# INFLUENCE OF RARE EARTH METALS ON MECHANICAL PROPERTIES OF PIPELINE STEEL

*To Duy Ca* National Metallurgical Laboratory, Jamshedpur 831007*

Rare earth metals (RE) additions to pipeline steel were improved necessary mechanical properties, comparing with CaSi addition treatment. The yield, ultimate tensile strenghths were raised with optimal RE addition amount was obtained to 0.05kg/t and ratio RE/S to 0.217. The percentage of elongation was increased with optimal RE addition amount was obtained to 0.07kg/t and ratio to 0.212. The comparision with pipeline steel of GOST 20, RE additions were affected on sulphide shape control, macrostructure and microstructure of steel ingots improving in yield, ultimate tensile and percentage elongation after rolling.

The results have been varified in full scale plant trials.

## 1. INTRODUCTION

Rare earth metals have high affinity for oxygen and sulphur, so RE are strong deoxidizers and desulphurizers in molten steel[1-12]. Rare earth metals are an effective means of providing sulphide shape control. Rare earth metals influence sulphide shape cotrol from the deformable MnS inclusions into undeformed oxysulphides or RE sulphides[2,13-15]. Rare earth metals inclusions are undeformed during hot rolling[16-20], resulting in heterogeneity in mechanical properties of the rolled products. Thus RE alleviates the detrimental effects of elongated MnS inclusions on toughness.

The problem is not yet in general agreement about desulphurizing ability of RE in molten steel. A lot of previous research works proved the optimal ratios of RE/S to be about three to one for the elimination of anisotropy caused by deformable inclusion [21-25]. Benefical effect results from improved hot ductility and a reduction in segregation. These results from the information of fine grainned structures achieved by the nucleating ability of the oxysulphide inclusions in the final product. Sulphide shape control provides improved ductility, deformability, weldability and fatigue resistance[26-30].This work desribes the influences of RE addition into ladle on necessary mechanical properties of pipeline steel. The results have been varified in ful scale plant trials.

## 2. EXPERIMENTAL

Plant trials were performed with steel containing 0.015%C, 0.35%Si, 0.03%Mn, 0.03%P, 0.03%S, 0.03%Al, melted in a 45t UHP electric arc furnace. The bath after addition special amount of FeMn, FeSi, Al was tapped into a ladle. Then the ladle was subjected to the RE addition in injection station. The added RE contained 45.2%Si, 21.6%RE, 4.3%Ca, 0.9%Mg, 7.2%Al and about 21%Fe.

Steel samples were taken from the rolled products. All the samples were subjected to complete chemical analysis. The selected samples containing RE and RE free were tested for mechanical properties.

**The author is at present Post Doctoral Fellow at NML/CSIR Jumshedpur*
*Dr. Manager of Department, on leave from Institute of Materials Science/VNCNST*
*Vice presiden, General Secretary of Hanoi Foundry and Metallurgical Association*
*Nghia do - Tu liem - Hanoi , Vietnam*

The necessary values of mechanical properties were determined in machine MTS with power velocity 30MPa/s and at temperature 20°C. The values for yield strength (YS), ultimate tensile strength (UTS) and percentage of elongation ($\delta_5$ and $\delta_{10}$) were measured. Three samples were taken from evry melt of pipeline steel. Four typical melts were tested; from them 3 melts were with RE and one melt contained only CaSi for comparison purpose.

## 3. RESULTS AND DISCUSSION

The results of yield, ultimate tensile strengths and percentage of elongation measured in samples after rolling are ploted in **fig. 1** and **2.**

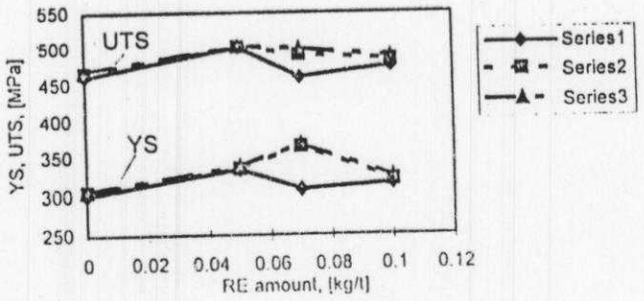


**Figure 1.** The relationship between RE additions and yield strength (YS), ultimate tensile strength (UTS)., (after rolling)

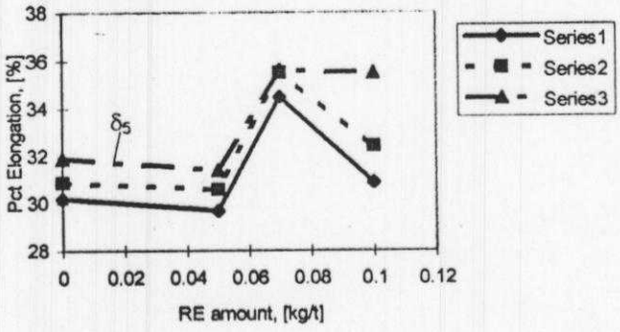


**Figure 2.** Effect of RE on percentage of elongation of pipeline steel (after rolling)

The comparision with CaSi treatmant shows that the RE addition to steel has increased yield and ultimate tensile strengths with optimal RE quantity at 0.05kg/t and RE/S ratio at 0.217. The percentage of elongation increased over 34% with optimal RE quantity at 0.07 kg/t and RE/S ratio at 0.212. The **fig. 1** shows that most points and lines are adjoining to earch orther, attaining a high peak at optimal RE quantity of 0.07kg/t.

The stretched samples with rare earth metals addition of 0.05kg/t and 0.1kg/t showed higher values of yield and ultimate tensile strengths compared to the samples

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treated with CaSi. The values for the stretched samples having RE addition of 0.07 kg/t were however different. They were lower than CaSi treated samples (see **fig.3)**

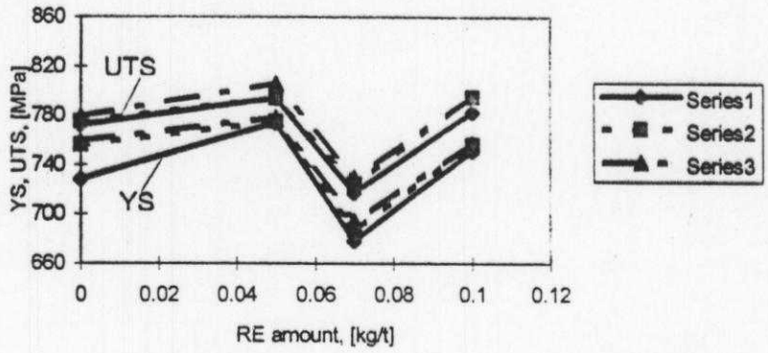


**Figure 3.** The relationship between RE addition and yield strength (YS) and ultimate tensile strength (UTS) (after stretching)

The **figure 4** shows that with RE addition of 0.07 kg/t recorded higher values for percentage of elongatione were than other samples. All samples containing RE however, had increased percentage of elongation.

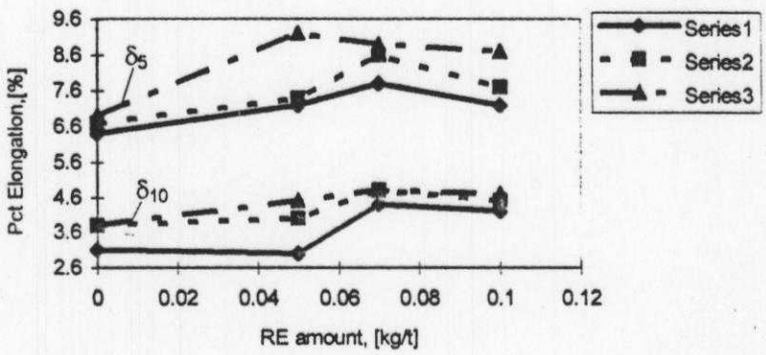


**Figure 4.** Effect of RE on percentage of elongation of pipeline steel (after stretching)

These results are very important for rolling pipes, because pipeline rolling process involves high deformation. The RE additions have positive effect on sulphide shape control, which is shown in **table 1**

**Table 1.** Effect of RE addition on characteristic of inclusions in pipeline steel

| Sample No | RE addition | Ratio RE/S | Inclusion amount | Observed sulphide | | | Observed oxide | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | number | inclusion size* | elongation ratio** | number | inclusion size | elongation ratio |
| | [kg/t] | - | [number/cm$^{-2}$] | [ area%] | over 10μm | | [area%] | over 10μm | |
| 11086 | 0.5CaSi | - | 25 | 190 | 0.0006 | 6.20 | 35 | 0 | 1.84 |
| 21807 | 1.1CaSi | - | 28 | 157 | 0.0009 | 5.08 | 90 | 0.0129 | 1.79 |
| 32106 | 0.02 | 0.08 | 47 | 206 | 0.00013 | 7.68 | 47 | 0 | 1.94 |
| 41815 | 0.03 | 0.12 | 18 | 124 | 0 | 6.54 | 36 | 0 | 4.47 |
| 52107 | 0.05 | 0.217 | 27 | 162 | 0 | 4.94 | 82 | 0 | 1.65 |
| 62113 | 0.07 | 0.212 | 19 | 108 | 0 | 7.62 | 59 | 0 | 4.03 |
| 72114 | 0.10 | 0.376 | 50 | 190 | 0.0006 | 4.89 | 55 | 0 | 2.12 |
| 81799 | 0.20 | 0.769 | 34 | 151 | 0 | 7.20 | 121 | 0.0017 | 1.56 |

*before rolling pipe ** elongation ratio l/d; l... inclusion length, d...inclusion witdth

The inclusions are very small-smooth; nearly there was no inclusion with size over 10μm; the elongations of sulphide inclusions were very minimal. These have resulted into the best deformability of pipeline steel during rolling.

The mechanical properties of the annealed samples are shown in **fig. 5** and **6.**

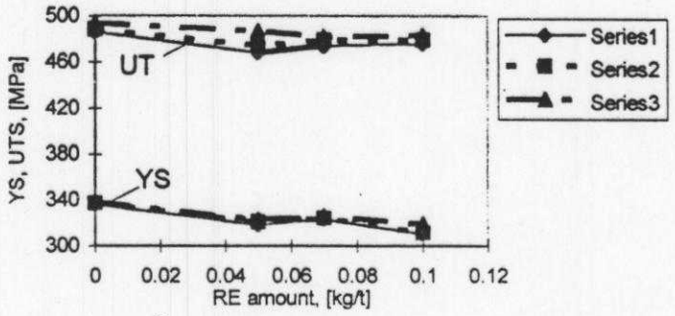


**Figure 5.** The relationship between RE addition and yield strength (YS) and ultimate tensile strength (UTS); ( after annealing)

The yield and ultimate tensile strengths dropped after annealing. The increase in percentage of elongations in all cases are quite obvious. Similar results were obtained in repeated experiments as shown in above figures represented by series 1, 2, 3.

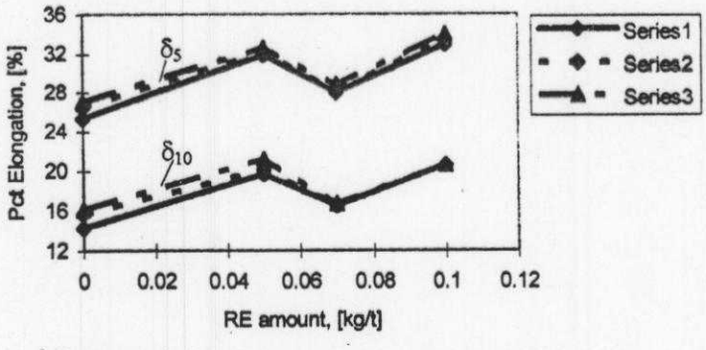


**Figure 6.** Effect of RE on percentage of elongation of pipeline steel ( after annealing)

These were the reasons for the improvement of mechanical properties of pipeline steel. These results are comparable with published works [33-38].

## 4. CONCLUSIONS

The plant trial showed that additions can improve yield. ultimate tensile strengths and percentage of elongation of pipeline steel GOST 20.

The comparison with CaSi treatment shows that the RE addition gives improved percentage of elongation with optimal quantity to 0.07 kg/t and RE/S ratio equal to 0.212. The yield and ultimate tensile strengths increased with optimal of RE quantity at 0.05 kg/t and RE/S ratio equal to 0.217, but after annealing the mechanical properties was due to altered sulphide shape control, macrostructure and microstructure of pipe ingots.

The RE additions affected improvement in mechanical properties of pipeline steels. The results have been verified in full scale plant trials and compared with published works.

## ACKNOWLEDGMENT

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# THE INDIAN INSTITUTE OF METALS

S. R. PRAMANIK
Managing Editor,
Metal News

"METAL HOUSE"
Plot 13/4, Block AQ, Sector-V
Salt Lake, Calcutta-700 091
Tel : 033-321 5006/321 5325
TELEX 021-7786 ICIC IN FAX : 033-321 5325
TELEGRAM : INDINSTMET, CALCUTTA


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Dr To Duy Ca
Visiting Scientist
National Metallurgical Laboratory
Jamshedpur 831 007
Bihar

Dear Dr To Duy Ca,

Many thanks for the revised manuscript of your paper entitled "Influence of Rare Earth Metals on Mechanical Properties of Pipe-line Steel". The paper has been accepted for publication in IIM Metal News. It will take some time before the papers already registered with us for publication are cleared. Hope you will bear with us.

With kind regards,

Yours sincerely

S R Pramanik