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Process Parameter Selection Guideline to Reduce Variation in Temper Hardness of Boron Steel Forgings

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***Abstract*—Boron Steel Heat Treatment requires nuanced understanding of the way Boron Behaves in the Steel Matrix. The selection of Parameters for its heat treatment is relatively unknown as it radically differs from Common Forging Material grades in Plain Carbon Steel or Alloy Steel. This study will help the heat treatment department to select parameters scientifically and therefore ensure that the Forging Properties are in conformance with the customer requirement.**

Keywords— Boron Steel; Heat Treatment of Boron Forgings; Tempering Hardness; Boron Forging;

I. INTRODUCTION

The addition of Boron to a steel matrix increases its hardenability. The fact that this addition is relatively inexpensive as compared to addition of Costly alloying elements like Chromium and Molybdenum has led to its increase in its usage in Heavy-Engineering Applications. However the Alloy Steel has been in use for decades, but the Boron Steel is a recent adoption to Mass production Practice in India. In terms of Technical Database, this material has much fewer research articles than those available for Common Plain Carbon or Alloyed Steel Grade.

However, despite of its lower cost, there are many manufacturers who have not been able to replace it as an alternate material due to its high variability in the Mechanical Properties obtained upon Quench & Temper Heat Treatment. The article aims to provide a framework through which they can achieve desired properties repeatedly.

II. MATERIAL BEHAVIOUR

Boron Steel enhances the hardenability of the Steel grade by retarding the heterogeneous nucleation of ferrite at the austenite grain surfaces. This effect is due to the reduction in interfacial energy as the boron segregates to the grain boundaries. This in turn makes grain boundary less effective as heterogeneous sites.

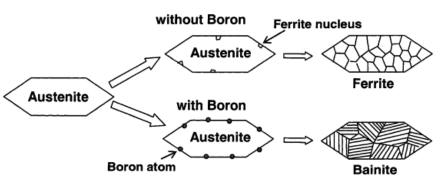

Fig.1 Behavior of austenite matrix with and without Boron

However when Boron is excessive, its retarding effect is decreased due to coagulation (or precipitation). So the segregated Boron is effective, but coagulated or precipitated Boron is ***ineffective.***

Moreover, excessive of Boron are not recommended because of the possibility of Boride and Carboboride formation and the effect of these compounds on Mechanical properties [1].

This therefore requires an optimization framework within the boundaries of which repeatable results can be obtained.

This requires a two pronged approach towards ensuring checks at Steel Maker end and checks while doing its Quench & Tempering of Normalized Forging.

III. INFLUENCE OF STEEL MAKING PRACTICE

Boron reacts with oxygen to form boron oxide (B_2O_3); with carbon to form iron borocementite ($Fe_3(CB)$) and iron borocarbide ($Fe_{23}(CB)_6$); and with nitrogen to form boron nitride (BN). Loss of boron by oxygen is prevented by making the boron addition to killed steels and by using good ladle and mold practices. Strong nitride formers (titanium, aluminum, zirconium) protect the boron from reaction with nitrogen. For example, if nitrogen is fixed by using titanium, satisfactory hardenability is obtained in the temperature range up to 1830°F (1000°C) provided that the steel contains about 5-20 ppm of boron [2-3]

To ensure the effectiveness of Boron in steel, the following factors needs to be considered –

1. Effectiveness increases with the amounts (within limits) of Mn, Cr, Mo and decreases with the increase in Carbon content. Its effectiveness is practically nil in steels of eutectoid carbon content.

2. Magnitude of the effect of Boron on the hardenablity seems to also depend upon the form in which the Boron exists in austenite and not solely upon the total amount present.

3. The presence of either high soluble Nitrogen or Oxygen is detrimental to the Boron effect.

IV. SOLUTION APPROACH

To ensure consistency in the Temper Hardness and the Final Properties of the Boron Steel Forging the action plan needs to be two pronged. One Part of it is related to the adoption of set parameters at Steel Makers end. The other part is the selection of Tempering Temperature at Manufacturer end for ensuring Specifications as per customer requirement.

A. Parameter control at Steel Maker end

1. The Titanium to Nitrogen ratio in the raw material is a very critical factor determining the hardenability. This factor monitoring helps to avoid the problem of "Ineffective Boron". (i.e. Boron fails to satisfy its primary purpose of inducing hardenability property). When Specifying Boron steel, we must put in an additional checking of ensuring that the Ti: Ni Ratio is greater than 4:1. These both are in trace amounts [4].
2. It is observed that the Hardenability peak is reached when the quantity of Boron is between 3 and 15 ppm. In case the quantity exceeds 30 ppm, the Boron constituents becomes segregated in the austenitic grain boundaries, which not only lowers hardenability, but also decreases toughness, cause embrittlement and produce hot shortness. The steel manufacturer must be asked to maintain it in the target range of 5-15 ppm only. The reason for this is to ensure an increasing behaviour across the range. It helps with the adoption of process parameter at Manufacturer end (explained later)
3. Since Boron has strong affinity to Oxygen and Nitrogen, these elements must be either removed or controlled for Boron to have its full effect. Boron must be added in presence of Titanium and Zircon to prevent reaction with Nitrogen. To prevent reaction with Oxygen it must be added in presence of Aluminium only.

B. Process Selection at Manufacturer end

The empirical fomula for the Ideal Diameter (DI) calculation is :

$$DI = DI\ Jominy \times fMn \times fSi \times fNi \times fCr \times fMo \qquad (1)$$

The numeric values of the functions in the above formula are dependent on the chemistry of the material. This formula has been of great help to Heat Treatment Line Managers in selecting parameters for Alloy Steels. However, there is no formula including this which can help calculate the Ideal Diameter of Boron Steel Material.

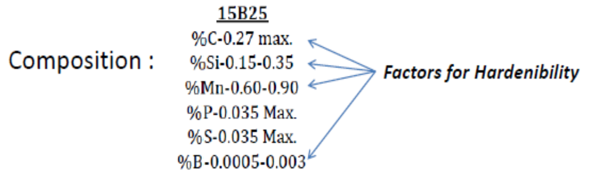

Fig 2. Boron Steel Grade 15B25 and factors affecting Hardenability

As boron steel doesn't showcase a direct linear correlation to Hardenability with its addition, therefore it is important that we divide it into grids where linearity in ensured going downwards or rightwards. The Ideal Diameter has to be equally divided into 3 groups as per the Maximum and Minimum allowable composition for the steel grade.

First Ideal Diameter of the Boron steel grade is calculated as per the empirical formula mentioned. Note that at this step, Boron Composition is completely neglected. In the next step we try to establish the grid as per Boron Composition of particular lot of Steel and the Ideal Diameter Value.

Boron Range →

	5-10 ppm	10-15 ppm
Di Range ↓	Grid A	Grid D
	Grid B	Grid E
	Grid C	Grid F

Table1. Establishing the grid as per chemistry and Di calculation

Now for each of the Grid the manufacturer will develop its regression analysis of Tempering Temperature applied versus Hardness Obtained. This way, a generic equation will be fixed for all the 6 grid of possibilities. These databases of all the grids will make sure that the manufacturer can select the Process parameter to maintain the desired Hardness level in the Engineering Component.

V. CONCLUSION

The entire solution approach framework will help the Manufacturers to discuss Controls required at Steel Maker's end. Ensuring these controls, the Manufacturer will prepare the database for the Grids for Boron Steel Grade that is being used at its end. With a simple spectroscopic check, the parameters can be selected from the developed database to ensure that the customer parameters are satisfied.

REFERENCES

[1] Hayrettin Düzcükoğlu and Selman Çetintürk, "Effect of boron addition on Mechanical Properties of 60SiCr7 Steel," International Journals of Materials, Mechanics and Manufacturing, Vol 3, pp. 117-120, May 2015.

[2] Hande Güler, Rukiye Ertan, Reºat Özcan," Effect of heat treatment on the Microstructure and Mechanical Properties of 30MnB5 Boron Steel, Materials and Technology 48, pp. 971-976, 2014.

[3] M. El. Shnnawy, A.I.Farrahat, M.I.Masoud, I.Ibdel Aziz, "Heat treatment effect on Microalloyed low carbon steel with different boron content, " International Journal of Mechanical Engineering , Vol 5, Issue 4, pp. 9-20, June 2016.

[4] T Kasuya and N. Yurioka, "Carbon equivalent and multiplying factor of steel," Welding research supplement , pp. 263-268, June 1993.