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EFFECT OF DIFFERENT QUENCHING MEDIA ON MECHANICAL PROPERTIES OF AISI 1018 LOW CARBON STEEL

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ABSTRACT

In this work, the mechanical properties of AISI 1018 low carbon steel after been treated by different quenching media (water, boiling water, boiling salt water, ice water, ice salt water) were evaluated. The microstructure of the specimen was examined by using optical microscopy (OM), while the mechanical properties were evaluated by using tensile test and hardness test. The results of this investigation showed that improving in mechanical properties such as yield strength about 580 MPa, ultimate tensile strength about 680MPa and Vickers hardness about 263.03Hv for the specimen quenching by ice water, and the hardness for ice salt water 290.8 Hv. For ice salt water quenching media, the formation of martensite phase more than another quenching media, this is revealed obviously by microstructure examination. Also retained austenite exists in as a secondary phase as a result of very fast cooling for ice salt water quenching media.

KEYWORDS

Heat treatment, quenching media, mechanical properties.

1. INTRODUCTION

The applications of steel for engineering parts are required a complete understanding the properties of the material and requirement of design [1]. For engineering materials, the mechanical properties must be the main an important requirements. The requirement mechanical and physical properties can be improved by the manufacturing method and the heat treatments [2]. Recently fast development in technology to achieve the best performance for steel alloys can be altering their mechanical properties by forming processes or heat treatments. Heat treatments involve heating and then cooling of alloys to alter the mechanical and physical properties without changing shape of the product. The main mechanical properties can be altering by heat treatment, the yield strength, tensile strength, hardness, elongation and impact resistance. Thermal and electrical conductivity are also can be alter by heat treatment [3]. Low carbon steel is widely used industrially for many engineering manufacturing and applications because of this type of steel are cheap and easy to fabricate. Mechanical properties of low carbon steel such as hardness and strength increase with increase in the concentration of carbon which dissolved in the austenite phase prior to the quenching heat treatment [4]. Low carbon steel is widely used to produce car body panel, automotive industry, beams for building, pipelines in oil application and the rods which reinforced the concrete because of this steel occupied 90% of engineering applications [5]. Steels are extremely hardened and the tempered to improve mechanical properties such hardness, strength and wear resistance. Quenching heat treatment is done at austenizing temperature to form austenite phase for enough time to promote the carbon to dissolve and then quench in suitable quenching media such as water, oil or polymer to achieve martensite, which is brittle and make the steel to use in very little applications. Choice the quenching medium depends on the chemical composition of the steel alloy, shape and size of the parts [6].

There are many investigation were published in this field investigated the effect of quenching treatment on mechanical properties of low carbon steel [7]. This treatment occurred by quenching from 900̊C and then cooling to the $\alpha + \gamma$ region and quenching, followed by tempering. The results of this work show that improvement in mechanical properties. While Amite kumar Tanwer studies the effect of different heat treatment such as annealing, normalizing and quenching on mechanical properties of low carbon steel and stainless steel [8]. The results of this work show an improvement the mechanical properties like tensile strength, yield strength and elongation for each low carbon steel and stainless steel. Whilst studied the influence of different quenching media such as water, oil ad brine [9]. The results of this work showed the highest values of mechanical properties were obtained such as tensile strength, hardness and decreasing in ductility and impact strength for brine more than water and oil, a studied the effect of quenching media (water, oil, polyvinyl chloride) on mechanical properties [10]. The results of this investigation showed that increasing in tensile strength, yield strength and constant hardening exponent (n) for water more than for oil or polyvinyl chloride.

The aim of this work is to study the effect of different quenching media (water, salt water, boiling water, boiling salt water, ice water and ice salt water) on mechanical properties of AISI1018 low carbon steel.

2. EXPERIMENTAL PROCEDURE

Material used

AISI 1018 low carbon steel specimens were machined by using lathe machine to the standard dimensions for tensile test and hardness. Table 1 and Table 2 Show the chemical composition and mechanical properties of AISI 1018 low carbon steel respectively.

Table 2: Mechanical properties of low carbon steel AISI 1018 [11].

Tensile strength (MPa)	Yield strength, (MPa)	Vickers Hardness	Modulus of elasticity (GPa)	Poisson's ratio	Elongation (%)
440	370	131	205	0.29	15

Preparation of the specimens

The specimens were prepared for tensile according to ASTM E8/E8M-09 as shown in Figure 1 [12]. Universal tensile machine (UTM) was used to evaluate the tensile properties. While the specimen for hardness test was machined at 1.5 cm in length and 1 cm in diameter and then the specimens were grinded by using emery papers with grit size 500 and 1000 μm. After grinding, the specimen was polished by alumina.

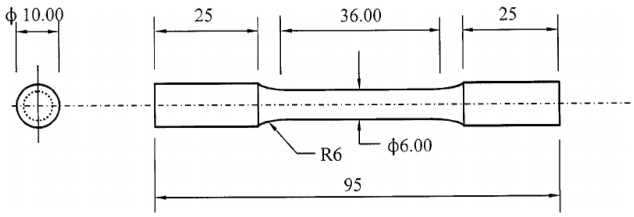

Figure 1: Tensile test specimen of low carbon steel ASTM E8/E8M-09 [12]

Heat treatment

The specimens for hardness test and tensile test were treated by quenching in various different quenching media such as:
1- Water.
2- Boiling water.
3- Ice water.
4-Salt water (10wt. % NaCl)
5- Boiling salt water
6- Ice salt water

Heat treatment was carried out by using electrical carbolated muffle furnace. The specimens were heated to 900°C with the soaking time 1 hr. and then cooling in different quenching media (water, boiling water, ice water, salt water, boiling salt water and ice salt water).

3. MECHANICAL TESTS

Tensile test

Tensile test was carried out by using universal tensile machine (UTM). The specimens were pulled until reaching the failure point and then mechanical properties such as tensile strength, yield strength, ductility and modulus of elasticity were measured. Tensile test was done for the specimens before and after heat treatment

Hardness test

Vickers hardness test was done to determine the hardness of the specimens before and after heat treatment. This test was performed by using 10 kgf as applied load for 15 sec. Vickers hardness number was calculated by using the following equation [13].

V.H.N=1.8544× $\frac{F}{d^2}$ (kgf/mm^2) .... (1)

At least three readings were taken for each specimen, and then average value of pyramid indenter diameter was measured.

4. MICROSTRUCTURE EXAMINATION

Microstructure examination was performed by using optical microscopy (OM) with magnification 200x to evaluate the phases for each quenching media. The specimens before and after quenching heat treatment were grinded by emery papers at grit size 320, 500 and 1000 μm. After grinding, the specimens were polished by using Alumina and then etched by Nital (2% HNO_3 + 98% alcohol)

5. RESULTS AND DISCUSSION

Microstructure Analysis

The microstructure of AISI 1018 low carbon steel before and after heat treatment in different quenching media at constant temperature 900°C for 1 hr. as soaking time are shown in Figure 2. Showing pearlite (dark) phase in ferrite (white) matrix.

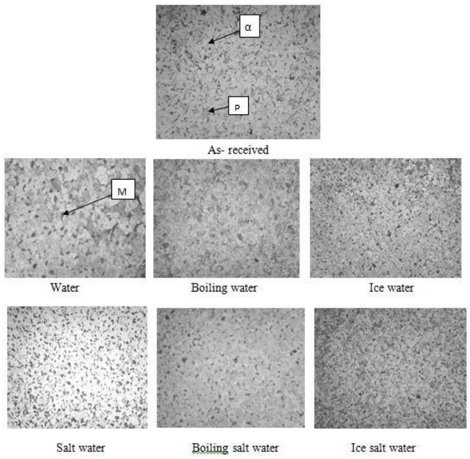

Figure 2: OM photomicrographs of the specimens after heat treatment.

Figure 2 shows that the microstructure of the specimen as-received is composed of ferrite more than pearlite, while the microstructure of the specimen quenched in ice salt water composed of martensite phase at highest proportion than the another quenching media (water, salt water, boiling water and boiling salt water) with little proportion of ferrite which cannot be transformed during the quenching [14]. It is perhaps attributed to that the ice salt water leads to rise cooling rate more than other quenching media and in turn leads to increase formation of martensite more than another quenching media. Ice salt water leads to form martensite more than another quenching media because of cooling rate more than water, salt water, boiling water and boiling salt water which accelerates the transformation of austenite to matensite. Increasing austenizing temperature make the grains to grow extremely, which in turn create coarse grains of martensite [15].

The quenched specimens were retreated by tempering heat treatment to alter hard and brittle martensite to sorbite phase, which it consist of fine carbides dispersed in the ferrite matrix. Tempering heat treatment will improved the mechanical properties such as increasing the ductility and young modules.

Mechanical properties analysis

The improving in mechanical properties such as tensile strength and hardness for the quenched specimens comparing with the specimen as-received is return to the microstructural transformation during quenching treatment. Figure 3 and Figure 4 showed the influence of quenching media on tensile strength and hardness respectively for AISI 1018, it can be showed that the maximum tensile strength will obtained for ice salt water about 680 MPa. The quenching in boiling water gives the minimum value of tensile strength about 380 MPa comparing with water only 438 MPa. At austenizing temperature the carbon will disperse to form the austenite phase, while the quenching will lead the austenite transform to the martensite phase like needle in structure which is very hard, but brittle. Amount of martensite phase is different according to quenching media, it is attributed to the diffusion less transformation in quenching is responsible to obtain high tensile strength because of the carbon atoms will prevent dislocations to move and then increasing tensile strengt. This is agreed with a studies by some researchers [15]. On the other hand, quenching heat treatment leads to increase the hardness as well as increasing in tensile strength, which perhaps return to the higher amount of martensite. So the value of hardness for ice salt water about 290.8 Hv more than for the specimen as-received 131 Hv because of high cooling rate.

While the value of hardness for the specimen in boiling water about 197.1 Hv and boiling salt water 239.4 Hv because of slowly cooling rate, and then stress relief will happen and permit the dislocations to move. This is in line with [16]. The microstructure of quenched specimen is brittle and hard martensite phase, which will transform to sorbite phase by tempering. Sorbite phase will improve the mechanical properties, decreasing hardness and increasing the percentage of elongation as a result of increasing the ductility. This is in line with [17]. The mechanical properties such as tensile strength and hardness for the quenched specimens will improve for the specimen quenched by ice salt water more than another specimens, this is return to the microstructure transformation during quenching treatment.

6. CONCLUSIONS

1- Microstracture examination reveals that ice salt water leads to form martensite phase more than another quenching media.
2- Hardness test depicts that ice salt water give the higher value comparing with another quenching media.
3- Ice salt water improves the mechanical properties because of its higher cooling rate.
4- Ice salt water improves the mechanical properties such as hardness, yield strength and tensile strength.

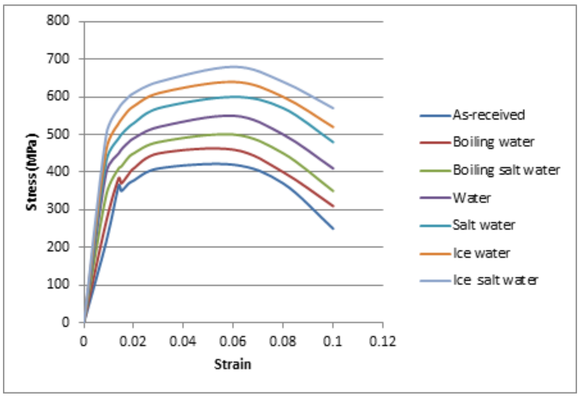

Figure 3: Relationships between stress-strain curves for all the specimens treated in different quenching media

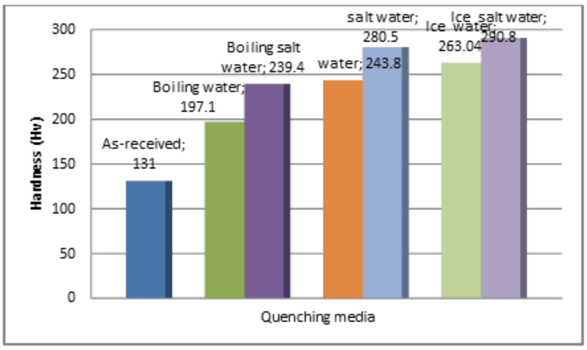

Figure 4: Relationships between hardness and quenching media

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