ROLE OF MN ATOMS ON TENSILE PROPERTIES OF LIGHT WEIGHT CHQ STEEL

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ABSTRACT

Alloying elements always play a crucial role in any steel grade to change the mechanical properties and each element plays his role. The present work has been performed to reveal the role of Mn atoms on tensile properties of experimental steel. Two steels were chosen A and B, in steel A no Mn was present but in steel B Mn was present. Both steels were heat treated at 850°C and 1175°C for 1hr holding time and then microstructure was taken and grain size distribution was calculated using matrox inspector and the results were plotted by using origin data software. The mean grain size of steel A at 850°C indicates the 13.10µm and that of the steel B is 33.10µm. Similarly the mean grain size at 1175°C for steel A is 9.02µm and 18.50µm for steel B. The mean grain size in steel A decreases from 13.10µm to 9.02µm at 850°C and mean grain size at 1175°C decreases to 33.10µm to 18.50µm. Tensile testing was performed to see the effect of Mn particles on tensile properties and it was observed that the strength ratio increases in the steel B in which Mn is present but on the other side steel A in which Mn is absent does not show such behavior. The presence of Mn atoms at the grain interface was confirmed by line scanning in the SEM and line scanning shows the peak of Mn present at the interface of two grains.

KEYWORDS: *Mn atoms, grain growth, tensile properties, strength*

INTRODUCTION

Cold heading quality (CHQ) steels are supposed to be non-heat treated so the strength in these steels are achieved by cold heading operations such as rolling, forging, blanking etc. Due to its non-heat treatable qualities they become cost effective as well as mass production makes it more cost effective steels amongst other grades of the same series. Due to cold heading operations they become good surface finish and isotropic properties. The small components such as pinions, rods, nails, bolts, nuts and screws are often made from CHQ steels. Because of the non-heat treating, their mechanical properties are directly controlled by adding the allying elements and chemical composition. Manganese and silicon chemically present plays a major role to control the strength and elongation. Mn increases hardness and tensile properties because Mn atoms chemically gather around the grain boundaries and may partition the grain interface. When these steels are subjected to metal working such as rolling, forging and hot deformation, these manganese atoms at the grain interface restrict and retard the dislocation to move further, consequently grains become smaller and strength of these steels increase at some rate. The present work based on the practical experiment to observe the role of Mn on the mechanical behavior of the CHQ steels. Diny, worked on TWIP steel's tensile and deformation response as well as microstructural features of that steel **(**Dinia *et al.*, 2010) and they found that addition of Mn achieve high strength-hardness. Gibbs (2011) research work on stability of gamma formation and its influence upon tensile properties of that steel which was Mn-Enriched-gamma TIP, transformation-induced Plasticity of Steel. Jeong et al. (2017), Yun-boXu (2017), Z.Z. Zhao (2017), Wei Wu (2018), Christian Haase (2017) austenitic stain less steels, alloys of aluminum and nickel based super alloys are often used in oil and LNG for transportation and storage of these petroleum products, but due to their high cost their use is only in unavoidable cost effective high-Mn cold heading quality CHQ steels they show high toughness and ductility (Wang *et al.*, 2017; Yu *et al.*, 2017; Chi *et al.*, 2012; Sohn *et al.*, 2015; Kin *et al.*, 2014; Fu *et al.*, 2005). Mostly researchers around the world have given high attention on effect of Mn along with other alloying elements (Marquardt et al., 2002). A wide range of literature survey indicates that none of so far has studied this behavior on CHQ steels as well as effect of Mn atoms themselves along the grain interface and their effect on grain growth and tensile properties. A detailed study work has been performed in

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this research work to investigate the active role of Mn atoms on tensile-properties of CHQ steels.

MATERIALS AND EXPERIMENTAL PROCESS

The chemical composition of the investigated steels used in this experimental work has the following chemical composition in wt% has been indicated in Table.1

Steel A and B has the almost same chemical composition the only difference in both the steel is Manganese and Nitrogen, Steel A has no Mn and Steel B has manganese percentage but the lower amount of nitrogen as well with respect to steel A. The as rolled microstructure was taken by applying common metallurgical steps of grinding and polishing and the etchant was used to reveal the prior austenite grain boundaries was the classical combination of 20gm of picric acid, 11gm of Benzene sulfuric acid, 1.0gm of Iron chloride and 1.5gm of oxalic acid, all the composition was diluted in 500 ml of distilled water mixed in magnetic stirrer. The etchant was slightly heated to 40°C to make it effective and it can easily attack on the prior austenite grain boundaries to make them visible. The as rolled microstructure was firstly taken on the metallurgical microscope to make sure that the grain boundaries are revealed successfully then the microstructural pictures were taken by using scanning electron microscope; microstructure is shown in the Fig. 1. The both the steels were then heat treated at 850°C and 1175°C with holding time of 1 hour for both the steels as shown in Fig. 2 and 3.

Steel	C	Mn	Ni	Mo	Ti	B	N2	Si
A	0.196	--	0.25	0.104	0.019	0.0024	0.0079	0.253
B	0.196	1.04	0.25	0.1.4	0.019	0.0024	0.0068	0.253

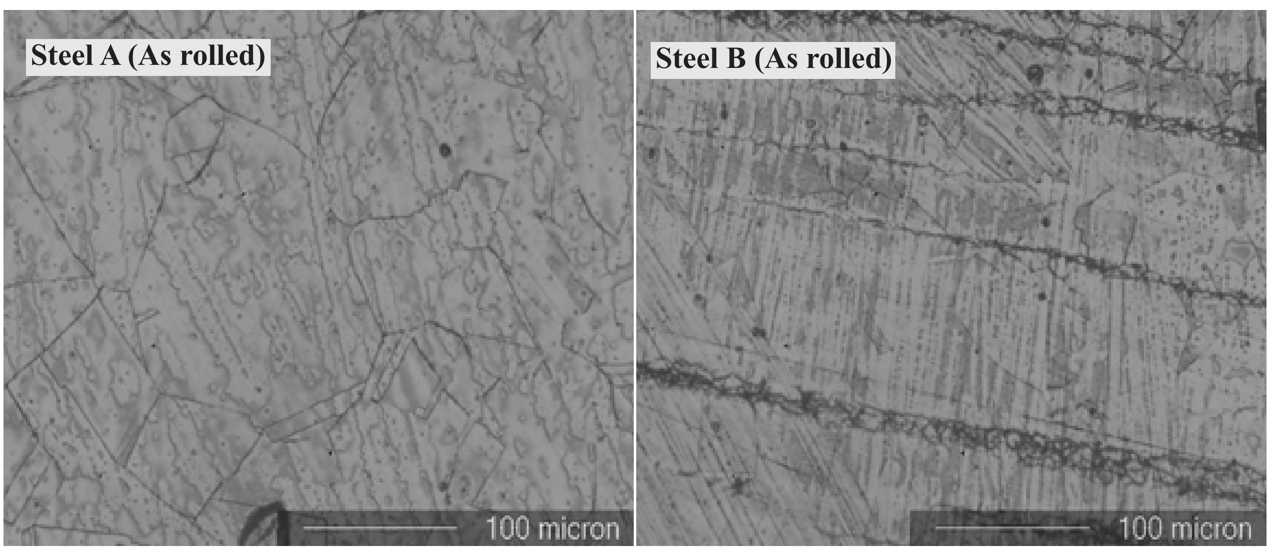


Fig. 1: as rolled microstructure of steel A and steel B

As shown by the micrographs the steel A without manganese present as a chemical element, the grain size of that steel is higher than steel B having Mn. At 850°C in steel A, mean grain size is about 13.10 **µ**m and that of 9.20**µ**m in steel B at the same temperature. Same is the case at higher temperature of 1175°C. The only difference is the Mn addition can stop the grain growth thus reducing the mean grain size but it is worth to observe that at 1175°C mean grain size is reduced for both the steels as has been indicated in Fig. 2A and 2B. It is due to the solubility of manganese atoms increases at higher temperature thus they lose their hindering force to stop the mobility of grain boundary thus grain size increases. The presence of manganese atoms along the

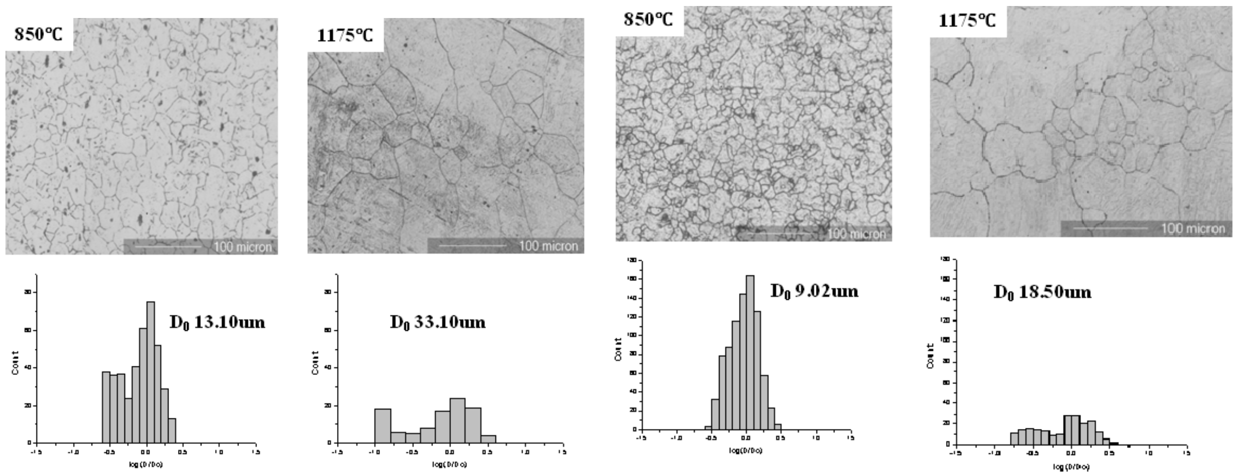
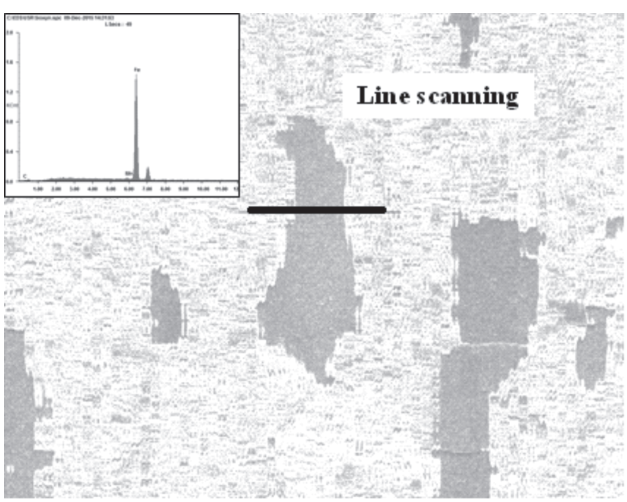


Fig. 2A: microstructure of steel having without Mn. Fig. 2B: microstructure of steel with Mn present.

grain interface however was confirmed by electron back scattered data EBSD by using the SEM line scanning method across the ferrite and pearlite interface as shown in Fig. 3A. The grain coarsening temperature GCT of both under observed steels was also plotted as shown in Fig. 3B.

Fig. 3A EBSD with line scanning by SEM across the grain interface. Fig. 3B shows the grain coarsening temperature as a result of Mn atoms present at the interface.

The Mn atoms segregate at the partitioning of two phases like ferrite/austenite grain boundary interfaces is



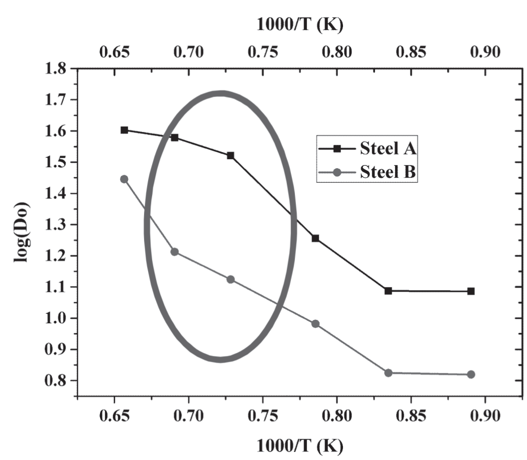


Fig. 3A: EBSD with line scanning by SEM across the grain interface. Fig. 3B: grain coarsening temperature as a result of Mn atoms present at the interface

supposed to be a reasonable approach for investigating the influence of Mn segregated atoms upon the phase modification response in steels, it is also observed that Mn,

As a chemical element influence the transformation behavior like boron, by decreasing the grain boundary energy of austenite. Thus mobility of grains boundary is restricted when a segregated monolayer of Mn atoms dispersed at the interface and this is the main reason for reducing the mean grain size of the steel and steel becomes strengthened. The driving force behind this grain growth is the

The depletion in grain boundary's size & area as well as the free energy stored in a grain boundary is the major driving potency for grain's growth. However, the segregation of Mn atoms present at grain interface suddenly changes this grain growth regime gradually. Grain growth activity of the grain boundary is retarded at low temperature ranges; however as the temperature rise at the abrupt grain growth will occur which is termed as GCT as has been indicated in Fig. 3B, in which an unexpected and spontaneous growth arise with the existing grains. This irregular and unusual grain growth occurs in a combination of fine, very fine along with broad and very coarse grained microstructure, as has been observed in the microstructure of steel B at 850°C and 1175°C arrow indicates the abnormal grain growth. The samples for making tensile test were made from both the steels A and B in as rolled condition samples were made by using the ASTM E8 standard method. The result of tensile test is shown in Fig. 4.

The tensile curves as shown for both steels A and B at 850°C for holding time of 1hour indicates that at lower temperature steel A without Mn obtain the strain about 0.13 at stress about 1200MPA and that of steel B is 0.25 strain at stress about 10^3MPA. Surprisingly the case is quite different for steel B which has Mn addition in its chemical composition, at 1175°C steel A strain rate decreases to 0.13 at a stress of 1500MPa and for steel B elongation increases and reaches to 0.3 at 1stress of 1200 MPa. It indicates that at elevated temperature of 1175°C Mn atom's partitioning at grain interface of ferrite and pearlite becomes weaker due to increasing the solubility and resistance of the Mn atoms lost their dragging force consequently steel shows more elongation. To validate this effect hardness testing was performed as shown in Fig. 5. Steel A has HRC value lower than steel B, in which Mn was present. It indicates that hardness and strength is higher in steel B.

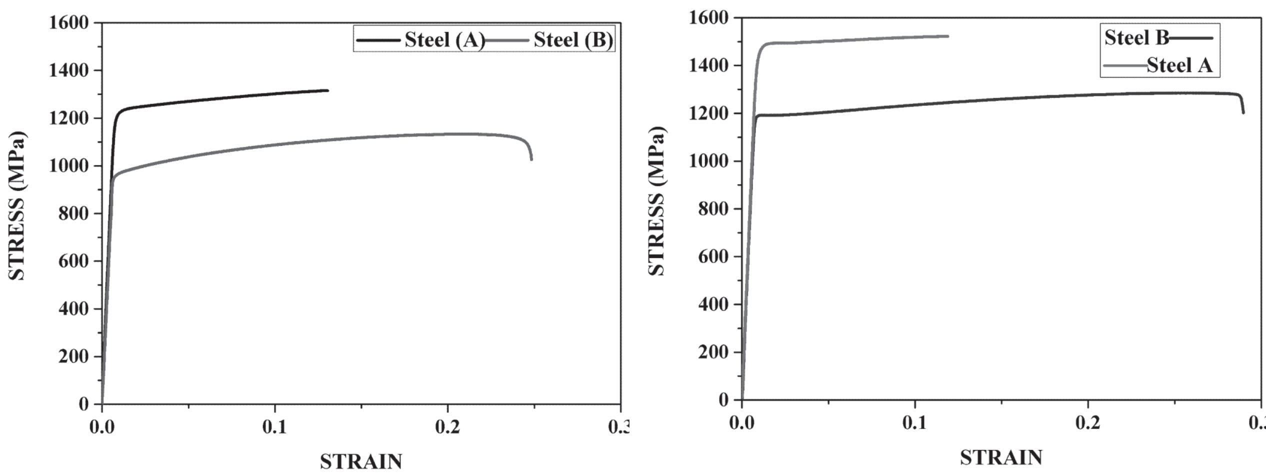


Fig. 4: stress and strain behavior of steel A and steel B

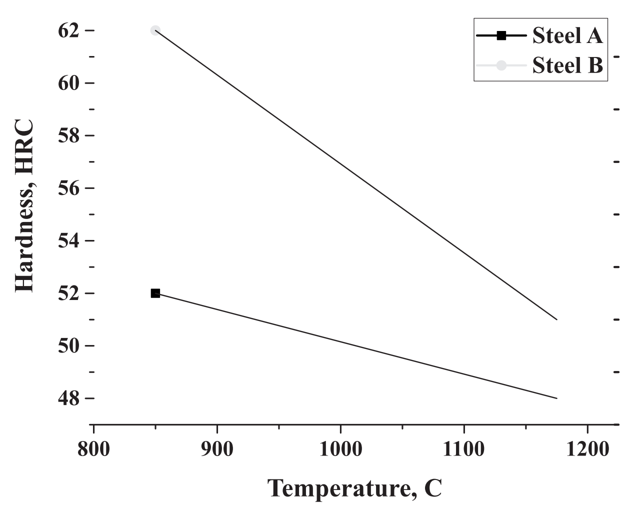


Fig. 5: hardness curves for steel A and B indicates the variation in HRC values

CONCLUSION

The effect of Mn addition in the chemical composition of cold heading quality steel was investigated, micro-structure and grain size was taken after heat treatment at 850°C and 1175°C respectively and the mean grain size was plotted by using the origin software the mean grain size of steel A at 850°C indicates the 13.10**µ**m and that of the steel B is 33.10**µ**m. Similarly the mean grain size at 1175°C for steel A is 9.02**µ**m and 18.50**µ**m for steel B. The mean grain size in steel A decreases from 13.10**µ**m to 9.02**µ**m at 850°C and mean grain size at 1175C decreases to 33.10**µ**m to 18.50**µ**m. Tensile testing was performed to see the effect of Mn particles on tensile properties and it was observed that the strength ratio increases in the steel B in which Mn is present but on the other side steel A in which Mn is absent does not show such behavior. The presence of Mn atoms at the grain interface was confirmed by using line scanning in the SEM and line scanning shows the peak of Mn present at the interface of two grains. It is therefore concluded that Mn particles have great influence on the grain size by decreasing grain size ration and therefore strength can be increased.

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