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Effect of Quenching and Heating Temperature on the Microstructure and Mechanical Properties of AISI 1020

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Abstract– Sample of medium carbon steel AISI 1020 was examined after heat-treated at 900 ºC in a muffle furnace for 1 hour before quenching in poll of water maintained at 10, 20, 30, 40 and 50 °C respectively. The mechanical behavior of the samples was investigated using universal tensile testing machine for tensile test and Brinell hardness machine for hardness testing. The tensile strength and hardness values of the quenched samples were relatively higher than that of the unheated-treated sample, suggesting improved mechanical properties. However, samples quenched in water displayed better mechanical properties compared with that of unquenched samples.

Keywords – AISI 1020, Tensile strength, Hardness value, Carbon steel, Quenching.

1. INTRODUCTION

Steel is arguably world's most "advanced" material. It is a very versatile material with wide range of attractive properties which can be produced at a very competitive production cost [1]. It is an alloy of iron with definite percentage of carbon ranges from 0.15 - 1.5% while plain carbon steels are those containing 0.1 - 0.25% [2] [3]. Literature sources revealed that the applications of steels for engineering components require a complete understanding of material properties and design requirement. [1] [4] revealed that the mechanical strength of carbon steels can be improved by quenching in appropriate medium. However, the major influencing factors in the choice of the quenching medium are the kind of heat treatment, composition of the steel, the sizes and shapes of the parts. The subject of mechanical testing of materials is an important aspect of engineering practice [5].

Generally, the mechanical properties of plain carbon steels increases with the increase carbon concentration dissolved in austenite prior to quenching during hardening heat treatment, which may be due to transformation of austenite into martensite[3]. Therefore, the mechanical strength of medium carbon steels can be improved by quenching in appropriate medium. The major influencing factors in the choice of the quenching medium are the kind of heat treatment to be employed, composition of the steel, the sizes and shapes of the parts.

2 METHODOLOGY

2.1 Material and Methods

The material used for this work is AISI 1020 mild steel; 10mmØ by 1200mm long. The sample was obtained from Nigeria Rolling Mill, Oshogbo, Nigeria. The chemical composition of the steel sample was determined at the Universal Steel Limited, Lagos. The as-received steel sample was cut into eleven pieces, 10mm by 100mm for the heat-treatment and mechanical properties. Machining of the samples for hardness and tensile strength (Fig. 1) was done in accordance with ASTM E18 standard (1992).

TABLE 1
Composition analysis of AISI 1020 (wt. %)

C	Si	S	P
0.189	0.207	0.021	0.22
Cr	Mn	Ni	Cu
0.101	0.497	0.073	0.174
Nb	Al	W	Mo
0.0050	<0.0001	<0.001	0.0026
V	B	Ti	Fe
0.0018	0.0011	0.0004	98.7
Co	Pb	Zn	As
0.0092	0.012	0.0016	0.0014
Bi	Sn	Ca	Ce
0.0009	0.0069	0.0003	0.0023

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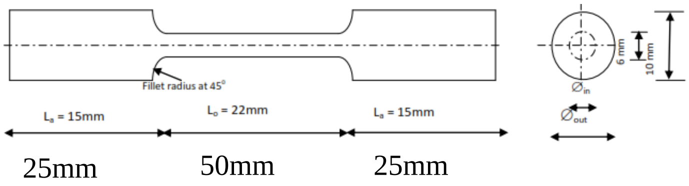

Fig. 1: Machined specimen for tensile test

2.2 Heat-treatment process

The heat-treatment process was carried out using an electric muffle furnace-vecstar 232 model with temperature rating of 1200 ºC. The prepared samples were heated to temperature of 920 ºC for 1 hour. Each of the samples was quenched in water maintained at temperatures of 10, 20, 30, 40 and 50 ºC respectively. A thermocouple was attached at a specified location on each of the specimen to obtain the actual temperature of steel independently because of a possible temperature variation to that of the heating furnace.

2.3 Determination of mechanical properties

Mechanical properties of the heat-treated samples were determined using standard methods. For hardness testing, all the samples were grinded and polished. Average Brinell Hardness Number (BHN) readings were determined bytaking two hardness readings at different positions on the samples, using a Brinell hardness tester. For tensile properties, the tensile specimens were loaded into a 2000 kg MosantoTensometer hooked up to a data logger. Load-elongation data were recorded and converted into stress-strain graphs. Yield strength, tensile strength, Young's modulus and % elongation were determined in accordance with ASTM E18 standard test procedures.

3.RESULT AND DISCUSSION

Presented in Table 2 is the result of the AISI 1020 sample heat-treated at 900 °C, quenched at five different quenchant temperatures. The as-received sample has hardness, tensile strength, yield strength, % elongation and Young modulus values of 179 BHN, 1004.56 N/mm², 1058.12 N/mm², 9.975 % and 7852.05 N/mm².

TABLE 2
Properties of heat-treated AISI 1020 steel at different quenching temperature

Heating Temp. °C	Quenchant Temp. °C	Tensile Strength (N/mm^2)	Percentage Elongation	Young Modulus (N/mm^2)	Yield Strength (N/mm^2)	Hardness (BHN)
	10	1082.990	11.893	8253.079	1082.990	183
900	20	1676.467	16.930	8325.519	1680.676	156
	30	1694.987	15.207	12061.015	1695.829	216
	40	1766.120	16.283	12211.025	1766.120	221
	50	1880.606	21.827	8940.925	2030.028	161

3.1 Effect of quenchant temperature on hardness

Fig. 2 shows the graph of hardness values of the heat-treated samples against the quenchant temperature. The hardness values of the steel samples increases considerably with the quenchant temperature. As clearly shown in theFig. 2, at heat-treated temperature of 910 °C and quenchant temperature of 40 °C, maximum hardness value of 161 was obtained.

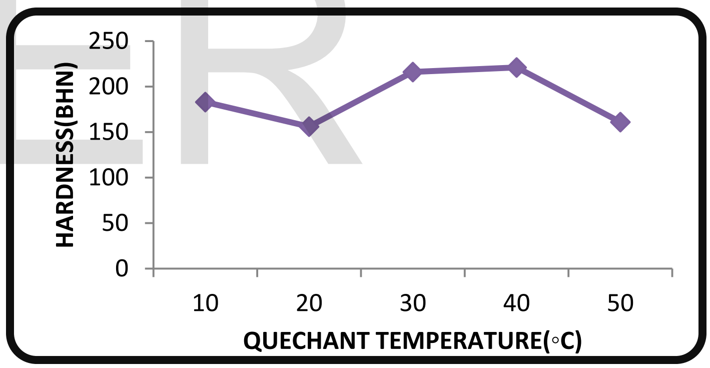

Fig. 2: Graph of hardness against quenchant temperature

3.2 Effect of quenchant temperature on tensile strength

Presented in Fig. 3 is the tensile strength against the quenchant temperature. It was found that as the temperature of quenchant increases, the tensile strength of the material increases progressively. This may be attributedto the presence of minor alloying elements such as Cr, Cu and Sn present in the material. Thus, increase in quenchant temperature favor the tensile strength of the heat-treated sample.

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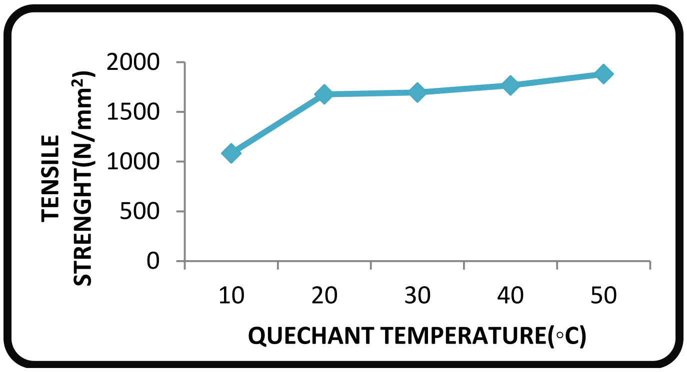

Fig. 3: Graph of tensile strength against quenchant temperature

3.3 Effect of quenchant temperature on percentage elongation

As depicted in Fig. 4, the temperature of quenchant increases in respect to the percentage elongation of thematerial. It was found that at quenchant temperature 50 °C maximum % elongation of 21.827% was obtained.

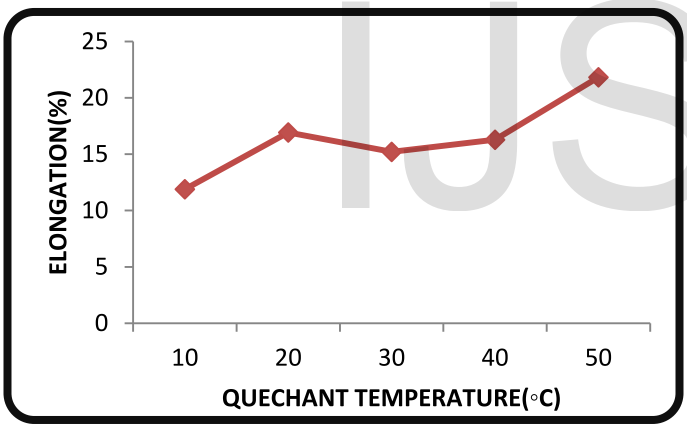

Fig. 4: Graph of elongation against quenchant temperature

3.4 Effect of quenchant temperature on modulus of elasticity

Fig. 5 shows the relationship between young modulus and quenchant temperature. Maximum modulus was observedat quenchant temperature of 40 °C above which there a decrease in young modulus of the material.

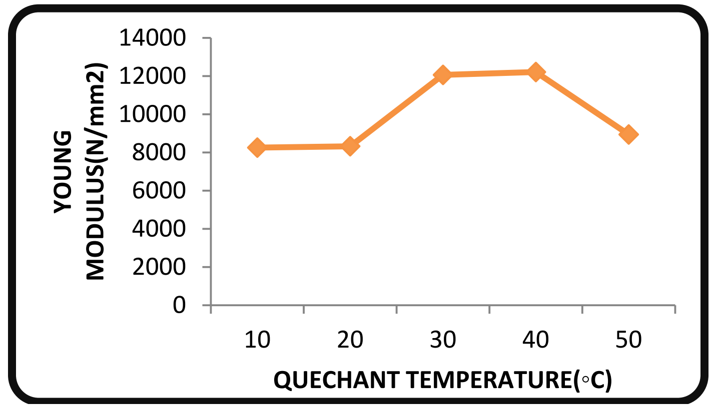

Fig. 5: Graph of young modulus against quenchant temperature

3.5 Effect of quenchant temperature on yield strength

Presented in Fig. 6 is the relationship between the yield strength and quenchant temperature. It was found the yield strength of the heat-treated sample increase proportionately with the temperature of quenchant. As clearly shown in theFig. 6, at heat-treatment temperature of 910 °C and quenchant temperature of 50 °C, maximum the yield strength value of 2030.028 N/mm2 was obtained. Thus, the higher the quenchant temperature the higher the yield strength.

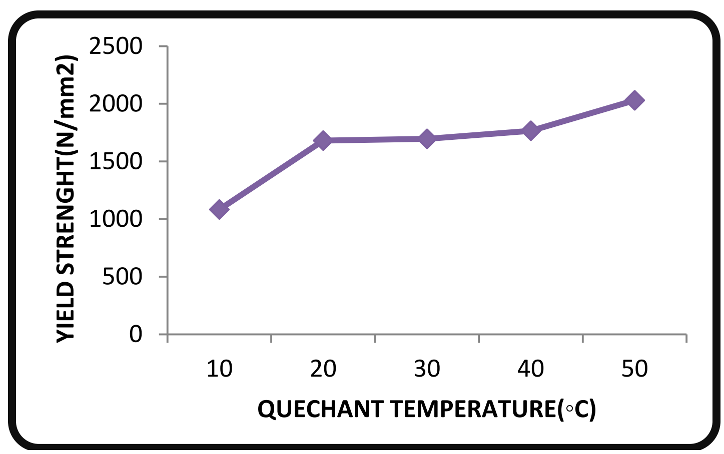

Fig.6: Graph of yield strength against quenchant temperature

4. CONCLUSION

Effect of heat-treatment and quenchant temperature was observed on AISI 1020 steel sample. The study revealed

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that high quenchant temperature had better improvement on the mechanical properties of the steel samples. Generally, it was found that the higher the quenchant temperature the higher the mechanical properties of the steel samples.

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