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Study of Mechanical Property and Corrosion Behaviour of Heat Treated Low Carbon Steel

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Abstract: In this work , low carbon steel is heated at different conditions and different volume fraction of martensite are obtained after intercritical heating followed by air, water and oil quenching at different intercritical temperature. The tensile strength of low carbon steels are measured. Corrosion properties are evaluated using immersion test. It was observed that the tensile strength increased with increase in martensite volume fraction .The corrosion rates for low carbon steel is found to be lower than that for ferrite- pearlite steel.
Keywords: Low carbon Steel, Corrosion, Tensile Test, Heat Treatment.

I. INTRODUCTION

In last three decades dual-phase (DP) steels possessing a composite microstructure consisting of hard martensite islands embedded in a soft ferritic matrix have evoked much interest. The early investigations have revealed that DP steels possess a number of unique properties making them attractive for applications such as very good quality sheet materials for automotive bodies. Use of DP steels is mainly due to their continuous yielding, low 0.2% offset yield strength, high ratio of ultimate tensile strength (UTS) to yield stress , high work hardening rate, and high uniform and total elongations. Because of above properties, thinner gauge sheets of DP steels can be used while maintaining the required strength levels. This is particularly interesting for the automotive industry that faces the contradictory requirements of decreasing vehicle weight while improving the fuel efficiency of automobiles along with maintaining the safety standards. However in order to meet durability of sheet metal products over long periods, the corrosion resistance becomes crucial [1].

Low carbon steel has carbon content of 0.15% to 0.45%. Low carbon steel is the most common type of steel as its price is relatively low while its provides material properties that are acceptable for many applications. It is neither externally brittle nor ductile due to its low carbon content. It has lower tensile strength and malleable [2].

Corrosion is the deterioration or destruction of metals and alloys in the presence of an environment by chemical or electrochemical means. In simple terminology, corrosion processes involve reaction of metals with environmental species. The most common method for estimating corrosion rate from mass loss is to weigh the corroding sample before and after exposure and divide by the total exposed area and the total exposure time making sure that appropriate conversion constants are used to get the rate in the required units .The method in mm/yr can be represented by the following equation.

$$CR = (k \times \Delta w) \div (A \times T \times \rho)$$

Where, CR = Penetration (Corrosion) rate , Δw = Weight loss in gram , A = Exposed area of the sample , T = Time of exposure in hours, k = Constant for unit conversion = 8.76×10^4 and ρ = density of low carbon steel (7.88 gm/cm^3). Weight loss technique was used in which sample known weight before and after immersing to the solution is analysed and results are collected [3].

Steels whose structures consist of mixtures of ferrite and martensite are often referred to as dual phase steel. DP steels are low carbon steel that posses a microstructure consisting of a ferrite and martensite. In DP microstructure although small amounts of retained austenite, bainite and/or pearlite may also be present [4]. By increasing the temperature martensite volume increases at higher rate [5,6].

The strength values of the investigated dual phase steels are higher than that of the as-received (normalised) steel. The higher strengths of the dual phase steels are known to be due to the presence of the harder second phase (martensite) [3]. The yield strength of these steels is linearly increased by increasing the martensite volume fraction, while the ultimate strength first increases by increasing martensite volume fraction and then remains nearly constant [7].

S.C. Ikpeseni et al [8] during teir investigation on dual phase low carbon steel observed that the corrosion rate of dual phase steel developed from 0.23%C steel via intercritical annealing heat treatment increases with increase in intercritical annealing temperature and martensite volume fraction in 0.1M HCl solution. They also revealed that martensite volume fraction increases as a function of temperature. Again, the corrosion rate of the duplex microstructure steels was found to be slightly higher than that of normalized steel.

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Imtiaz Soomro et al [9] in investigating properties of plain carbon steel came to inference that the amount martensite fraction increases with increasing temperature and time during intercritical annealing. Higher percent martensite volume fraction lowers the martensite carbon content and change the morphology from plateto lath type. Also martensite tetragonality ratio was found be dependent of carbon content. Decrease in carbon content softens the martensite and significantly improves its plastic formability. The hardness and TS was found to increase with increasing Vm% with optimum value of 1277 MPa and 41 HRC. A further increase in Vm% was found to decrease both TS and hardness. The toughness of DUAL PHASE specimens was lower compared to as-received and increase with increasing Vm%.
E. Salamci et al [10] during study of mechanical and corrosion behavior of dual phase steel concluded that the martensite volume fraction increases with an increase in intercritical annealing temperature. The slow cooling rate for FC752 allows the epitaxial ferrite to grow on the existing ferrite attributed to increasing in intercritical annealing temperature or decreasing in cooling rate. Mass loss of all the investigated specimens remained almost similar for the early stages (i.e., up to 3 days) after which the mass loss was deviated as the immersion time prolonged. The mass loss is approximately 30% less for FC752 at 28-day exposure time as compared to WQ725. Corrosion rate increased with increasing martensite volume fraction. However, this phenomenon was inhibited in the epitaxial ferrite containing samples, attributed to the presence of epitaxial ferrite hindering corrosion by smoothing the compositional fluctuations between retained ferrite and martensite as well as reduced dislocation density.

II. EXPERIMENTAL DETAILS

1) *Work piece:* The material used for the present work is low carbon steel AISI 1018. For corrosion test specimen size was 25mm×25mm×4mm. For tensile test, I-shaped specimens were made. The chemical composition of low carbon steel AISI 1018 is shown in table I below.

Table I: Composition of Low Carbon Steel AISI 1018

Element	Composition
Iron (Fe)	98.9%
Carbon (C)	0.16%
Manganese (Mn)	0.77%
Phosphorous (P)	0.023%
Sulfur (S)	0.017%

2) *Machine:* Muffle Furnace available at RR Institute of Modern Technology, Lucknow. For tensile test, UTM was available at Integral University, Lucknow.
3) *Performance Measures:* The performance measures assessed for this research are Corrosion Rate, Tensile Strength.

Fig. 1: AISI 1018 Specimens after corrosion test

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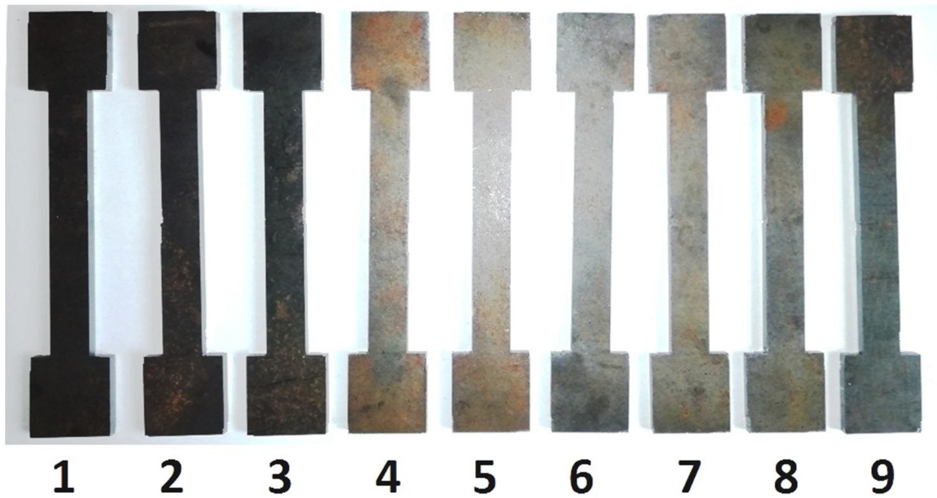

Fig. 2: AIS 1018 I-shaped Specimen after tensile test

Table III: Showing Parameters Used For Experimentation

S.No.	Parameters	Units	Level 1	Level 2	Level 3
1	Temperature	°C	710	730	750
2	Quenching Type		Air	Water	Oil

Table IIIII: Experimental Values Of Corrosion Rate And Tensile Test

Exp. No	Temperature	Quenching Type	CPR (mm/year)	Ultimate Tensile Strength
1	710	Air	0.76088	462
2	710	Water	0.237157	479
3	710	Oil	0.138342	510
4	730	Air	0.662064	458
5	730	Water	1.279662	489
6	730	Oil	0.612657	525
7	750	Air	0.671946	461
8	750	Water	0.207513	484
9	750	Oil	0.19269	538

III.RESULTS AND DISCUSSION

A. *Influence of heat treatment on Corrosion (Penetration) Rate*

All the corrosion experiments were conducted at 300 K with corrosive medium open to air. For the study of corrosion behavior flat samples of (25 x 25) mm^2 were cut from the normalized and dual-phase steels after heat treatment. Samples were polished up to 4/0 grade emery paper before performing the corrosion tests. Corrosion test was performed in 5% NaCl solution. Corrosion properties were studied by using immersion test in 5% NaCl solution for 360 hours (15 days). The ASTM established recommended procedure for immersion test as covered by designation G-31 was employed.

The corrosion rate was calculated by weight loss method. From immersion test results, corrosion rate is estimated by using the following :

$$CR = (k \times \Delta w) \div (A \times T \times \rho)$$

Where, CR = Penetration (Corrosion) rate, Δw = Weight loss in gram , A = Exposed area of the sample , T = Time of exposure in hours = 360 Hours, k = Constant for unit conversion = 8.76×10^4 and ρ = density of low carbon steel (7.88 gm/cm^3).

With the change in microstructure from ferrite-pearlite to ferrite-martensite (dual- phase) the CPR decreases.

Table IVV: ANOVA of Corrosion Rate

Source	DOF	SS	Adj MS	F Value	Contribution
Temperature	2	0.4680	0.2340	2.24	41.91%
Quenching Type	2	0.2302	0.1151	1.10	20.62%
Error	4	0.4184	0.1046		37.47%
Total	8	1.1166			100%

Analysis of variance of corrosion rate of heat treated AISI 1018 is shown in the above table IV. It is clear from the table that temperature is the most dominating parameter for corrosion rate with a contribution of 41.91%. Quenching type is the least influencing parameter for corrosion rate with a contribution of only 20.62%.

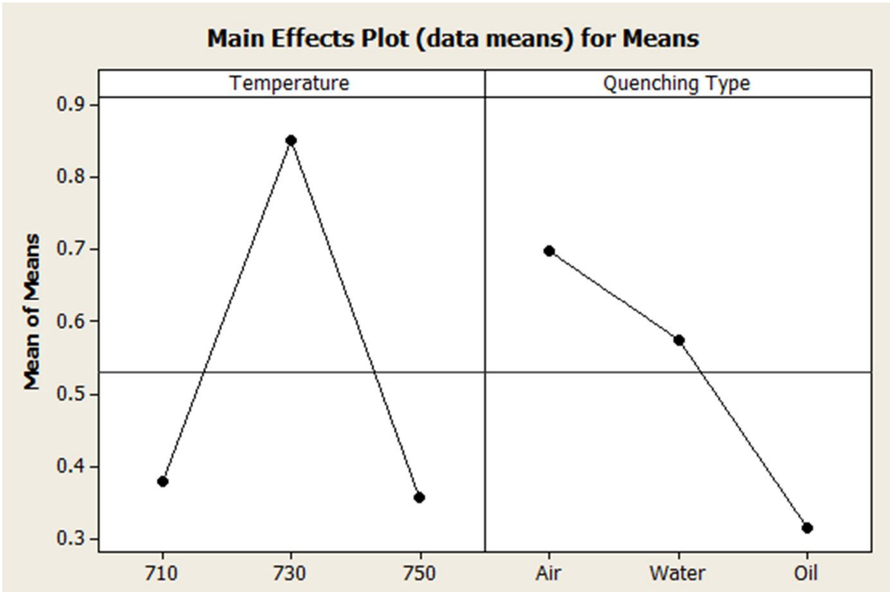

Fig. 3. Main effect plot between Corrosion rate, Temperature and Quenching Type

The above graph in figure 3 shows the main effect plot for corrosion rate with temperature and quenching type. The graph shows that the corrosion rate is highest when the temperature of heat treatment of AISI 1018 is kept 730°C. But at 710°C and 750°C, the corrosion rates obtained is lowest. The average corrosion rate for the present set of experiment is 0.5292mm/year.

Air quenched AISI 1018 is observed to have highest corrosion rate while oil quenching leads to least corrosion rate as observed from the above graph

B. Influence of Heat Treatment on Ultimate Tensile Strength

The ultimate tensile strength values of the investigated low carbon steel AISI 1018 are higher than that of un-treated AISI 1018. The higher values of the tensile strength are known to be due to the quenching of specimen.

Table V: ANOVA Of Ultimate Tensile Strength

Source	DOF	SS	Adj MS	F Value	Contribution
Temperature	2	176.2	88.1	1.28	2.62%
Quenching Type	2	6282.9	3141.4	45.68	93.30%
Error	4	275.1	68.8		4.08%
Total	8	6734.2			100%

Analysis of variance of ultimate tensile strength of heat treated AISI 1018 is shown in the above table V. It is clear from the table that temperature is the least dominating parameter for ultimate tensile strength with a contribution of only 2.62%. Quenching type is the major influencing parameter for ultimate tensile strength with a contribution of only 93.30%.

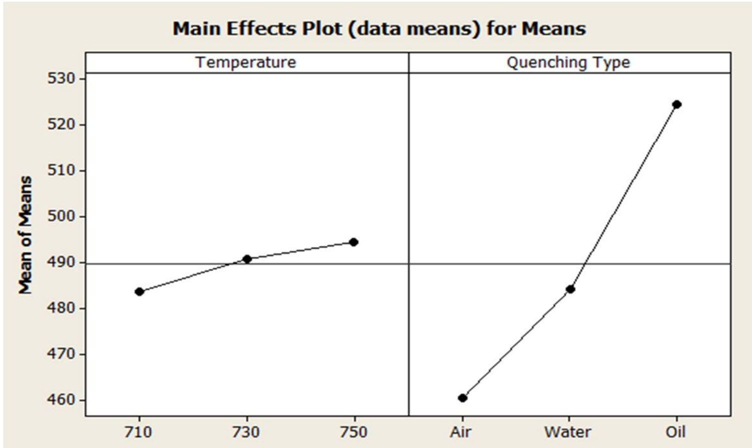

Fig. 4: Main effect plot between Ultimate Tensile Strength, Temperature and Quenching Type

The figure 4 shows the main effect plot for UTS. It shows that the UTS increase with both temperature and quenching type. Quenching type has major influence on UTS and Oil quenching imparts highest level of ultimate tensile strength to AISI 1018 under present heat treatment conditions. Temperature is the least influencing parameter with a contribution of only 2.62%. Thus its effect on UTS is almost negligible.

IV. CONCLUSIONS

Plain low carbon steels was heat treated using different inter-critical temperature (710°C, 730°C and 750°C) and quenched in air, water and oil. The mechanical and corrosion behavior of the resulting steels is compared and the conclusions from the investigation are as follows :

A. Temperature is the most dominating parameter for corrosion rate with a contribution of 41.91%. Quenching type is the least influencing parameter for corrosion rate with a contribution of only 20.62%.
B. The corrosion rate is highest when the temperature of heat treatment of AISI 1018 is kept 730°C. But at 710°C and 750°C, the corrosion rates obtained is lowest. The average corrosion rate for the present set of experiment is 0.5292mm/year.
C. Air quenched AISI 1018 is observed to have highest corrosion rate while oil quenching leads to least corrosion rate.
D. Type of quenching is the most dominating factor for ultimate tensile strength and has a contribution of 53.88% towards it.
E. Ultimate Tensile Strength increase with both temperature and quenching type. Quenching type has major influence on Ultimate Tensile Strength and Oil quenching imparts highest level of ultimate tensile strength to AISI 1018 under present heat treatment conditions.
F. Temperature is the least influencing parameter with a contribution of only 2.62%. Thus its effect on Ultimate Tensile Strength is almost negligible.

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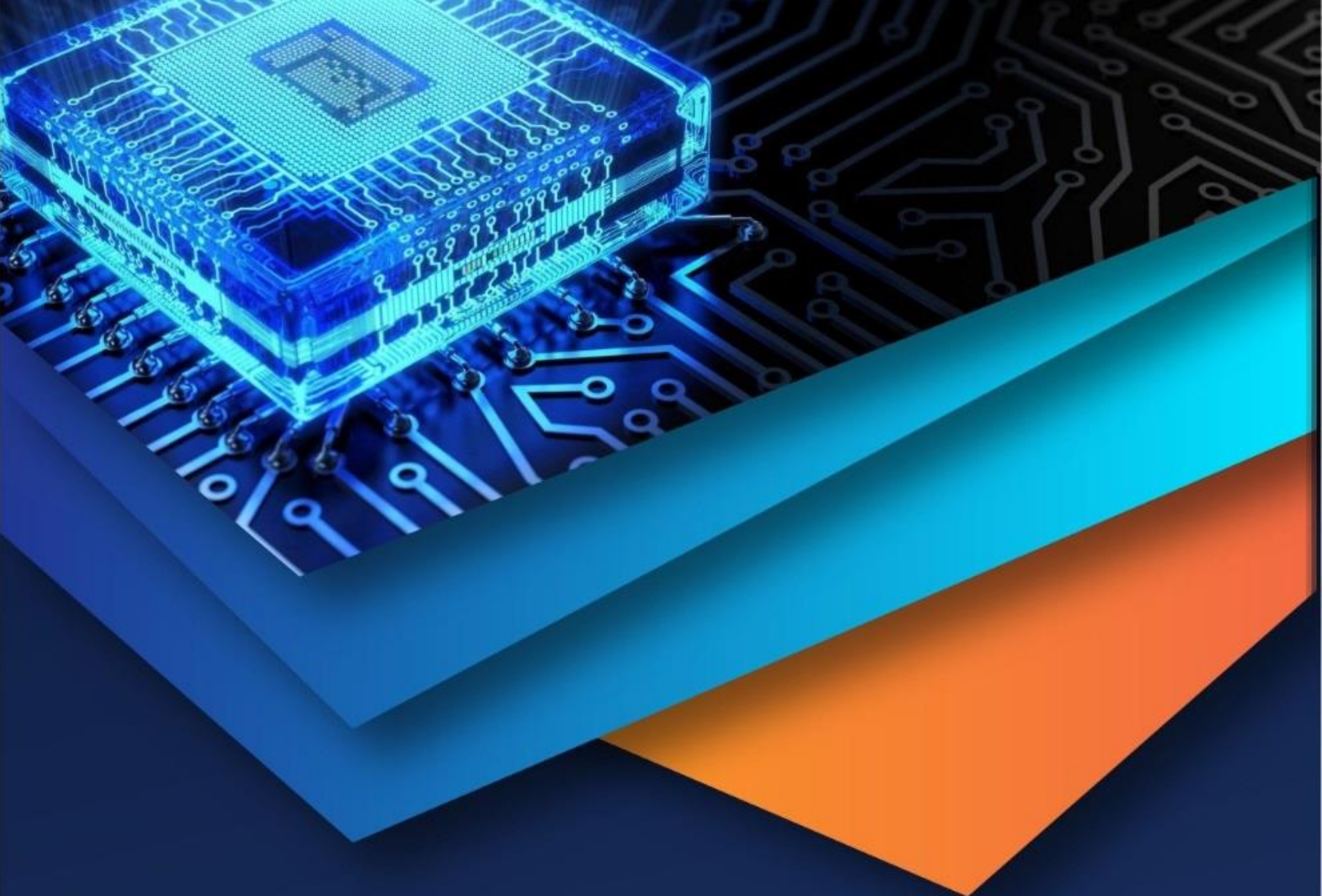

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