SURFACE HARDNESS BEHAVIOUR OF HEAT TREATED Ni-Cr-Mo ALLOYS

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Abstract

Low carbon steel is easily available and cheap having good material properties that are acceptable for many applications. Hardening and tempering process are used as a major heat treatment method. The purpose of heat treatment of low carbon steel is to improve the ductility, toughness, hardness and tensile strength. Hardening and tempering process of metals offer enormous advantages to the manufacturing industry because the heat treatment results can reveal optimum combination of mechanical properties. In this research, Ni-Cr-Mo alloys have been chosen for this purpose of investigate the characteristics of hardness and tensile strength of the low carbon alloy steel specimen. The steel samples were heat treated in electric furnaces (for carburizing, case-hardening and tempering processes) at different temperature levels and soaking to the particular time and then cooled in quenching media. The specimens were heat treated at 900^0C for 1hr and the specimen then undergone to tempering process for different temperature level such as 250^0C, 350^0C, 450^0C and 550^0C for different tempering time (60min, 75 min and 90 min). The hardness properties of the treated and untreated samples were determined using standard operating procedures. All heat treatment components were checked for rockwell hardness and tensile strength.

The experimental results revealed that mechanical properties of selective alloy were significantly changed by tempering treatment. By increasing the tempering time and temperature, hardness value decreases gradually also ductility increases simultaneously. The objective of this research is to find the effect of hardness and tensile behavior of heat treated 20 Ni55 Cr50 Mo20 alloy steel under the processes of different tempering temperature and time.

Key words: Ni-Cr-Mo alloys, Heat treatment, Oil quench, Tempering, Surface hardness

1. INTRODUCTION

Low carbon steel has many industrial applications [1]. The metals are grouped into ferrous and non-ferrous materials [2]. Among steel low and medium carbon steel are perhaps the most versatile engineering materials. Mechanical properties of low carbon steel can further be improved by different heat treatment procedures which include annealing, normalizing, hardening and tempering [3]. Owing to the importance of low carbon steels, aim of the present work is to improve the hardness behavior of low carbon steel, which is extensively used as a wear resistance material in the manufacturing industries.

Carbon steels in general are easy to work [4] with exhibiting excellent machinability and weldability. As the carbon content increases, the ease of machinability decreases. The amount of carbon present in steel has a pronounced effect on the properties of steel and on the selection of suitable heat treatments to attain certain desired properties. As carbon content rises, the metal becomes harder and stronger but less ductile and more difficult to weld [5]. Plain carbon alloy steel is found a maximum of 1.5% Carbon and often some alloying element like copper, manganese and silicon in low carbon steel. In surface engineering, the hardness of the heat treated steels are higher than that of the as-rolled, also found, this was probably due to the higher volume fraction of the harder martensite in the steel [6]. The process parameters for heat treatment of 20 Ni55 Cr50 Mo20 alloys steels are noted as follows: Forging commence 1150^0C maximum, forging finish 900^0C minimum, normalizing at 850^0C- 880^0C (Cool in air), soft annealing 650^0C- 700^0C (cool in air), carburizing 880^0C- 930^0C, core hardening 850^0C- 880^0C in oil/salt quench, intermediate annealing 630^0C- 650^0C, case hardening 800^0C- 830^0C (Oil/salt quench), tempering 150^0C- 200^0C to relieve stresses and to avoid grinding cracks.

2. HEAT TREATMENT IN MANUFACTURING

The process of heat treatment is carried out first by heating the material and then cooling with quenchants namely water and oil. The purpose of heat treatment is to soften the metal and also to change the grain size to modify the structure of the material and to relive the stress set up in the metal. The ability of heat to change or modify the physical characteristics of matter is an important aspect of manufacturing, since the characteristics of metal can be improved by treating them with heat in various ways. Many kinds of service requirements make for a considerable variety of heat treating is noted as; Relief of stresses, modification of cold worked material, development of physical properties. The heat treatment processes is to modify the microstructure and consequently change the properties [8] of the work piece. Apart from these, hardening is strongly recommended when the strength and hardness are the prime desired properties in design [9]. During the heat treatment process, the material usually undergoes phase micro structural and crystallographic changes [10]. It is also used to increase the strength of materials by altering certain manufacturability objectives especially after the materials might have undergo major stresses like forging and welding [11]. The heat treatment generally is classified [12] in to, annealing, hardening, normalizing and tempering; Thermo chemical processes which consist of carburizing, nitriding. Carburizing process are help to improve metal [13] and make them to versatile [14].

Low carbon steel is the most common types of steel as its price is relatively low while it provides material properties that are acceptable for many applications. Low carbon steel cannot be hardened by heat treatment by direct methods. Low carbon steel, needs a more refined process to modify the carbon changes behavior of the material at high temperature. Carburizing is thermo chemical treatment, in a carburizing [15] process, carbon is diffused in the surface layer of a component in a high temperature environment under a controlled atmosphere. The material modification process, Change the behavior of the steels will increase service life i.e., strength properties e.g. cryogenic treatment or some other desirable properties [16]. Low carbon steel is primarily heat treated to create matrix microstructure and associated mechanical properties not readily obtained in the as-cast condition. As-cast matrix microstructures usually consist of ferrite or pearlitic on combinations of both, depending on cast section size and/or alloy composition. In this case hardening tempering [17] is the process of heating the hardened steel to a temperature up to lower critical temperature (A_1), soaking at this temperature, and then cooling. The low carbon steel are used for making gears, pinions, shafts, steering mechanism, automobile gear box and transmission components, differential ring gears, aircraft engines, cam shafts, spline shafts, etc. The Some popular uses of low carbon steel for various engineering application for support bracket for application tractor, gear teeth profile, crane wheels, crane able drum, gear wheel and pinion blanks and brake drum, machines worm steel, flywheels, ball bearings, railway wheels, crank shaft, shackles of lock, bevel wheel, hydraulic clutch on diesel engine for heavy vehicle, fittings overhead electrical transmission lines, boiler moldings, etc.

3. METHOD OF ANALYSES

To evaluate the surface hardness behavior of Ni-Cr-Mo alloys on the low carbon steel, the investigation was carried out thus; (i) Chemical composition (ii) Heat treating the low carbon 20Ni55Cr50Mo20 steel, (iii) Hardness test of the low carbon steel to analyze its behavior after the treatment.

3.1 Chemical composition and specimen preparation

The material has carbon steel with carbon content of 0.23% carbon as determined by chemical composition analysis. Sample of 20Ni55Cr50Mo20 steel bar with 25mm diameter and 1m length was purchased. The chemical composition of the steel sample is noted in the following table:

Table: 1 Chemical composition of the specimen.

%of C	% of Si	% of Mn	% of P	% of S	% of Cr	% of Mo	% of Ni
0.18	0.15	0.70	0.035	0.040	0.50	0.20	0.55

3.2 Heat treatment processes

To commence the operation, the furnace was initially calibrated to determine the furnace operating temperature based on the pre-set furnace temperature. Representative samples of low carbon steel were subjected to heat treatment processes. The various forms of the heat treatment processes are noted as follows:

3.2.1 Hardening Process

This material is low carbon steel, hence the specimens are sent to carburizing process (Carburizing at 880^0C) in a depth of 2 mm case-depth. After the carburizing process the specimen utilized with hardening process. The specimens to be hardened were placed inside the furnace and heated to a temperature of 900^0C.

3.2.2 Tempering Process

The hardened specimens are sent to muffle furnace for 1 hour tempering process under the temperature range of 250^0C to 550^0C. The various stages for tempering are noted as follows. First stage of tempering: up to 250^0C; Second stage of tempering up to 350^0C; Third stage of tempering up to 450^0C. Fourth stage of tempering up to 550^0C. The desired properties and micro- structures depend on tempering temperature and time. The above four stages, define the strength, hardness and toughness required in service application.

4. HARDNESS TESTING

After the successful of heat treatment operation, the various heat treated samples were taken for the hardness testing. The hardness properties of the treated and untreated samples were determined using standard methods. Rockwell Hardness readings were found by taking readings at different positions on the samples. This machine measures the resistance to penetration by measuring the depth of impression and the hardness is indicated directly on the scale attached to the machine.

5. RESULTS AND DISCUSSIONS

The hardness properties of the steel specimens after various heat treatment processes are shown in following tables. The chemical composition of test sample is % of C-0.18, %of Si -0.15, % of Mn -0.70, % of P -0.035, % of S -0.040, % of Cr -0.50, % of Mo -0.20, % of Ni -0.55. Its equivalent grade agrees with AISI 8620(DIN) Standard Specification [18]. The heat treated specimens were now subjected to hardness test, using standard Rockwell testing machine. The resulting values are obtained from the hardness test and plotted the curves/Figures 1 to 8 shows the range of tempering temperature and the variation of hardness value. The data generated from these graphs for each of the heat treated specimens processes output result in hardness values were analyzed. Results can clearly compare with, all the heat treatment processes output, and also plotted the graph for hardness variation in different range of tempering temperature variation.

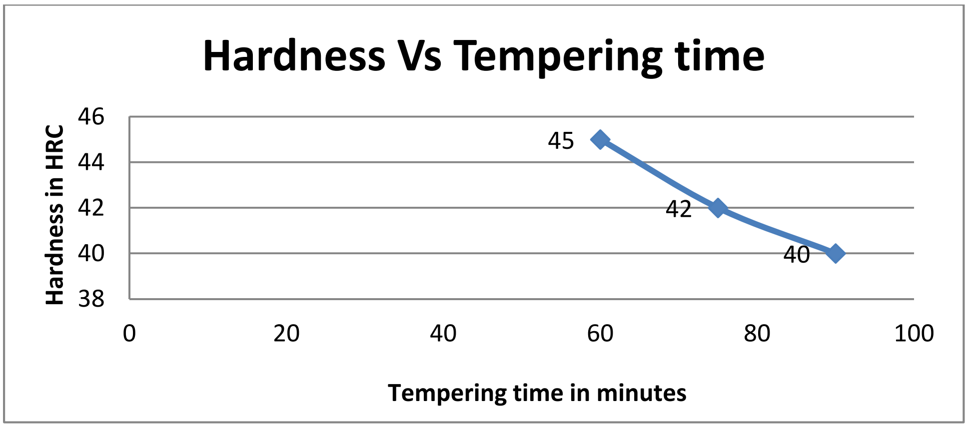

Figure: 1 Hardness Vs Tempering temperatures of 250^{0}C

The data generated from these graphs for each of the heat treated specimens i.e., Hardening at 900^{0}C and tempered at 350^{0}C in different tempering time in 60,75and 90 min. The processes output were analyzed and hardness behavior is shown in Figure 2

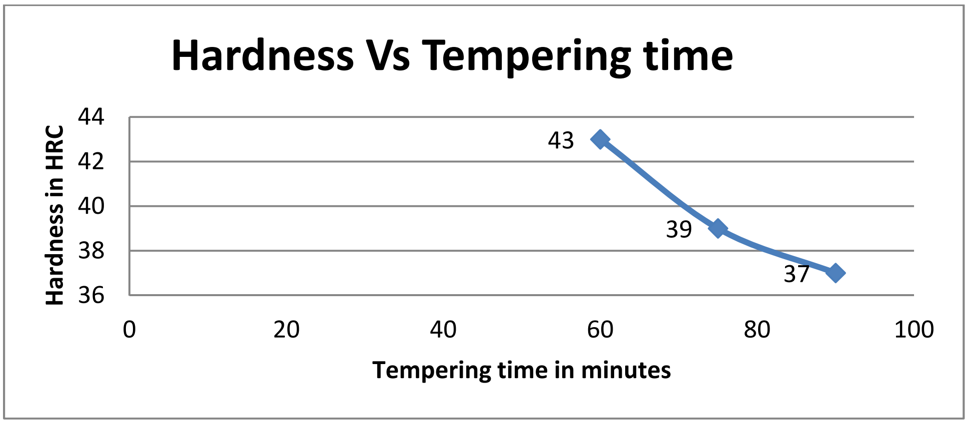

Figure: 2 Hardness Vs Tempering temperatures of 350^{0}C

The data generated from these graphs for each of the heat treated specimens ie, Hardening at 900^{0}C and tempered at 450^{0}C in different Tempering Time in 60,75and 90 min. The processes output results in hardness values were analyzed and hardness behavior is shown in Figure 3.

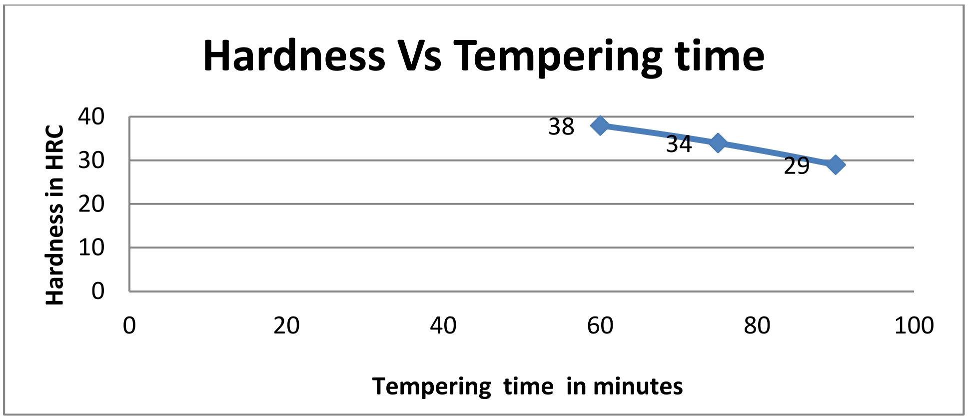

Figure: 3 Hardness Vs Tempering temperatures of 450^{0}C

The data generated from these graphs for each of the heat treated specimens i.e., Hardening at 900^{0}C and tempered at 550^{0}C in different tempering time in 60,75and 90 min. The processes output were analyzed and hardness behavior is shown in Figure 4.

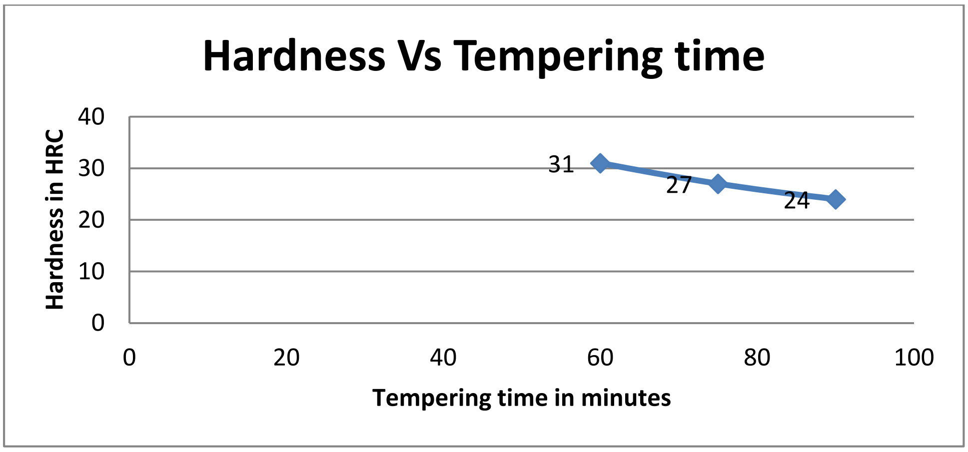

Figure: 4 Hardness Vs Tempering temperatures of 550^{0}C

The data generated from these graphs for each of the heat treated specimens i.e., Hardening at 900^{0}C and tempered in different Temperature at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C in Tempering time in 60 min. The processes output results in hardness values were analyzed and hardness behavior after the 60 minutes tempering time is shown in Figure 5.

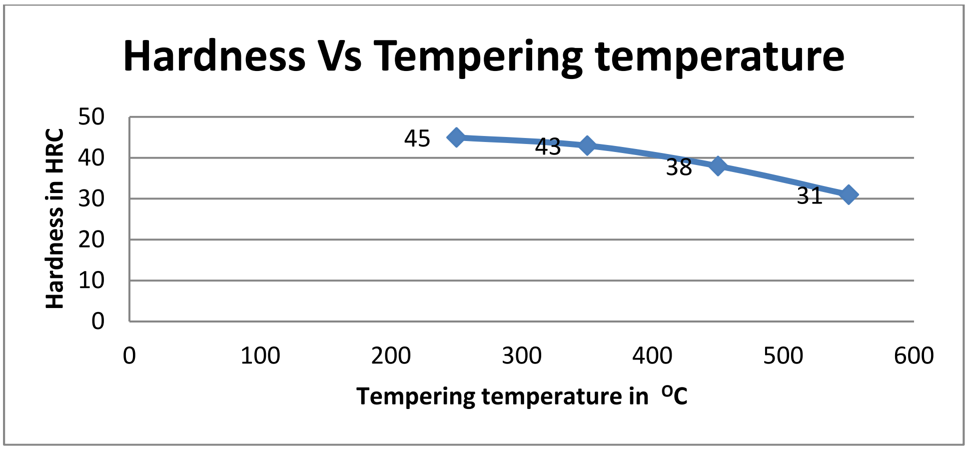

Figure: 5 Hardness Vs Tempering temperatures for tempering time of 60 min.

The data generated from these graphs for each of the heat treated specimens i.e., Hardening at 900^{0}C & tempered in different temperature at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C in tempering time in 75 min. The processes output were analyzed and hardness behavior after the 75 minutes tempering time is shown in Figure 6.

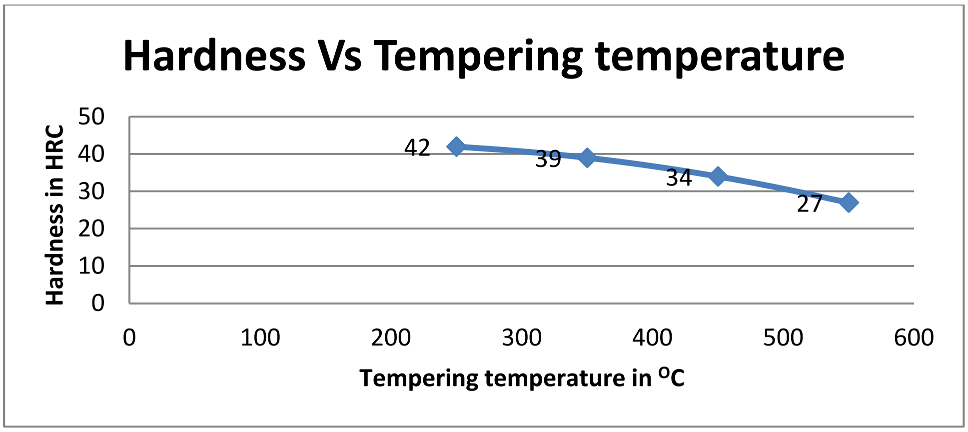

Figure: 6 Hardness Vs Tempering temperatures for tempering time of 75 min.

The value of hardness in hardened at 900^{0}C and tempered at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C specimens of the same material are reported, and hardness behavior after the 75 minutes tempering time is shown in Figure 6. The data generated from these graphs for each of the heat treated specimens i.e., Hardening at 900^{0}C and tempered in different temperature at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C in tempering time in 90 min. The processes output results in hardness values were analyzed and hardness behavior after the 90 minutes tempering time is shown in Figure 7.

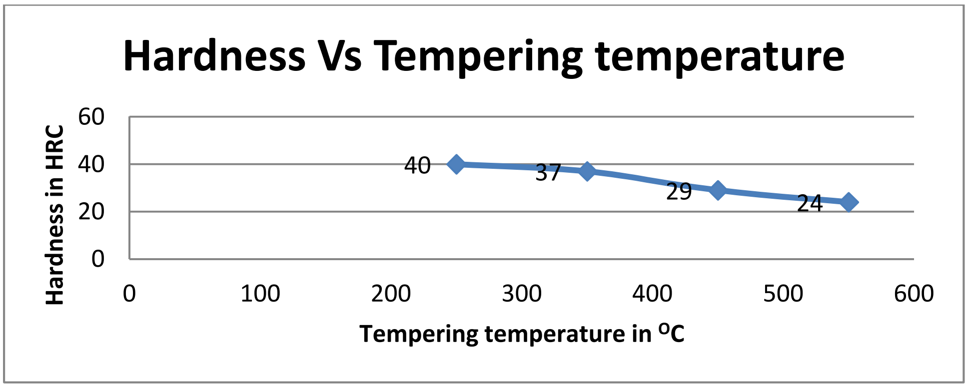

Figure: 7 Hardness Vs Tempering temperatures for tempering time of 90 min.

On comparison the properties of the oil quenched and subsequently tempered material with as-received one, it may be seen that the hardness values of the specimens tempered at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C are higher than the as-received ones but with a decrease in hardness from 48 HRC in 250^{0}C, 43 HRC in 350^{0}C, 38 HRC in 450^{0}C and 31 HRC in 550^{0}C in the duration of 60 minutes tempering. The specimens tempered at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C are higher than the as-received ones but with a decrease in hardness from 42 HRC in 250^{0}C, 39 HRC in 350^{0}C, 34 HRC in 450^{0}C and 27 HRC in 550^{0}C in the duration of 75 minutes tempering. Also the specimens tempered at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C are higher than the as-received ones but with a decrease in hardness from 40 HRC in 250^{0}C, 37 HRC in 350^{0}C, 29 HRC in 450^{0}C and 24 HRC in 550^{0}C in the duration of 90 minutes tempering. The results discussed above clearly suggest that the hardness of the low carbon steel studied in this work could be improved by oil hardening after the carburizing heat treatment with decrease the hardness is tends to improve the toughness and ductility in general.

CONCLUSION

The surface hardness behavior of 20Ni55Cr50Mo20 alloy steel can be altered through various heat treatments. The results obtained confirmed that improvement in hardness properties that can be obtained by different heat treatments investigated in this study. The oil hardening after carburizing and subsequent tempering of the steel in the temperature range 250^{0}C-550^{0}C resulted in a corresponding decrease in hardness (HRC) Value. 2. In the above tempering temperature range (at 250^{0}C, 350^{0}C, 450^{0}C and 550^{0}C), hardness (HRC) value of the steel decrease gradually, after the processing of tempering in different time range ie.60, 75 and 90 minutes. 3. Toughness and ductility is the only the criteria of tempering at high temperature for 2 hours gives the best result among all tempering experiments. From the various result obtained and concluded that the mechanical properties vary depending upon the various heat treatment processes. Hence depending upon the properties and application requirements it need for a suitable heat treatment process to modify the hardness properties.

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