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Effect of Hardness and Microstructure on En 353 Steel by Heat Treatment

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Abstract : *En 353 steel is an easily available and cheap material that is acceptable for heavy duty applications. Heat treatment on En 353 steel is improved the ductility, toughness, strength, hardness and relive internal stress in the material. X-ray diffraction (XRD) method is used to analyze the composition and the phase of the alloy material. The experimental results of hardness and microstructure are done to get idea about heat treated En 353 steel. It is found that the hardness of the En 353 steel is improved after the heat treatment and the microstructure is changed from ferrite to martensite.*

Keywords -*En 353 steel, Heat treatment, Hardness, Microstructure.*

I. INTRODUCTION

En 353 steel has carbon content of 0.17% and the most common form of steel as it's provides material properties that are acceptable for many automobile applications such as heavy duty gear, shaft, pinion, cam shafts, gudgeon pins [1,8]. It is neither externally brittle nor ductile due to its lower carbon content and lower hardness. As the carbon content increases, the metal becomes harder and stronger.

The process of heat treatment is carried out first by heating the metal and then cooling it in water or oil or air. The purpose of heat treatment is, to enhances the transformation of austenite to martensite i.e. (soft material to hard material), to change the grain size, to modify the structure of the material and relive the stress set up in the material. It is a one-time permanent treatment process and it is change the entire cross section of the material [5, 7]. The martensitic phase transformation is usually used to increase the hardness of the steels [2].The various heat treatment processes are annealing, normalizing, hardening, quenching and tempering.

According to this work basically focus on carburizing; it is a process of improving carbon on case. These are done by exposing the part to carbon rich atmosphere at the high temperature (close to melting point) and allow diffusion to transfer the carbon atoms into the steel. So, these work concentrations go through pack carburizing which can easily do in experimental setup. The carburizing process does not harden the steel it only increases the carbon content. In heat treatments, both chemical composition and microstructure properties of a case can be changed [6].

The aim of this paper is to examine the hardness, XRD and effect of microstructure of before and after heat treatment on En 353 steel. In heat treatment, the machined specimens are loaded in the chamber at below 800°C. Carburizing takes places at 920°C for 120 minutes then it is cooled by air and relaxing time is 75 minutes. The purpose of the relaxing time is to arrest the in and out of the carbon and it is followed by oil quenching at 820°C for 30 minutes, oil temperature is below 80°C then by tempering at 250°C for 90 minutes. In general, the untemper material structure has the high hardness and also more brittle. Hence the tempering process should be done to reduce the brittleness, to relieve the internal stress and to increase the toughness and ductility of the material.

Nomenclature :

- AHT - After Heat Treatment
- BHT - Before Heat Treatment
- CHT - Conventional Heat Treatment
- HV - Vickers Hardness test

II. METHODOLOGY

After heat treatment, the specimens for structure investigations are conventionally prepared and etched using nital. The Leica DM 2500 M microscope is used to the observations of obtained structures before and after the heat treatment. The specimen with a diameter of 10 mm and a length of 50 mm are subjected to the Hardness test using the MH6 machine. X-Ray Diffractometer is one of the most powerful techniques for material structural analysis. Bruker AXS D8 Advance XRD machine is to analysis the crystallite size, strain and dislocation density.

III. RESULTS AND DISCUSSION

3.1 Chemical Analysis

In order to ensure the material of the specimen is done with help of the optical emission spectroscope (OES). The result is obtain from the chemical analysis, carbon - 0.171 %, silicon - 0.3 %, manganese - 0.56 %, phosphorus - 0.012 %, sulphur - 0.13 %, Chromium – 0.953 %, Nickel - 0.989 %, molybdenum - 0.16 % and remaining percentage is iron respectively. A sample of ϕ 30 × 10 mm is polished using 60 grit papers and two sparks is introduced on the surface to find the chemical composition of the material. After ensuring the chemical composition, the raw material is machined according to the dimension for various tests [3].

3.2 Hardness

Vickers hardness measurement is done on the specimen as per the IS 1501-2002 procedures by using Vickers hardness tester (MH6). Hardness measurement is made with 200 g loads, dwell time of 10 seconds and diamond indenter is used for test. The impression is done on the circular faces at the centre of the specimen. The hardness values are taken corresponding to the diagonal length of the indentation. Two samples (i.e. BHT and AHT) and five readings are taken from the each sample from case to core. The average value is calculated from five readings. The hardness values of BHT (case and core) samples are, 193.7 and 201.8 HV respectively. The hardness values of AHT (case and core) samples are 684.5 and 387.8 HV respectively. It is clearly noticed that the base material (BHT) has the low hardness. The AHT specimen has high hardness when compared to the BHT sample as shown in Fig. 1.

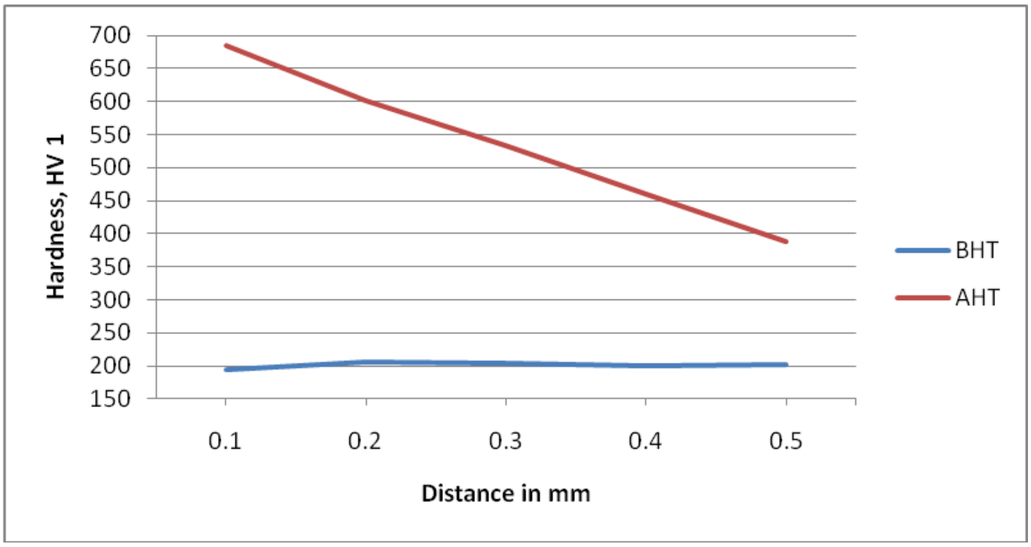

Figure 1 Micro hardness of the specimen

3.3 Microstructure

The change of microstructure in the material due to conventional heat treatment (CHT) is the main reason for the improved mechanical properties. Hence the microstructure examination is carried out to find the structure of BHT and AHT. The samples are polished using SiC emery paper of grit 280 and velvet cloth using white kerosene as coolant. These samples are etched with nital and dried in air. Finally, microstructure examination is carried out using optical microscope.

The effectiveness of the heat treatment process in refining and homogenizing the structure for En 353 steel is shown in Fig. 2 to Fig. 7. Fig. 2 to Fig. 4 show the microstructure of BHT is ferrite and spheroidized pearlite with at the grain boundaries distributed throughout the structure and Fig. 5 to Fig. 7 show the microstructure of AHT is fine tempered martensite, retained austenite and traces of ferrite distributed throughout the structure.

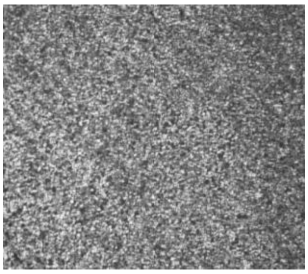

Figure 2 the microstructure of BHT (100x)

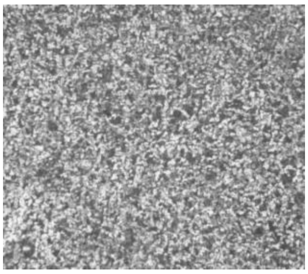

Figure 3 the microstructure of BHT (200x)

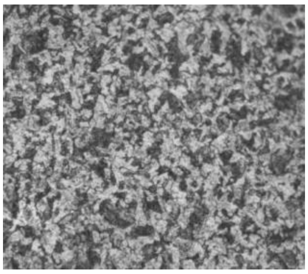

Figure 4 the microstructure of BHT (500x)

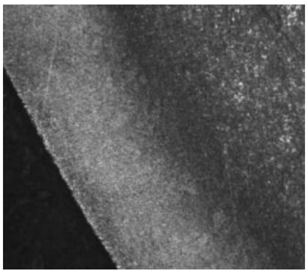

Figure 5 the case microstructure of AHT (100x)

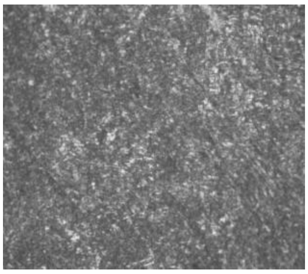

Figure 6 the core microstructure of AHT (200x)

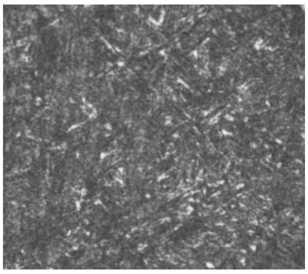

Figure 7 the core microstructure of AHT (500x)

3.4 XRD Analysis

X-Ray Diffractometer is one of the most powerful techniques for material structural analysis. Bruker AXS D8 Advance X-Ray diffractometer fit with vertical goniometers, low and high temperature attachment. The angle range is 360°, the maximum usable angular is 3° to 135° and wavelength is 1.5406 Å**.** X-ray diffraction analysis is carried out under the following condition: Cu radiation, 40 KV voltage, 35 mA current and maximum angular speed 30°/s. When the x-ray is passed into the substrate and it is reflected back to the detector the angle made by the reflected ray to the substrate is denoted as θ. The value of θ is increased by changing the position of specimen by keeping the θ as reference β, D, ε, ρ are calculated. The different values are obtained by the varying θ value for certain range.

The structural characteristics of En 353 steel material after heat treatment are analyzed by x-ray diffraction analysis. Fig. 8 shows the X-ray diffraction of En 353 steel specimen after heat treatment respectively. The estimated crystallite size, strain and dislocation density are calculated from 2θ which lights the present of polycrystalline nature of the material. The calculated structural parameters are presented in the Table 1.

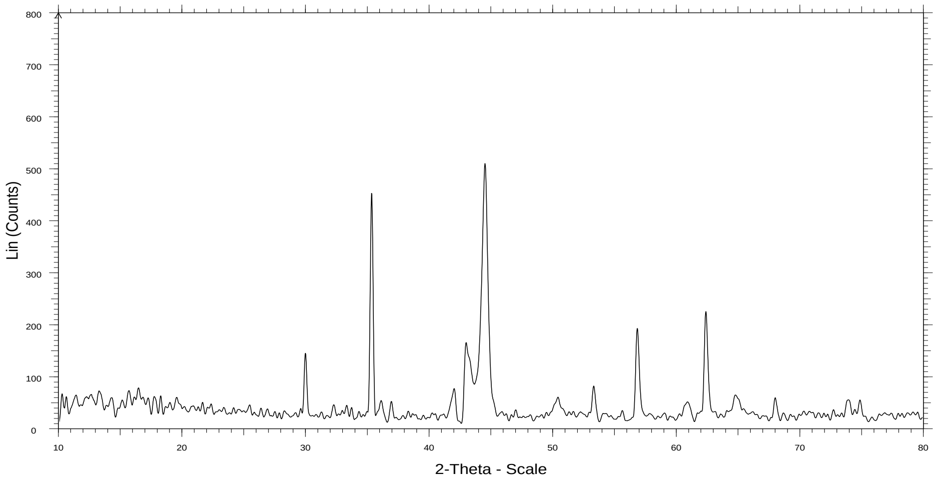

Figure 8 X-ray diffraction peaks of AHT

Table 1 X-ray diffraction test results of AHT sample

Cos θ	**Sin θ**	**d-Spacing**	**FWHM**	**β**	**Wavelength, λ**	**Crystalline size, D**	**Strain, ε**	**Dislocation density, ρ**
0.966	0.2585	2.9797	0.244	0.004256	1.54047905	337.189630	0.0010279	8.79532E-06
0.952	0.3034	2.5385	0.264	0.004605	1.5403436	315.934678	0.0010969	1.00186E-05
0.879	0.4761	1.6178	0.326	0.005686	1.54045964	277.256040	0.0012501	1.30088E-05
0.855	0.5182	1.4863	0.318	0.005547	1.54035986	292.221892	0.0011860	1.17105E-05

The wave length is calculated by using

$$\lambda = 2d \sin\theta \qquad (1)$$

The growth along the peak can be determined by calculating the crystallite size for the peak using (2) Scherrer formula.

$$D = \frac{0.9\lambda}{\beta \cos\theta} \qquad (2)$$

The full width at half maximum (β) is calculated by using (3) equation.

$$\beta = \text{FWHM} \times \frac{\pi}{180} \qquad (3)$$

Strain and dislocation density

The strain (ε) and the dislocation density (ρ) are calculated from the Williamson-Hall (4) and (5) equation

$$\frac{\beta \cos\theta}{\lambda} = \frac{1}{D} + \frac{\varepsilon \sin\theta}{\lambda} \qquad (4)$$

$$\rho = \frac{1}{D^2} \qquad (5)$$

Where, geometrical factor, 0.9 and,

λ - The wavelength of X-ray (1.54060 Å),

θ - The Bragg diffraction angle in radian and
β - The full width at half maximum of most intense peak.
FWHM - Full Width and Half Maximum
D - Average crystallite size

To ensure a high-quality product, diagrams and lettering MUST be either computer-drafted or drawn using India ink. Figure captions appear below the figure, are flush left, and are in lower case letters. When referring to a figure in the body of the text, the abbreviation "Fig." is used. Figures should be numbered in the order they appear in the text. Table captions appear centered above the table in upper and lower case letters. When referring to a table in the text, no abbreviation is used and "Table" is capitalized.

IV. CONCLUSION

Before and after the heat treatment process the mechanical properties of the En 353 steel are examined. The results obtain under the experimental conditions of this work the following conclusion are drawn.

[1] High hardness is obtained in carburizing 120 minutes at 920°C for En 353 steel.
[2] Micro hardness values of AHT are found to be higher than BHT.
[3] The specimen is having greater hardness on case sample than the core sample.
[4] Pictorial view of case/core microstructure indicates that the heat treated specimen is martensite.
[5] Thus life of material can be enhanced by the conventional heat treatment process.

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