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Review on Effect of Thermo-mechanical Treatment on Low and Medium Carbon Steel: Microstructure, Corrosion and Hardness

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Abstract—*With emerging needs of steel in commercial, structural and industrial fields, steel has undergone various modifications as per needs and requirements so as to increase its strength, corrosion resistance, toughness, durability and hardness. In order to meet the increasing demands of steel with respect to its wide applications, it has become necessary for Engineers to study steel and shift the focus towards improving its existing properties. This review paper focuses on how thermo-mechanical heat treatment is emerging out as a viable solution by means of varying the microstructure characteristics of steel and thus, their mechanical properties. This review is concerned with effect of thermo- mechanical treatment on mechanical properties of medium carbon steel and mild steel with an objective of making structurally suited steels. A comparative analysis on effect of microstructure and mechanical properties will be presented by working at different temperatures of heat treatment. Also, corrosive properties of mild and medium carbon steel, before and after treatment will be analysed in this study.*

1. INTRODUCTION

Structural steel is an ideal material for the construction of bridges, buildings and other large structures. Today, most commercial, industrial and even residential buildings are constructed with help of structural steel, therefore the quality and properties like high strength, high corrosion resistance, superior ductility and weldability are important factors. The properties can be improved by the use of the alloying elements, mechanical working or by heat treatment. But, thermo-mechanical treatment of steels has emerged as an appealing process for producing high strength steels.

Heat treatment is a process that involves heating and cooling operations on metals which results in desired microstructure and mechanical properties. The three main stages of heat treatment are:

Heating the material to a specific temperature, holding at that temperature for a certain period of time and then cooling it.

Thermo-mechanical treatment is a metallurgical operation that combines mechanical deformation with thermal processes so as to have an ideal blend of strength, ductility, toughness, corrosion resistance which over all makes a material suitable for structural purposes.

TMT process consists of heating hypo eutectoid steel to the two phase($\alpha + \gamma$) region and quenching to produce a dispersion of martensite in a ferrite matrix. Direct water quenching will result in formation of martensite at surface while core will remain as austenite and ferrite. On further cooling, the core transforms to ferrite-pearlite composite microstructure, while surface remains as martensite. Robin Steveson[1] observed the effect of heating the low carbon steel to 760° C and rapidly quenching it. A second phase, martensite was observed, having different properties than ferrite. This second phase was located preferentially at grain boundaries and grain boundary triple point. Noor Manzi Ismail [Et al.] [2], obtained results for medium carbon steels that showed higher hardness value when quenched in water. In this study, the effect of quenching on hardness and microstructure was observed. A higher hardness value was obtained after quenching with a microstructure of martensite while the ferrite structure had lower hardness value but higher ductility. Piotr Skubisz [Et al.] [3], concluded in his research work that thermo mechanical treatment on a medium carbon micro alloyed steel in a forging process resulted in a significant improvement in tensile strength (70 MPa increase) and yield stress (50MPa increase) Hasan MF[4] observed that heat treatment and cooling rates affect mechanical properties in a way that hardened mild steel has maximum hardness as compared to normalized and annealed mild steel. With increase in cooling rates, the hardness value increased due to formation of martensite which is a strong, hard and stable phase in steel at ordinary temperature. Abdussalam Abdulla Mohamed Gebril[5] in his study of effect of heat treatment on medium carbon steel (0.37% carbon) found that heat treatment resulted in decrease of corrosion rates with higher strength as compared to that of non heat treated specimens due to martensitic formation. Also, the hardness value (VHN) of hardened medium carbon steel was higher than that of non-treated one. A. ray [Et al.][6] conducted a comparative study on corrosive properties of cold twisted deformed [CTD] rebars, plain carbon TMT and low alloy TMT. He observed high corrosion rate in CTD rebars due to surface torsional stresses followed by plain carbon TMT rebars, with least corrosion rate in alloyed [Ni and Cr] TMT.

During an internship program, a research work was carried on "Corrosion of Steel Rebars " under Dr. V.S Raja at IIT Bombay, corrosion rate of ferrite and martensite was studied. The samples were taken from different sources: MAHALAXMI (Fe 500D) TMT Rebar, GUARDIAN (Fe 500 D) TMT Rebar, TATA STEEL (Fe 500D) TMT Rebar. Samples were molded and prepared for electrochemical studies and microscopic observation. Corrosion behaviour of Core and surface part of different samples was studied extensively and a comparative study of their corrosion rates was made. It was inferred from the study that corrosion rate of core (ferritic part) of different samples is more than their respective surfaces (martensitic part), due to formation of galvanic couple between the two phases with ferrite having a lower (more negative) corrosion potential.

2. EXPERIMENTAL

Preliminary analysis (before Thermo-mechanical treatment)

Sample Preparation: Samples of Medium Carbon steel (0.43% C) from a rod and Low Carbon steel (0.25% C) from Rebar were cut mechanically in workshop into coupons.

Dimensions of samples:

Diameter of medium carbon steel sample = 24 mm

Height of medium carbon steel sample = 25 mm

Diameter of mild steel sample = 16 mm

Height of mild steel sample = 25 mm

3. RESULTS

3.1 Atomic Emission Spectroscopy

AES was used to study the composition of both samples which is represented in table 1 & 2:

Table 1: Compositional analysis of medium carbon steel

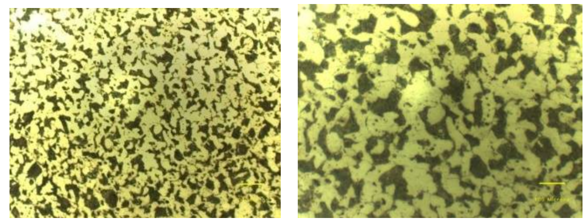
Medium Carbon Steel					
Elements	**C**	**Si**	**Mn**	**P**	**S**
Percentage	0.43	0.18	0.46	0.01	0.06

Table 2 Compositional analysis of Low Carbon steel

Low Carbon Steel					
Elements	**C**	**Si**	**Mn**	**P**	**S**
Percentage	0.25	0.12	1.07	<0.008	0.009

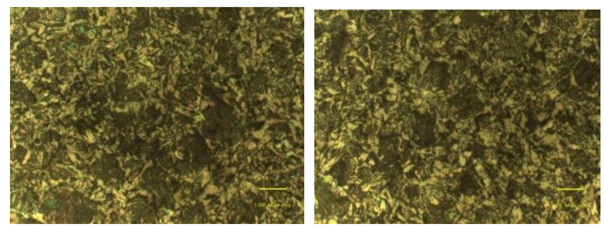
3.2 Microstuctural Analysis

The microstructure of both samples (Untreated) was observed using Optical Microscopy which revealed two phases composed of pearlite and ferrite as represented in Fig. 1.1 & Fig. 1.2



(a) (b)

Fig. 1.1 Microstructure of Medium Carbon Steel (a) at 200X, (b) at 400X



(a) (b)

Fig. 1.2 Microstructure of Low Carbon Steel (a) at 200X, (b) at 400X

3.3 Hardness Test

Micro hardness test was conducted using Vicker's hardness testing machine using a diamond pyramidal indentor. The results obtained are tabulated in Table 3:

Table 3: Hardness values of Low Carbon Steel Sample

Load	Dwell time (seconds)	D1 (mm)	D2 (mm)	Hardness value (VHN)
200 g	3	0.0479 0.0453 0.044	0.0456 0.0453 0.044	**169.6** **188.5** **191.6**
500 g	3	0.0718 0.0735 0.0711	0.073 0.0752 0.0725	**177.0** **167.7** **179.8**
1000 g	3	0.1016 0.1051 0.1023	0.103 0.1052 0.1047	**177.3** **167.7** **173.1**
2000 g	3	0.1474 0.148 0.1463	0.1469 0.1508 0.1495	**171.4** **166.2** **169.5**

4. FUTURE WORK

After preliminary investigation, the samples will be subjected to thermo mechanical treatment where deformation will be carried out using simple hammers. For both medium & mild carbon steel, five different temperatures will be chosen in ($\alpha + \gamma$) region of iron carbon phase diagram to which the samples will be heated. Afterwards the samples will be transferred to another furnace maintained at a temperature of 450° C and held for a specific period of time determined from TTT diagram. The samples will be subjected to deformation using hammer blows with subsequent quenching. Microstructural analysis, hardness profile and corrosion resistance of quenched samples will be determined. A comparative analysis will be drawn from this study and hence an appropriate temperature will be selected for heat treatment of structural steel.

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