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Evaluation of Effect Heat Treatment on Mechanical Properties of Low Carbon Steel with Different Cooling

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In this study, Low carbon steel C 17 were selected to investigate the effect different cooling during the heat treatment on mechanical properties. The samples were heated in a heat treatment furnace at approximately 980°C for almost 1 hour and then cooled by different quenching media (water, air, oil). The results show that Oil quenching also had a slight effect on the metal tensile strength and hardness. The change in the ultimate stress was observed. Upon water quenching, the result was 745 N/mm², while the ultimate stress of the sample before heat treatment was 431 N/mm².Meanwhile, hardness after water quenching. The hardness before treatment was 126 HB, and after treatment and water quenching, it was 263 HB. The impact test did not fracture despite the increased hardness because the metal still retained a high degree of ductility.

Keywords: Low Carbon Steel, Treatment, Cooling, Water, Air, Oil, Hardness, Ductility.

1. Introduction

Carbon content is of great importance as it contains a hot metal that the reduction of iron are in the high furnace results from 2% to 5.7%[1, 2]. Carbon could be melted easily and patiently in melds that is not subject to roads or rolling or pistons and undergoing a practical mechanism the formation of a mechanical on hot or cold. There are two types of placebo iron: placebo iron white and lead-blind iron white placebo iron carbon is a chemical compound with iron in the form of iron carbide[3]. Fe3C lead placebo iron is more folded and durable than white iron and is used Part of it as a cast iron in the manufacture of cast products. On less carbon than placebo iron or cast iron between (2%-1.0) this means iron steel where steel can be defined as iron with less than 2.0% carbon content the iron and steel industry is an important industrial sector that plays a role Key to the industrial and economic development of society. It can be geometrically classified according to the carbon content into low carbon steel its carbon content does not exceed 0.25% this type is characterized by its high ductility[4]. Medium carbon steel with a carbon content ranging from 0.3% to 0.6% and characterized by its high mechanical resistance of ductility and toughness, High carbon steel, with a carbon content of more than 0.6% and up to 1.4% and characterized by high hardness[5, 6]. The mechanical properties of steel can be controlled by adding alloying elements¸ as well as through various heat treatments [7-9]. Wang et al.[10] Investigated the effect of cooling rate on the mechanical properties of a low-carbon low-alloyed steel and the results showed increase in strength is observed when needle-shaped cementite precipitates form during water quenching within elongated micro grains. Deng et al.[11] Studied the effect of a slow-cooling heat treatment on the mechanical properties of high strength steels and showed that heat treatment improved the material ductility, especially for the Q690 steels. Sultan et al [12] studied the Effect of heat treatment on the mechanical properties and microstructure of martensitic stainless steel AISI 410. The result showed highest tensile strength (1595.62 N/mm2) and hardness (39 HRC) value and lowest Percentage elongation 14.71%, also tempered specimen gave the highest hardness. The value of the yield strength of (1055 N/mm2). Elkiesa [13] invested the effects of heat treatment on reinforcing bars which is produced by the Libyan iron and steel company. The result of the hardness of the cooled sample in water after the hardening process is higher than the hardness of the cooled sample in the oil after the hardening process. In this work, the effect of heat treatment on low carbon steel C 17 has been illustrated by different cooling media on the mechanical properties such as tensile, hardness and impact.

2. Experimental work

Low carbon steel C 17 were chosen in this study. The dimensions of the spacemen were 400 mm × 130 mm × 10 mm as showed in Figure 1. The appropriate temperature for processing must be determined¸ as well as the time inside the oven¸ and through the iron carbon curve the suitable temperature was 950c∘. Then, the time for the sample inside the oven is determined by the following equation

$$keep\ time = \frac{30 * thicknees}{25}$$

After the time of keeping the samples in the oven¸ they were taken out and placed¸ which are air cooling and water and oil and stir the samples inside the cooling media well so that cooling process is equal in all parts of the sample¸ then perform mechanical tensile – hardness test as follows .

Figure.1 Specimen dimension of tensile

The chemical composition of the sample were analysis and the main elements were showed in the table as below:

Table 1: chemical composition of the sample

Element	Percent %
Fe	98.2
C	0.176
Si	0.0245
Mn	1.11

The mechanical performance of joints was evaluated through tensile shear load by using universal tensile test machine. Hardness values were evaluated. Also the impact test were applied in this study. The sample was prepared according to the required specifications, before heat treated Sharpie was shocked and the sample were not broken, and this indicates that the mineral still retains a percentage

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of High ductility, which leads to the bending of the specimen without breaking it. The maximum stress was 431.71, yield resistance and breaking point were 302.56 N/ mm and 295.27 N/ mm respectively. The hardness test of the base metal was prepared by means of Bernel device to measure the hardness the average reading (126 HB).

Figure2 . Specimen before impact test

3. Results and Discussion

3.1 Air cooling

As a result of the impact test of the sample heat treated with, the sample was prepared according to the required specifications, and an incision was made In the middle of the sample with a depth of 2 mm in a U-shape and the samples were tested and the sample were not broken, and this indicates that the mineral still retains a percentage of High ductility, which causes the specimen to bend without broken

Table 2 .The results of the tensile and impact test of the samples after cooling in air

Sample Number	Maximum stress N/mm	Yield strength N/mm	Breaking point

Sample 1	440.36	341.28	274.97
Sample 2	424.70	327.07	276.44

The hardness was tested for the sample heat treated in the air-cooled medium, which was prepared according to the required specifications and the results in the table as below:

Table 3. Result hardens test of sample after cooling in air

Sample Number	Result 1	Result 2	Result 3	Medium
Sample 1	126HB	125HB	126HH	126HB
Sample 2	126HB	126HB	125HB	126HB

3.2 Oil cooling

The sample were prepared according to the required specifications and an incision was made In the middle of the sample with a depth of 2 mm in a U-shape and the specimens were tested using a device Sharpie was shocked and the sample were not broken, and this indicates that the mineral still retains a percentage of High ductility, which leads to the bending of the specimen without broken.

Table 4. The results of the tensile and impact test of the samples after cooling in oil

Sample Number	Maximum stress N/mm	Yield strength N/mm	Breaking point
Sample 1	453.37	360	278.61
Sample 2	476.70	384	287.59

Also, the hardness results of the sample heat treated in oil cooling medium were absorbed in the table as below:

Table 5. Result hardens test after cooling oil

Sample Number	Result 1	Result 2	Result 3	Medium hardness
Sample 1	137HB	137HB	137HB	137HB
Sample 2	137HB	137HB	137HB	137HB

3.3 Water cooling

Tensile testing of samples heat treated in water cooling medium The sample were cooled completely in water with stirring, the results in the table as below:

Table 6. Result after water cooling

Sample Number	yield strength N/mm	Maximum stress N/mm	Breaking point
Sample 1	600	745.78	592.10
Sample 2	600	734.20	509.48

The hardness of the sample heat treated in water cooling medium which were prepared According to the required specifications and the results showed below:

Table 7. Hardness after cooling water

Sample Number	Result 1	Result 2	Result 3	Medium hardness

Sample 1	263HB	263HB	262HB	263HB
Sample 2	263HB	263HB	262HB	263HB

The results of maximum stress, yield strength and breaking point showed in Figure 4. Maximum values were obtained in water cooling system, while minimum values were in air cooling. These changes are primarily due to the formation of specific microstructures and the induction of internal stresses caused by the rapid cooling rate. Increasing of stress due to formation of hard martensite and fine grain structure. While yield strength due to trapped carbon atoms impede dislocation movement.

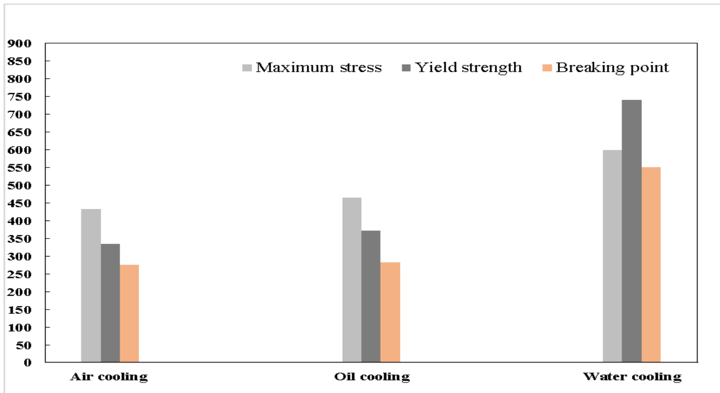

Figure 3. Maximum stress, yield strength, breaking point in different cooling

Hardness profile is illustrated in Figure 4. Maximum hardness value was 263 HB which was obtained with water cooling, whereas minimum value was 126 HB obtained air cooling. The graph showed the highest hardness after heat treatment with water rather than the other cooling type. High hardness after water quenching is due to the rapid formation of martensite, a very hard crystalline structure, and the retention of supersaturated carbon atoms within the steel's crystal lattice

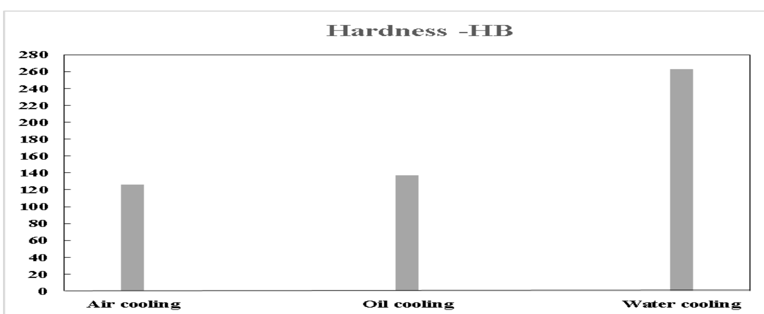

Figure 4. Hardness in different cooling

4. Conclusion

The current study demonstrated that Low carbon steel C 17 were selected to investigate the effect different cooling during the heat treatment on mechanical properties performance was investigated. The following conclusions were drawn:

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1- The maximum hardness of the metal and tensile strength during heat treatment were obtained due to water cooling.

2 - The large quantities of cooling caused to increases the speed of cooling.

3- Increasing the percentage of carbon in the metal leads to an increase in hardness and tensile after heat treatment.

4 - Low carbon steel after being heat treated in the pre-cooling. It is caused to increase hardness and tensile resistance and directly effect on elasticity and ductility.

5- To obtain high performance on mechanical properties of low carbon steel by water cooling after heat treatment.

5. References

1. Ahmed, H., et al., *Effect of carbon concentration and carbon bonding type on the melting characteristics of hydrogen-reduced iron ore pellets.* journal of materials research and technology, 2022. **21**: p. 1760-1769.
2. Pang, Z., et al., *The Low-Carbon Production of Iron and Steel Industry Transition Process in China.* Steel research international, 2024. **95**(3): p. 2300500.
3. Luo, N., et al., *Synthesis and characterization of carbon-encapsulated iron/iron carbide nanoparticles by a detonation method.* Carbon, 2010. **48**(13): p. 3858-3863.
4. Shin, G., et al., *Microstructural evolution and mechanical properties of functionally graded austenitic–low-carbon steel produced via directed energy deposition.* Materials & Design, 2023. **227**: p. 111681.
5. Mohd Fauzi, M.A., et al., *In vitro microstructure, mechanical properties and corrosion behaviour of low, medium and high carbon steel under different heat treatments.* Journal of Bio-and Tribo-Corrosion, 2019. **5**(2): p. 37.
6. Jiang, B., et al., *Mechanical properties and microstructural characterization of medium carbon non-quenched and tempered steel: Microalloying behavior.* Materials Science and Engineering: A, 2019. **748**: p. 180-188.
7. Isfahany, A.N., H. Saghafian, and G. Borhani, *The effect of heat treatment on mechanical properties and corrosion behavior of AISI420 martensitic stainless steel.* Journal of alloys and compounds, 2011. **509**(9): p. 3931-3936.
8. Kandpal, B.C., et al., *Effect of heat treatment on properties and microstructure of steels.* Materials Today: Proceedings, 2021. **44**: p. 199-205.
9. Sanusi, K.O. and E.T. Akinlabi, *Experiment on Effect of heat treatment on mechanical and microstructure properties of AISI steel.* Materials Today: Proceedings, 2018. **5**(9): p. 17996-18001.
10. Liang, G., et al., *Effect of cooling rate on microstructure and mechanical properties of a low-carbon low-alloy steel.* Journal of Materials Science, 2021. **56**(5): p. 3995-4005.

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ISSN 2958-6119

11. Ding, F., et al., *Experimental study of the effect of a slow-cooling heat treatment on the mechanical properties of high strength steels.* Construction and Building Materials, 2020. **241**: p. 118020.

12. Sultan, S, et al., *The Effect of Heat Treatment on The Mechanical Properties and Microstructure of Martensitic Stainless Steel AISI 410.* Libya for Applied and Technical Science, 2016. **3**: p. 8-15.

13. Elkiesa, *Study of the effects of heat treatment on reinforcing bars Which is produced by the Libyan Iron and Steel Company.* Libya for Applied and Technical Science, 2025. **13**: p. 81-92.