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The Effect of Heat Treatment on the Hardness of Medium Carbon Steel

Jamal Nayief Sultan, Iman Zaidan Alshih Yahya, Emad Toma Karash*, Majid Khaleel Najem

Mechanical Technology Department, Mosul Technical Institute, Northern Technical University, Mosul 41000, Iraq

Corresponding Author Email: emadbane2007@ntu.edu.iq

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ABSTRACT

When a suitable balance of hardness, strength, and toughness is required in civil engineering and construction, wear-resistant medium carbon steels are frequently utilized. The ability to resist plastic deformation brought on by stress or abrasion is measured by hardness. High hardness materials are typically more brittle and prone to fracture but also stronger and more resistant to corrosion. A double-quenching procedure was used in the current investigation and contrasted with the traditional single-quenching process. Additionally, a variety of cooling media are used during quenching treatments. The results demonstrate that distilled water is the most effective cooling medium to cool the models in the heat treatment of medium carbon steels because it is free of salts, suspended particles, and metal contaminants. The results show that the hardness increased following the first quenching and tempering by 37.5% above the hardness value predicted by the original model, and it increased once more following the second quenching and tempering by 10% over the hardness value following the first heat-treatment. The previous austenite grain limits and the high-angle beam limits are the main factors that give a share in to the increased hardness, and the main elements that affect how effectively they function are the high slip transmission factor and the high spacing angle between slip levels.

1. INTRODUCTION

The effects of quenching and tempering on the mechanical characteristics of wear-resistant steels have been the subject of numerous studies. Correctly raising the tempering temperature can increase impact toughness; however, temperamental brittleness manifests when the mild temperature rises above a certain threshold. As tempering temperature rises, hardness gradually decreases [1]. Two variables were used in this study: the first is the cooling medium (water, air, or oil), and the second is the cooling period. It was discovered that using water produced the best outcomes (10, 70, 80) minutes. Additionally, it was discovered that bringing out martensitic results in a notable increase in hardness [2].

The steel that was first produced in this study was austenized at 890°C for four hours, and then it was quenched in water. Several tempering processes were carried out in one or more phases at 590°C. It was found that the hardness was significantly impacted by these treatments [3]. The microstructure and hardness of AISI 1020, 1040, and 1060 steels were investigated under various circumstances [4]. The samples in this investigation were subjected to single cooling and double cooling, with the individual cooling carried out at (750, 800, and 850°C), followed by cooling with oil. The double cooling was then heated to 900°C and cooled in oil. Second, corrosion was assessed for the samples (single cooling and double cooling) using a machine mounted on a disk by varying the loads (5, 10, 15, 20 and 25) Newton with a sliding time of 10 minutes and a different time (5, 10, 15, 20, 25 and 30) minutes with a constant load of 15 Newton. The samples were reheated at (750, 800, and 850°C) and put out with oil. Personalized quenching, which raises the hardness value [5]. The effects of attenuation and cooling at higher temperatures were investigated before standard austenization, cooling, and tempering at 200°C were applied. The steel in question is (CrNiMoWMnV). There is 0.18 and 0.32% of carbon. In addition to the hardening process, double austenite and quenching were utilized to create martensite with only small amounts of sediment. The steel with a carbon content of 0.18 showed an improvement in hardness, while the steel with a carbon content of 0.32 showed a decrease in hardness values [6]. In the study of Ourrad et al. [7], the space of an electric oven was heated to a temperature of 950 degrees, and after that, the water, oil, and mechanical properties were hardened. In the study of Ismail et al. [8], it was created using the austenite and martensite fabric that was saved. Ibrahim et al. [9] investigated the effects of heat treatment on the microstructure and mechanical properties of NST 37-2 steel (annealing, normalizing, hardening, and tempering). Three different heat treatments were used in this study to obtain ritual rituals at temperatures of (300, 450, and 600°C), soaking timers for a lengthy and fantastic period of time. The outcome was the highest extract in the image that was put out with water and the open air. This investigation found that the attenuation temperature, cooling rate, waiting time, and heating rate all had an impact on C4S4 steel, with water cooling having a greater friendship coolant (owing to martensite development) [10]. The effects of quenching fluids on the mechanical characteristics of medium carbon steel were investigated in the study of Benarrache et al. [11]. The results indicated that the quenched samples' tensile strength and hardness values were significantly higher than those of the molded samples. The findings of this investigation revealed that the retained austenite content grew from (3.6-5.1%) in the multi-step tempering temperature, while the retained austenite content declined by about 2% following. At 520℃, quadruple hardening produced the maximum hardness values while hardness dropped. Above that, the hardness reduced, and in the event of water cooling, the hardness was higher [12]. In the work of Sultan et al. [13], the alloy underwent thermal treatment, which entails three distinct steps: solution heat treatment, cooling, and solution heat treatment with artificial aging. In order to get a variable quenching rate, in addition to the influence of aging hardness, two different temperatures and five distinct quenching media were used. Different categorization times (from 5 minutes to 22 hours) and two different aging temperatures (180℃ and 210℃) were employed. A significant increase in hardness results from raising the quenching rate up to 3 m/s, and the hardness also rises as the solution temperature rises. In this investigation [14], low carbon steel was carburized at temperatures between 850 and 950℃ for ten minutes, and then it was cooled with water and oil. The outcome was the achievement of a high hardness when cooling with water (to avoid spindle deformations and bends). In the work of Johnson et al. [15], medium carbon steel quenched samples were used to test the cooling process at four different polymer concentrations (0, 10, 15, and 20%). (polyclinic glycol). The ideal mixture to get high hardness is one that contains 10% polyolefin glycol [16]. In this investigation, samples of medium carbon steel were soaked for 45 minutes and tested for heating between (900 and 980℃). As a consequence, the samples that were cooled with palm oil performed better than the samples that were cooled with water. Composition that is consistent and evenly distributed has more pearl structure, which increases hardness [17]. Since the mechanical properties control element is the mechanical properties control element, the carbonaceous element in this study was studied from the carbonaceous control element. High reputation as an alternative to petroleum SAE40-based motor oil. The highest hardness was obtained in this study when carbon steel samples were heated to temperatures of (730, 760, and 790℃) and soaked for periods of (30, 45, and 60 minutes, respectively), using coconut water (CW) and water and motor oil (SPE). Heating at a temperature of (760℃), soaking for 45 minutes, and quenching with coconut water and water under the same conditions produced the highest hardness [18]. The mechanical characteristics (hardness) of medium carbon steel AISI 1039 were investigated in this study using a variety of cooling media, including cold water, oil, hot water, and water. sample), heating temperatures (960, 920, 880℃), soaking time for one hour, and cooling (with water + ice) [19]. Austenitic stainless steel AISI 316L was employed as a sample in this investigation. Seven hours of carburizing were spent at 900 meters, followed by a cooling procedure using various media (water - SAE 40 oil - air). According to the findings, the carbon content rose from (0.031% to 0.627%). Carbon The hardness of the water-cooled samples increased as the carbon concentration significantly increased [20]. In the investigation of Hsia and Chou [21], the steel alloys 4140, D2, and S7 were utilized, and traditional cooling methods (water, air, and oil) produced martensite and high hardness in the case of water cooling, while unconventional cooling methods, including olive oil and peanut oil, produced the same results. Water and olive oil have the same impact on steel 1045 as Quench Fast and Super Quench, according to the results, thus they can both be employed. Give a quick, safe, and environmentally friendly way to cool things down. The research results showed that utilizing alternative media to conventional refrigerants produced equivalent hardness, hence there is no benefit to employing the cooling techniques that have been announced [22]. In this investigation, water was used to cool down the medium carbon steel C1045 after treatment at various temperatures. The findings demonstrate that high cooling temperatures can produce materials with greater toughness. Outcomes In order to reduce required mechanical characteristics, such as hardness temperatures (900, 880, 840, 800, 760℃), high tensile strength bolts were heat treated. This non-destructive test can evaluate the quenching technique utilized in the production of fasteners. The greatest temperature was reached (920℃). The smallest particle size, the maximum hardness, and water cooling at the highest temperature (920℃). Medium carbon steel is fundamentally an iron alloy with a carbon content more than 0.25 to 0.65 percent [23, 24]. Additionally, it was found that annealed samples had the opposite characteristics to hardened samples in terms of tensile strength, hardness value, and ductility [25]. Used a variety of chilling techniques to examine the hardness of 1040 steel. The samples were prepared, heated to a temperature between 750℃ and 850℃, and then cooled using one of three techniques. The investigation's findings demonstrated that hardness is influenced by heating time, temperature, and cooling technique [26]. Steels become more hardenability when carbon is added because it causes pearlite and ferrite to form martensitic courage at slower cooling rates [27, 28]. Medium-carbon steel mechanical properties after various quenching temperatures and cooling rates [12]. Medium carbon steel mechanical properties after various cooling rates [29], and medium carbon steel mechanical properties after annealing, normalization, and hardening [24]. There are many studies that studied the effect of hardness in different minerals [30]. In this study, it will be examined how hardness, microstructure, and cracking are affected by carburizing, repeated quenching, and tempering operations. The current study's goals are to understand how cooling rates affect hardness and cracking, as well as to identify an effective cooling medium that would produce refractory products with martensitic microstructure without cracking.

2. MATERIALS AND METHODS

2.1 Materials

Table 1. Results of the utilized metal's chemical analysis

Element *Wt. %*	Standard Value [31]	Actual Value
C	0.377	0.482
Si	0.303	0.221
Mn	0.678	0.256
P	0.013	0.011
S	0.024	0.033
Mo	0.0067	0.0788
Cu	0.0158	0.0154
Fe	Balance	98.596

A lathe was used to cut AISI 1040 medium carbon steel specimens to the required sizes for the hardness test. The chemical composition of AISI 1040 steel is shown in Table 1.

2.2 Carbonization processes and heat treatments

Circular bending fatigue samples were heated for four hours in an airtight field made especially for that purpose from a powder mixture of (75% C) and (25% $BaCO_3$). An unstable fuel gas is produced when air and carbon in the carburizing medium come into close contact (CO). The reaction indicates that when an unstable monoxide comes into touch with sample surfaces, it dissociates. The hardness of the steel specimen is prepared and categorized as follows, into 3 groups (A, B, and C):

All carbonated samples were heated for 20 minutes at a temperature that would quench them at 870°C, according to their diameter, and then cooled to room temperature using a variety of cooling solutions. After that, the samples were all heated for 20 minutes at room temperature, reaching 230°C.

After a second quenching treatment at 770°C for 20 minutes. In distilled water, the Group (B) and Group (C) were cooled to room temperature.

The specimens for the Group (C) were heated for two hours at 250°C, followed by allowing the air to cool to room temperature air.

2.3 Mechanical testing of specimen

Using accepted techniques, the hardness of the heat treated and base samples is assessed. Dimensions of the standard hardness samples are shown in Figure 1.

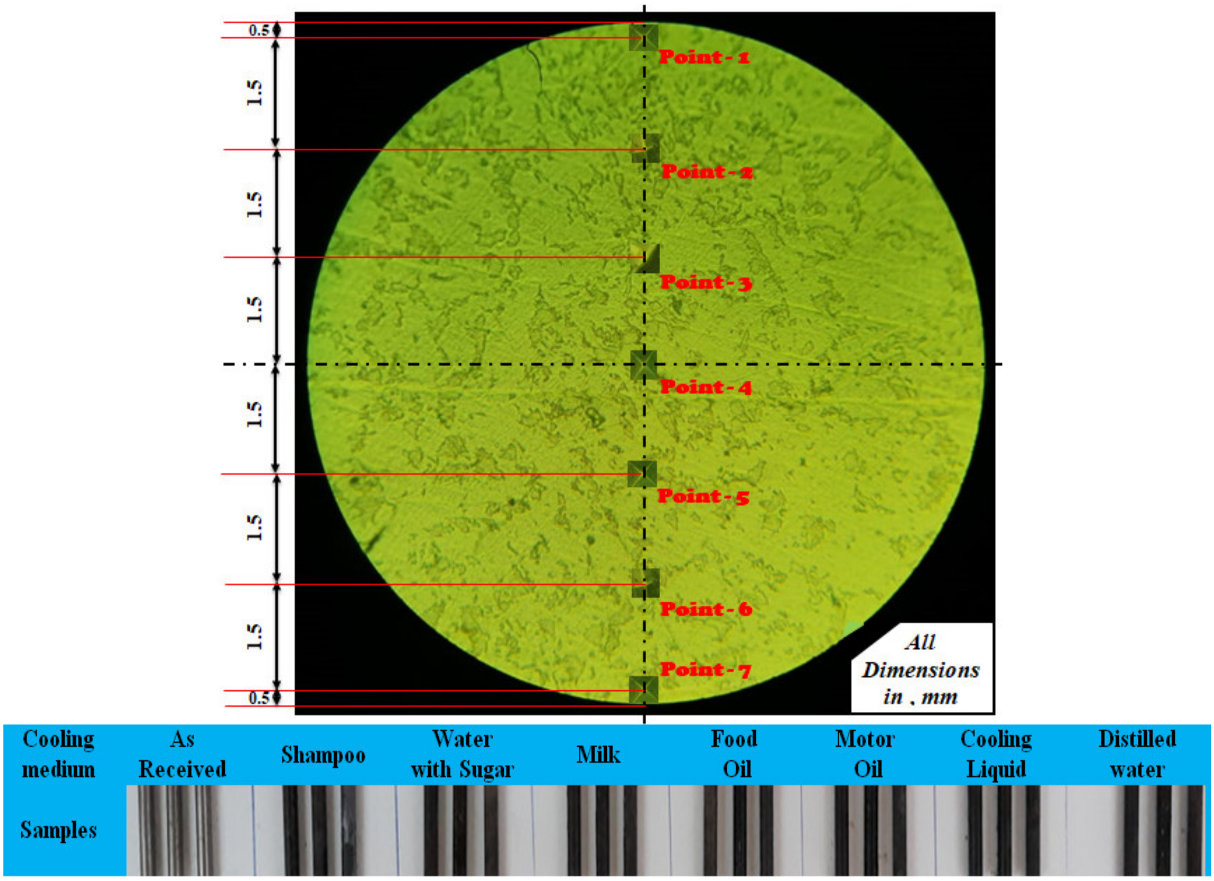

Figure 1. Dimensions of the standard hardness samples

3. RESULTS AND DISCUSSION

3.1 Microstructure test Group A

The generated structures were examined both before and after heat treatment using the Leica DM 2500 M microscope.

Figure 2 shows the microstructure of the first group samples (Group A), which were quenched from 770°C using a variety of quenching liquids before being tempered at 230°C temperatures.

3.2 Hardness test Group A

Figure 3 shows the findings of hardness resistance for various heat treatment models (Group A) with the original model.

It is apparent from Figures 2 and 3 the microscopic structure of the samples in Group (A) and the hardness tests for the same samples that the highest value of hardness for this group compared to the original model, where the hardness value was (109 HV) was in the model that was quenched in distilled water, at the edges of the model, and the hardness value was (272 HV), however, this value decreases as move toward the center of the model, where the hardness value was recorded in the model's midsection (236 HV). While the lowermost hardness value was for the specimen that was quenched in food oil, where the value of hardness at the edges was (176 HV), and the mid model the value of hardness decreases to (128 HV).

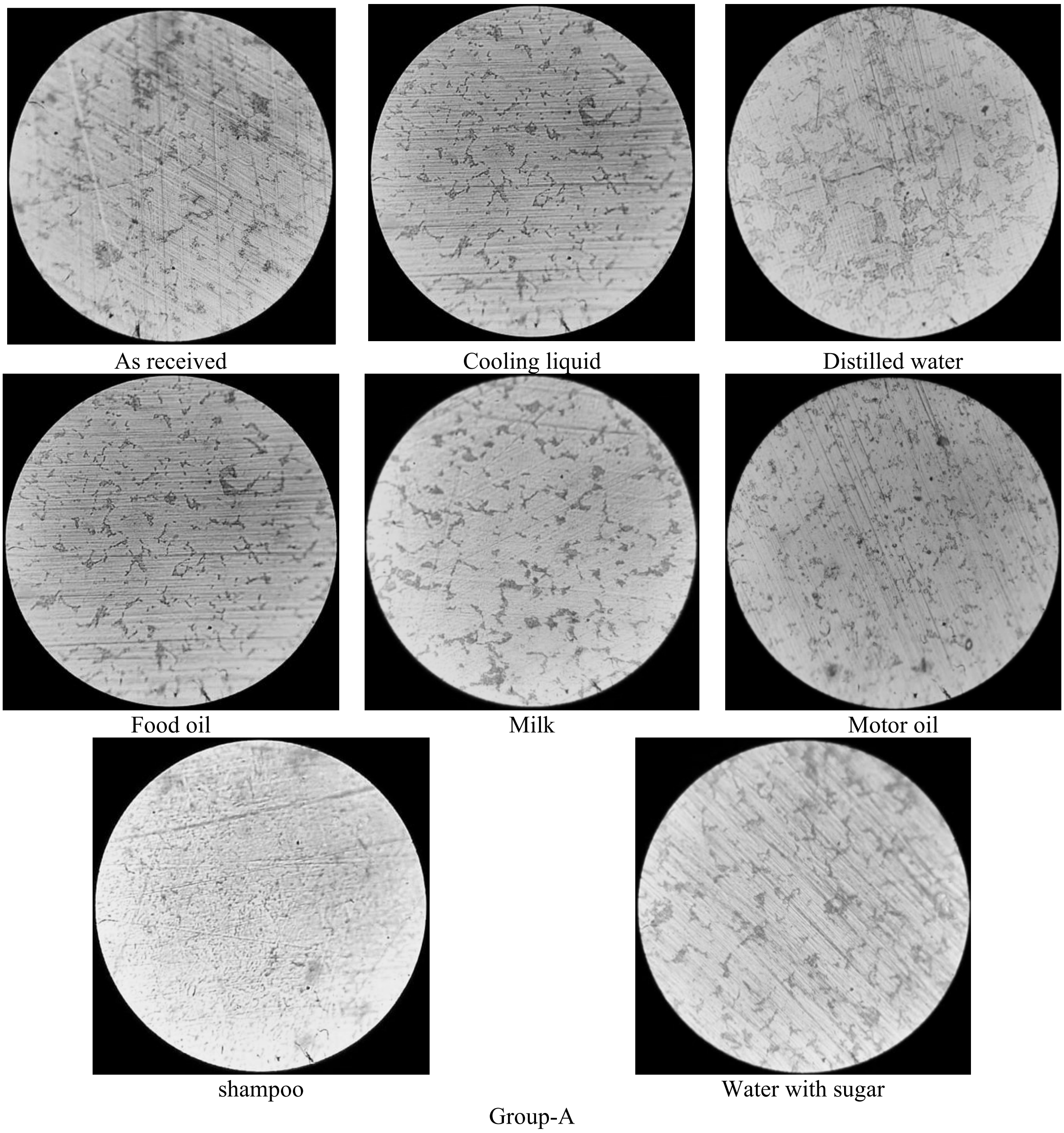

Figure 2. Shows the microstructure of the first group sample (Group A)

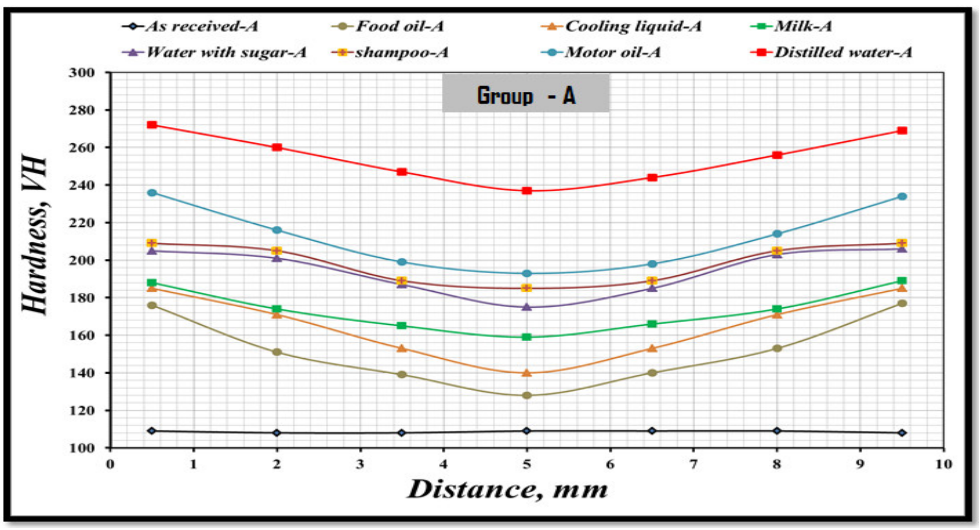

Figure 3. Compares the hardness resistance findings for different heat treatment models (Group A) with the original model

3.3 Microstructure test Group B

The microstructure of the second group samples (Group B) is shown in Figure 4. Carburized steel samples were quenched at 770℃ using a variety of quenching liquids, including milk, food oil, motor oil, shampoo, water and sugar, and cooling liquid. They were then tempered at 230℃ temperatures, and a second quenching process at 770℃ using distilled water as a quenching liquid was then performed.

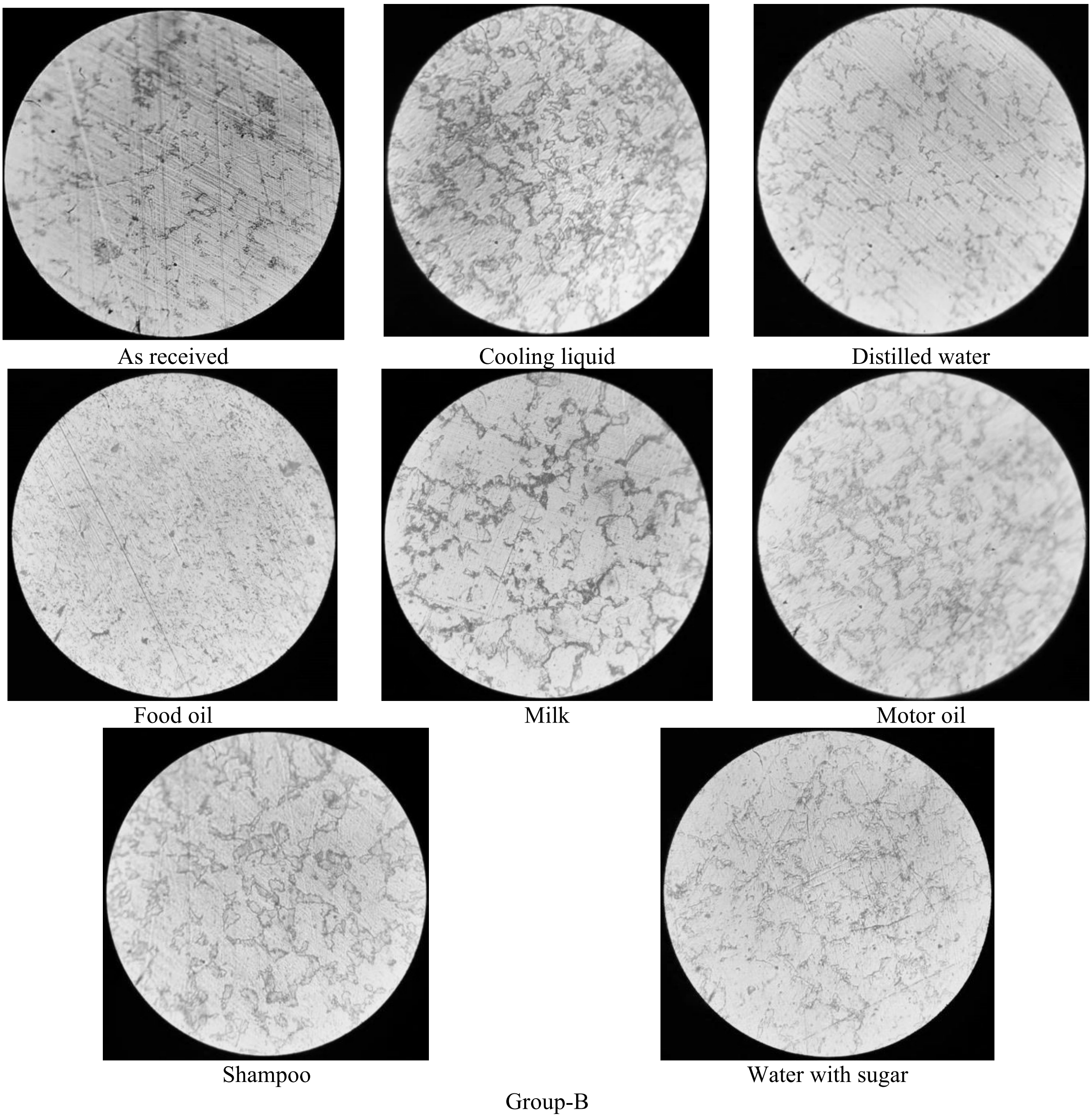

Figure 4. Shows the microstructure of the second group sample (Group B)

3.4 Hardness test Group B

Figure 5 shows the hardness resistance results for several heat treatment models (Group B) to the original model.

Figures 4 and 5 show the microscopic structure of the samples in Group (B) and the outcomes of the hardness examinations performed on the same samples. These results show that the hardest samples in this group compared to the original model had a hardness value of (109 HV) when quenched in distilled water, and that their edges had a hardness value of (155 HV), which decreased as they moved toward the center of the model, where the hardness value was (150 HV). The model that was quenched in food oil had the lowest hardness value, with edges that were (128 HV) hardness and a mid-model that was (128 HV).

3.5 Microstructure test Group C

Figure 6 shows the microstructure of the third group samples (Group C), in which the carburized steel samples were quenched with various quenching before being tempered at 230℃ temperature and quenched once more with distilled water. After that, they underwent a second tempering process at 250℃.

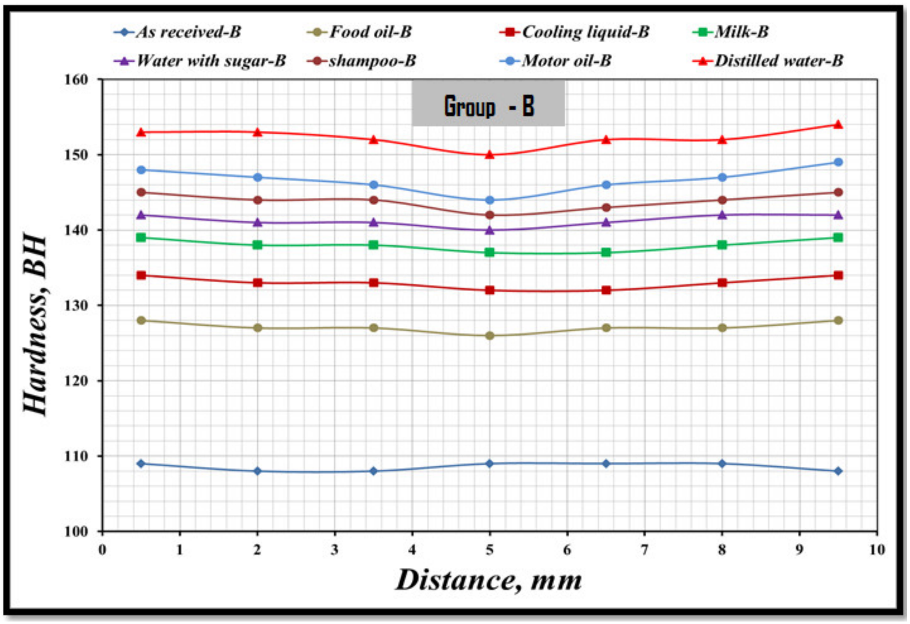

Figure 5. Compares the hardness resistance findings for different heat treatment models (Group B) with the original model

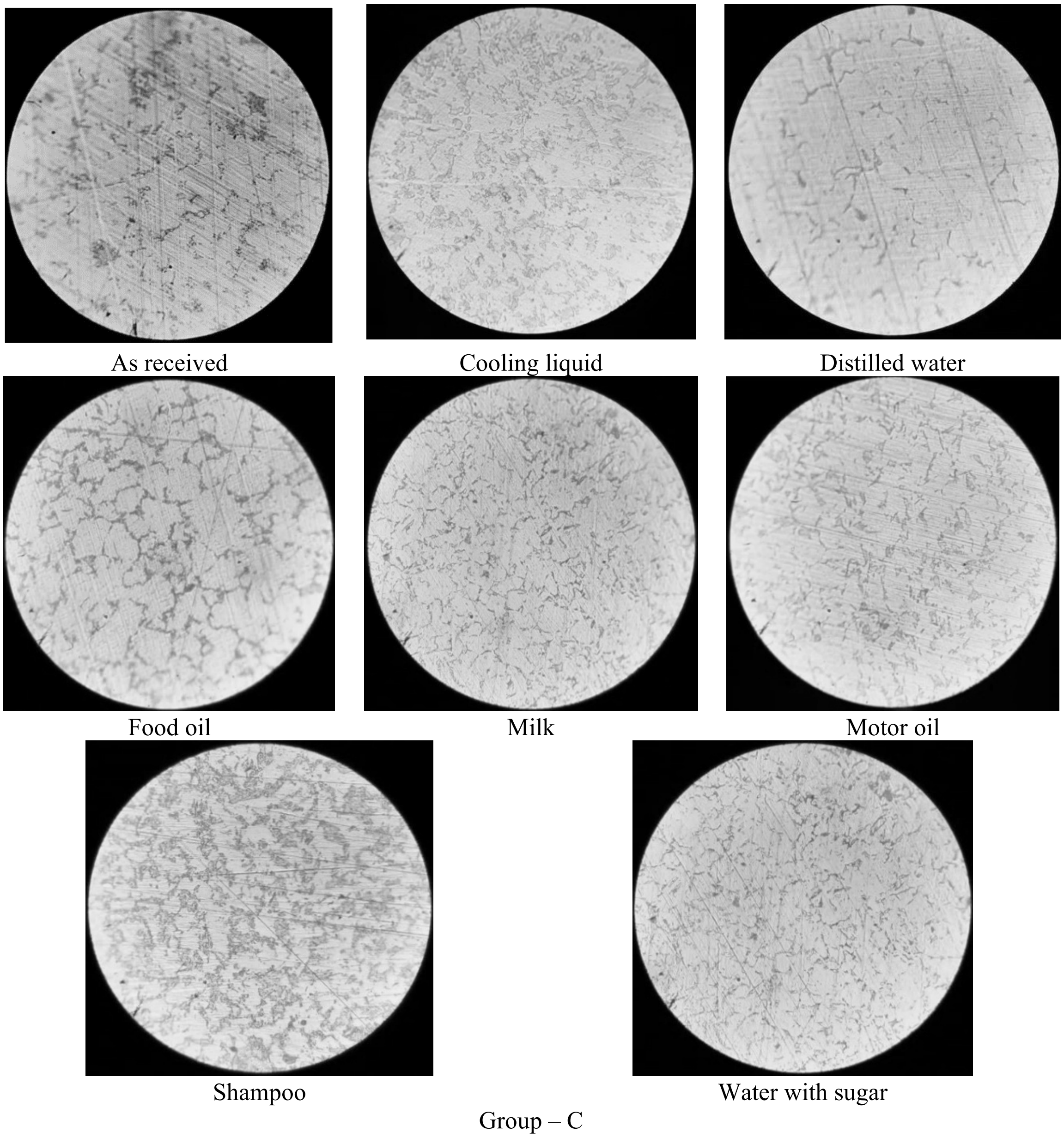

Figure 6. Shows the microstructure of the third group samples (Group C)

3.6. Hardness test Group C

Figure 7 contrasts the outcomes the resistance of the hardness tests conducted using various heat treatment models (Group C) with the original model.

Figures 6 and 7 depict the microscopic structure of the samples in Group (C) and the results of the hardness tests performed on the same samples. The results show that the hardest samples in this group compared to the original model had a hardness value of (109 HV) when quenched in distilled water, while the hardest sample had a harder value of (303 HV) at the edges of the model but at center sample decrease to (250 HV). The model that was quenched in food oil had the lowest hardness value, with the edges having a hardness value of (214 HV), and the middle model having a hardness value that decreased to (173 HV).

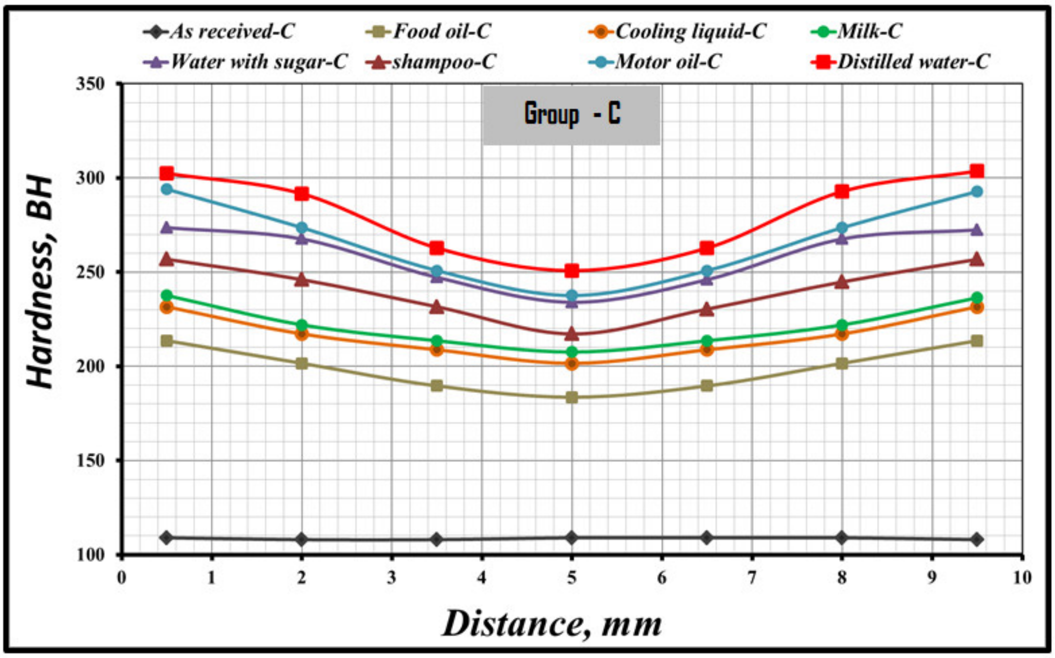

Figure 7. Compares the hardness resistance findings for different heat treatment models (Group C) with the original model

4. CONCLUSIONS

The findings indicate that the following processes carburizing, quenching, and tempering help to raise the hardness of steel:

1. The carbonated and heat-treated (first quenching and tempering) samples showed high values for the hardness levels. The aforementioned martensitic layer, chromium carbide precipitation, and revision-induced reduction of residual austenite are the causes of this.
2. The hardness values were significantly higher in the carbonized regions of the samples than in the unaffected regions, such as the center of the samples, where the hardness values were the lowest of all the samples. The carbonized samples caused the formation of carbide phases of chromium in the surface and an increase in the hardness values.
3. The outcomes demonstrate a definite decline in the hardness values when the quenching process was carried out without a tempering procedure being made. This is due to the fact that the hardness is influenced by the chemical makeup of the steel alloy as well as its fine microstructure. The microstructure of this alloy changes in this instance, necessitating a reconsideration of how the steel alloy's microstructure should be organized. Moreover, to lessen internal tensions and the brittleness produced by the quenching process.
4. It was discovered that the second tempering and double-quenching processes both increased the hardness and strength while reducing the initial austenite grain size.
5. The findings indicate that distilled water is the optimum medium for quenching, which is a crucial point.

5. FUTURE STUDIES

The optimal cooling medium temperature for the microstructure and mechanical properties of alloy steels will be ascertained by experimenting with different temperatures using distilled water, which is one of the most important upcoming studies on this topic.

The authors propose further experimental work on alternative heat treatments, with the use of ice for cooling, and a study of the mechanical properties and microscopic structure of the models used to perform the various heat treatments. Additionally, the researchers advise comparing the various models and performing mechanical tests (such as impact resistance, tensile resistance, bending resistance, fatigue resistance, corrosion resistance, flood resistance, and other tests) on models that have been hardened and cooled in water at various temperatures. to produce extremely effective models through application in real-world scenarios.

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