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Hardness and Microstructural Behavior of Normalized Steel-Welded Joint under Varying Temperature

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Abstract

The effect of normalizing on a weld joint and heat affected zone of various grades of steel with known composition were estimated. Microexamination of samples was also done on the steel containing 0.22 wt % C to 0.36 weight percent of carbon. after normalizing at 700^{0}C, 800^{0}C and 900^{0}C respectively. From the results, significant microstructural modifications due to heat treatment were noticed. The as- rolled 0.22 %C and 0.24 %C respectively consist of little pearlite regions in ferrite matrix. While the 0.36 %C consist of uniformly distributed pearlite regions (dark) in ferrite matrix (white) especially at austenization temperature of 800^{0}C and 900^{0}C above the upper critical temperature for all the steel grades. While those normalized at 700^{0}C were fine pearlites, with varying amounts of spheroids of ferrite nucleated within the matrix.

Keywords: Normalizing; temperature; welded steel joint

1. Introduction

Most universal engineering materials at present consist of steels [1]. They are mainly joined by welding,

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especially using the arc welding process because it is available, relatively easy to operate and uses consumable electrode. During welding process, the part of the weld immediately under the flame or arc is in the molten condition, the section that has been welded is cooling down from this condition, while the section to be welded is comparatively cold [2, 3].

The challenges noticeable with the welded steel joint are strain behaviour and crack in service. Studies have shown that the heat affected zone give course heterogeneous microstructure and high crack tendency as a result of induced stress over time [4, 5]. Normalising is often seen with steel to provide a uniform and fine-grained structure [5]. The development is used to achieve an expectable structure and a reassurance of the properties of steel's as it relate to mechanical and physical application [6].

In special application after cold working processes such as forging, and casting, the microstructure is frequently unhomogeneous with outsized grains, and impurity components like carbide and most time barite which out rightly impact regressively on the steel's chemical, physical and mechanical properties [7]. In special cases were precision are require and accurate machinability, normalising are needed for reduce pit evolution and fine-grained homogeneous microstructural properties. The behaviour and response of steel during normalising process is also factor to consider. Study by [8] prove that the temperature of a material is often heated to a peak value temperature close to the hardening temperature thereby causing changing in the grain formation from austenitic to ferritic propagation

The occurrence of martensite could propagate internal embrittlement, annealing and normalizing of joints in the metal are widely used in different application especially were stresses occurs [8]. In some application, they should possess high surface hardness, corrosion resistance coupled with toughness in order to satisfy these entire requirements [8, 9]. Hence, steel undergoes heat treatment to improve it structure and to obtain higher specify mechanical properties [9]. The present study, attempt to investigate the effects of normalizing heat treatment on mechanical properties and microstructure of different plain carbon steel weld and to establish the progression of change which has been less reported from literatures.

2. Materials and methods

Two-meter length each of two different grades of low carbon steel and a grade of medium carbon steel rod of known chemical composition were obtained from the Universal Steel Limited, Ikeja Lagos State. The Chemical compositions are as shown in Table 1, 2 and 3 respectively. Three different grades of steel of 10mm diameter were used in this work, to include: 0.22%c steel, 0.24%c steel and 0.36%c steel. Arc welding electrodes E6013. Mild steel electrode. Each grades of steel material, with the grooved sample of 180mm length was processed. Make a groove of 6mm wide and deep into each rod as shown in figure1. The groove was filled with welds, using arc welding with an electrode type E 6013 mild steel of current (100A) and a terminal voltage of 80v. Subsequently the welds joint were exposed to normalizing process as shown in the table 4

The hardness test was carried out for each specimen at the weld joint and the heat affected zones beside the weld joint. This is done to verify the hardness compared to an ordinary weld joint. Each sample was subjected to grinding using hand file to remove both metallic and non-metallic Inclusion to have a flat surface. The surface are further subjected to further grinding using silicon carbide abrasive paper of different mesh sizes ranging from 220, 320, and 400 to 1000 mesh size to have a mirror like surface, using water as a solvent in the removal of the fine particles from each operation, to have a good surface finish. Furthermore, polishing clothe follows the grinding operation to have a better appearance. Etching follows to aid good visibility of the micro structure of each sample. The samples are subjected to micro examination using a metallurgical microscope.

Table 1: Spectrochemical analysis of as received sample 0.22%C

Fe	**C**	**Si**	**Mn**	**S**	**P**	**Cr**	**Ni**
98.3890	0.2210	0.1450	0.6820	0.590	0.390	0.850	0.800
Ni	**Cu**	**Nb**	**Al**	**B**	**W**	**Mo**	**V**
0.800	0.2660	0.0001	0.0340	0.0001	0.0001	0.0001	0.0001

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Table 2: Spectrochemical analysis of as received sample 0.24%C

Fe	**C**	**Si**	**Mn**	**S**	**P**	**Cr**	**Ni**
97.7550	0. 2490	0.2520	0.8640	0.590	0.550	0.2520	0.3600
Nb	**Al**	**B**	**W**	**Mo**	**V**	**Li**	
0.0001	0.0340	0.0001	0.0001	0.0001	0.0001	0.0001	

Table 3: Spectrochemical analysis of as received sample 0.36%C

Fe	**C**	**Si**	**Mn**	**S**	**P**	**Cr**	**Ni**
97.500	0.3680	0.242	0.8380	0.0560	0.0460	0.1780	0.1410
Cu	**Nb**	**Al**	**B**	**W**	**Mo**	**V**	**Ii**
0.3410	0.0001	0.0390	0.0010	0.0001	0.0001	0.0001	0.0001

Table 4: Design process of annealing and normalizing heat treatment formulation

	Normalizing temperatures
1	700^0c, hold for 1 hour
2	800^0c, hold for 1 hour
3	900^0c, holds for 1 hour

3. Results and Discussion

3.1. Normalising effect on microhardness characteristics of various steel grades

Figures 1 to 4 show the variation of the hardness values of welded samples normalized at various temperatures. The results of the normalized process show a general trend of increase in hardness values with increase in carbon content. However, hardness values for normalized samples were observed to be the highest ranging from 42.1 for 0.22 %C to 50.2 HRC for 0.36 %C steel as normalizing temperatures increases from 700^0C to 900^0C. Considerable increases in hardness values were obtained as a result of the fine nature of the microstructure. No doubt the increases carbon infringement contains in the working sample within the weld pool and recrystallization behaviour of the heat affected space could have generated the significant in mechanical performance seen. This is in par with the study undertaken by [5]

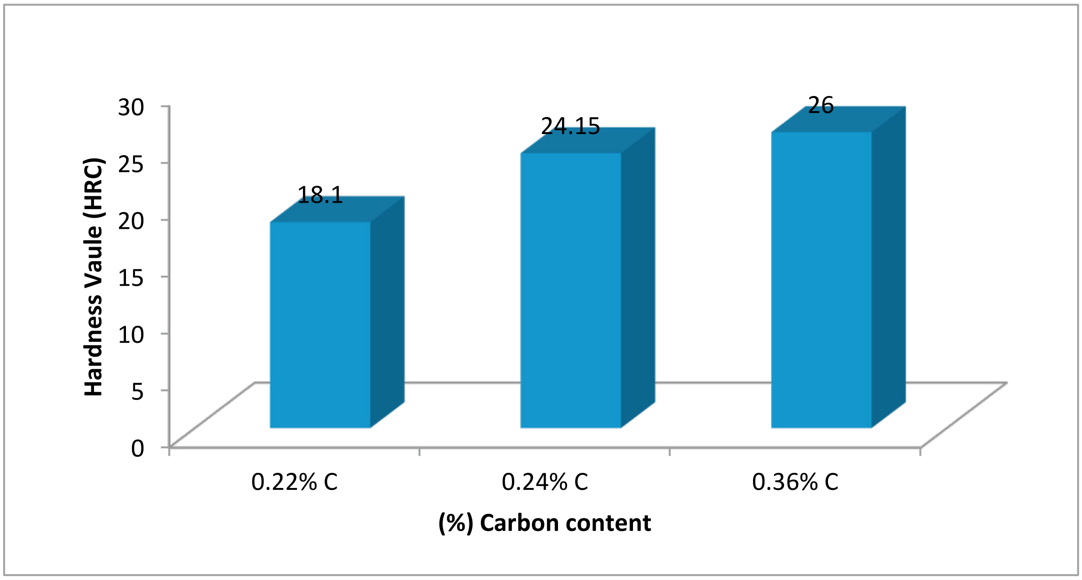

Figure 1: Hardness values for as – received 0.22%C, 0.24%C and 0.36%C steel

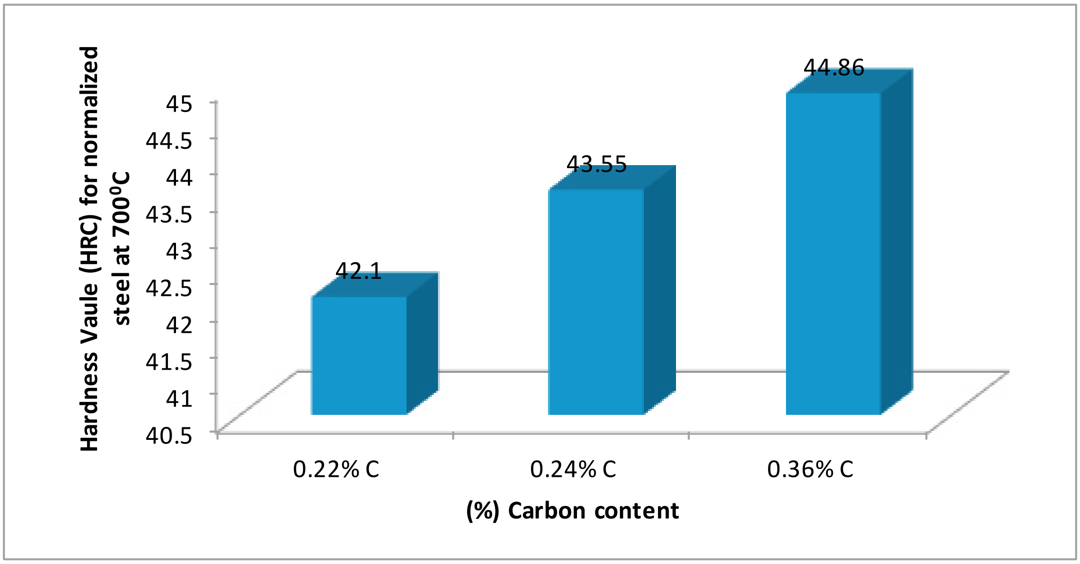

Figure 2: Hardness values for Normalized 0.22%C, 0.24%C and 0.36%C steel samples at 700^{0}C

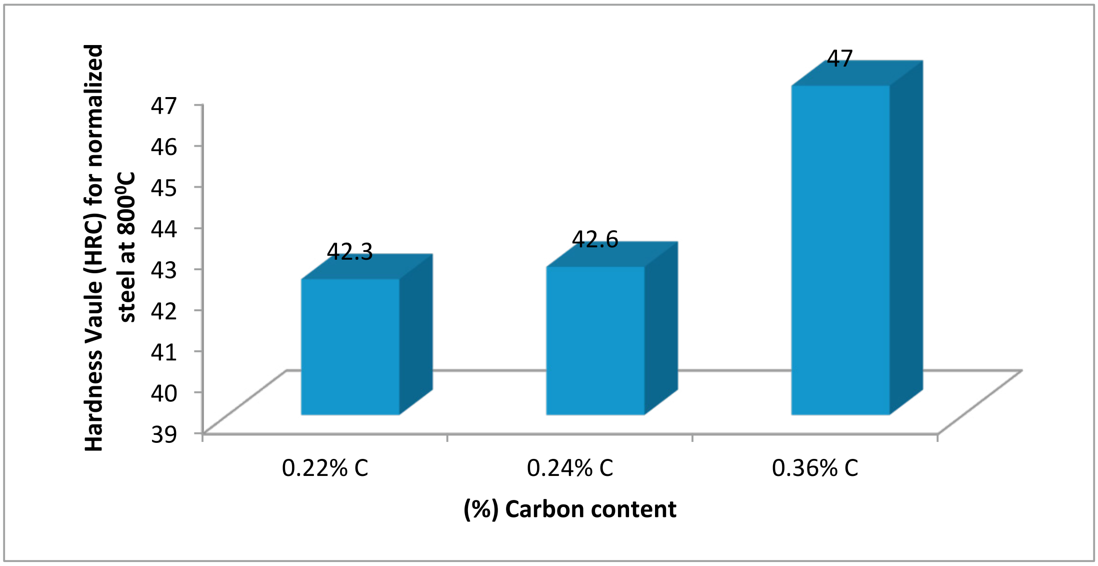

Figure 3: Hardness values for Normalized 0.22%C, 0.24%C and 0.36%C steel samples at 800^{0}C

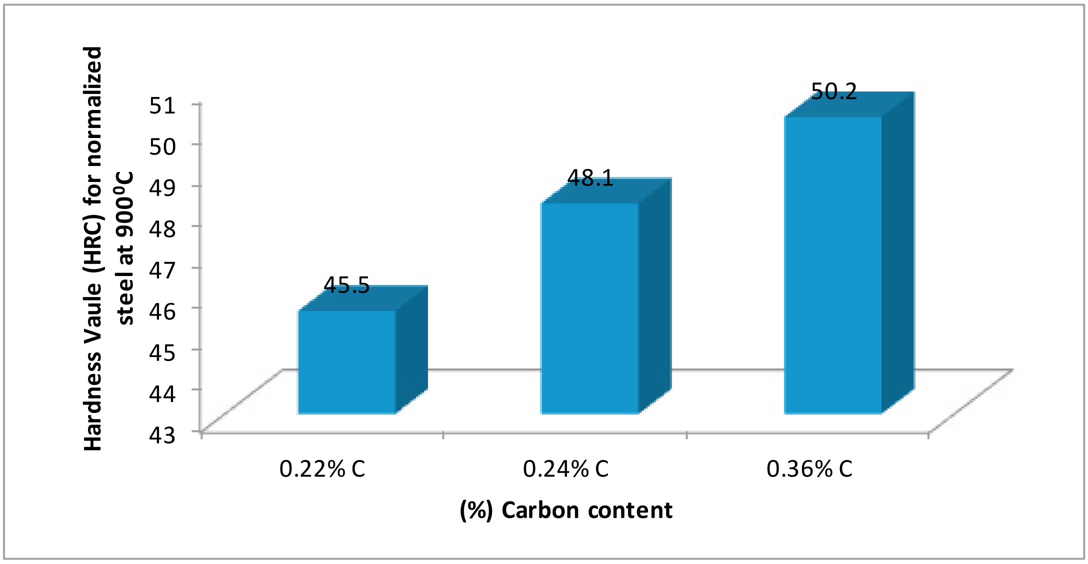

Figure 4: Hardness values for Normalized 0.22%C, 0.24%C and 0.36%C steel samples at 900^0C

3.2. Normalising effect on microstructural properties characteristics of various steel grades

Figure 5-8 shows the microstructural evolution of the heat-treated steel grade with different carbon content. The as-rolled 0.22 %C and 0.24 %C respectively consist of little pearlite regions in ferrite matrix. while the 0.36 %C consist of uniformly distributed pearlite regions (dark) in ferrite matrix (white), which confirms that they were produced by hot rolling. Hence as the carbon content increases, the pearlite regions were observed to increase as well. Another visible observation is the soft structures noticed across the different steel grades.

In all, a fine pearlite structure was obtained for welded sample normalized at austenization temperature of 800^0C and 900^0C above the upper critical temperature for all the steel grades. This leads to a consequential increase in hardness values. This is expected judging from the high carbon equivalent value for hardenability and austenization above the upper critical point as attested by [4]. While those normalized at 700^0C were fine pearlites, with varying amounts of spheroids of ferrite nucleated within the matrix. Heat affected zone, contains evolution of grains with typical martensitic and pearlite phase within the interface. Most area with HAZ contains weaker strength in the weld region with tendency of initial failure occurrence in service under severe stress.

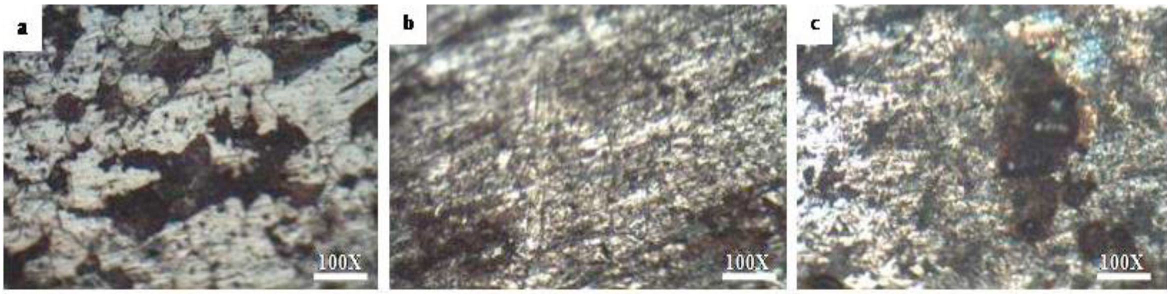

Figure 5: Microstructure of As - received a) 0.22 %C steel b) 0.24 %C steel c) 0.36 %C steel

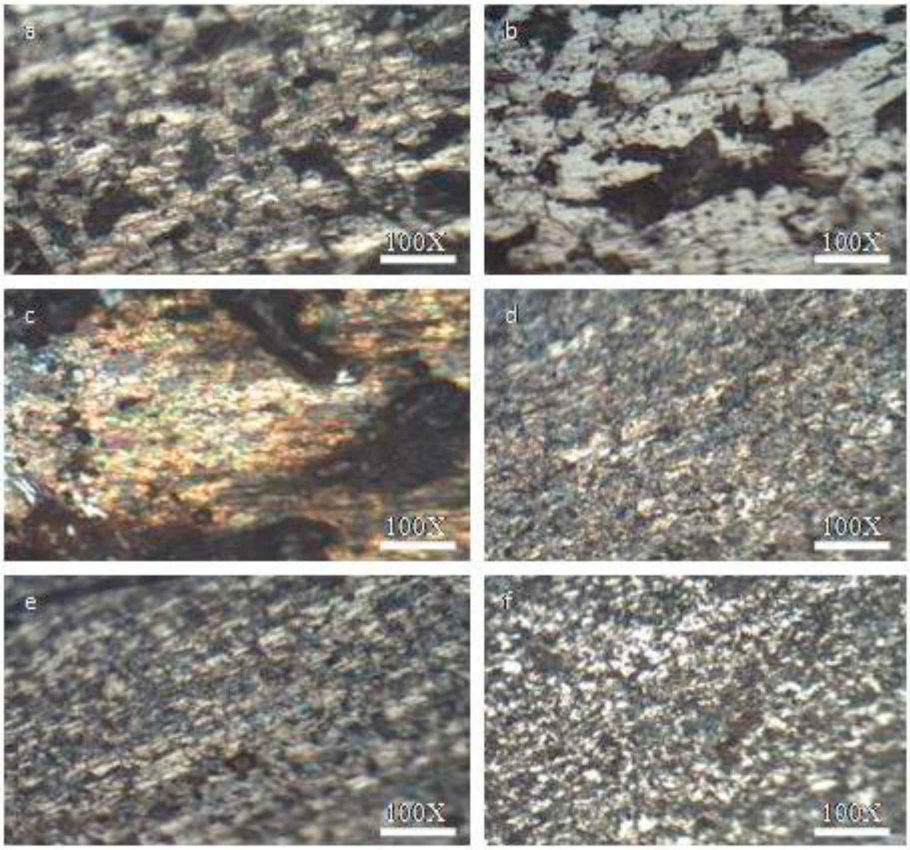

Figure 6: Microstructure of (a) 0.22% C at welds pool normalized at 700^{0}C (b) 0.22% C at the heat affected zone normalized at 700^{0}C (c) 0.24% C at welds pool normalized at 700^{0}C (d) 0.24% C at the heat affected zone normalized at 700^{0}C (e) 0.36% C at welds pool normalized at 700^{0}C (f) 0.36% C at the heat affected zone normalized at 700^{0}C

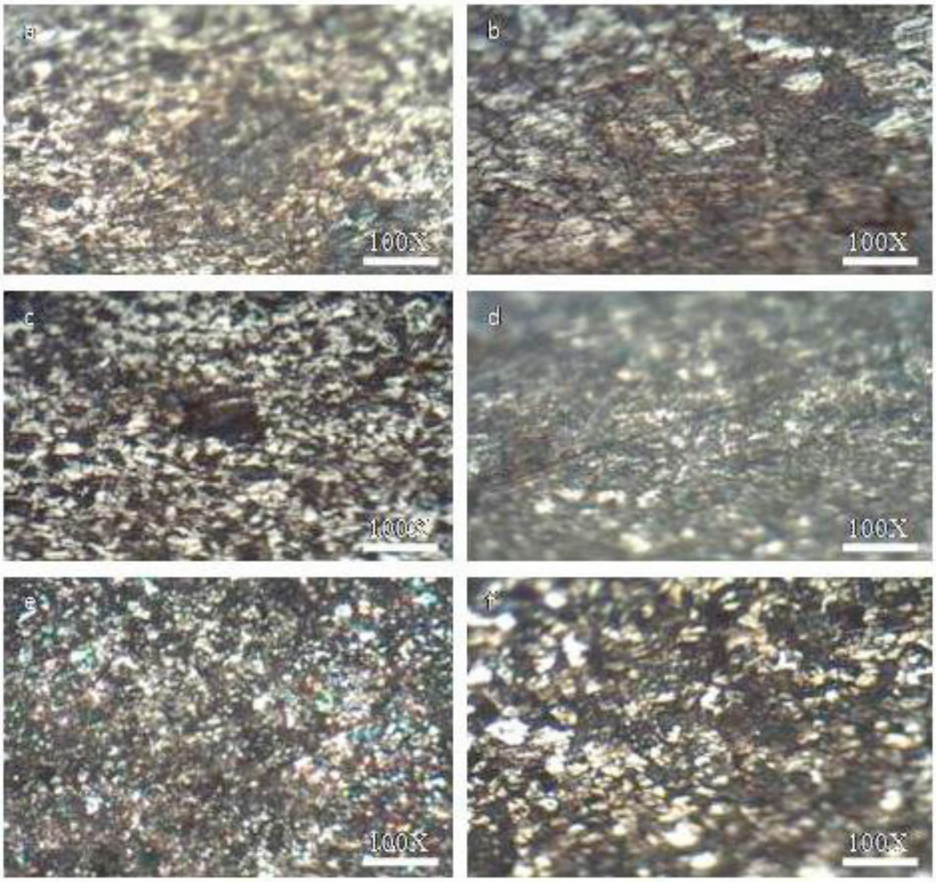

Figure 7: Microstructure of (a) 0.22% C at welds pool normalized at 800^0C (b) 0.22% C at the heat affected zone normalized at 800^0C (c) 0.24% C at welds pool normalized at 800^0C (d) 0.24% C at the heat affected zone normalized at 800^0C (e) 0.36% C at welds pool normalized at 800^0C (f) 0.36% C at the heat affected zone normalized at 800^0C

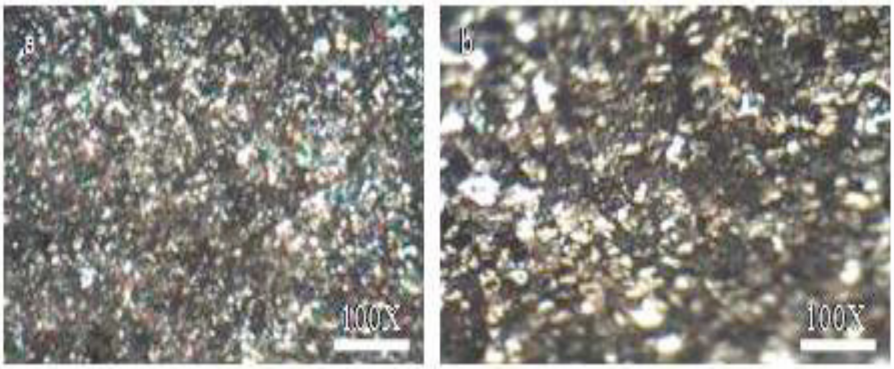

Figure 8: Microstructure of (a) 0.36% C at welds pool normalized at 900^0C (b) 0.36% C at the heat affected zone normalized at 900^0C

Conclusions

In conclusion, the result of the study shows that the hardness values of the specimen varies with the carbon contents of the specimen. Generally, there was increase in hardness values with increase in carbon content. Normalizing significantly affects the microstructure and thus the mechanical properties of the weld. In all, fine pearlite structure for austenization temperatures above the upper critical temperature of 800^0c and 900^0c for all steel grades investigated were seen but a fine pearlite matrix structure with varying amounts of spheroids of ferrite nucleated within the matrix for austenizing temperature of 700^oC in all investigated steel grades were obtained.

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