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Enhancement of Mechanical Properties of Mild Steel and Stainless Steel through Various Heat Treatment Processes

Dr. M. Jinnah Sheik Mohamed[1], A. Abdul Munaf[2], Dr. Mohammed Musthafa[3]
[1]*Faculty in Mechanical Engineering, Shinas College of Technology, Shinas, Sultanate of Oman*
[2]*Associate Professor/Mechanical Engineering, Rajalakshmi Institute of Technology, Chennai*
[3]*Assistant Professor/General studies, Jubail University College, Kingdom of Saudi Arabia*

Abstract: Engineering materials, mostly steel, are heat treated under controlled sequence of heating and cooling to alter their physical and mechanical properties to meet desired engineering applications. Heat treatment is a combination of timed heating and cooling applied to a particular metal or alloy in the solid state in such ways as to produce desired mechanical properties (yield strength, ultimate tensile strength and percentage elongation). Annealing, normalizing and quenching are the most important heat treatments often used to modify the mechanical properties of engineering materials particularly steels. In this paper, the Authors studied about the mechanical properties like Tensile strength, Yield stress and Elongation for different steels such as Mild steel & stainless steel and find out the effect of various heat treatments like annealing, quenching and normalizing on material properties through testing on samples using UTM. First of all, Metal rods are machined on lathe machine as per drawing of samples. Drawing is based for testing of samples on Universal Testing Machine (UTM) then heat treatment processes are done in muffle furnace on 850^0 C and holding time is 3 hours, and then cooled as per different heat treatment methods. After that heat treated samples are used for testing of different material properties. Result shows that heat treatment will be better for improving material properties of mild steel and stainless steel.
Keywords: Mild steel; stainless steel; annealing; normalizing; hardness; tensile strength; yield stress; UTM

I. INTRODUCTION

Heat treatment is a combination of timed heating and cooling applied to a particular metal or alloy in the solid state in such ways as to produce desired mechanical properties (yield strength, ultimate tensile strength and percentage elongation). Annealing, normalizing and quenching are the most important heat treatments often used to modify the mechanical properties of engineering materials particularly steels. Annealing is the type of heat treatment most frequently applied in order to soften iron or steel materials and refines its grains due to ferrite-pearlite microstructure; it is used where elongations and appreciable level of tensile strength are required in engineering materials [1]. In normalizing, the material is heated to the austenitic temperature range and this is followed by air cooling. This treatment is usually carried out to obtain mainly pearlite matrix, which results into strength and hardness higher than as-received condition. It is also used to remove undesirable free carbide present in the as-received sample [2]. Steels are normally hardened and tempered to improve their mechanical properties, particularly their strength and wear resistance. In quenching, the steel or its alloy is heated to a temperature high enough to promote the formation of austenite, held at that temperature until the desired amount of carbon has been dissolved and then quenched in oil or water at a suitable rate. Also, in the hardened condition, the steel should have 100% martensite to attain maximum yield strength, but it is very brittle too and thus, as quenched steels are used for very few engineering applications. By tempering, the properties of quenched steel could be modified to decrease hardness and increase ductility and impact strength gradually. The resulting microstructures are bainite or carbide precipitate in a matrix of ferrite depending on the tempering process. Steel is an alloy of iron with definite percentage of carbon ranges from 0.15-1.5%, plain carbon steels are those containing 0.1-0.25%. There are two main reasons for the popular use of steel: It is abundant in the earth's crust in form of Fe_2O_3 and little energy is required to convert it to Fe. It can be made to exhibit great variety of microstructures and thus a wide range of mechanical properties. Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, restore ductility after a cold working operation. The reason for its importance is that it is a tough, ductile and cheap material with reasonable casting, working and machining properties, which is also amenable to simple heat treatments to produce a wide range of properties [3]. They are found in applications such as train railroads, beams for building support structures, reinforcing rods in concrete, ship construction, tubes for boilers in power generating plants, oil and gas pipelines, car radiators, cutting tools etc [4]. The objective of the present study is to investigate the effect of heat treatment (annealing, normalizing and quenching) on the mechanical properties of mild steel and stainless steel.

II. EXPERIMENTAL METHODS

A. Material Specifications

The specimen preparation is the initial process of heat treatment. The specimen size should be compatible to the testing machine specifications. Steel samples have been purchased from steel trader. The sample was Mild steel rod Grade Fe 415D (IS 1786:2008) [5]. It is one of the Indian standard specifications of the mild steel or soft steel. The second material purchased from market was stainless steel rod SS 304. This steel contains nickel and chromium with iron and carbon. It is rust proof and has high hardness with moderate ductility. The materials have following properties:

Table 1 Chemical composition of steels

Steel Designation	Percentage in weight (%)							
	C	Mn	Si	S	P	Cr	Ni	Fe
Mild steel	0.25	0.7	0.28	0.05	0.05	--	--	98.67
Stainless steel	0.09	2	1	0.03	0.045	18	8	70.84

Table 2 Mechanical properties of raw material

S.No.	Material	Density (Kg/m^3)	Poisson's Ratio	Young's Modulus (GPa)	Tensile strength (MPa)	Yield strength (MPa)
1	Mild steel	7850	0.30	200	550	450
2	Stainless steel	8098	0.30	210	830	550

B. Specimen Preparation

Material purchased from market have round section rod. The specimen which were tested on UTM for mechanical properties after heat treatment have a standard size and shape as shown in Fig.1. So for obtaining standard specimen for testing, bar of raw material are machined on lathe machine using turning, taper turning and facing operations on them [6].

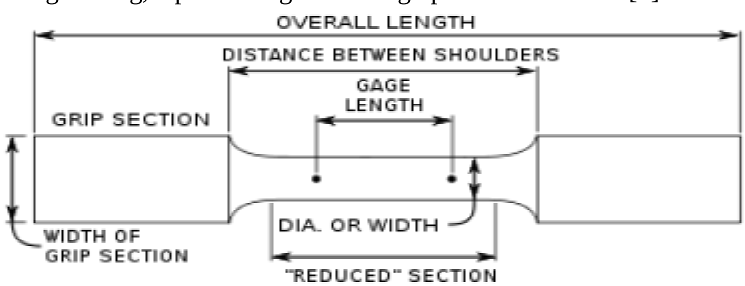

Fig. 1 Testing Specimen

C. Heat Treatment

The properties of metal and alloy can be changed by heating followed by cooling under definite condition to make them suitable for specific purpose or application. Steel can be hardened to resist cutting action and prevent abrasion. The rate of cooling and manner of cooling are the controlling factor in heat treatment process. Heat treatment is not only increases the hardness but also increases the tensile strength and toughness [7]. Different heat treatment processes are carried out in temperature controlled furnaces/Electric Muffle furnace having higher heating temperature up to 1200^0 C as shown in Fig.2. There are various heat treatment processes, such as annealing, normalizing and quenching, etc.

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1) *C. 1 Annealing:* The metal specimens were heated up to a temperature of 950^0 C. At 950^0 C the specimens were held for 2 hours in furnace as shown in Fig.2. Then the furnace was switched off so that the specimen's temperature will decrease with the same rate as that of the furnace [8]. The objective of keeping the specimens at 950^0 C for 2 hours is to homogenize the specimen. The temperature 950^0 C lies above recrystallization temperature, so that the specimens at the temperature gets sufficient time to get properly homogenized .The specimens were taken out of the furnace after 24 hours when the furnace temperature had already reached the room temperature .

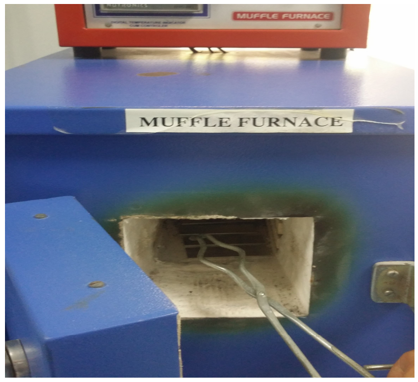

Fig. 2 Electric Muffle Furnace

2) *C.2 Normalizing:* At the beginning the specimen was heated to the temperature of 950^0 C. There the specimen was kept for 2 hours. Then the furnace was switched off and the specimen was taken out. Now the specimen is allowed to cool in the ordinary environment. i.e. the specimen is air cooled to room temperature. The process of air cooling of specimen is called normalizing [9].
3) *C.3 Quenching:* The specimen was heated to the temperature of around 950^0 C and was allowed to homogenize at that temperature for 2 hours. The water/oil bath was maintained at a constant temperature in which the specimen had to be put. After 2 hours of time, the specimen was taken out of the furnace and directly quenched in the bath. After around half an hour the specimen was taken out of the bath and cleaned properly. Now the specimen attains the liquid bath temperature within few minutes [10].

Table 3 Heat treatment time and Temperature in Muffle Furnace for specimens

S.No.	Material	Temp (^oC)	Holding time (Hrs)	Melting Temp. (^oC)
1	Mild steel	900	2	1500
2	Stainless steel	900	2	1450

Table 4 Cooling process for specimens after heating

S.No.	Material	Annealing	Quenching	Normalizing
1	Mild steel	Cooled in furnace for 24 hrs.	Suddenly dip in water	Cooled in air
2	Stainless steel	Cooled in furnace for 24 hrs.	Suddenly dip in water	Cooled in air

D. Tensile testing of specimen on UTM

Tensile testing is probably the most fundamental type of mechanical test in which a sample is subjected to a controlled tension until failure. The properties that are directly measured through tensile test are ultimate tensile strength, maximum elongation and yield strength. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. For an-isotropic materials, such as composite materials and textiles, biaxial tensile testing is required [11].

III.RESULT AND DISCUSSION

A. Effect of heat treatment on tensile strength, yield strength and % Elongation

Result shows (Fig.3) that tensile strength of mild steel for normalizing heat treated specimen is larger than other heat treated or without heat treated specimens. Tensile strength for stainless steel specimen is more in without heat treated (WHT) than heat treated specimen (HT). Result shows (Fig.4) that yield strength of mild steel for normalizing heat treated specimen is larger than other heat treated or WHT specimens. Yield strength for stainless steel specimen is more in without heat treated than other heat treated specimen. Result shows (Fig.5) that elongation in tensile test of mild steel for normalizing heat treated specimen is larger than other heat treated or without heat treated specimens. Elongation in tensile test for stainless steel specimen is more in normalizing heat treated specimen is larger than other heat treated or without heat treated specimens.

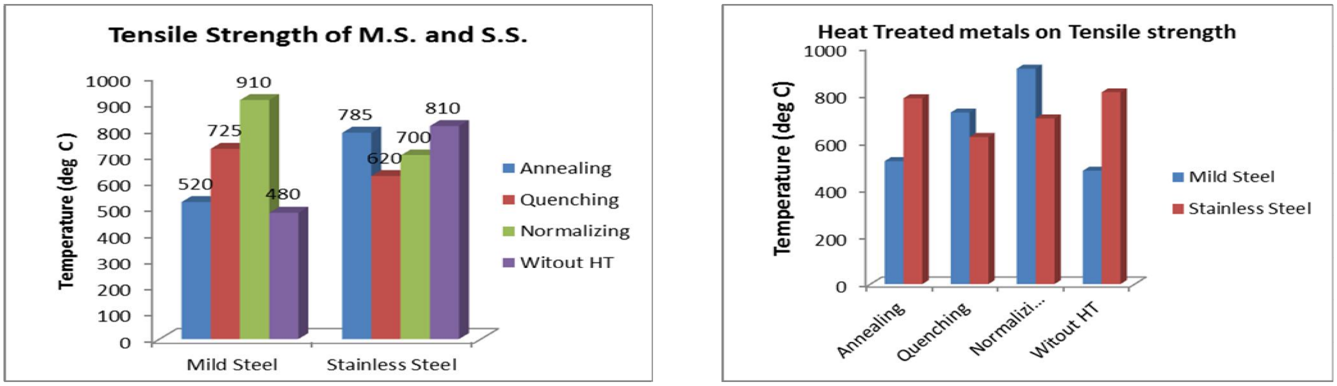

Fig. 3 Results of Tensile strength

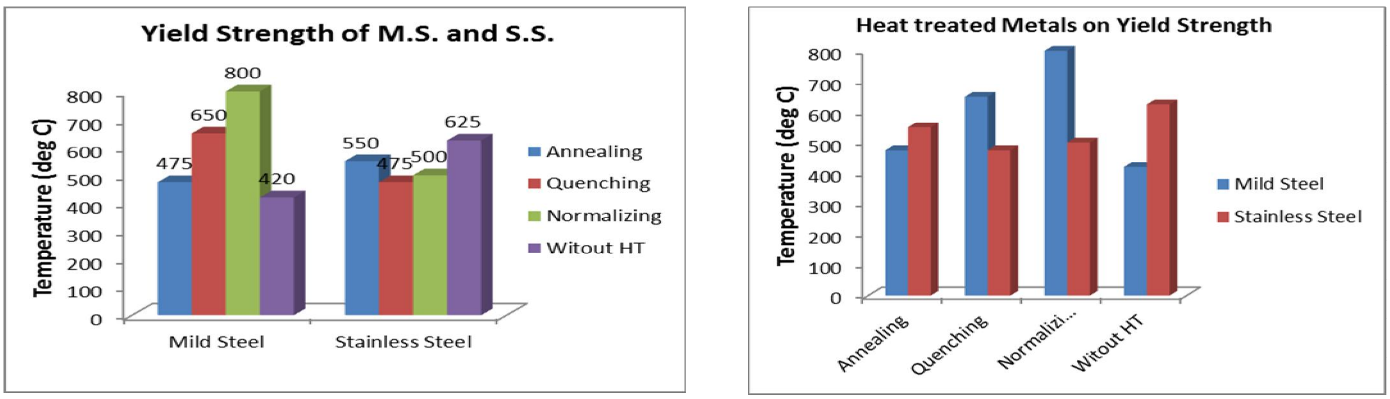

Fig. 4 Results of Yield strength

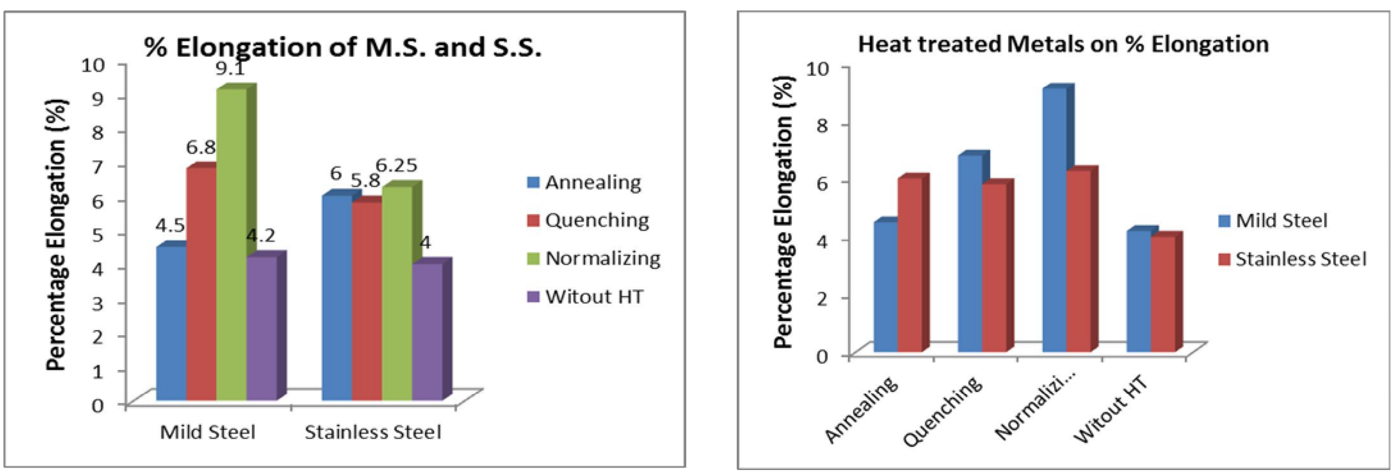

Fig. 5 Results of Elongation in Tension

B. Effect of heat treatment on micro hardness on Mild steel

The microhardness of the steel varied with the heat treatment method. In comparison with the hardness results for all the heat treated samples, the average hardness of the controlled (as-received) sample, 185HB was significantly high as shown in Fig.6. This was followed by the age-hardened samples with 162.5HB, the normalized samples having 136HB and the annealed samples with 129HB. The decrease in hardness when compared with the controlled was expected for annealed, normalized and age-hardened samples.

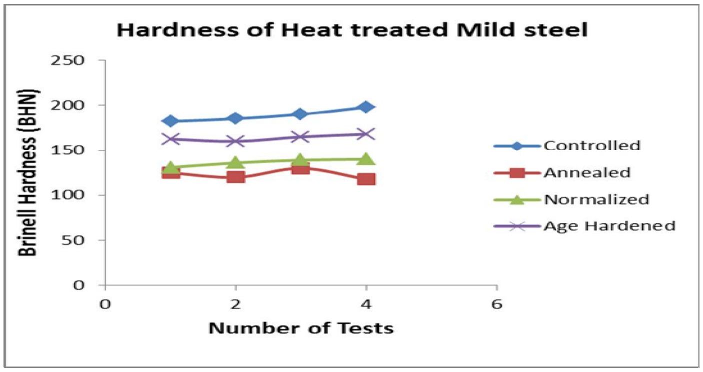

Fig.6 Brinell Hardness Results of heat treated mild steel

IV. CONCLUSIONS

The various heat treatment processes such as Annealing, Normalizing, Quenching, etc have been carried out for different materials and following points have been observed and declared from the research:

Tensile strength, yield strength and elongation have best results in normalized heat treated mild steel specimen than all other specimens of mild steel and stainless steel. Without heat treated stainless steel specimen shows better results for Tensile strength and yield strength than heat treated stainless steel specimens. Without heat treated stainless steel specimen shows poor results for elongation in Tension than heat treated (Normalizing, Annealing and quenching) stainless steel specimens.

In Testing of without heat treated specimens of mild steel and stainless steel, Tensile strength and yield strength are more and elongation is less for stainless steel than mild steel specimen. In stainless steel specimens, Annealing heat treatment gives better results than other heat treatment process. In Mild Steel specimens, Normalizing heat treatment gives better results than other heat treatment process. Also the decrease in hardness when compared with the controlled was expected for annealed, normalized and age-hardened samples.

V. ACKNOWLEDGMENT

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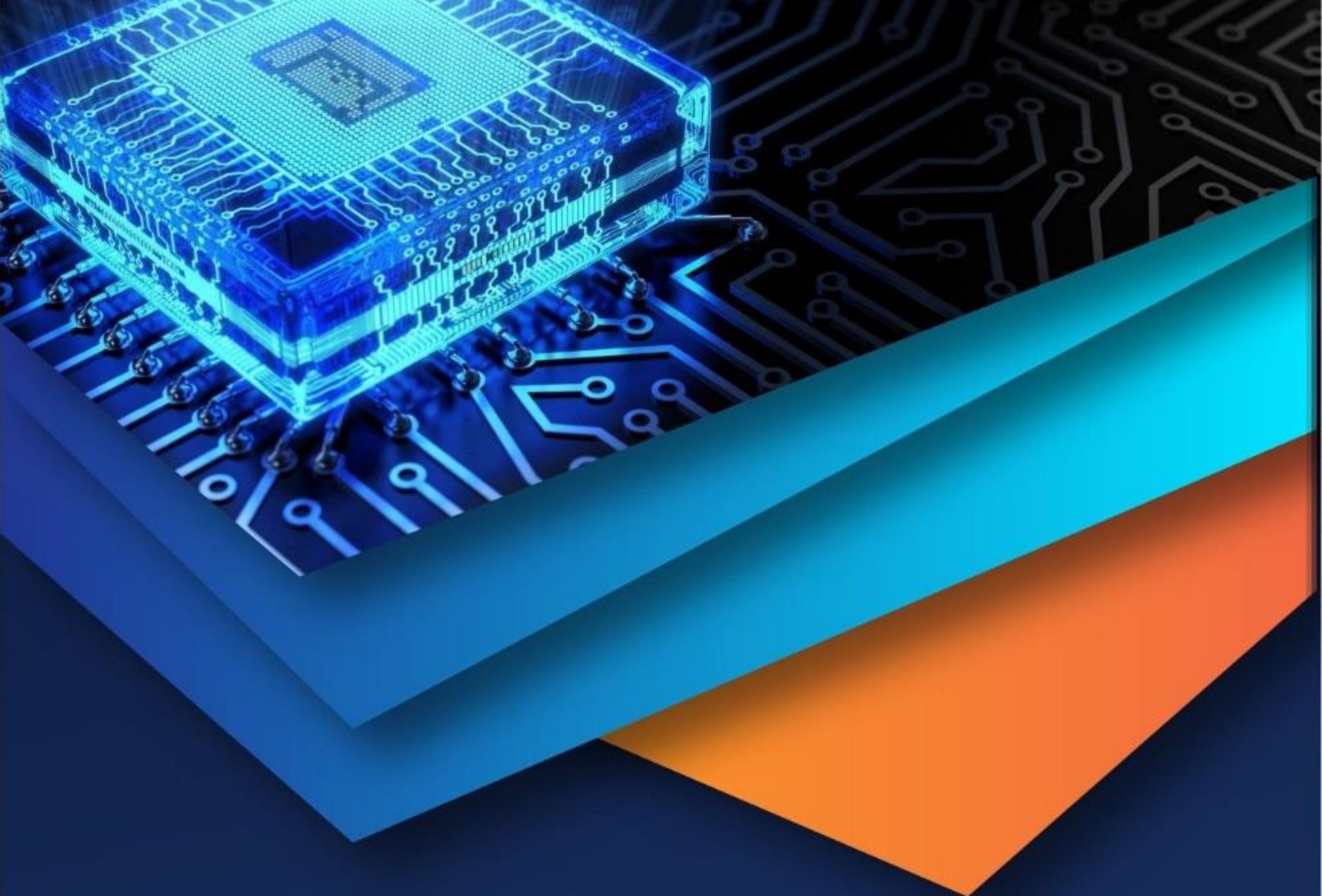

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