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Effect of Ferritic – Martensitic Constituent on Mechanical Property and Corrosion Behaviour of Medium Carbon Dual Phase (DP) Steel

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Original Research Article

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Abstract: This investigation was carried out to study the effect ferritic-martensitic constituent on mechanical property and corrosion behaviour of medium carbon DP steel. Several stages of heat treatment were applied on the as-received medium carbon steel which composed of lamellarizing, quenching and tempering process. As-received medium carbon steel was assigned as a reference sample for comparison analysis. Mechanical property was evaluated using Vickers hardness to examine the effect of changing the ferritic-martensitic constituent of the medium carbon steel. Besides, the effect of this constituent on the corrosive behaviour of the medium carbon DP steel was investigated using 1 M hydrochloric acid solution.

Keywords: Dual phase; ferritic-martensitic phase; mechanical; corrosion.

INTRODUCTION

Steel has played a major role as one of the main material used in the most of engineering application. One of steel type is medium carbon steel due to its relatively low price and superior mechanical properties such as high strength and toughness[1]. Several applications of medium carbon steel are widely used in construction of buildings, bridges, diesel pump injection parts and automated packing machinery parts[1,2].

The mechanical properties of medium carbon steel can be improved by heat treatment process; austenitizing, quenching and tempering, hence provide tremendous load carrying stability. The studies of heat treatment process in improving mechanical properties have been done previously by many researcher[3,4].

The used of dual-phase (DP) steels in automobile industries have been last for three decades. DP steels possessing a composite microstructure consisting of hard martensite islands embedded in a soft ferritic matrix have evoked much interest due to the combination of high strength, good machinability and high toughness[5,6]. The martensitic phase increases strength, while ferrite matrix, generally continuous, gives excellent ductility[7]. The mechanical properties of DP steels can be altered by varying its martensite volume fraction. However, the benefits obtained in mechanical properties have to be viewed in light of other properties such as corrosion resistance. e. Medium carbon DP steels can be used for applications in mineral and mining processes which do not require any welding operation[8].

Further research is needed in order to know the potential of dual phase steel in various applications. Therefore, there are several investigations have been done by researchers to know the effect of dual phase microstructure on the corrosion behaviour[8,9]. The dual phase microstructure has a very good corrosion resistance [10]. A study on measuring the galvanostatic corrosion behaviour of DP steel with varying morphologies and martensite content has been assessed in comparison to ferrite-pearlite steel in 3.5% NaCl solution [9]. They found that the martensite content increases and higher degree structural refinement will increase the corrosion rate. Besides, the hardness value of dual phase steel is increase 100% compare to normal steel (ferrite –pearlite) microstructure due to the presence of harder martensite phase [5]. Therefore, further investigation should be done to know the effect of effect of ferrite and martensite of dual phase steels to corrosion behaviour and mechanical properties. This study was carried out to study the effect of martensite-ferrite constituent phase of the medium carbon dual phase steel on corrosion behaviour and hardness.

EXPERIMENTAL PROCEDURES

To achieve these objectives, rods of as-received medium carbon steels were used, with carbon contents of 0.35 wt%. Several steps of heat treatment were applied on the samples which are composed of lamellar zing, quenching and tempering. The detail of heat treatment stages is described in Fig. 1. Sample with no heat treatment process acts as a reference sample.

The heat treatment processes and samples are summarized in the Table 1 below:

Table-1: Description of heat treatment process for each sample

Sample	Heat treatment	Parameter details
A(reference)	-	Quenching = heat up to 950 ℃ (90 minutes) and quench in water Lamellarizing = 750 ℃ (soaking time 20 minutes) Tempering = 480 ℃ (soaking time 30 minutes)
B	L+T	
C	Q+L+T	
D	Q+Q+L+T	

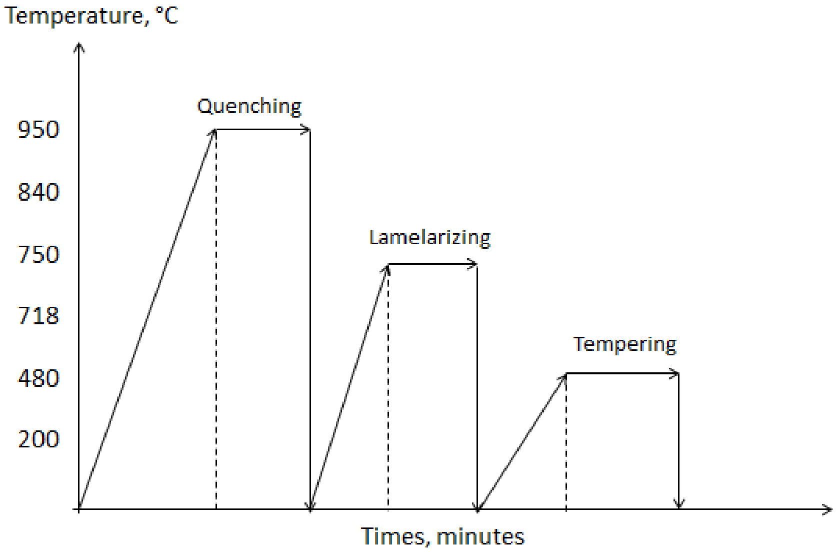

Fig-1: Temperature-time graph describing heat treatment process

For metallographic examination, samples of as-received and heat – treated specimen were cold-mounted and ground on a water lubricated hand grinding set-up of emery paper (180, 240, 320, 400, 600, 800, 1000, 1200 and 1500 grit) were used in that order. Next, the disc polisher with polishing cloth of Topper Grinding Polishing Machine and suspension of fine alumina powder in water was used as a polishing medium for the finely polish of the specimen surface ion. Then, the fine polished specimens were washed by using distilled water and ethanol, and then the specimens were dried. Next, the polished specimens were etched for 5 to 10 seconds by using etchant (2% Nital – 2% HNO_3 and 98% of Ethyl or Methyl alcohol) to reveal the microstructure. The optical microscopic examinations were carried out on a metallurgical microscope at a magnification of 50X.

For mechanical testing, the Digital Metallic Vickers Hardness Tester was used for hardness test method. There are five points of pyramid-shaped diamond was indented on the specimen to get the average value of HV. For corrosion test, the weight loss was considered as a main factor. The initial weight of the samples was measure before immerse in the 1 M HCl solution. The cross-sectional area of each of the specimens was calculated; each of the specimens was also weighed on a chemical balance and the weight recorded. After several duration of immersing, specimens were retrieved, washed properly in water, dried and weighed on a weighing balance to determine the weight loss during exposure. The corrosion rate was calculated using:

$$mpy = \frac{3.45\ x\ 106W}{ATD}$$

Where, W is the weight difference, A is the cross-sectional area, T is the duration of immersion and D is the density of specimen.

RESULTS AND DISCUSSION

Figs. 2(a-d) show the microstructures that are obtained from the experiment. The microstructure of the un-treated carbon steel consists of ferrite and pearlite structure while the microstructures for heat treated carbon steel consist of dual phase ferrite-martensite microstructure. Sample A shows no presence of martensite due to no heat treatment at dual phase region on this sample. As shown in Fig. 2a, the microstructure shows that only appearance of ferrite (white region) and pearlite (dark region), which is normally for medium carbon steel. For sample B (Fig. 2b), application of heat treatment process (L+T) to the sample does not change much the microstructure. However, slightly portion of austenite can be seen on the microstructure which could be attributed to the lamellarizing treatment was done near to the dual phase region (α+γ). However, with the applying of heat up to 950 ℃, followed by quenching in water media, the microstructure of medium carbon steel has changed to ferrite-martensite as can be seen for sample C (Fig. 2c). This is due to the sample that undergone heat treatment process to γ-austenite phase at temperature 950 ºC which changes the pearlite to austenite. During quenching process which is rapid cooling in the water, the austenite will then transform to martensite. With the multiplication of quenching process to the medium carbon steel, then followed by lamellarizing and tempering, the presence of martensitic constituent can be seen more clearly as shown for sample D in Fig. 2d.

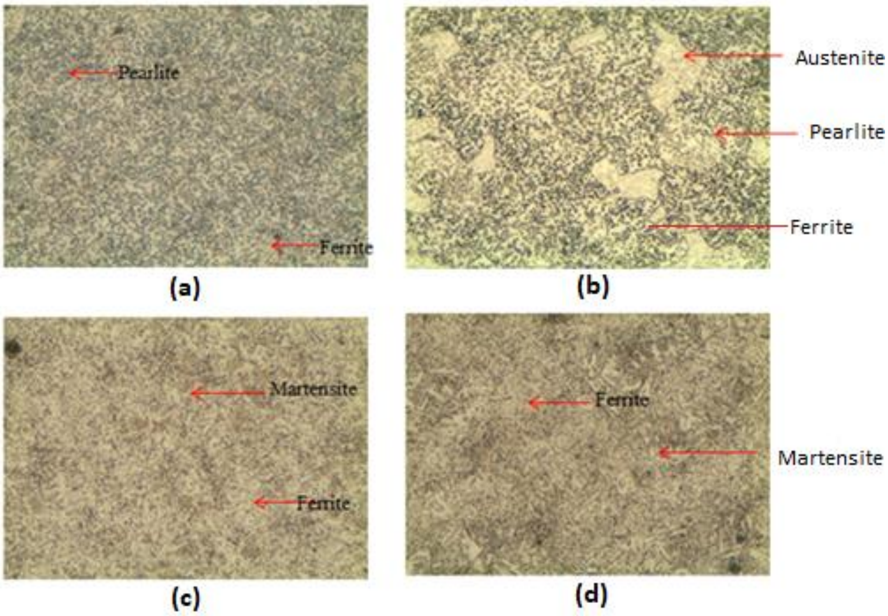

Fig-2: Microstructure transformation of medium carbon steel due to the heat treatment processes

Table 2 represents the average hardness value of the medium carbon steel samples. The Vickers hardness values of the heat treated steels are higher than the hardness value for untreated steel. This is because the hardness value of dual phase is higher comparing to un-treated steel that has ferrite-pearlite microstructure. Therefore, the dual phase steel has better hardness properties as it composite microstructure consisting of hard martensite islands embedded in a soft ferritic matrix. Martensite is a metastable of iron phase which is supersaturated in the carbon that is the product of diffusion less transformation to austenite phase. Therefore, the hardness for heat treated sample D is higher with value 247.4 HV due to the present of martensite higher than ferrite.

Table-2: Vickers hardness value of medium carbon steel after different heat treatment process

Sample	HV_{avg}
A (Un-treated)	193.2
B (L+T)	218.8
C (Q+L+T)	227.5
D (Q+Q+L+T)	247.4

Graph of weight loss and corrosion rate for the samples in the exposure time have been plotted in Fig. 3. Based on the graph, the value of corrosion rate for heat treated sample D is higher than sample C and followed with sample B. This is due to the increases amount of martensite and refinement of structure, thus lead the corrosion rate of dual phase medium carbon steel increase. As the martensite content increase in the heat treated samples, the higher degree of structural refinement also increases in corrosion rate [11]. The corrosion form in sample D is faster than sample C because there is larger in interfacial between ferrite and martensite. Therefore, the gap between ferrite and martensite in sample B is smaller than sample C which lead this sample has least corrosion rate compare with other samples.

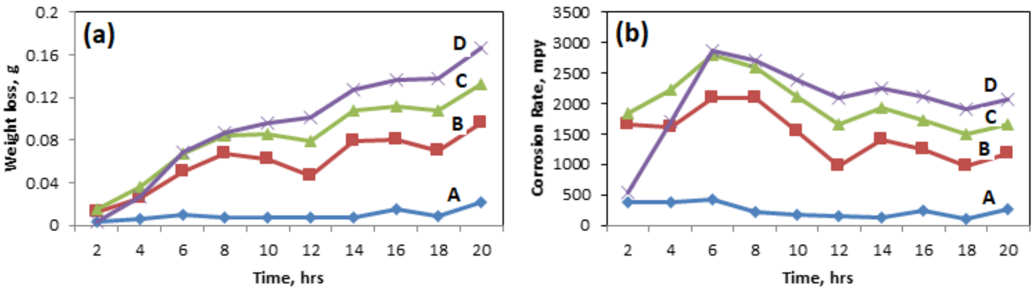

Fig-3: Weight loss and corrosion rate after several hour of immersion in 1M HCl

CONCLUSIONS

The results revealed that the heat treatment processes composing of lamellarizing, tempering and quenching affecting ferrite-martensite constituent phase. This changes on microstructure reflecting on the mechanical property as observed in hardness value. It was observed that the hardness increased with increase in martensite volume fraction. The corrosion rate of medium carbon steel for un-treated sample is the lowest one compared to the heat treated samples which there is no present of ferrite–martensite on that sample. The samples that have higher content of martensite have the ability to corrode faster. Therefore, the result for corrosion behaviour from this research is different with the previous research which is the mechanical properties of untreated medium carbon steel cannot be improved.

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