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Nano particles effect on transformation behavior as a function of heat treatment of commercial steel used for automobile parts

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Abstract

A scientific study has been performed in this research work based on experimental results and ramification to divulge the advancement of second phase particles and their influence on ferrite and austenite phase transformation in less carbon-manganese added steel. Two steel grades were used steel A and steel B. Steel A has no aluminum, but steel B has aluminum present. To fade out the already present particles, as received, steel under investigation was solution heat-treated at 1200°C. Then both the steel samples were heat treated at 750°C and 810°C under 15, 20, 35, and 70 sec incubation time in the cyanide added liquid bath furnace. It was rapidly cooled from the elevated temperature at room temperature in ordinary water. The conventional metallography steps were performed to reveal the microstructure. In two etchant solutions, microstructural features were observed by advanced Olympus optical microscope under polarized light by etching. A scanning electron microscope was used to get the critical micrographs. It was concluded that aluminum combined with nitrogen stimulates the fine aluminum nitride (AlN) particles. These particles were the major source to hinder the grain boundary mobility. Consequently, phase transformation was interrupted in aluminum added steel and lowered the critical temperatures. Surprisingly there was no such attitude observed without aluminum added steel.

Keywords: Phase transformation, AlN particles, Austenite, aluminum.

Introduction

Aluminum conventionally is used as a de-oxidant element by steel smelters. Steel decay its oxide layer with aluminum that's usual practice and hits an imperative role [1-5]. Aluminum formed an oxide layer (Al2O, reducinges the oxygen percentages in steel and expediting manufacturing killed steel.[6-9] Aluminum forms aluminum nitride under the atmosphere of nitrogen, having other elements like titanium, vanadium and niobium with different aspects. Researchers working on grain refinement techniques deliberately add aluminum in combination with nitrogen to form the second phase particles, commonly known as aluminum nitride (AlN) particles. They can form during melting and casting [3, 10-12]. They are strong impurity elements that get together around the grain boundaries and provide dragging force to stop the mobility of grain boundary when the steel is reheated or during heat treatment. Consequently, they retard the grain growth and grains remain finer [10, 13-15]. This technique is the cheapest and easy method of grain refinement. Still, during the last decay, there is very little work done to know that AlN particles refine the grain size and delay the formation of austenite and retard the transformation characteristics of gamma below the AC_1 lower critical temperature and above AC_3 critical temperature. No one has given the attention that aluminum nitride particles can be useful for grain refinement technique, but it also affects the austenite formation kinetics limiting the grain boundary movement. [3, 14, 16, 17] these riddle and unrevealed features of AlN particles have been studied in the present research work. [3, 18-23].

Materials and Experimental Procedure

Two steel samples were used in this investigation steel A and steel B. steel A has no aluminum content and steel B has aluminum present in it. The content of nitrogen is also present in both the steels. The chemical composition of both the steels in wt% is shown in table 1.

Table 1.
Chemical composition of both steel A and steel B.

Steel A	0.39 C	0.28 Si	0.76 Mn	0.005 N	-	-
Steel B	0.42 C	0.28 Si	0.77 Mn	0.152 Cr	0.034 Al	0.012N

Steps obtained received material: Solution treatment (two hours at 1200°C) hot rolling (rolling reduction of 80% over a four-pass), Specimens cuts to reduce the size of the sample (reached at 800°C, normalized). For making the easy experimental process, 10x10x10 cm samples from the bulk steel were cut from the steel plate's center in sufficient amounts and quantity. The samples were heat-treated as shown in the cycle below in fig.3: Both the steel samples were heat-treated with 10°C per minute in the lead bath furnace. Four heat treatment temperatures were selected. The first sample was heat-treated at 720°C much below the recrystallization temperature to ensure AlN particles' nucleation was not supposed to appear at 720°C to set a benchmark. Similarly, the second sample was performed at a higher temperature than the first one and it was done at 750°C, approximately near or above the AC_1 line. The third sample was taken to heat at about the steel's inter-critical annealing zone, and this temperature was 770°C. The last sample of the experimental steel was heated in the austenitic domain at 810°C. This series of heat treatment temperatures were used to know the morphology of phase transformation start and phase transformation finish temperatures. This investigation was helpful to know the actual nucleation sites of AlN particles. For all the temperatures mentioned above, the samples were dipped in salt bath furnace for a holding time of 15, 20, 50, and 70 seconds. After the long heat treatment work, the samples were cut from the center perpendicular to the rolling direction to observe the inside's surface microstructures. Heat-treated samples were mounted in a resin solution in the cold mounting state. They were then brought to grinding and then immediately, these samples were

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polished using 0.05 and 0.02 % alumina solution in the soft polishing cloth simultaneously. The classical etchant used for etching purposes is as follows in Table 2. The revealed microstructure is shown in Figure. 1.

Table 2 Etchant used for the development of microstructure.

Etchant A	Etchant B
$Na_2 S_2O_5$ -1.5 g Distilled water -100 ml	Picric acid - 4g Ethanol -100 ml

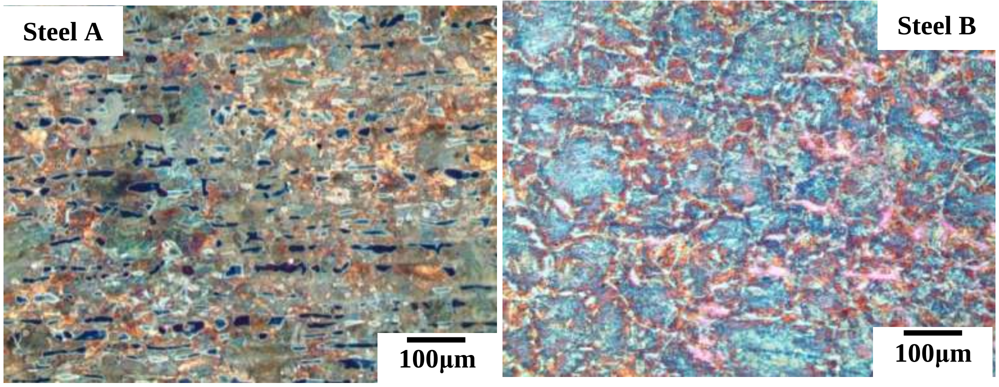

Figure 1: Microstructure of as rolled steel sample A and B exhibit ferritic and pearlitic network.

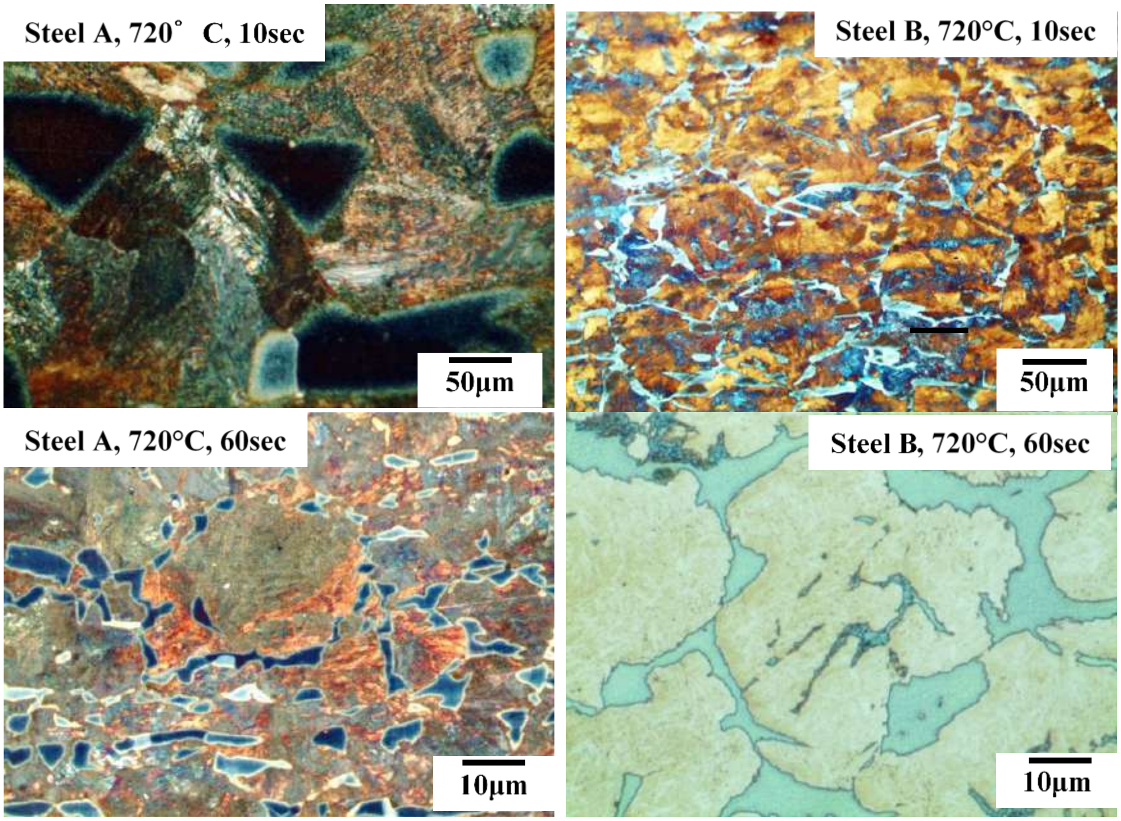

Figure 2: Microstructure of steel A and B after heat treatment at 720°C under 15sec holding rate.

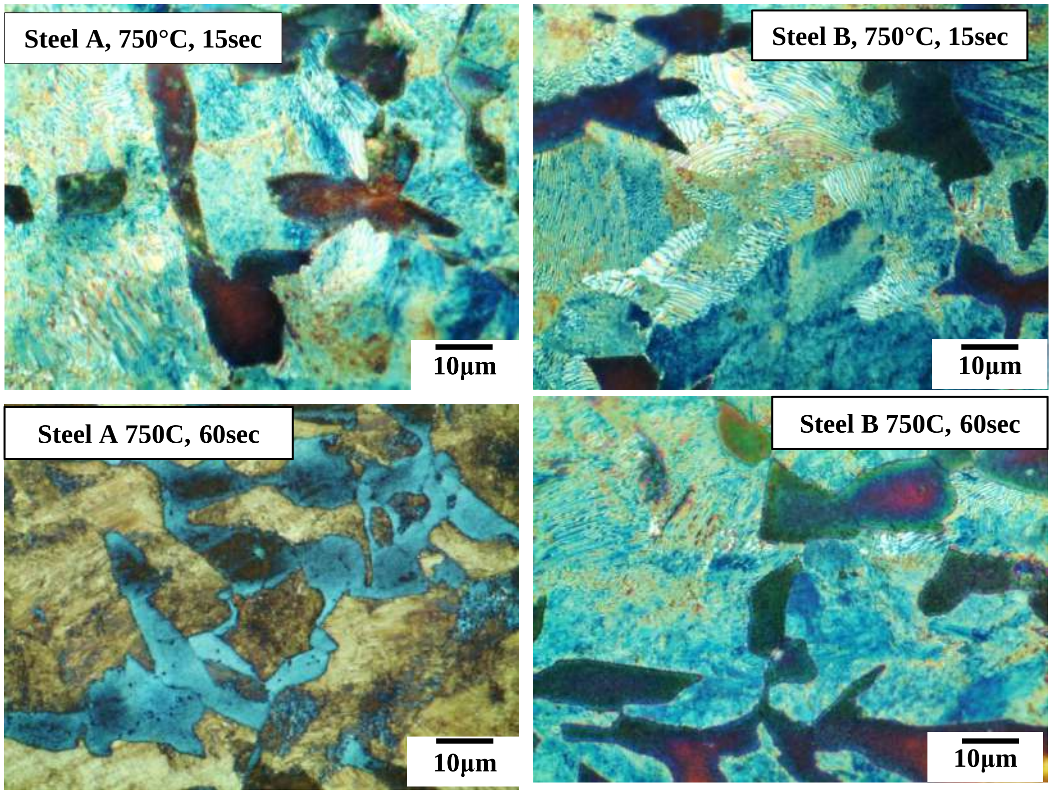

Figure 3: Microstructure at 750°C for 15sec and 70sec showing the austenite has started to transform by consuming pearlite in steel A but in steel B austenite formation is lower than steel A.

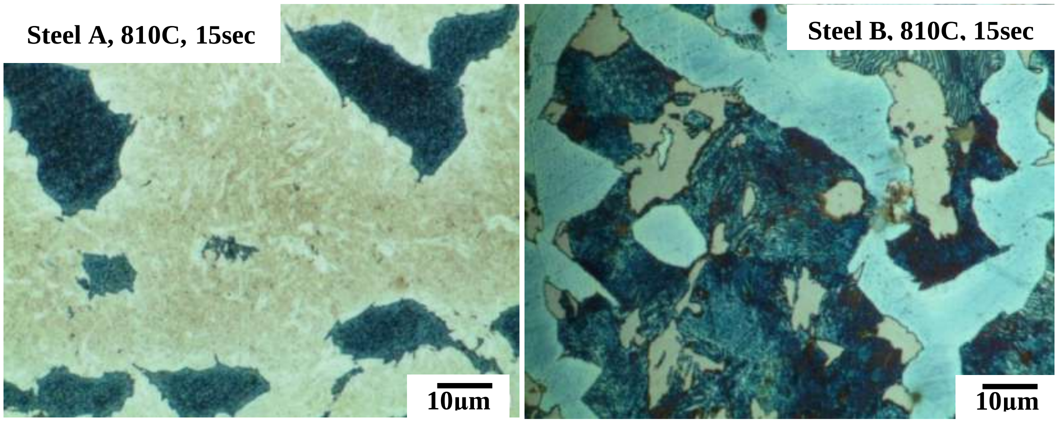

Figure 4: The left side of a picture shows that almost all the pearlite has consumed making austenite, but the ferrite network still exists.

In steel A at 750°C, all the ferrite and pearlite has transformed to martensitic after reaching at 810°C after 70-sec holding.

Results and Discussion

1. Steel A (without nano particles)

The austenite nucleation appears mostly at 750°C in our experimental steel. The holding time plays an essential role in nucleating the new austenite nucleation. A new Austenite grain predominantly nucleates within a pearlitic colony [18-19]. At 750°C, holding time of 15 and 20 sec, there is no change or minor change in microstructure. The Austenite nucleation and growth were observed at the holding time of 35 and 70sec. The nucleation and growth sites are mostly pearlite areas. With increasing time, ferrite packet size increases slightly, but the pearlite phase slowly and gradually decreases to give rise to gamma phase nucleate [20-21]. In the pearlite phase, cementite plates provide a carbon source to nucleate the Austenite. Grain at the ferrite-pearlite interface and also it is a shorter distance to help for Austenite nucleation growth.

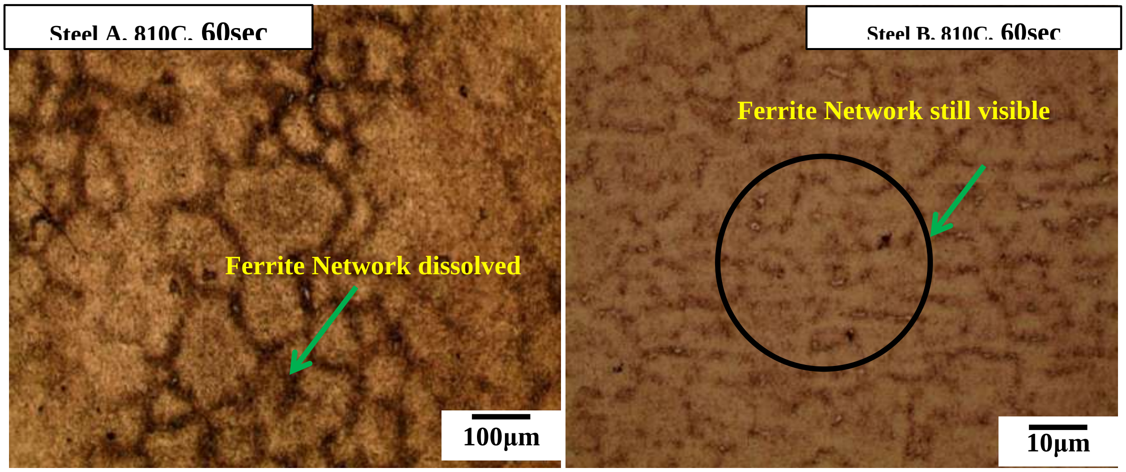

Figure 5: Optical micrographs for both sheets of steel showing the dissolution of ferrite and pearlite.

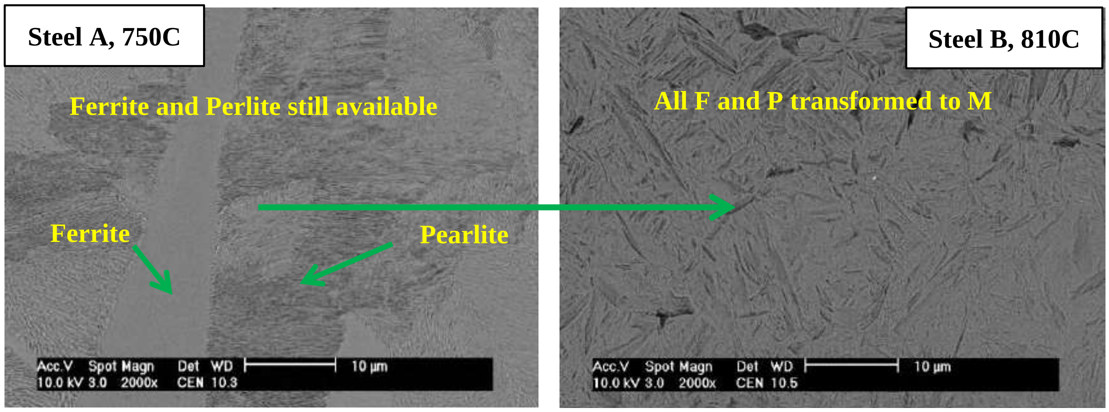

Figure 6: SEM micrographs taken at 750°C as well as 810°C for both the steels A and B.

2. Steel B (with nanoparticles)

A combination of Nital and LePera solution has been applied to observe the microstructural features and it has been concluded that LePera etchant gives good contrast. Widmanstten Ferrite plates grow at an austenitic temperature which is just above T0. Thus, crystal structure change has been achieved by this deformation, and this change is in the form of martensite. In AlN steel, AIN particles pin the prior grain boundaries above the lower critical temp, hence hindering grain growth as resultant grain size is refined [22-23]. In AIN, steel phase transformation is observed to be slow compared to steel. A possible reason is that phase transformation kinetics is partially controlled by substitute diffusion of Cr or Mn. Mn retards the reaction and these elements partition b/w the parent and product phase. The volume fraction of austenite in steel A is higher than AlN ST, so it is strongly believed that AIN refines prior austenite grain size.

Conclusion

These micrographs exhibit the quenching up of heating with distinct holding rates. The microstructure evolution is shown at 810°C. The darker areas evolve into an unceasing network and clone the beginning grain size. The ferritic stage prevails along the darker lines, apparently at the previous region. Austenitic grain grows at the grain boundaries and diffuses into neighboring ferritic interfaces within the pearlite microstructure. Descending from the austenitic region at a higher temp before quenching, the Bainite phase (charcoal region) appeared in the proximity of pearlitic grains. With increasing holding time up to 35sec, the structure homogenizes, and the percentages of ferritic region decrease and completely vanish at a 70sec holding rate. The soaking time and holding temp: has an imperative role in the formation of austenite. The heating rate has a crucial effect on the nucleation of austenite in the ferrite-pearlite colony. Cementite plates are the primary source for carbon diffusion in austenite within pearlite. Austenite growth is higher in pearlite colonies due to shorter diffusion distances. Aluminum addition also has thermodynamic effects. It delays the austenite phase transformation. Thus, it can increase the lower and upper critical temperatures AC_1 & AC_3. It can improve the grain coarsening temperature.

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