



Effect of Various Heat Treatment Processes on Mechanical Properties of Mild Steel and Stainless Steel

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Abstract: In this paper, Author studies about the mechanical properties like Tensile strength, yield stress and elongation for different steels such as low carbon steel and stainless steel and find out the effect of various heat treatment 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 treatments processes are done in muffle furnace on 900^o C and holding time is 2 hrs. Than cooled as per different heat treatment. After that heat treated samples are used for testing of different material properties. Result shows which heat treatment will be better for improving material properties of mild steel and stainless steel.

Keywords: Low carbon steel; stainless steel; annealing; quenching; normalizing; 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 [3].

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 a mainly pearlite matrix, which results into strength and hardness higher than in as received condition. It is also used to remove undesirable free carbide present in the as-received sample [1]. 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 quench in oil or water at a suitable rate. Also, in the harden 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 temperature. 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 Fe₂O₃ 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. Although the number of steel specifications runs into thousands, plain carbon steel accounts for more than 90% of the total steel output. 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.

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. Experiment

A. Material Specifications

The first and foremost job for the experiment is the specimen preparation. The specimen size should be compatible to the Testing machine specifications. We purchased the First steel samples from local steel trader. The sample was Mild steel rod Grade Fe 415D (IS 1786:2008). 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. We can say that it is basically an austenitic matrix. The materials have following properties:

Table 1 Chemical composition of steels

Steel Designation	Constituent percentage in weight							
	C	MN	Si	S	P	Cr	Ni	Fe
Mild steel Fe 415D	0.23	0.60	0.30	0.040	0.040	-	-	Rest
SS 304	0.08	2	1	0.03	0.045	18	8	Rest

Table 2 Mechanical properties of raw material

S.No.	Material	Density ($\times 1000 \text{ kg/m}^3$)	Poisson's ratio	Elastic Modulus (GPa)	Tensile strength (MPa)	Yield strength (MPa)
1	Mild steel rod (Fe 415 D, IS 1786:2008)	7.7 – 8.03	0.27-0.30	190-210	400-550	300-450
2	Stainless steel rod (SS304)	8.03	0.27-0.30	190-210	500-827	207-552

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 figure 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 as shown in fig.2.

Fig. 1 Testing Specimen

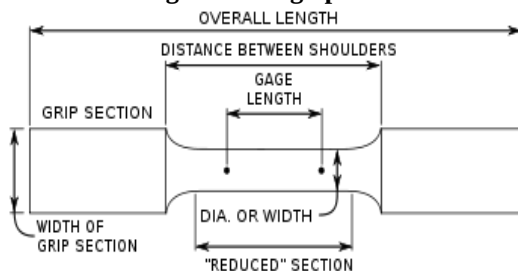


Fig. 2 Specimen Preparation on lathe



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 the manner of cooling are the controlling factor in heat treatment process. Heat treatment not only increases the hardness but also increases the tensile strength and toughness. Different heat treatment processes are carried out in temperature controlled furnaces and over here we use Electric Muffle furnace having higher heating temp. up to 1200°C as shown in fig.3. There are various heat treatment processes, which we have adopted for testing, annealing, normalizing and quenching.

C.1 Annealing

The specimens were heated to a temperature of 900 deg Celsius. At 900 deg Celsius the specimens were held for 2 hour in furnace. Then the furnace was switched off so that the specimens' temperature will decrease with the same rate as that of the furnace. The objective of keeping the specimens at 900 deg Celsius for 2 hrs is to homogenize the specimen. The temperature 900 deg Celsius lies above recrystallization temperature. So that the specimens at that temperature gets sufficient time to get properly homogenized. The specimens were taken out of the furnace after 24 hrs. when the furnace temperature had already reached the room temperature.

Fig. 3 Electric Muffle Furnace



Fig. 4 Annealed stainless steel specimen



C.2 Normalizing

At the very beginning the specimen was heated to the temperature of 900 deg Celsius. There the specimen was kept for 2 hour. 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.

Fig. 5 Normalized stainless steel specimen

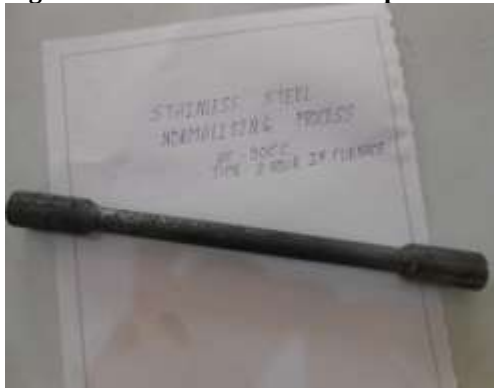


Fig. 6 Quenched stainless steel specimen



C.3 Quenching

The specimen was heated to the temp of around 900 deg Celsius and was allowed to homogenize at that temp for 2 hour. An water/oil bath was maintained at a constant temperature in which the specimen had to be put. After 2 hour 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 temp within few minutes. But the rate of cooling is very fast because the liquid doesn't release heat readily.

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

S.No.	Material	Temp. ($^{\circ}\text{C}$)	Holding Time (Hrs.)	Melting Temp. ($^{\circ}\text{C}$)
1	Mild Steel	900	2	1350-1550
2	Stainless Steel	900	2	1399-1454

Table 4 Cooling process for specimens after heating

S.No.	Material	Annealing	Quenching	Normalizing
1	Mild Steel and stainless steel	Cooled in furnace for 24 hrs.	Suddenly Dip in water/oil bath	Cooled in air room temp.

D. Testing of Specimen on UTM

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a 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 anisotropic materials, such as composite materials and textiles, biaxial tensile testing is required.

Fig. 7 Test specimen in UTM



Fig. 8 Test value on UTM



III. Result and Discussion

Result shows in fig.9 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 than heat treated specimen. Result shows in fig.10 that Yield strength of mild steel for Normalizing heat treated specimen is larger than other heat treated or without heat treated specimens. Yield strength for stainless steel specimen is more in without heat treated than heat treated specimen.

Result shows in fig.11 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. Result shows that elongation is more for stainless steel specimen in all heat treated process.

Fig. 9 Results of Tensile strength

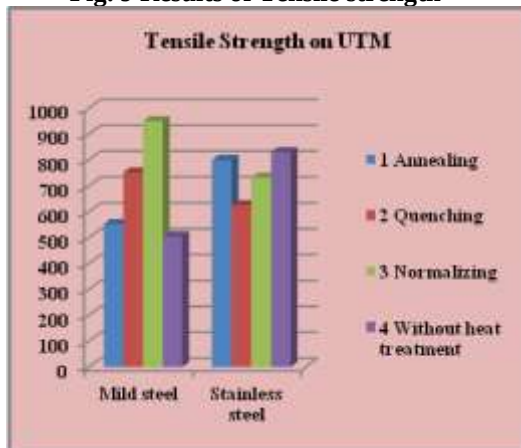


Fig. 10 Results of Yield strength

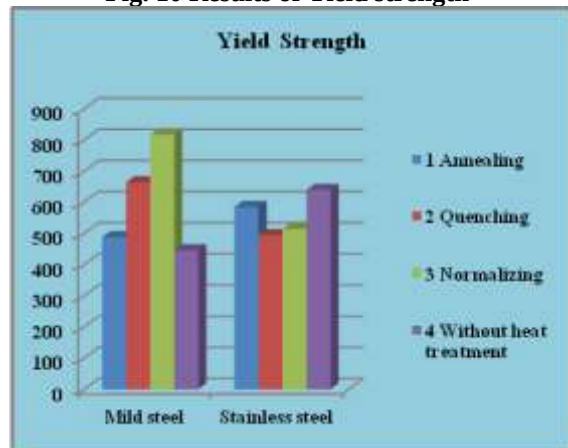


Fig. 11 Results of Elongation in Tension

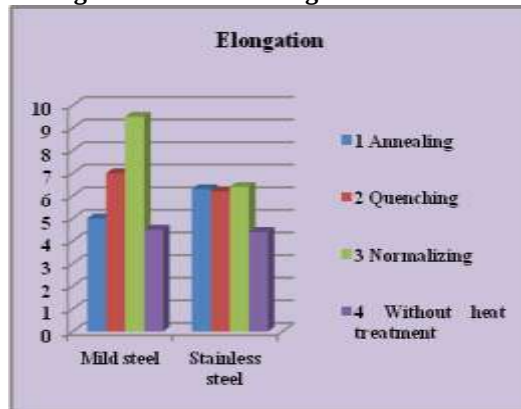


Fig. 12 Results of Tensile strength

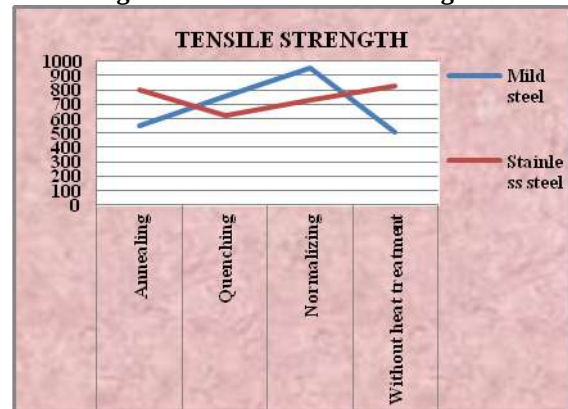


Fig. 13 Results of Yield strength

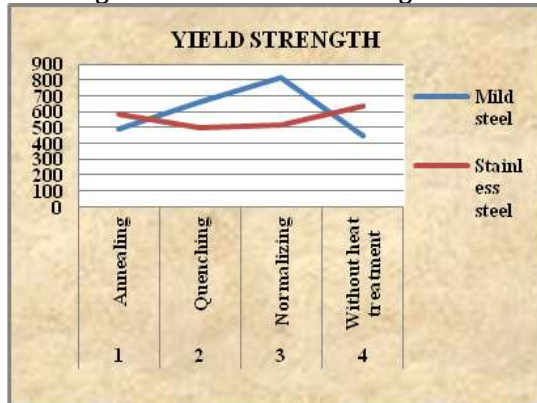
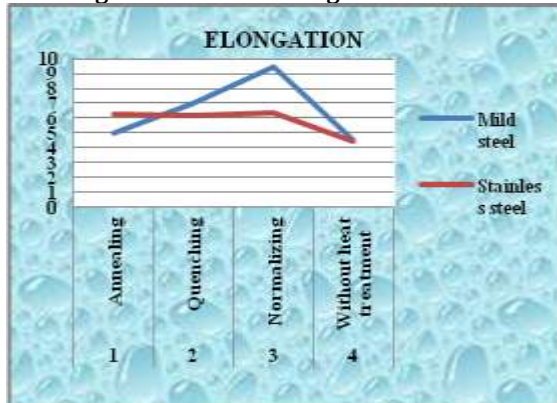


Fig. 14 Results of Elongation in Tension



IV. Conclusions

Following points have been pointed out in 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.

V. References

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