International Journal of Mechanical Engineering Research.
ISSN 2249-0019 Volume 7, Number 2 (2017), pp. 99-107

http://www.ripublication.com

Effect of Volume Fraction on Impact strength Behaviour and Hardness of Dual Phase Steel

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Abstract

Dual phase steels are an important branch of high strength low alloy steels. These materials have a combination of specific mechanical properties such as high tensile strength, high work hardening rate, good ductility, these favorable properties are related to microstructure of dual phase steel in which soft ferrite network provides good ductility and martensite phase plays the load bearing role. Dual phase steel consists of essentially a dispersion of martensite in ferrite matrix. The objective of this project is to study the impact strength behaviour and hardness based on the presence of martensite in dual phase steel. This study was conducted on six samples of dual phase steel which have different percentage of martensite. A total of 6 specimens were prepared by intercritical annealing process to study the effect of temperature to the formation of martensite. The low carbon steels specimens were heated for 60 minutes in a specified temperature ranging from 720^0C to 850^0C followed by rapid cooling in mega quench oil (grade 42). The energy absorbed, as determined by the subsequent rise of the pendulum, is a measure of impact strength. This measurement is performed through a system named FIT 300EN. The result shows that a specimen with higher percentage of martensite is likely to increase in impact strength obtained. Hardness test for each specimen was conducted to compare its hardness with low carbon steel. The results obtained indicate that the specimen hardness is proportional to the amount of martensite in dual phase steel.

Keywords: Dual phase steel, Impact strength behaviour, Hardness, Intercritical annealing, Martensite

1. INTRODUCTION

Dual-phase Steels, consist of essentially a dispersion of martensite in a ferrite matrix, are produced by intercritically annealing and cooling at such a rate as to give the desired structure [1,2,3]. In general there are no gages or strength limitation on these steels, a higher strength is obtained by having a higher percentage of martensite in the structure [4]. However, these steels are generating the most interest of all the HSS since they offer the highest formability (ductility) and will play a major role in weight reduction at any given strength level. Dual phase steels are of interest to all automobile and truck manufacturers because they offer the potential for fuel economy increases through weight reduction, while maintaining an acceptable Size and cost of the product. Strength of dual phase steels is linearly proportional to the percentage of martensite in the structure [4,5]. The results from a study of a series of Fe-Mn-C alloys [4] that were heat treated in the inter critical alpha plus gama region and then quenched to give structures containing various amounts of martensite, and martensites with different carbon contents. The strength of these dual phase steels appears to be independent of the carbon content of the martensite. The compression test data for the strength differential effect [7]. It appears that the martensite in the dual phase steels only contained about 0.2-0.3%C. From a study of several series of alloys it was concluded that for dual phase steels containing up to about 30% martensite, ductility of the composite is sensitive to the strength and ductility of the matrix [4,8]. In particular the ferrite matrix should be as strong as possible and have a high ductility; unfortunately in general the higher the strength the lower is the ductility. However, in low interstitial content iron, the ductility is essentially independent of the grain size, i.e. strength [8,9]. The intercritical heat treatment should insure a “clean”, low interstitial content ferrite as the interstitial C and/or N atoms will preferentially partition to the austenite regions. The addition of some substitutional solute atoms may be beneficial to the dual phase steel properties since they may increase the strength proportionally more than they decrease the ductility [8]. It has been found that silicon additions do indeed improve the ductility at a given strength level of dual phase steel. On the other hand phosphorous additions which are effective ferrite strengtheners did not improve the strength/ductility combination in dual phase steels; phosphorous in ferrite decreased the ductility faster than it increased the strength. David trezo et al [10], produced Dual-Phase steels by heat treatment in the ferrite austenite phase field followed by quenching so as to transform the austenite to dislocated martensite of high strength and toughness [11-14]. These steels can provide a wide range of strength and ductility combinations by simply altering the temperature of the heat treatment. The strengthening mechanism is determined by the amount and morphology of the second phase, generally consisting of a strong load carry martensite. Martensite can be tough or brittle depending mainly on the carbon content. Any brittleness due to the martensite is mitigated by the presence of the ductile matrix of ferrite which binds the martensite. Thus the mechanical properties are determined by the composite morphology, the martensite volume, carbon content, and by the addition of alloying elements.

B. Mintz [15] on his studies on "The Influence of Martensite on the Strength and Impact Behavior of Steel" [16,17] on low temperature intercritical annealing in to the two phase region at 730^0C has shown this type of heat treatment is ideal for producing simple martensite /ferrite structures . Heating up to inter critically annealing temperature produces small martensite islands and films surrounding the ferrite grains , where as cooling down to the intercritically annealing temperature produces large grains (colonies) of martensite. The lower carbon, low Mn steel was examined to cover the low martensite volume fraction, while the higher C, higher Mn steel was designed to cover the higher martensite volume fractions [15]. Mehmet Erdogan [18] in his studies on "Effect of austenite dispersion on phase transformation in dual phase steel" stated that in addition to martensite, the resulting, microstructures may consist of epitaxial ferrite, pearlite, bainite or retained austenite depending on cooling rates and intercritical annealing temperature used. [19] created microstructure maps which illustrated the transformed products quantitatively as a function of cooling rate for a particular heat treatment temperature. They demonstrated that the total volume fraction of transformed phases was approximately constant for all cooling rates.

2. EXPERIMENTAL WORK

A. *Material Preparation and Heat Treatment*

Common low carbon steel has been selected in this study. The raw material was in the form of 16mm long plates. It was cut into 6 specimens and each specimen is 350X50X16mm. The hardness of the specimens is 131Hv. The chemical composition of low carbon steel is shown is Table 1. The lower (Ac_1) and the upper (Ac_2) intercritical temperature were approximated as 720^0C and 850^0C respectively.

Table 1. Chemical composition of the base Material.

Element	C	Mn	S	P	Si	Cr	Mo	Ni
Wt%	0.183	0.678	0.021	0.022	0.051	0.050	0.020	0.039

6 specimens were selected to study the effect of temperature to the formation of

martensite. Specimens were heated in the furnace at various intercritical temperatures (Table 2) for 60 minutes and quenched in oil bath in order to transform the pearlite to martensite. The first specimen was heated at under the lower intercritical temperature (Ac_1) which is 720^0C and the temperature is increased for the following specimens until the upper intercritical temperature is achieved.

Table 2. Temperature Selected.

Specimen	1	2	3	4	5	6
Temperature ^{o}C	720	750	780	810	830	850

After the intercritical annealing process, all the specimen microstructure will be observed. Before the observation, After cutting operation all the specimens were grounded on surface grinding machine to remove surface roughness. The specimens were grounded further to obtain perfect smooth surface with the help of motor driven emery belt (belt grinder). Intermediate and fine grinding was carried out using emery papers of progressively fine grades. Six grades of abrasives used are No.220 grit, No.320 grit, No.400 grit, No.660 grit, No.800 grit, No.1000 grit papers. The specimen is first grounded with No.220 grit paper, so that scratches are produced roughly at right angles to those scratches initially existing on the specimen. Grinding is then continued with No.320 grit paper until previous scratches were removed. The process is repeated with the No.400 grit, No.600 grit, No.800 grit and No.1000 grit papers. A very small quantity of diamond powder paste (particle size is about 6 microns) of oil soluble is placed on the nylon cloth covered surface of a rotating polishing wheel. Specimen was pressed against the cloth of the rotating wheel with considerable pressure and was moved around the wheel in the direction opposite to the rotation of the wheel, to ensure a more uniform polishing action. Finally to Remove fine scratches existing on the specimen, it is polished with polishing compound with Alumina powder (particle size is about 0.05 microns) is placed on a cloth covered over a rotating wheel. Distilled water is used as lubricant. Before etching, the specimen is thoroughly washed in running water in order to make the grain boundaries visible and then the specimen is etched with 2 % nital. This imports unlike appearances to the metal constituents and thus makes weld bead geometry apparent under the microscope or naked eye. But the application of the 2 % nital reveals the clear appearance of the metal. Optical metallurgical microscope of magnification 2000X is used to take the microstructural photographs at room temperature at 500X.

B. *Charpy Impact Test*

The charpy V-notch impact test is the most common fracture toughness test.. The test is conducted in room temperature on a pendulum type instrumented impact testing machine (model FIT 300 EN), of capacity 0 - 300 Joules. For all the 6 samples Impact energy is recorded. The specimen preparation and conducting of Charpy Impact test as per ASTM E23 is shown in Fig. 1.

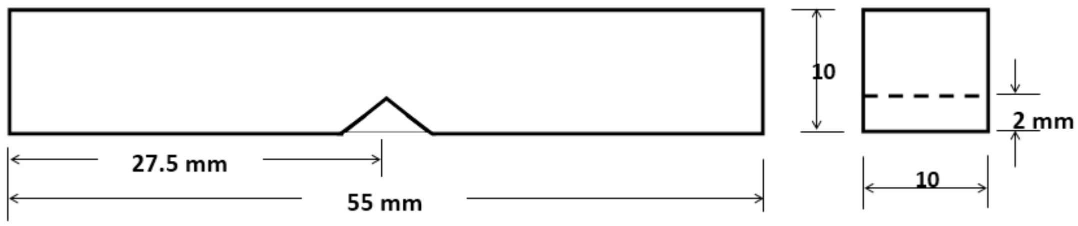


Figure 1: Charpy V – Notch Impact Specimen

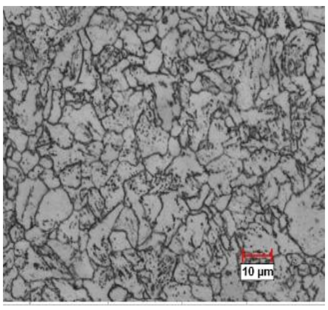
C. *Hardness Test*

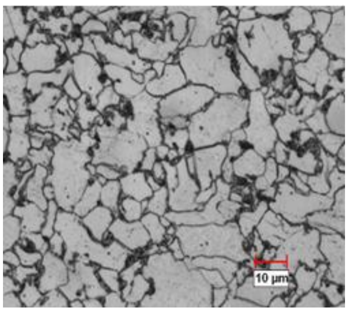
The hardness of the specimens were determined using HWMMT-X7-Micro Vickers hardness tester. The purpose of this test is to make comparison of the hardness properties between the specimens (intercritical annealing temperature between the 720°C to 850°C) with the low carbon steel. The hardness was measure at three different locations of the specimen, and then the average value was taken.

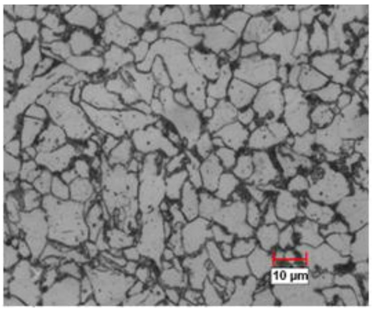
3. RESULTS AND DISCUSSION

A. *Microstructure*

Microstructure of the dual phase steel has been characterized as shown in Fig 2. The magnification of each micrograph is 500x. The micrographs are shown the different of percentage of martensite in every temperature.







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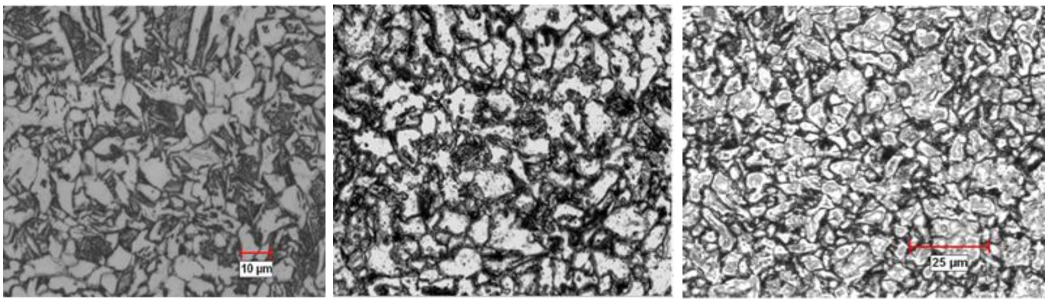

4) 5) 6)

Fig. 2 Microstructure of dual phase steel with different intercritical annealing temperature

The grain size of iron decreases and percentage of carbon increased at the time of inter critical temperature. If the maximum solubility percentage of carbon is explained by the shape and size of interstitial positions which makes it difficult to accommodate the carbon atoms. The carbon significantly influences the mechanical properties of ferriteas shown in specimen1. Martensite transformations occur when the quenching rate is rapid enough to prevent carbon diffusion, the grain size of the ferrite is high (white colour). The large number of atoms experienced and slight displacement of each atom relative to its neighbours. The percentage of carbon and its diffusion rate is very less. The grain size of the ferrite is higher compared to martensite as shown in specimen 2. As the intercritical tempersture increased the grain size of ferrite decreased due to diffusion of carbon. Ferrite regions mixed with the martensite domains having globular or plate morphology are observed in the dual phase steel microstructure as shown in specimen 3. Ferrite regions mixed with the martensite domains having globular or plate morphology are observed in the dual phase steel microstructure. The grain size of the ferrite is decreased because the diffusion rate of carbon is increased. The mechanical properties like hardness & Impact toughness is increased. The needle like structure of martensite is formed after quenching. Due to increase in weight percentage of carbon content, the hardness increases with negligible ductility. After quenching the phase transformation of martensite structure is more when compared to previous microstructures. The tempered martensite formed in sudden cooling at 200 ^{0}C in tempering heat treatment process and as strong as martensite. The microstructure consists of ferrite and martensite as shown in specimens 4-6. Microstructure of dual-phase steel has equiaxed grains.

From the micrographs shown in specimens 1 to 6, the percentages of martensite obtained were between 5 % to 30% of martensite and the percentage increases with increase in temperature. Table 3 shows the details of percentage martensite formation.

Table 3. Volume fraction of Martensite.

Specimens	1	2	3	4	5	6
Temperature (^{o}C)	720	750	780	810	830	850
Volume Fraction of Martensite (%)	~5	~10	~15	~20	~25	~30

B. *Charpy Impact Test*

Charpy Impact test was carried out for six different percentage of martensite. From the Fig 3 shows the Impact energy increases with the intercritical annealing temperature is increases. This is as a result of the martensite alloy formed during the heat treatment processes which is very strong.

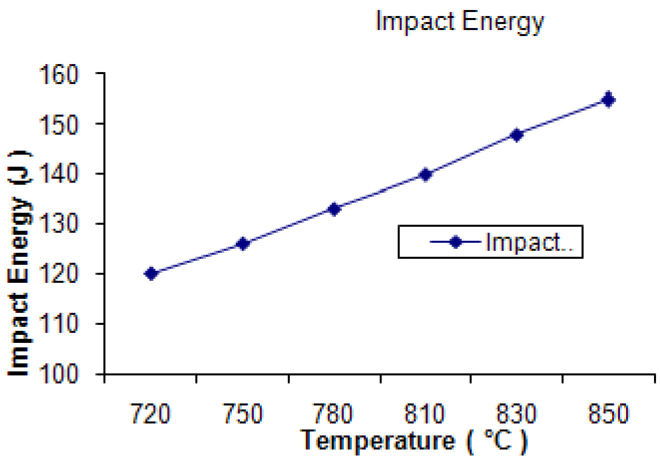

Fig.3 Impact energy versus the Specimen Temperature.

C. *Hardness test*

From the Fig 4, it shows that the hardness of the dual phase steels are increase by increasing the percentage of martensite. The dual phase steel has better hardness properties as it consists of ferrite and martensite structures. Martensite is a metastable iron phase supersaturated in carbon that is the product of a diffusionless transformation of austenite. The hardness in martensite is the result of severe lattice distortions produced by its formation, since the amount of carbon present is significantly higher than in solid solution.

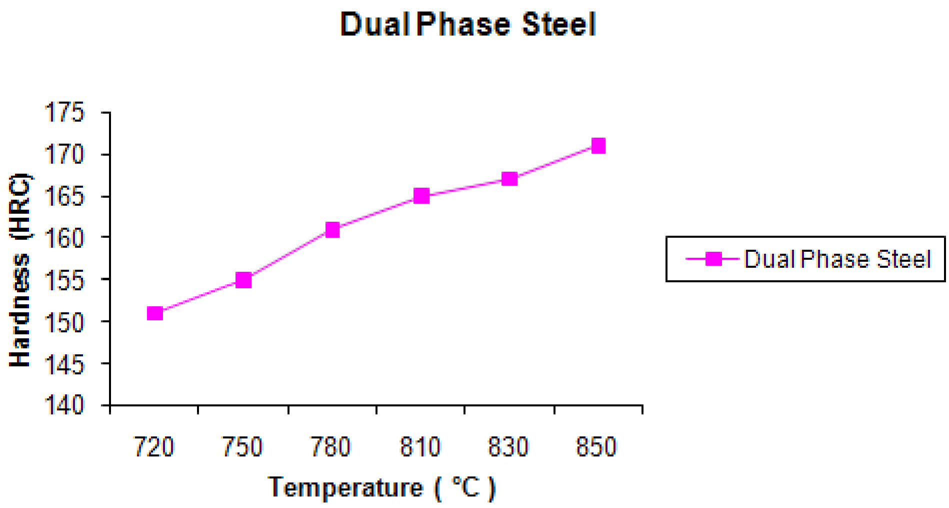

Fig4. Hardness of dual phase steel versus the sample temperature.

4. CONCLUSION

Dual phase steel is developed successfully with composite microstructures of ferrite and martensite (up to 30%) by intermediate quench treatment. mega quench oil (grade 42) can be used as the medium for rapid cooling. The volume fraction of martensite 5% to 30% in dual-phase steels increases with increase in the temperature of heating in the intercritical range. During heat treatment, this is accompanied by growth in the micro hardness of the dual phase steel. The microstructure of dual phase steels consists of light brown (martensite) and white (ferrite) phases and more over it is confirmed from the microstructures that the dual-phase steel has primarily equi-axed grains. The hardness properties of dual phase steel are better than low carbon steel. The microstructure of dual phase consist of martensite thus it gives higher hardness properties. There has been an increase in impact strength as the percentage of martensite increases (5% to 30%) in the dual phase steel. It shows that the percentage of martensite is proportional to the Impact energy.

REFERENCES

[1] S. Hayami and T. Furakawa, “A family of high strength, cold rolled steels”, PP. 311-320 in Proc. Microalloying Conf., Washington, D.C.; Union Carbide, N. Y,, 1970.

[2] M. S. Rashid, “GM 980X-A Unique High strength sheet with Superior formability,” SAE Preprint760206, February 1976.

[3] R. G. Davies, “The deformation behaviour of a Vanadium-Strengthened dual

phase steel," Met.Trans. A, 9A (1978), pp. 41-52.

[4] R. G. Davies, " Influence of martensite composition and content on the properties of sual phase steels, " Met.Trans. A, 9A (1978), pp. 671-79.

[5] J. f. Butler, et al, Vanadium HSLA Steels with Superior Formability" in Vanitec seminar on Vanadium cold passing and dual phase steel, W. Berlin, Germany Oct 1978.

[6] C.L Magee, et al, "The structure deformation and strength and ferrous and martensite, "Acta Met., 19(1971), pp. 345-54.

[7] J.P Hirth, et al, " on the strength- differential phenomenon in harden steel, " Met. Trans., 19(1970), pp. 3-8.

[8] R. G. Davies, "Influence of silicon and phosphorus on the mechanical properties of both ferrite and dual phase steels," Met.Trans. A, 10A (1979), pp. 113-118.

[9] W.B Morrison, "The Effect of Grain Size on the Stress-strain Relationship in law-carbon steel," Trans. ASM, 59, (1966), pp. 824-46.

[10] David trejo, et al "Mechanical Properties and Corrosion Susceptibility of Dual -Phase Steel in Concrete" Pergamon, Cement and Concrete research, Volume 24 No 7, pp 1245-54, 1994.

[11] U.S patent Nos. 4,170, 499; 4,170,497; 4,619,714; 4,613,385; 4,671,827; U.s trade mark "fermar".

[12] Koo, et al,"Design of duplex low carbon steels for improved strength: weight applications", Formable HSLA and dual- phase steels Ed.by A.T Devenpot, 1977, p.41.

[13] Kim, et al," Effects of the Constituents on the mechanical Behavior of Low Carbon Steels", Scripta METALLURGICA Vol.18.pp. 817-820, 1984, Pergamon Press.

[14] Koo, et al, "On the Law of Mixture in Dual-phase Steels" Met.Trans. 11A, 852(1980).

[15] B.MINTZ, The influence of martensite on the strength and impact behavior of steel, Metallurgical and materials transactions , Volume 28A, October 1997-2003.

[16] B. Mintz,et,al; metal.trans. A 1988, vol 19A, pp.1481-90.

[17] A.Nassar , et,al. sci. tecnol,1991,vol. 7,pp.699-706

[18] Mehmet Erdogan " Effect of austenite dispersion on phase transformation in dual phase steel" pergamon, Scripta Materialia, 48,2003, pp. 501-506.

[19] Lawson Rd, Matlock DK, Krauss G. In: RA, Bramfitt BL, editors. Fundamentals of dual- phase steels, New York: AIME: 1981. P.347.