) is used as micro-alloying element for the production of high strength steel. Precipitation of vanadium nitrides (VN) is the underlying strengthening mechanism in V bearing steels. The requirement of V in steel can be brought down by 20-30% by modifying levels of V and N (nitrogen) in steel (nitrogen in steel with nitrovan can be as high as 120 ppm)

The N in steel after tap is around 30-40 ppm. There is no reliable method of raising steel nitrogen at LF (Ladle Furnace) without contaminating the steel. Nitrovan vanadium, which is the alloy of V & N serves the purpose of raising steel N and raising the steel strength further. Table 3 shows chemistry of normal Fe-V and nitro vanadium. There are two varieties of nitro vanadium, one having nitrogen 12% whilst other having nitrogen 16%.

Table 3: chemistry of normal Fe-V vis-a-vis nitro vanadium

Material	V, %	N, %
Fe-V	50-55	Trace
Nitro Vanadium	79	12/16

The purpose of using nitro vanadium [3] is as follows:

1. The quantity of V-alloying will halve. This will help operators immensely in case V being added manually at LF
2. Strength of steel can be raised further

One of the issues with the use of nitro vanadium is the consistent recovery of nitrogen during LF treatment, Figure 1. Encircled portion in Figure 1 shows good recovery of nitrogen w.r.t amount of nitro vanadium addition. This has been addressed through standardizing ferro-alloys addition practice with respect to timing of nitro vanadium addition. As a result, nitrogen recovery to the extent of 60% has been made possible (100 ppm of nitrogen in steel has been achieved, Figure 1).

The trial result with nitro vanadium shows rise in the steel strength by 40-60 MPa (average) with same level of vanadium in steel. As a result, the vanadium in steel needs to be downwardly revised.

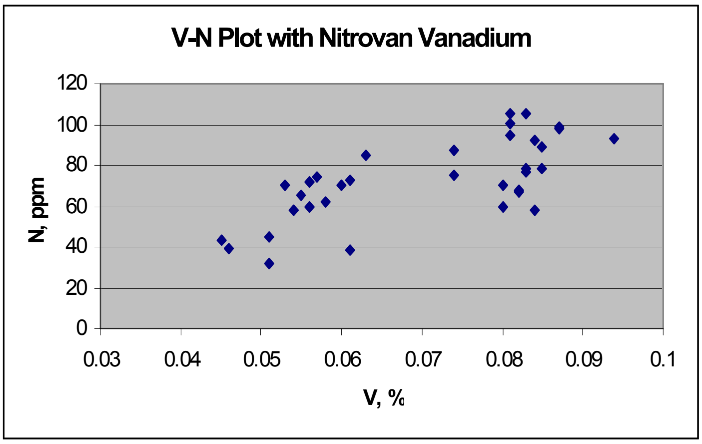

Figure 1: Nitrogen recovery for different levels of V in steel

4. OTHER FERROALLOYS

1. Ti Sponge & Low Al Fe-Ti

These ferroalloys have been tried at RH for the production of interstitial free steels (IF). These ferroalloys have been tried as they contain less Al over normal Fe-Ti. Production of IF steel calls for stringent quality requirement and Al in Fe-Ti can give rise to Al_2O_3 inclusions which deteriorates the steel quality.

Ti sponge being the purest variety of Ti alloy (98% Ti and no Al), was tried first. However, the recovery of Ti in RH was found to be erratic and as a result the use of Ti sponge was discontinued (Ti sponge being lighter, addition of it under vacuum gets carried away through higher speed of exhaust gas owing to skull build up inside the RH vessel, phenomenon is schematically shown in Figure 2, V2>V1 as A2<A1 following continuity equation i.e. A1*V1=A2*V2). Ti sponge has been replaced by Low Al Fe-Ti.

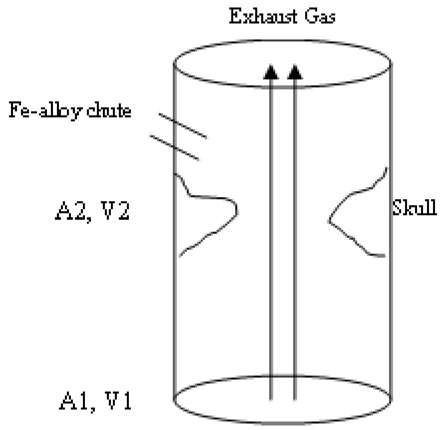

Figure 2: Higher speed of exhaust gas (V2) due to area (A) effect

2. *Fe-Al lump*

Fe-Al lump (eutectic mixture with Al~35%) has been tried in place of Al notch bar during tapping with a purpose to improve Al yield/recovery. The notch bar is lighter and hence the yield is poor (sp. gravity of Fe-Al is twice that of notch bar). Trial result shows (Table 4) consistent recovery with Fe-Al and lower final Al (0.03-0.042%), but the major disadvantage with Fe-Al is higher amount of addition (%Al being 1/3 of notch bar) and therefore manual addition at tap is not possible (only possible through bin addition). Cost of Fe-Al is also one of the deterring factors using this alloy.

Table 4: Trial result with Fe-Al

	Fe-Al Trial	*Normal Practice*
Total Al_{in}, kg	305	355
Al in steel/slag, kg	48/257	64/295
Al in steel, %	0.035	0.047

(* Normal practice and Fe-Al trial entails notch bar and Fe-Al addition at Tap. Proportionate addition of Al wire and cube at LF remains same for both cases)

3. *Fe-Nb lump*

Nb recovery sometimes show erratic trend in terms of Nb-fading [4]. Issue of Nb fading is addressed through fine tuning LF practices e.g. timing and amount of Fe-Nb addition and its dissolution in steel through combined effect of arcing and bottom purging. Size of Fe-Nb plays an important role in Nb recovery. Smaller size aloy clan have better melting and dissolution characteristics, however, small sized alloy being lighter doesn't go deep down the melt and the chances of loss through top slag is higher. Therefore, size of ferroalloys should be optimized depending upon plant specific steelmaking practices. Recently, some trials have been undertaken with wider size range of Fe-Nb and result of this change has been a good learning experience.

5. CONCLUSION

Ferro-alloys play an important role in improving the quality of steel products, and also help in improving the efficiency of steel plants. The specification of ferro-alloys is to be re-looked depending upon the plant specific requirements. There is ample scope to work out mutually beneficial cost effective solutions. This is very clear from trials on various ferro-alloys (with modified specification) mentioned in the article.

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