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INFLUENCE OF HEAT TREATMENT ON THE ABSORBED ENERGY OF CARBON STEEL ALLOYS USING OIL QUENCHING AND WATER QUENCHING

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ABSTRACT

Carbon steel alloys are modified by heat treatment processes so that structural components are able to withstand and sustain external forces and loads which specified operating conditions and have desired useful life. In this work, oil quenching and water quenching were tested and compared to low carbon steel, medium carbon steel and high carbon steel alloys. During quenching process, the specimens were heated at 900C° and soaked for 20 minutes in the furnace, three specimens were then quenched in oil and other three in water with the objective to improve impact toughness, the results obtained with instrumented Charpy impact tests showed that in low carbon steel the oil quenching treatment was able to increase impact toughness 159% and 107% by water quenching, for medium carbon steel, impact toughness by oil quenching increased 70% and water quenching increase 59%.The different behavior of high carbon steel appears when specimens heat treated, 85% impact toughness decrease in oil quenching and 50% decrease in water quenched.

KEYWORDS

Carbon steel, Oil quenching, Water quenching, Impact toughness.

1. INTRODUCTION

Many machine parts are generally subjected to suddenly apply loads called impact blows. The metals can be hard, high tensile strength and strong, but it may be not unsuitable for applications where it is subjected to sudden sharp blows. The capacity of a metal with stands for blows, vibrations and shocks without fracture for machines such as pneumatic hammers and power press punch and it depend on material toughness, so toughness property can be defined as the property of a material by virtue of which it can absorb maximum energy before failure takes place [1].

Results of heat treatment processes to improve mechanical properties of alloys, in the same time increase in level of toughness, hardness and increase durability. Heat treatment starts when alloys are heated above the critical transformation temperature for the alloys, and then cooled rapidly to cause the soft initial material to get transformation strong structure, much harder and increase toughness. The cooling of critical transformation temperature to room temperature cooled by air, or cooled by quenching in water, oil, or other liquid, depending on the amount of alloying elements in the parent material, the generated stress as a result of rapid cooling can be relieved by the tempering process. The manganese and carbon content in medium carbon steel make quenching and tempering the most common method of heat treatment for this type of steel.

Many researches regarding focusing on the heat treatment effect on toughness property of steel. For example, K. Kamei studied experimentally the effect of thermal treatments & Charpy impact test on impact toughness of EN31 steel material, the results show that Cryogenic treatment improves dimensional stability, hardness, and retained austenite to martensite and lead to decrease residual stresses [2]. I. Souki, D. Delagnes, P. Lours analyzed the effect of heat treatment on the fracture toughness in 5% Cr martensitic steel, the results shows heat treatment directly impacting the alloy hardness, result in drastic changes of fracture toughness and crack propagation rates [3]. Sérgio Souto Maior Tavares, recently an investigation on the influence of heat treatments on the impact toughness of stainless steel contain Ti-stabilized and 12%Cr super martensitic, different heat treatments were tested in a Ti-stabilized and 12%Cr results obtained showed that a triple quenching treatment improve the mechanical properties [4]. The main objective of this research is to study and compare the effect of quenching heat treatment on the absorbed impact energy of low carbon steel, medium carbon steel and high carbon steel [5-8].

2. EXPERIMENTAL DETAILS

2.1 Material and Specimen Preparation

Innov X-systems α – 2000 test device used to analyze the chemical composition of low carbon steel (sample A), medium carbon steel (sample B) and high carbon steel (sample C) as shown in table 1.

Table 1: Chemical composition of testing sample.

Material type	Sample	Wt (%)						
		Fe	C	Mn	Cr	Ni	Cu	Other
Low carbon steel	A	99.32	0.19	0.12	0.14	0.11	0.1	0.02
Medium carbon steel	B	94.91	0.31	0.45	0.17	1.04	2.73	0.39
High carbon steel	C	76.95	0.65	11.58	7.87	0.89	0.50	1.56

All preparations of specimens that used in this study followed the standard dimensions of ASTM generally used in Charpy impact test, as shown in figure 1. Nine samples prepared with the same dimensions (55mm x 10mm x 10mm), for heat treatment and impact testing.

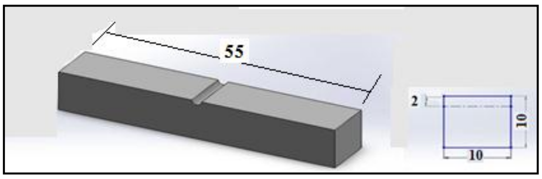

Figure 1: Specimen dimensions

2.2 Heat Treatment Process

The control parameters were considered for the proposed research study for multiple performance characteristics quenching at three different material carbon steel, quenching is mostly applicable to steel alloys where the aim is to convert the soft high temperature austenitic steel structure to hard martensite [9-12]. To achieve this convert, cooling by oil and water has to be fast enough to prevent the formation of other phases like pearlite and bainite. Oil quenching and water quenching procedure in this study accomplished in three major stages as shown in figure 2.

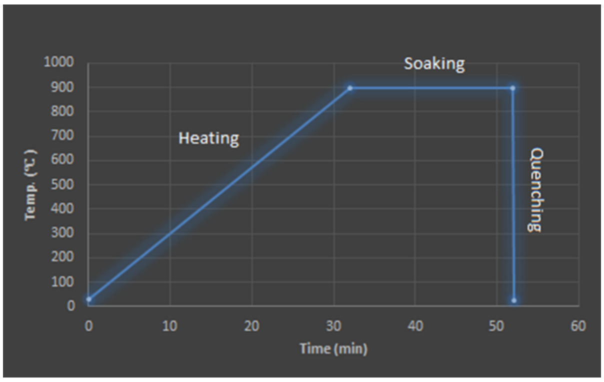

Figure 2: Heat treatment procedure

Figure 2 shows the heat treatment procedure, in first step the specimens heated slowly to 900 C ° in order ensure a uniform temperature in 32 minutes using Mikrotest muffle furnace, after the specimens are heated to the 900 C ° temperature, it is held at that temperature for 20 minutes until the desired internal structure changes take place, after a specimens has been soaked, it must be return to room temperature rapidly by cooling it with oil or water to complete the heat – treating process, table 2 and 3 shows the heat treatment details for oil and water quenching respectively [13].

Table 2: Oil quenching details

Specimen type	Heating temperature (C°)	Heating time(min.)	Soaking time (min.)	Cooling time (min.)
Low carbon steel	900	32	20	15
Medium carbon steel	900	32	20	15
High carbon steel	900	32	20	15

Table 3: water quenching details

Specimen type	Heating temperature (C°)	Heating time(min.)	Soaking time (min.)	Cooling time (min.)
Low carbon steel	900	32	20	7
Medium carbon steel	900	32	20	7
High carbon steel	900	32	20	7

2.3 Testing Machine

The Charpy impact test, consider a destructive testing method which determines directly the amount of energy absorbed after impact by a material during fracture, BROOKS testing machine used for specimen testing with effective weight of pendulum (20.17 Kg) released from a cocked position at a fixed height [14-18]. The response variable measured was impacted value in Joules, Charpy impact test is practical for the assessment measuring brittleness of metals, and the amount of energy absorbed by specimen can be evaluated from the equation (1).

$$E = E_i - E_f \quad (1)$$

Where (E) absorbed energy, (E_i) initial energy drop from 140° and (E_f) final energy reached after specimen failure. The initial and final energy depends on pendulum height before and after specimen contact and can evaluate from the potential energy equation (2).

$$E = m * g * h \quad (2)$$

Where (E) is the energy, (m) weight of the pendulum, (g) is the gravitational acceleration and (h) is the initial position and final position of the hummer.

3. RESULTS AND DISCUSSION

After heat treatment with tempering temperature 900 C°, results of impact testing of all specimens consist of heat treated and non-heat-treated are determined by recording the amount of energy absorbed by the three type of alloy steel specimens, they can be read directly in joules from the testing machine [19]. The fracture shapes obtain is shown as in figure 3.

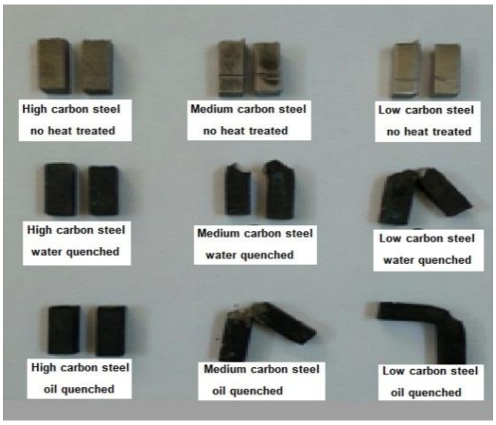

Figure 3: Specimens after fracture

Figure 4 summarizes the relation between the heat treatment effect of low carbon steel and absorbed impact energy at room temperature [20]. Before heat treatment the absorbed energy reached 112 J, after the heat treatment the specimen with water and oil quenching reached (232 J , 290 J) respectively.

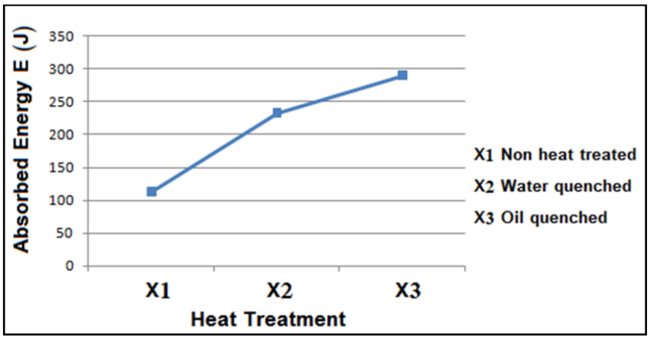

Figure 4: Low carbon steel absorbed energy before and after heat treating

The influence of heat treatment on the absorbed energy for medium carbon steel is shown in figure5, the absorb energy with non- heat treated reached 95 J, from the result obtain it is concluded that the absorbed energy of medium carbon steel after quench in oil is higher than quench by water quenched, it reached 161 J when the specimen water quenched and increased to 193 J when oil quenched [21].

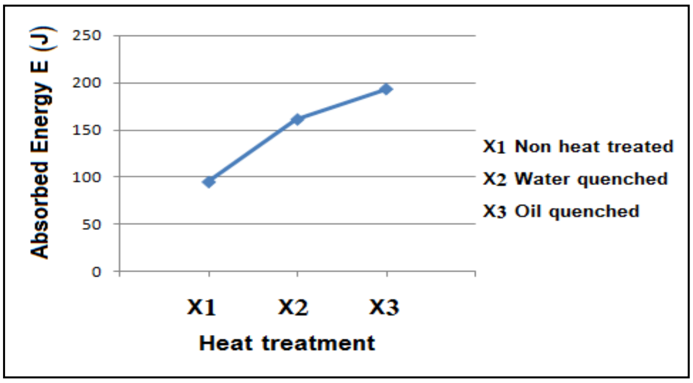

Figure 5: Medium carbon steel absorbed energy before and after heat treating

The behavior of high carbon steel defers from medium carbon steel and low carbon steel, all specimens cannot with stand with hummer impact, the absorbed energy approach to zero before heat treatment, even after heat treatment no significant increase in absorbed energy was measured [22]. The absorbed energy with no heat treatment equal 2 J and decreases and reached to 1 J and 0.3 J for water quenched and oil quenched respectively. Figure 6 shows the high carbon steel absorbed energy.

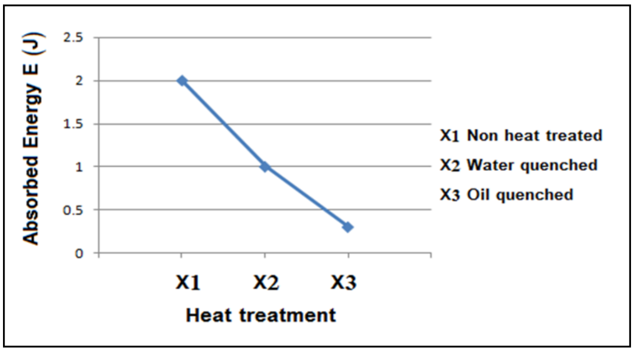

Figure 6: High carbon steel absorbed energy before and after heat treating

Comparing oil quenching with water quenching results for low carbon steel and medium carbon steel, we could deduce that heat treatment improves absorb energy by the specimen, but for high carbon steel there is no influence. Figure 7 comparing results of study.

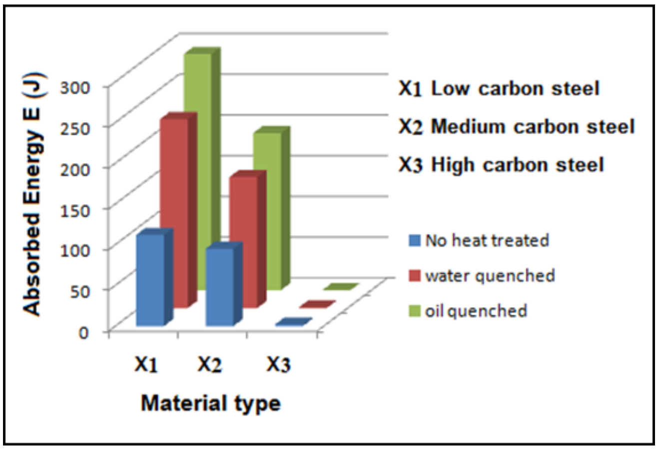

Figure 7: Results of heat treatment for three types of carbon steel

Comparing the result before and after heat treatment for three types of carbon steel in figure7, the absorbed energy in low carbon steel increased 107% when water quenched and increased 159% when oil quenched. Also absorbed energy increased in medium carbon steel after heat treating, it reached 69.5% and 103% for water quenching and oil quenching respectively [23]. But for the high carbon steel the absorbed energy remains nearly the zero magnitude before and after heat treatment.

4. CONCLUSIONS

The effects of carbon content and heat treatment type influence on absorbed energy property of the carbon steel materials, the observed results of this study are the following:

1- Independently of the on-heat treatment, absorbed energy depends on the carbon percentage to a certain extent; the steel with lower carbon content has the highest absorbed energy.

2- For low carbon steel and medium carbon steel, the absorbed energy, improves with heat treatment process, on the other hand, high carbon steel no significant improvement in absorbing energy with heat treatment.

3-Water-based caustic quench ants actually quench parts even more quickly than oil, in a comparable oil quenched and water quenched, the specimens of low carbon steel and medium carbon steel, reveal that oil quenching has higher toughness than water quenching.

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