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Influence Of Carbon Percentage On The Microstructure Of Dual Phase Steel

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***Abstract*— An investigation aimed at determining the importance of Carbon percentage in the microstructure development of Dual Phase steel is carried out by intercritically annealing the different samples of low carbon steels which consists of different percentage of carbon (0.16%, 0.18%, 0.20%). The samples are heated in muffle furnace to above Ac3 temperature (920°C), soaked the sample for 30 min and quenched in Ice brine solution to get complete martensitic structure. Later the samples are inter critically annealed at 740°C, 760°C, 780°C, 800°C, 820°C (between Ac1 and Ac3) for 60 minutes and quenched in oil at room temperature. Microstructure examination revealed that steel containing 0.18% C yields a better microstructure which consists of around 46% Martensite and remaining Ferrite and minute amount of retained Austinite, which is a good combination of Strength and toughness. The uniaxial tensile test results shown that at Specimen containing 0.18%C with 46% Martensite content yielded maximum Tensile strength with comparatively higher toughness Microhardness test shows that hardness increases with increasing in Carbon percentage and has higher values at 0.18%C.**

Keywords*— *Intercritical Annealing; Martensite; Ferrite; Dual phase(DP) steel;ICHT(Intercritical Heat Treatment)

I. Introduction

Dual Phase (DP) steels are part of the Advanced High Strength Steels (AHSS) family, and were developed to increase steel strength and formability with enhanced capacity of energy absorption. The simplest of the DP steel in this category contain 0.08-0.2percent Wt C, 0.5-1.5percent Wt Mn, but steels micro alloyed with vanadium are also suitable, while small additions of Cr (0.5% wt) and Mo (0.2-0.4% Wt) are frequently used. These steels have relatively low yield stress of the order of 300-350 MN / m^2. The path of evolution of DP steel as illustrated by numerous investigators direct towards understanding the role of large number of micro structural variables, which influence their mechanical properties.[3] Volume fraction, amount of retained austenite is some of the micro structural variables. The study on the structural-tensile property co-relations in DP steels has led to explain the relationship between strength and volume fraction of martensite. Attention has been paid to characterize toughness behavior of DP steels in order to produce them for structural applications. There exist several methods to produce DP steels, which yields various types of distribution of ferrite and martensite in the microstructures. There appears an agreement that the strength of DP steel is linearly proportional to the percentage of martensite in the structure, in turn the carbon content of present in the material [2][5].

II. Literature

An increase of the intercritical temperature increases the fraction of austenite formed, which transforms into martensite during rapid cooling, improving hardness and strength. However, there is a balance between two opposite effects: for low martensite fractions, carbon content of this phase is high, while with increasing the fraction, carbon content decreases. This carbon content of martensite controls the hardness of the phase and hence affects the final properties of material. It has been reported that there is a range of martensite fractions (35-50%) in which mechanical properties of DP are optimized, associated to a balance between martensite fraction and hardness of both phases [13][15]. The composition also defines the possibility to obtain the dual structure in different diameters or thickness and technological aspects like weldability [13]. Although it has been generated a large amount of information, there are still discussions about the evolution of mechanical properties of these steels with carbon content.

The aim of this work is to study the influence of the carbon content on the obtained microstructure and mechanical properties of DP from conventional structural steels.

III. Materials and Methods

A. *Materials*

Commercial low carbon steels were selected as the starting material for making dual-phase microstructures by suitable heat treatments. The as-received steels were in the form of 8 mm thick hot-rolled plates in quenched and tempered condition. The chemical composition of the steel was ascertained with the help of a Baird Optical emission spectrometer. The determined Chemical compositions of the steels is as shown in the Table I

Table I

Specimens	C	Mn	S	P	Si	Cr	Mo	V	B	N
A	0.16	1.32	0.002	0.013	0.44	0.03	0.09	0.056	0.0019	0.4
B	0.18	1.4	0.001	0.018	0.30	0.01	0.11	0.035	0.0010	0.6
C	0.20	1.5	0.002	0.015	0.50	0.02	0.02	0.065	0.0018	0.8

B. *Heat Treatment Procedure*

The as received structural steels were then cut into specimens and subjected to double quenching, where they are first heated in Muffle Furnace shown in Fig. 1 and soaked at 920^o for 30 minutes and quenched in 9 percent ice brine solution (7^{o}C) as shown in Fig. 2. Later the specimens were held at different Inter-critical temperatures individually (740^o,760^o,780^o,800^{o}820^{o}C) for 60 minutes and quenched in oil at room temperature. The schematic representation of the above heat treatment process is shown in Fig. 3. The specimens 'A' are named A74, A76, A78, A80, and A82, The specimens 'B' are named B74, B76, B78, B80, and B82, The specimens 'C' are named C74, C76, C78, C80, and C82, for identification.

Fig. 1 Muffle Furnace

Fig. 2 Quenching

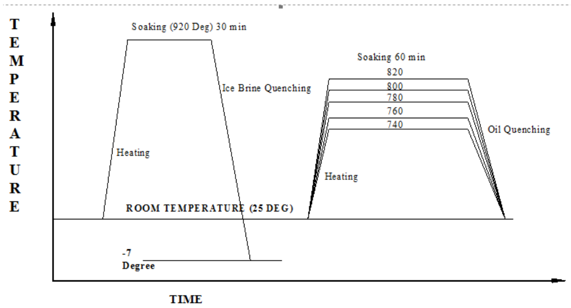

Fig. 3 shows the schematic representation of the Heat Treatment Process carried out

IV. Experimentation

A. *Microstructure Examination*

Metallographic examinations are carried out on the heat treated specimens to know the microstructure. Test samples for metallographic examinations were cut from the heat treated blanks in the transverse direction of the rolled plates using a Buehler isomet 2000 diamond saw in order to avoid any deformation or burning on the surfaces. These were first ground on successively finer silicon carbide abrasive papers, followed by polishing on buehler metlap platen no 8, platen no 4 and on a nylon cloth using 9 micrometer, and 1 micrometer diamond slurry respectively. The final polishing was carried out ontexmet paper cloth using a colloidal suspension (Buehler Masterpolish) at a wheel speed of 140 rpm. The polished test specimens were etched with proper etchants (Nital sodium meta bi sulphide) and subjected to microstructure examination using EPHIPHOT NIKON microscope with 400x magnification. The test results revealed the presence of Ferrite and Martensite Phases in the Microstructure with varying proportions and thus the specimen can now be called as Dual phase steel and are shown in the following Fig.4, Fig. 5 and Fig. 6

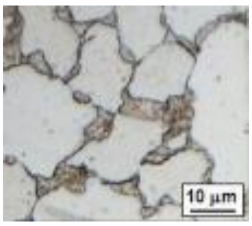

Fig. 4

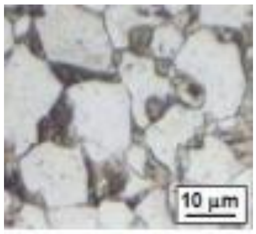

Fig. 5

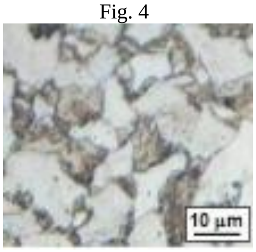

Fig. 6

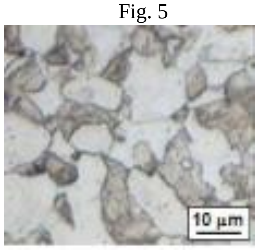

Fig. 7

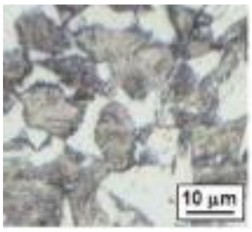

Fig. 8

Fig.4-8 shows the Dual phase microsturctures of the A74,A76,A78,A80,A82 respectively

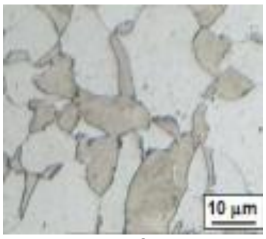

Fig. 9

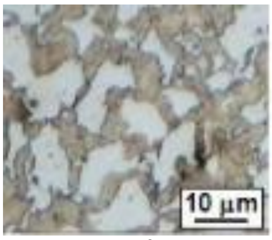

Fig.10

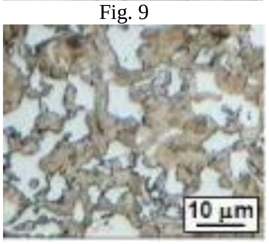

Fig. 11

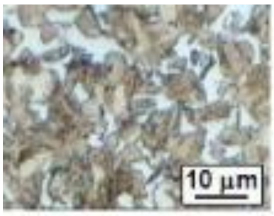

Fig. 12

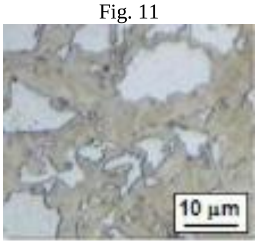

Fig. 13

Fig.9-13 shows the Dual phase microsturctures of the B74,B76,B78,B80,B82 respectively

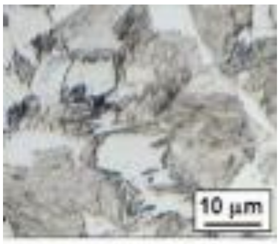

Fig. 14

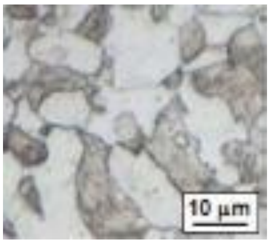

Fig. 15

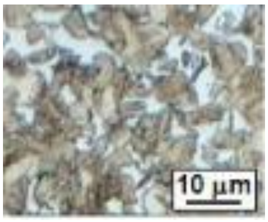

Fig. 16

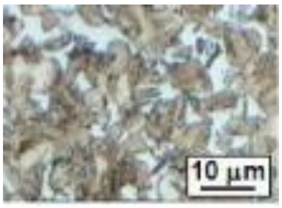

Fig. 17

Fig. 18

Fig.14-18 shows the Dual phase microsturctures of the C74,C76,C78,C80,C82 respectively

In the above microstructures the white field represents Ferrite phase and the dark field represents the Martensite phase.In all cases it was observed a dual structure consisting of equiaxial grains of ferrite and martensite islands. Martensite increased with increasing temperature ICHT, associated to a higher austenite fraction formed. Also, it is worth to note that B78, B80, C78 and C80 steel presented smaller grain sizes than the rest of the specimens. .

B. Volume Fraction Determination

To determine the volume fraction of the phases involved, by a systematic manual method, in which point-counting technique was employed by following the ASTM standard E562 and there by estimating the volume fraction of an identifiable constituent of phase from sections through the microstructure. TABLE II and Fig. 19 shows the variation of Martensite volume percentage with respect to the increase in the Intercritical Temperature. From Fig. 19 It can be observed that the Martensite Volume percentage increases with increase in the ICHT where Martensite is a function of Percentage of Carbon present in it.

TABLE II

Specimen code	**Volume percentage**		**Retained austinite (%)**
	Ferrite (%)	**Martensite (%)**	
A74	70	30	2
A76	60	38	2
A78	57	42	1
A80	54	45	1
A82	49	50	1
B74	74	25	1
B76	64	35	1
B78	56	46	-
B80	48	52	-
B82	42	58	-
C74	71	28	1
C76	60	40	-
C78	48	52	-
C80	42	58	-
C82	38	62	-

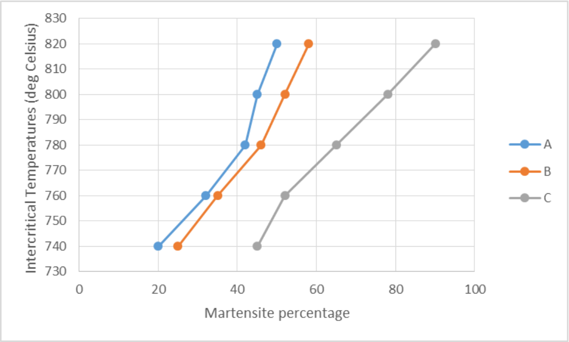

Fig.19 shows the graph of ICT v/s Martensite %

C. *Tensile test*

To determine the Yield strength, Tensile strength, percentage elongation uniaxial tensile tests were carried out according to ASTM standards on all the DP steel specimens prepared by ICHT. The test results are tabulated in the TABLE 3, TABLE 4 and TABLE 5

TABLE III YIELD STRENGTH

Specimen → / ICT ↓	A	B	C
740	658	715	680
760	678	742	712
780	685	790	670
800	690	778	642
820	698	755	590

TABLE IV TENSILE STRENGTH

Specimen → / ICT ↓	A	B	C
740	725	870	970
760	748	930	935
780	770	980	895
800	790	955	850
820	765	940	810

TABLE V PERCENTAGE ELONGATION

Specimen → / ICT ↓	A	B	C
740	15.2	17.3	18.2
760	14.8	20.5	14.7
780	13.8	25.4	12.5
800	12.4	24.1	10.1
820	10.2	22.5	8.7

The Tensile tests yielded the following results

- DP Steels consists of 0.18% carbon has higher Yield strength and Higher Tensile strength which is very much higher than regular low carbon steels.
- Specimen B subjected to ICHT at 780^o i.e. B78 has higher Yield and tensile strength compared to others, this is because of the small grains present in the microstructure and the optimum Martensite volume fraction present in the DP Steel.
- B78 has better combination of ferrite and martensite. It has slightly higher percentage of ferrite which leads to higher ductility and elongation due to this elasticity. The presence of Martensite increases the strength, hence ultimate tensile strength also got increased with increase in carbon content and increase in ICHT. But Increase in martensite volume increases the brittleness of the material which is not desirable.

The behaviours of different DP specimens discussed are consistent with literature reports and can be explained from partition of stresses and strains between both phases, based on the modified law of mixtures (Hance (2005), Kuang et al. (2009)). In all cases it was observed a continuously yield behavior which is characteristic of this kind of dual structures attributable to the presence of high density of free dislocations in ferrite/martensite interfaces, due to austenite/martensite transformation (Sherman et al. (1981), Kumara et al. (2008), Matlock et al. (1979)). Moreover, it was generally observed a high strain hardening, typical of these materials. This aspect is usually evaluated by the stress relationship index.

D. Hardness test

TABLE VI MICROHARDNESS

Specimen → / ICT ↓	A	B	C
740	240	280	270
760	255	293	285
780	270	310	295
800	283	320	310
820	290	332	325

Brinell Hardness test were carried on each of the specimen and above are the results of the test. From it can be observed that hardness value increases with increasing Martensite volume fraction. But at higher hardness material becomes brittle and machining becomes cumbersome. If the material is brittle catastrophic failure may occur and crack propagation will takes place at faster rate.

Clearly this result indicates that DP steel with fine distribution of ferrite and martensite will have high hardness values. Hence we can conclude that B78 has better combination of hardness and ductility with respect to crack propagation.

V. CONCLUSION

DP steels can be obtained from low carbon steels with carbon percentage 0.16 to 0.20 through ICHT technique. The use of ice brine solution and oil for quenching gives finer microstructure comparatively.

The intercritical temperatures also effect the martensite volume fraction. The increase in the intercritical temperature increases the martensite volume fraction, which is inturn dependent on the percentage of carbon present in the material. Carbon content highly influences the development of Martensite phase, and all the mechanical properties mainly tensile strength, yield strength, and Hardness increases with increase in carbon content, percentage elongation decreased with increase in martensite volume, but once the carbon content reaches 0.2% martensite volume fraction is too high that the material become too brittle and leads to catastrophic failure. The best combination of mechanical properties in the analyzed DP steels can be obtained with carbon content 0.18% with ICHT at 780^{o} which consists of 46% Martensite.

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