THE USE OF RARE EARTH METALS FOR MODIFICATION OF NON-METALLIC INCLUSIONS IN SILICON STEEL

To Duy Ca*, G.V. R.. Iyer**

* Scientist at Institute of Materials Science, Hanoi-Vietnam

** Scientist at National Metallurgical Laboratory, Jamshedpur-India

ABSTRACT

The rare earth metals (RE) are used effectively in steelmaking in recent years. The silicon steels usually have defects leading to lower fatigue and toughness characteristics and cracking in production and the use. A study of silicon steels Si3 has shown that they contain coarse aluminates and silicates which possess high elongation. This work performed experiments to remove these defects and modify remain inclusions in silicon steel Si3.

Experiments were prepared with RE additions from 0.5 kg/t to 2,5 kg/t to study the influence of RE on these effects. The melts were carried out in induction furnace (130 kW) with MgO furnace wall. The RE addition into Si3 steels was from FeSiRE (25%RE, 25%Si, 3%Ca, 5%Al and balance Fe). The melt was poured into ladle having RE addition in the bottom with stirring by wood stick. The samples was tapped into small cooper molds for analysis of chemical compositions and inclusion's study by Neophot II, JEOL-35CF-LINK 860/II and DX-5000.

The results of inclusion compositions are the following: 3-34%Al, 2-45%Si, 2-5%Ca, 9-30%S, 1-22%Mn, 40-76%RE and oxygen balance.The results show that with RE addition from 0.5 to 1.0 kg/t mainly formed oxysulphide inclusions of types like RE_2O_2S, $RESiO_2S$ and $REALO_2S$ while all manganese sulphides nearly.The dissolved RE reacts with the dissolved sulphur and precipitates RE sulphides. These primary RE sulphide inclusions act as nuclei for the precipitation of RE oxysulphides according to reaction: 2/RES/ + 2/O/ = /RE_2O_2S/ + /S/. These primary oxysulphide phase are confined to the outer surface. The secondary RE sulphide and complex sulphides are probably precipitated during the solidification of steel, are formed surrounding the primary cores disappeared.The RE addition of 1.0 kg/t changed manganese sulphides of type II and silicates into globular oxysulphide of type Ib. With RE addition over 2.0 kg/t the cluster sulphide inclusion of type IV formed.

The results of effect of RE addition on inclusion quantity and size are as the following : the lowest inclusion number of 0.0188 area% (1576incl/cm^{-2}) observed in sample with RE addition of 0.5 kg/t. Whilst total sulphide number was the lowest e.g. only 360 incl/cm^{-2}. The RE additions refined inclusions to smaller than 4μm (from 72,9 to 80,87% e.g. only 0.0059 to 0.0534 area%) and negligible inclusion over 10μm appeared.The optimal RE addition into silicon steel is 0.5 kg/t. The over limit of RE addition of 2.0 kg/t was appeared harmful cluster inclusion of type IV.

The results of present work consulted and compared with about 40 published and unpublished works, the authors wish to continue in next time.

Table 1. Chemical composition of inclusions in silicon steels

Sample No	Chemical composition (wt%)						
	Al	Si	Ca	S	Mn	RE	O
S_0	58	16	5	11	10	0	balance
S_1	34	15	5	11	0	35	balance
S_2	4	2	3	15	1	76	balance
S_3	3	45	3	9	0	40	balance
S_4	14	31	2	30	22	41	balance

Table 2. Influence of RE additions on inclusion quantity and size

sample No	total quantity		oxide		sulphide		inclusion size		
	number /cm^{-2}/	area /%/	number /cm^{-2}/	area /%/	number /cm^{-2}/	area /%/	1-4μm /%/	4-10μm /%/	over10μm /%/
S_0	9982	0.0561	9945	0.0560	38	0.0001	0.0323	0.0126	0.0112
S_1	1576	0.0188	1216	0.0166	360	0.0022	0.0059	0.0116	0.0014
S_2	4747	0.0404	1145	0.0084	3603	0.0315	0.0170	0.0218	0.0016
S_3	7065	0.0636	4194	0.0451	2871	0.0186	0.0167	0.0190	0.0094
S_4	10545	0.1419	7618	0.1248	2927	0.0171	0.0534	0.0626	0.0259

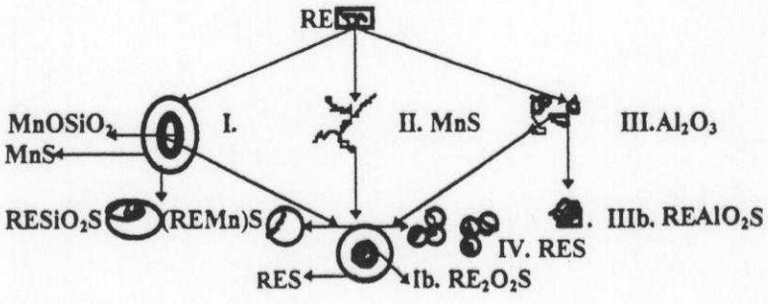
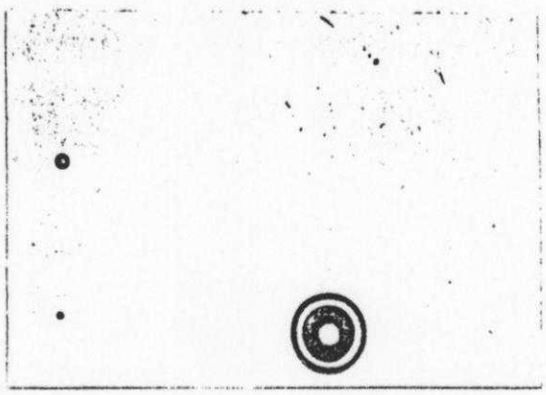


Figure 1. Schematic of formation and morphology of inclusion in steel



A: 2Al, 28Si, 0.1Ca, 5S, 7Mn, OBalance

Figure 2. Typical inclusion appearing in silicon steel
(Without RE addition)

Figure 4. Micrograph of sulphide of type IV in silicon steel (RE addition of 2.0 kg/t)

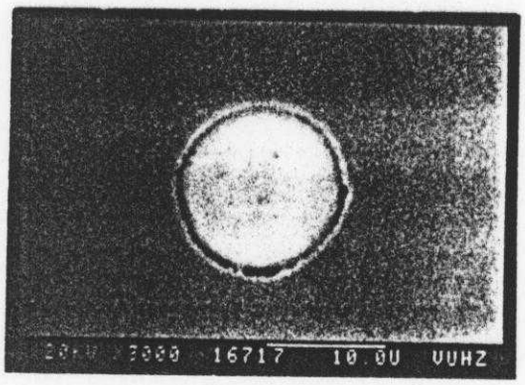


Figure 3. Micrograph of sulphide of type Ib in silicon steel, (RE addition of 0.5 kg/t)

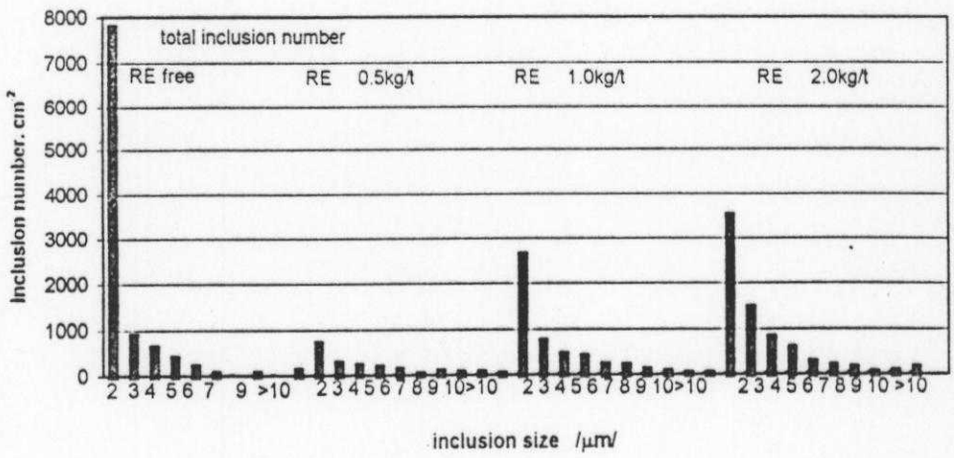


Figure 5. Effect of RE additions into silicon steel on quantity and size of inclusions

To Duy C. *Rare Earths in Alloy Steel*

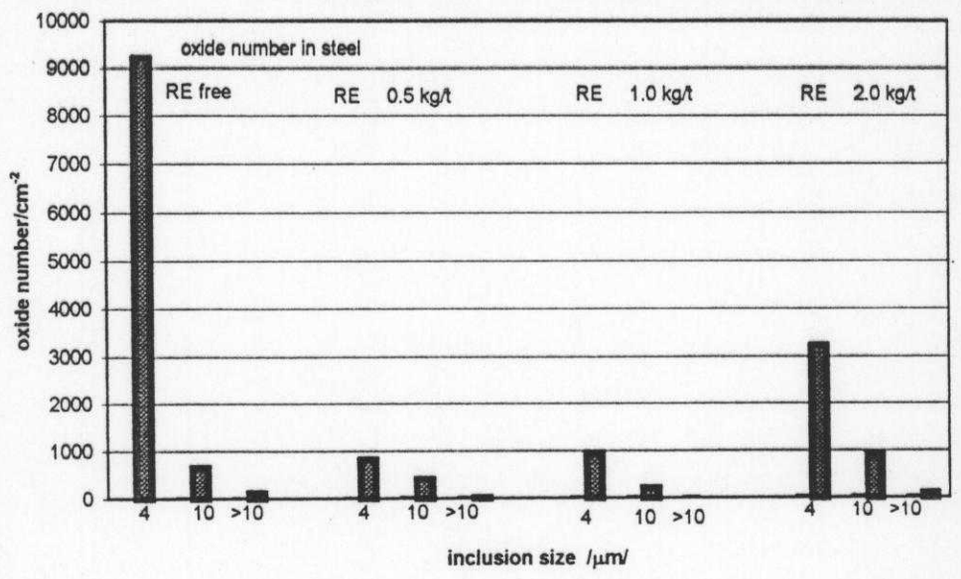


Fig. *Effect of RE additions on quantity and size of oxides in silicium steel*

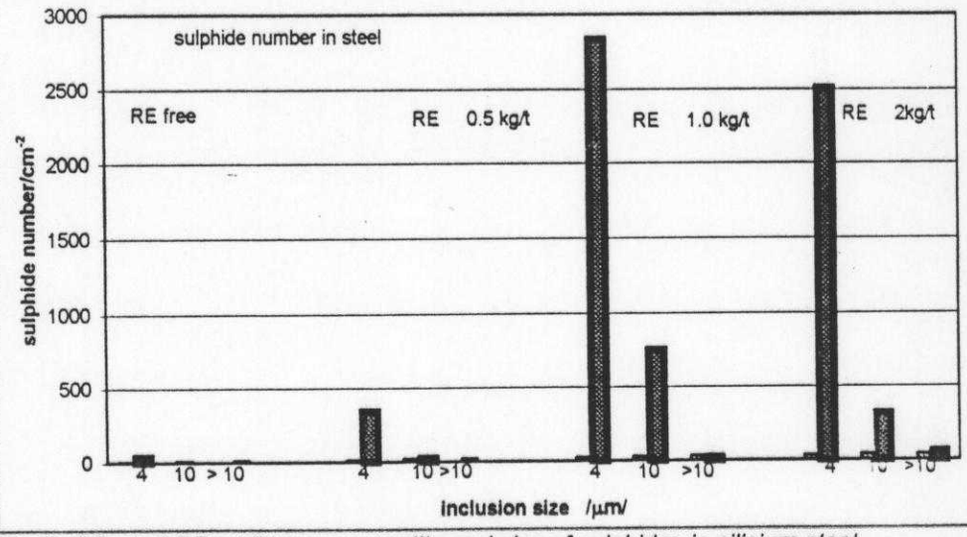


Fig. 6. *Effect of RE additions on quantity and size of sulphides in silicium steel*

To Duy C. Rare Earths in Alloy steel

71	0.0055
50	0.0057
0	0.018
57	0.0114
35	0.003
12	0.0122

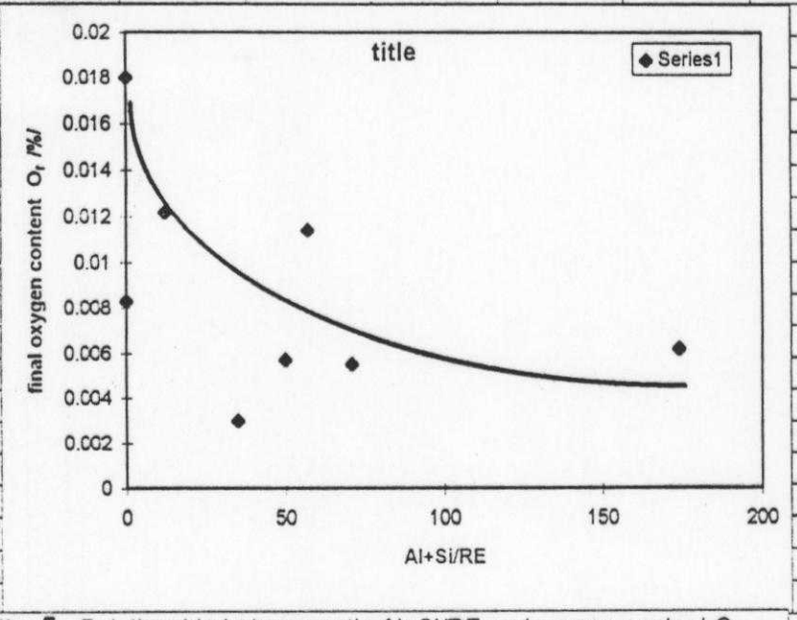


Fig. 7. *Relationship between ratio Al+Si/RE and oxygen content O_t*

4	240	147
5	294	105
6	188	107
7	135	78
8	194	51
9	88	48
10	120	0

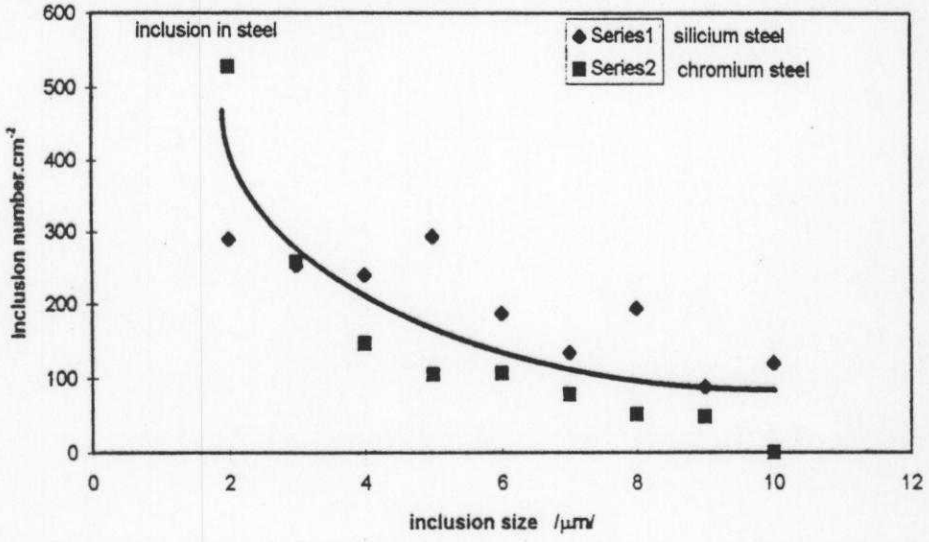


Fig. 8. *Relationship between inclusion number and inclusion size in alloy steels after RE additions*

0	0.0083
174	0.00619

AUTHORS' DECLARATION

Name of Authors: (1) To Duy Ca

Title of the paper:

I/We certify that my/our paper is an original paper and has not been published in part or whole elsewhere and will not be published or communicated to any other Institute or publisher without the express written permission of the Indian Institute of Metals.

The principal author of the above paper is To Duy Ca

All authors to sign please

To Duy Ca
(Signature/s)

National Metallurgical Laboratory JAMSHEDPUR 831 007

Date &Place