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EFFECT OF HEAT TREATMENT PROCESSESON MATERIAL

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ABSTRACT

The importance of various heat treatment operations on medium carbon steel in order to avoid problems that may arise from incorrect steel material selection or faulty heat treatment operations, which could result in serious disruption in terms of human safety, higher costs, and premature failure of machine components, is of great concern. Heat treating medium carbon steel can easily change mechanical qualities including ductility, toughness, strength, hardness, and tensile strength to meet a specific design purpose. Tensile specimens were made of medium carbon steel and went through several heat treatment methods such as annealing, normalizing, hardening, and tempering. The stress-strain curve of the heat treated samples revealed their stiffness, ductility, ultimate tensile strength, yield strength, and hardness. The yield strength (□y) of the tempered specimen was found to be higher than that of the hardened, normalized, and annealed specimens, presumably due to grain re-arrangement. The ultimate tensile strength (□u) was found to be in the following order: hardened>tempered>normalized>annealed.

KEYWORDS: *Austenite, Ductility, Medium Carbon Steel, Marten site, Strain Hardening Parameter.*

1. INTRODUCTION

Heat treatment(1) is the process of heating and cooling materials under controlled conditions in order to affect their material properties. Heat treatment is also used to improve the strength of materials by changing specific manufacturability objectives, particularly after the materials have been subjected to substantial pressures such as forging and welding(2). However, it was previously recognized that steel's mechanical properties were closely linked to the microstructure generated during heat treatments which are used to attain high hardness and tensile strength while maintaining ductility(3). The material modification technique alters the behaviors of steels in a positive way to increase service life, such as stress relief or strength qualities, such as cryogenic treatment, or other desirable properties(4).

Heat treatment is divided into three categories:

1. Thermal treatment, which includes softening processes such as annealing and normalizing, and hardening processes such as hardening and tempering;
2. Thermo chemical processes(5) such as carburizing, nitriding, and boronizing; and
3. Thermo me chemical processes, which include mechanical working operations during the heat treatment cycle.

Though heat treatment is not a new field, it has yet to be put to good use because most studies focus on the procedure as a whole(6). It has not been localized for an improvement/modification on attaining the desired outcomes from these steel materials that abound in our daily lives, especially where the majority of steel goods are made from recycled waste(1). As a result, these tests must be carried out in order to ensure that the material compositions are correct before they are put to final use(7).

The current research focuses on the impact of heat treatment on the mechanical characteristics of medium carbon steel, with the goal of improving the steel's structural and physical suitability for individuals involved in the design, manufacture, and maintenance of steel products(8).

2. METHODSOFANALYSES:

The experiment was carried out in the following way to determine the effect of heat treatment on medium(9).

Carbon steel:

(i) The tensile specimens were made from 0.30 percent carbon steel.

(ii) The medium carbon steel is heat treated.

(iii) Tensile test of medium carbon steel to see how it will behave following treatmen**t**

2.1 Preparation of the Tensile Specimens:

Thematerialusedforthisstudyisamediumcarbonsteelwithcarboncontentof0.30%carbonasdetermined byX ray diffraction technique. The specimens were then prepared for atensiletest (10) using a standard format of ASTM .

2.2 Heat treating the Medium Carbon Steel

To heat treat the medium carbon steel, standard heat treatment processes were used (11). For each process, five distinct samples were prepared, and the average values were obtained, on which the analyses were based.

2.3 Tensile Test of the Medium Carbon Steel

The tensile test was performed on the specimens after they had been heat treated as needed to assess the mechanical characteristics of the steel and to compare it to the non-heat treated specimen that had also been subjected to the same tensile test(4).

3. DISCUSSION

3.1.1 Hardening process:

At 850degree C. temperature, there is transformation of the steel to austenite(12). The samples were retained at this temperature for a period of two hours (because of its mass) during which the transformation must have been completed, after which they were later removed from the furnace and dropped inside different containers of water for rapid cooling to room temperature. The hardening(13) operation was carried out on five medium carbon steel samples having the same dimensions(14).

3.1.2 Tempering process:

The as-quenched marten site in hardened carbon steel specimens is not only highly hard but also fragile. The presence of marten site causes the brittleness(15). Tempering, on the other hand, removes the brittleness. Hardness, ductility, toughness, strength, and structural stability are all improved by tempering. Tempering entails heating the hardened steel specimen to 350 degrees Celsius. The prevalent marten site is an unstable structure at this temperature, and the carbon atoms diffuse from marten site to create a carbide precipitate, as well as ferrite and cementite. This method enables for microstructure(14) changes to lower the hardness to the desired level(16).

3.1.3 Annealing process:

The specimen was subjected to a comprehensive annealing process(17), which involved slowly heating the metal to 870°C. It's kept at this temperature for long enough (approximately an hour) for all of the material to turn into austenite. It is then carefully cooled to room temperature inside the furnace. Coarse pearlite with ferrite or cementite makes up the grain structure(14).

3.1.4 Normalizing process:

Each sample of medium carbon steel that needed to be normalized(11) was placed in the furnace and heated to 850°C. The samples were kept at this temperature for two hours to ensure complete austenite transformation. They were afterwards taken out of the furnace and placed in the open air to cool. Meanwhile, to act as control samples, another set of sample specimens that had not been heat treated were obtained immediately for the tensile test(17).

3.2 MaterialTesting

The varied heat treated samples were taken for the tensile test after the successful heat treatment operation. The test was carried out on a Universal Standard Testing Machine(18). All of the specimens were tensile tested at different strain rates of 200, 500, 1000, 1500, and 1650 mm/min.Each specimen was introduced one by one into the machine jaws, and after properly fastening the specimen at both ends, a tensile test was performed up to the fracture limit. Figure 1.

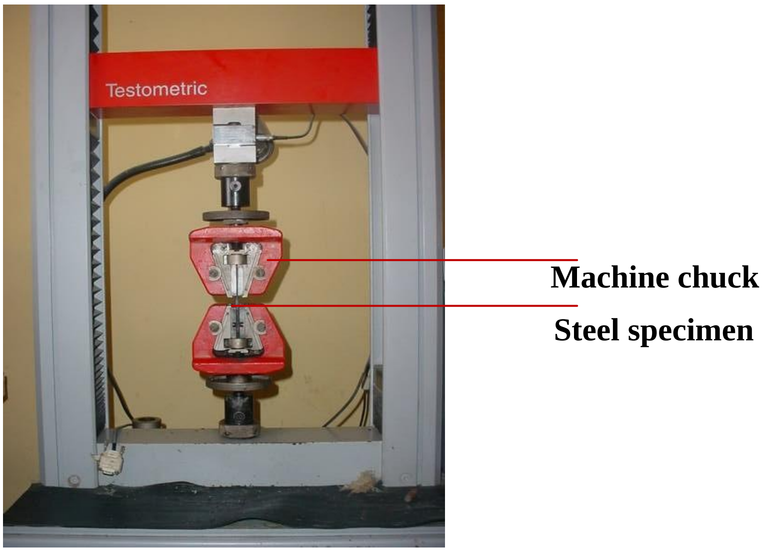

Figure1: The arrangement of the specimen on the machine chuck.

For all of the specimens that were used for further investigation, the machine recorded the stress, strain, elongation, yield strength, and ultimate tensile strength(19). The engineering stress/strain values were calculated using the stress/strain values received from the tensile test, which were based on the original cross sectional area of the test specimens(18).

The heat-treated specimens were then put through a tensile test with a typical universal testing machine called a U.T.M (Ten so meter), which is calibrated in Newton units. Figures 2 to 5 depict the engineering stress-strain curves derived from the test for annealed, normalized, tempered, and hardened materials, respectively(20). The data generated from these graphs for each specimen was translated to actual stress-strain data using equations 1 and 2 and examined for various heat-treated specimens using equations 1 and 2. To get material-related parameters for each specimen, a non-regression analysis was used. Table 1 lists the material-related properties discovered(21).

TABLE1: THE MATERIALS PROPERTY FOR DIFFERENT HEAT TREATED SPECIMENS BASED ON TRUE-STRESS TRAIN DATA

Operation	*(□y)(MPa)*	*□u(MPa)*	*C*	*n*	*m*
Annealed	270	410	0.0562	0.0267	0.98495
Normalized	330	460	0.0830	0.0308	1.1144
Tempered	440	610	0.0274	0.2500	1.12615
Hardened	650	700	0.0143	0.0400	0.8442

From Table 1, *(□y)* is the yield strength (kN/mm^2) while □*u* is the ultimate tensile strength of the material (kN/mm^2) at room temperature and a strain rate of 1/s. C is the strain – rate sensitivity constant, n is the strain hardening parameter and m is the thermal softening parameter for each specimen.

The yield strength (□*y*) of the tempered steel specimen was found to be higher, presumably due to grain re-arrangement caused by the subsequent tempering procedure(22). Hardened specimens have higher yield strength than normalized and annealed specimens, whereas normalized specimens have higher yield strength than annealed specimens, which have the lowest yield strength. Plain carbon steel has a good mix of strength and ductility because to the dual phase strengthening mechanics(23). The steel's hardness rises as the cooling rate rises, as does the percentage of pearlite, which rises as the percentage of mertensite rises. The ultimate tensile strength (u) was found to be in the following order: hardened > tempered >normalized> annealed, presumably due to the refining of the primary phase after repeated cooling operations. The lower the slope of the stress-strain curves in the plastic area, and thus the lower the strain hardening parameter, the higher the toughness of a material(24). As the strain hardening parameter rises, the material's stress rises as well.

The graphs also showed that, with the exception of the hardened specimen, all of the heat treated specimens had a significant increase in toughness, indicating that, while hardened material has a very high ultimate tensile stress (□*u*), it does so at the expense of toughness, so where toughness is a major concern, the material should be oil tempered for a satisfactory result(25).

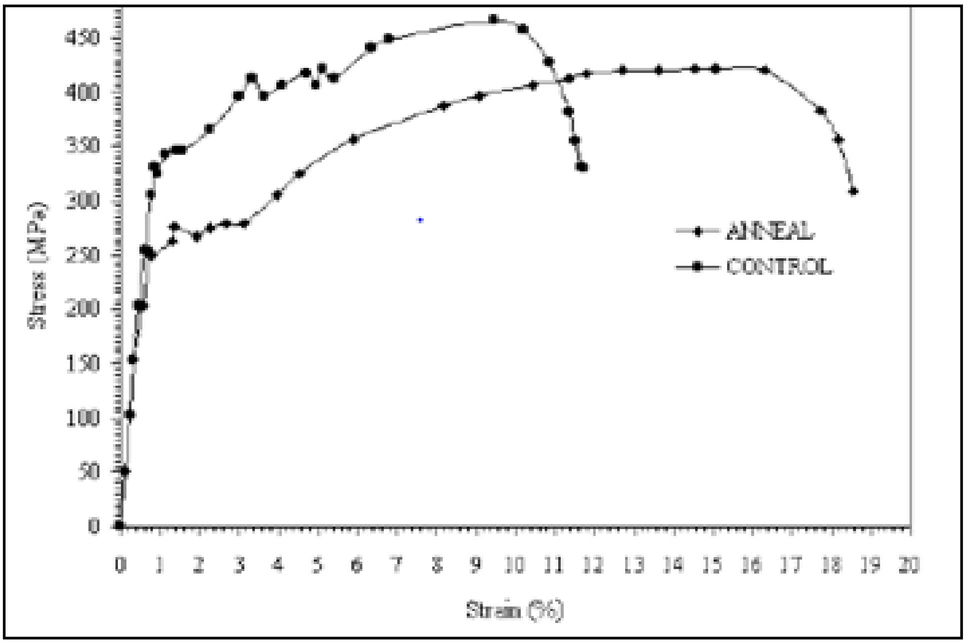

Figure 3: Stress versus strain for annealed and control specimen

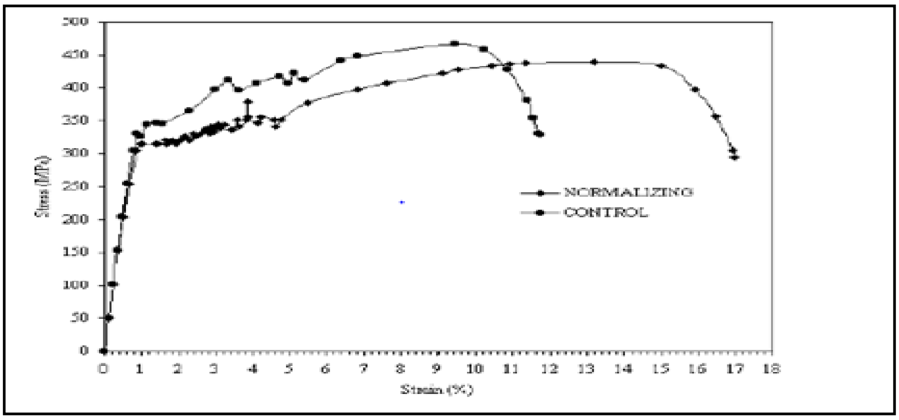

Figure 4: **Stress versus strain for normalized and control specimen**

The strain produced for each of the specimen was in the order of annealed > normalized >tempered > hardened as observed from Figures 2 - 5 which gave a clear indication of the final state of the materials as a result of the treatment received.

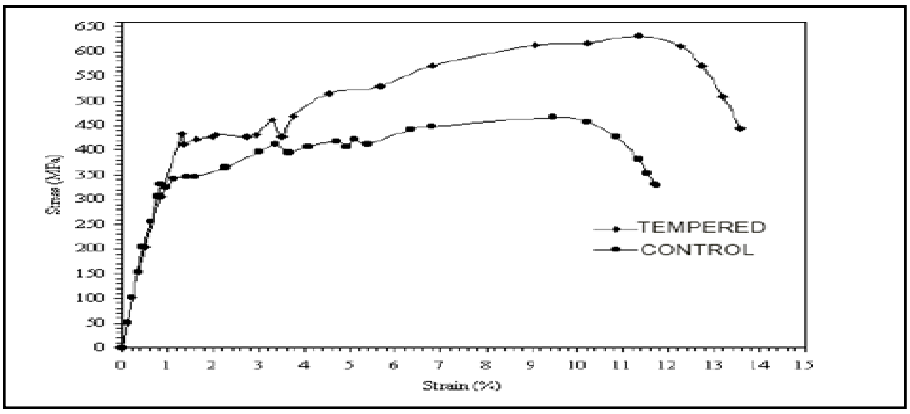

Figure 4: Stress versus strain curves for tempered and control specimen

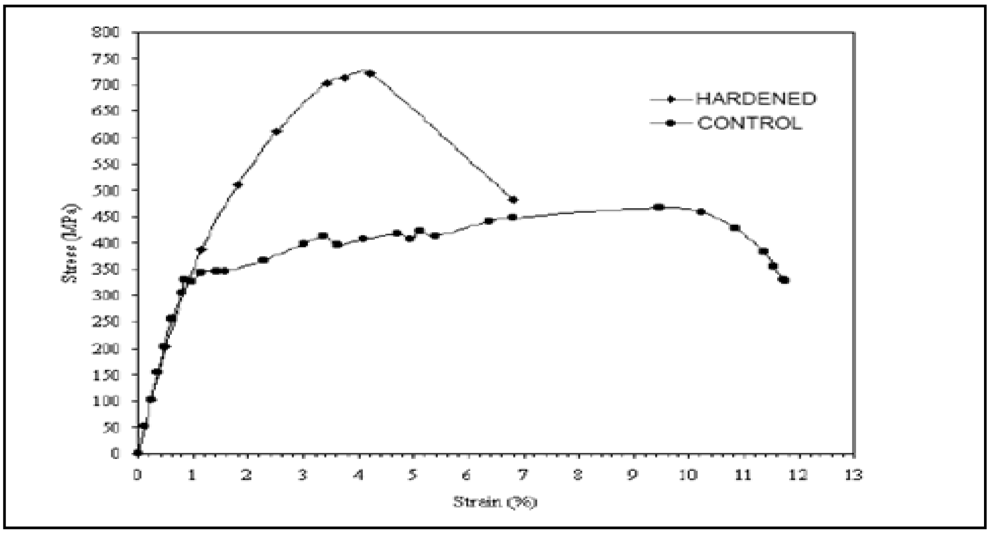

Figure 5: Stress versus strain curve for hardened (water quench)

3. CONCLUSION

It can be deduced from the findings that mechanical properties are highly dependent on the various types of heat treatment operations and cooling pace. As a result, a suitable method of heat treatment should be chosen based on the properties and applications that may be required for any design purpose. Annealing medium carbon steel will produce adequate results for high ductility and minimum toughness. As a result, it's critical to describe the condition of the carbon steel when it's purchased so that testing may be performed to confirm the material's compositions before it's used.

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