Investigation of the Effects of Various Heat Treatment Processes on Microstructure & Hardness with Respect to Corrosion Behavior for Carbon Steels

Khushal Khera, Anmol Bhatia, Sanjay Kumar, Mehul Bhatia

Abstract— In this paper, the effect of heat treatments on microstructure and mechanical properties of EN -31 and EN-8 carbon steel are being studied. Further both the carbon steels are compared on the basis of their mechanical properties as well as the rate of corrosion, then the hardness of both the carbon steel are noted before and after the heat treatment processes. The heat treatment processes i.e. Annealing, Tempering & Oil quenching (hardening) are done. The hardening temperature for EN-31 varies from 820^{0}C - 860^{0}C whereas the hardening temperature for EN-8 varies from 750^{0}C - 900^0 C. The mechanical properties such as the hardness and tensile strength among three process, the oil quenching sample posses highest hardness and the annealed sample posses highest elongation. That is how heat treatment plays an important role in the mechanical properties and corrosion resistance of the experimental steel.

Index Terms— EN-31, EN-8, heat treatment, microstructure, mechanical properties.

I. INTRODUCTION

Heat treatment is the controlled process of heating and cooling of metal to alter their mechanical and physical properties without changing the product shape. The heat treatment process is defined as heating a metal at various temperatures, holding them for various time duration and cooling at various rates, it helps to improve the machining, formability, restore ductility after a cold working operation.
The purpose of various heat treatment processes are as follows: [5]

- To soften the material.
- To improve machinability.
- To improve cutting properties of tools.
- To increase strength and hardness of material.
- To improve the various properties i.e. corrosion resistance and heat resistance.
- To remove the stress and strain induced in the cold working process.

ANNEALING: Annealing is process of softening the material such as carbon steel or metal to make it less brittle by heating it to a particular temperature, Maintaining it at that temperature for a particular duration and then Cooling it slowly to normal temperature at a particular rate .[6]

Fig. 1 Annealing Process

TEMPERING: Tempering is process which is used to increase the toughness of iron based alloys. Tempering is usually done after hardness to reduce some of the excess hardness. [5]

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Fig. 2 Tempering Process

Tempering is done by heating the metal to some temperature below the critical temperature and allowed to cool in air gradually. [5]

OIL QUENCHING- Quenching is a process in which steel are strengthen and hardened. This is done by heating the carbon steel at certain temperature, varying material to material. Tempering is done to reduce the brittleness that may increase from quench hardening process .Gear shafts and wear blocks are certain items that can be quenched or hardened. In this process the carbon steel is heated to a require temperature and the soaking is done. Soaking can be done in air, bath or in vacuum. Soaking time in air should be 1-2 minutes for each mm of cross-section. The time required for soaking in salt or oil bath is 0-6 minutes [6]. The temperature at which material is heated varies from 815^0C -900^0C. [5]

Fig. 3 Oil Quenching Process

II. MATERIAL SELECTION AND METHODOLOGY

Step 1 – Conducting industrial visit to select the tool steel grade.

Step 2 - The two types of carbon steel chosen for the research purpose are EN-31 and EN-8.

Step 3 – These two specimens are selected because they have wide range of applications.

Specimen A (EN-31) - The applications of EN-31 are , they are used in roller bearing components, such as brakes, cylindrical, conical and needle roller.

Fig. 4 Specimen A (En-31)

Specimen B (EN-8) - The applications of EN-8 carbon steel arethey are used to make components of small cross section , require low tensile strength as well as heavy forging in a normalized conditions for automotive & general engineering axles, clutch shaft , presses and punches parts, piston rod & gear rods .

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Fig. 5 Specimen B (En-8)

Step 4 – Further cutting and grinding of specimen A & B are done and then appropriate size of EN-31 & EN-8 are selected.
Table 1: Showing appropriate size of the specimens.

Table 1

Specimen	DIAMETER	LENGTH
A	20 mm	50 mm
B	20 mm	40 mm

Step 5 – Chemical composition of untreated tool steel EN-31 & EN-8. **Table 2**:- Chemical composition of EN-31 (Specimen A) taken by X-Ray spectrography test.

Table 2

C	Si	Mn	Cr
0.95	0.25	0.55	1.30

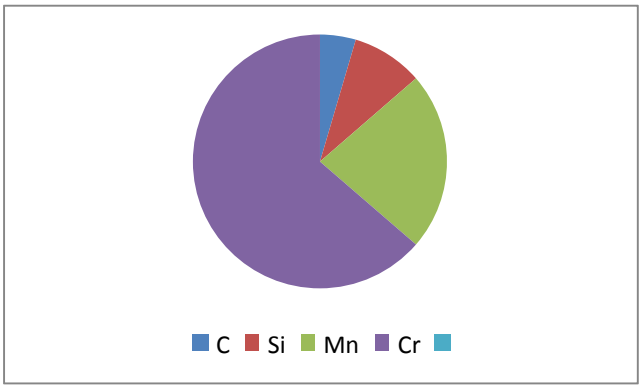

Fig. 6 Chemical Composition of EN-31

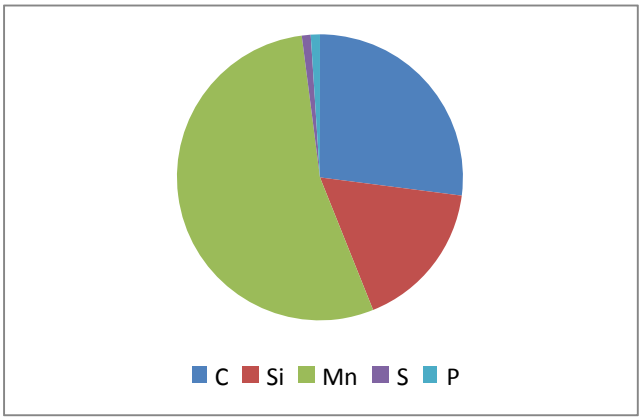

Fig. 7 Chemical Composition of EN-8

Table 3:-Chemical composition of EN-8 (Specimen B)

Table 3

C	Si	Mn	S	P
0.38	0.062	0.78	0.068	0.068

Step 6 – Further various heat treatment processes, such as Annealing, Oil quenching, Tempering of tool steel i.e. EN-31 & EN-8 are done.
Step 7 – The hardness of untreated and treated tool steel are tested.

III. RESULT AND OBSERVATION

Hardness of both the specimens is observed at different temperatures is summarized in **Table 4:**

Table 4

Heat treatment	Temperature (in ^{0}C)	Time (in hours)
Annealing	780^{0}C	16 hour
Oil Quenching	880^{0}C	2 hour 20 min
Tempering	250^{0}C	1 hour 25 min

In **table 5**, the following are the observations, for the hardness of specimen A and B before and after heat treatment process.

Table 5

Heat Treatment	Specimen A		Specimen B	
	EN-31 (Before)	EN-31 (After)	EN-8 (Before)	EN-8 (After)
Oil Quenching	6-8 HRC	60–62H RC	15-17H RC	28–30 HRC
Tempering	6-8 HRC	57–59H RC	15-17H RC	28–30 HRC
Annealing	6 - 8 HRC	9– 10 HRC	15-017H RC	-4 to -5 HRC

IV. MICROSTRUCTURES OBSERVED

MICRO STRUCTURES OBSERVED BEFORE CORROSION:

EN - 8

- Normal: as rolled structure of Pearlite & Ferrite are observed.
- Annealed: well distributed Pearlite in ferrite matrix.
- Oil quenched: martensitic structure.
- Tempered: tempered martensitic.

EN-31

- Normal: Pearlite & ferrite.
- Annealed: Pearlite & ferrite.
- Oil quenched: martensitic structure.
- Tempered: tempered martensite.

Micro structures observed after corrosion:
The change after corrosion on the outer surface was observed and it was seen that pitting occurred on the outer surface due to oxidation of steel. No change was observed on the microstructures of the specimens.

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