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Compressive and Wear Properties of Heat Treated "High Carbon Steel"

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Abstract:

The aim of this project is ,tells about to improve the material properties of the specimen of conventional HCS by heat treated at different temperature like 500deg C,700deg C,900deg C both normalizing and quenching processwill changes its physical, chemical, and mechanical properties compare to conventional HCS. Initially specimen preparation will be done with the help of lathe and shaper machine . specimen subject on UTM machine for compression test and shear test, wear test on pin on disc and micro structure with SEM analysis .By an overall analyzing the graphs, compression strength and shear strength value observed increases at 500deg of normalizing process and 500deg of quenching process ,%elongation and % reduction will decreases respectively compare to others and normal HCS respectively. Also wear rate by volume, time and specific wear rate increases the micro structure changes from hyper to hypoeutectic particles so refine size of grain structure with homogeneous arrangement of grains consist ,better elastic characteristic and observed so it has changed from brittle to ductility ,improve mach inability, increased hardness and improve internal stress of material improves life of specimen.

Keywords — **High carbon steel, heat-treatment, Quenching and Normalizing, compressive, shear, wear and microstructure properties.**

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I. INTRODUCTION

This the study regarding the wear test properties on different heat treatment process .wear resistance varies with respective alloy steel with % C 2.3,%Fe0.7,%Cr 0.4,5%Mo 0.5and some % of Si which is used for lining manufacturing for rolling mill .the specimen will be heated at the 900deg C and quenching process is done in oil bath which shows hardness value increases but further increase in the temperature about 960 deg C the hardness value decreases with the further increase in the temperature. It has been moderate at 940 deg C if its heat above less hardness if it's bellow high hardness .this effect of quenching will fall an impact on toughness it decreases due to increase temperature above 960 deg C. Due to tempering process if temp is greater than 400 deg C hardness value will reduce .but if its tempering process done around 300 deg C has good wear resistance which can be used for increase the service life of the rolling mill liner .[1] It's an investigation study for an experimental on shear stress for the effects on the steel fiber and polymer latex in concrete .due to variation of the % of composition of steel fibers from 0-7% at an interval of 1%for latex polymer matrix 15% of concrete used .prisms has 2 different dimension of single and double type blocks larger in the size broken under double shear test [2]. They found that phase stability and modify grain size of structure for the hardness value. Due to increase the hardness value of HCS grain refinement, increase the dislocating of density, formation of nano twinning etc Due to tempering process in the solution the ferrite phase decreases in microstructure consequently. If ferrite phase dissolved in solution but material hardness changes to ferrite and austenite presence in the structure..[3].Tensile and compressive test conduct with the help of UTM machine to study the behavior of mechanical properties. Also compared to properties wrt to tensile versus compressive deformations.[4].The fracture interface with base and heat affected zone material for studying the mechanical properties of tensile and shear test. The similar and dissimilar metals combine the various grade of steel which has different strength and the hardness value. Critical interface avoids the accuracy greater than 90 %.but experiment conduct will have 5% greater than the calculated value to avoid fracture.[5] in this paper describe about both micro and nano the compressive stability will be present in the austenite formation in HCS.so by using standard test method like compressive testing, electron backscattering diffraction imaging, X-ray diffraction, optical microstructure, nano-indentation, electron probe micro-analysis and micro-indentation instrument used to measure the stability of retain of austenite and martensite in HCS under CS and transformation take place from micro to nano level.Intally it will plastic deformation with martensite due to increase in the load this lead strain hardening with increase of hardness value by 30%.Based on the characteristic of stress obtained which control microstructure in HCS and its properties.[6].

II. MATERIAL AND METHODOLOGY

In this work, high carbon steel was purchased and the samples were prepared as per ISO standards. Thesamples were subjected heat treatment for different temperature such as 500, 700 and 900 degree C in muffle furnace and subjected to both normalizing and quenching process. Figure 1 shows the specimens prepared for different tests. the specimens subjected to Quenching and normalizing process. The properties of the samples were determined using universal testing machines, wear testing machine(pin on disc). The scanning electron microscope tests were conducted to find the microstructure of the samples.

Figure 1: All Specimens for different test

Normalizing is the process of heating specimen at high temperature in muffle furnace and cooling in atmospheric air-cooling medium which should be equal to room temperature. The specimen were heated to 500, 700 ,900 deg C and cooled to room temperature. This is the most common form of heat treatment and gives steel high strength and hardness. Also this process can refine grain structure, improves hardness, tensile strength and mach inability, causes low ductility and removes both strain and dislocation. The microstructure mainly consists of the ferrite and cementite.

Quenching is the process of heating specimen at high temperature in muffle furnace and cooling in oil bath as medium which maintain to room temperature. In this work, the specimens were heated to 500, 700 , 900 deg C and cooled in oil bath until the specimen temperature reaches the room temperature. The quenching increases the hardness of the steel, however it also increase brittleness and the steel is susceptible to breaking and cracking. The formation of pearlite changes to austenite because of fast cooling oil so microstructure consists of ferrite marten site and cementite.

III. EXPERIMENTAL WORK

1.Test Conducted on UTM

Generally to find the mechanical performance of the specimen,compression,shear

A. Compression Test:

To study the material behaviour of mechanical properties of conventional and different heat treated specimen of HCS. the specimen is compressed, and data obtained directly is deformation versus the applied load is recorded .The values directly measure from software and calculation done like compressive strength, percentage elongation, percentage reduction , yield strength and young modulus of the material

B. Shear Test

A shear test is a method for determining the behaviour of materials under a shear load. Due to force body to slider relative to each other in parallel direction to their plane of contact is called shear forceultimate load obtain , the stress wrt to shear force to end also note produce fracture in the plane of cross section is called shear strength. The shear test is used to determine ultimate shear stress of single shear when load applied in plane will result single specimen into 2 pieces.

2. Wear Test

Generally wear test was conducted by “pin on disk” machine with ordinary condition. Test will be done for different applied load and sliding speed which is used to measure the wear rate by volume, time and specific wear rate of the specimen directly measured from the computer software in system.

3. Microstructure Test

To study its microstructure by using SEM analysis.Selection of particular area of the specimen for investigating the material properties of a metal or alloy cutted into small size Flat surface should be obtained on the specimen using fine coarse filing or grinding process.Different grades of emery paper are used for intermediate and fine grinding.Rough polishing should be carried out with small amount of diamond powder covered with nylon cloth on rotating surface of polishing wheel.

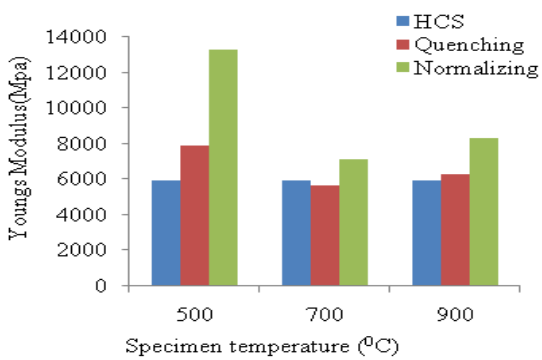
IV. RESULTS &DISCUSSION

The high carbon steel specimens were subjected to heat treatment processes and subjected to varioustesting to find properties. We have used electric muffle furnace for heating the specimens. There as on of heat-treating steel is to control its mechanical properties by changing the distribution of carbon within the product and microstructure of specimen.Also the heat treatment process soften the metal, changes the grain size, adjusts the structure of the material and relieves the stress set up in the material due to hot working process and cold working process.The specimens were subjected to tensile test by using universal testing machine. The specimens’ ultimate tensile strength, percentage elongation, percentage reduction, yield strength and young modulus of the material were determined.The hardness test conducted on the specimens to determine Rockwell hardness no using rockwell hardness tester. The hardness is the ability to resist permanent indent, generally this permanent indentation represents with respective load applied. If the hardness is higher in metal then it causes high resistance to deformation. Scanning electron microscope was used to study the microstructure and chemical composition of the specimens. The election of particular area of the specimen for investigating the material properties of a metal or alloy was cut into small size. The flat surface was obtained on the specimen using fine coarse filing. The different grades of emery paper were used for intermediate and fine grinding. The rough polishing was carried out with small amount of diamond powder covered with nylon cloth on rotating surface of polishing wheel. The chemical composition of specimens is shown in the Table 1. From the table it is observed that the carbon content is gradually reduced compare to conventional HCS. The Si, Mn and Cu content of higher in normalizing and lower in quenching process. The Fe content is higher than the HCS. The Cu content is the lowest as compared to HCS .

Table I: Chemical composition of specimen

SMPL	C%	Si%	Mn%	S%	P%	Fe%	Cu%
HCS	0.9	0.19	0.4	0.02	0.18	97.7	0.54
900Q	0.57	0.19	0.22	0.02	0.12	98.7	0.1
700Q	0.65	0.2	0.51	0.02	0.28	96.7	0.4
500Q	0.61	0.38	0.11	0.02	0.22	98.4	0.1
900N	0.54	0.26	0.41	0.02	0.19	98	0.4
700N	0.49	0.13	0.41	0.02	0.08	98.2	0.17
500N	0.39	0.22	0.56	0.02	0.26	96.3	0.1

A. **Graphical representation of a Compression test**



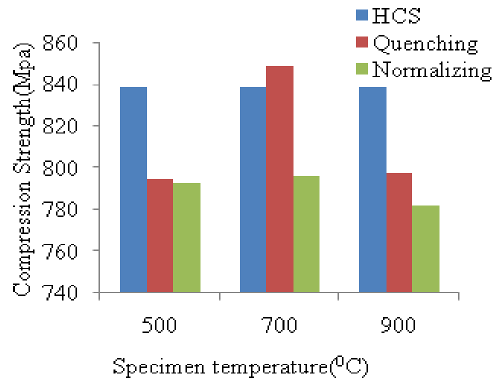


Figure 2 Effect of heat treatment compression strength and young's modulus at different temperature for CT

The variation in compression strength of heat treated specimens at different temperature is shown in figure 2. From the figure, it is observed that the heat treatment significantly affects the compression strength of the specimens. The compression strength value of the specimens subjected to quenching and normalizing reduces with increase in temperature, because during heat treatment process the carbon content reduced gradually fast and uniform cooling which modified grain size due to elastic deformation It is observed that the compression strength of quenched specimen is higher than the normalized specimen. It is also reported in the literature that the effect of specimen quenching in oil on mechanical properties like compression strength has been increased , while medium hardness. The youngs modulus value of the specimens subjected to quenching and normalizing reduces with increase in temperature, because during heat treatment process the carbon content reduced gradually fast and uniform cooling which modified grain size due to elastic deformation It is observed that the young's modulus of normalized specimen is higher than the quenched specimen. These results conclude that young's modulus increases for the specimen when oil quenching and air cooling process at 500^0 C temperature compare to conventional HCS .but compression strength increases for the specimen when oil quenching and air cooling process at 700^0 C temperature compare to conventional HCS.

B. Graphical representation of a Shear test

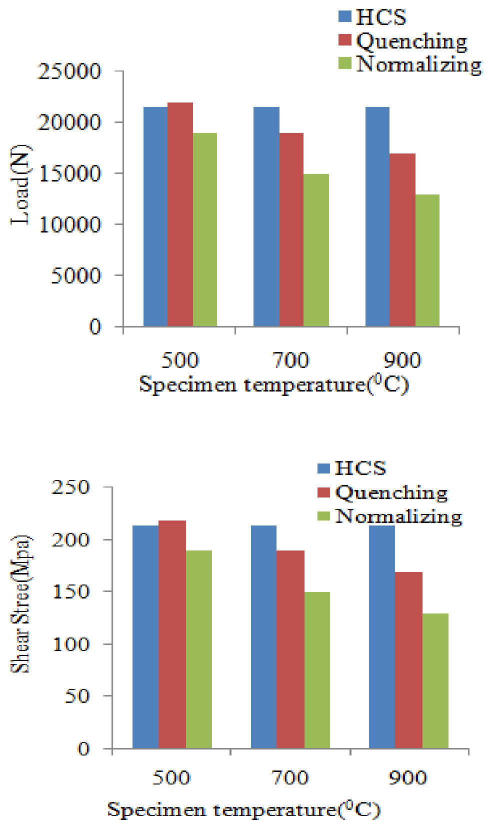
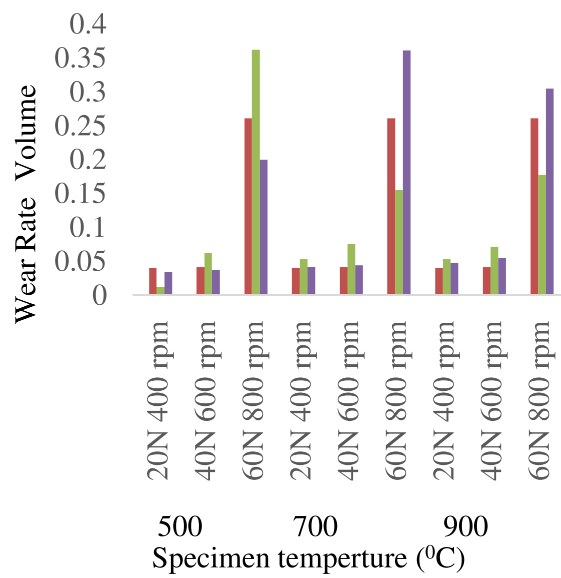
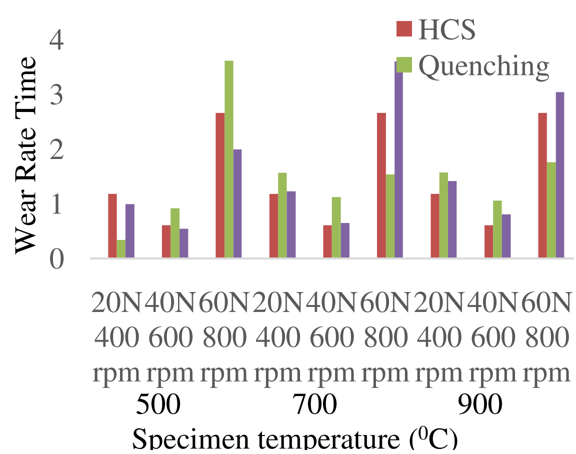


Figure 3 Effect of heat treatment shear stress and load at different temperature for ST

The variation in shear stress and load of heat treated specimens at different temperature is shown in figure 3. From the figure, it is observed that the heat treatment significantly affects the ultimate shear stress and ultimate load of the specimens. The ultimate shear stress and ultimate load value of the specimens subjected to quenching and normalizing reduces with increase in temperature, because during heat treatment process the carbon content reduced gradually fast and uniform cooling which modified grain size due to elastic deformation It is observed that the ultimate shear stress and ultimate load of quenched specimen is higher than the normalized specimen. It is also reported in the literature that the effect of specimen quenching in oil on mechanical properties like ultimate shear stress and ultimate load has been increased , while hardness decreases. These results conclude that shear stress and ultimate load increases for the specimen when oil quenching and air-cooling process at 500^0C temperature compare to conventional HCS.

C. Graphical representation of a Wear test





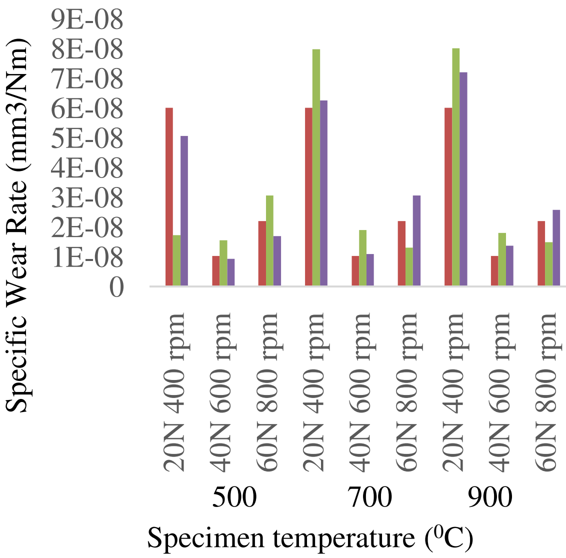


Figure 4 Effect of heat treatment on specific wear rate at different load and speed for WT

Figure 4 shows the Effect of heat treatment Comparison of wear rate by volume, time and specific wear rate conduted for different speed and load like 20N(400rpm) ,40N(600rpm) , 60N(800rpm) value of conventional HCS with heat treated process for quenching and normalizing process. These results conclude that Wear rate by volume,time and specific wear rate increase for specimen 700^0 C when oil quenching process for 20N(400rpm) ,40N(600rpm) and also increase for specimen 900^0 C when air cooling and oil quenching process ,but for 60N(800rpm) and also increase for specimen 700^0 C when air cooling and 500^0 C oil quenching process compare to conventional HCS.

D. SEM image representation of a Microcture test

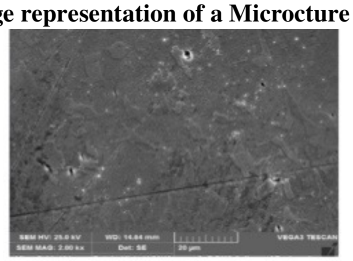


Figure 5 (a) SEM image of HCS at 20 µm of 2000x

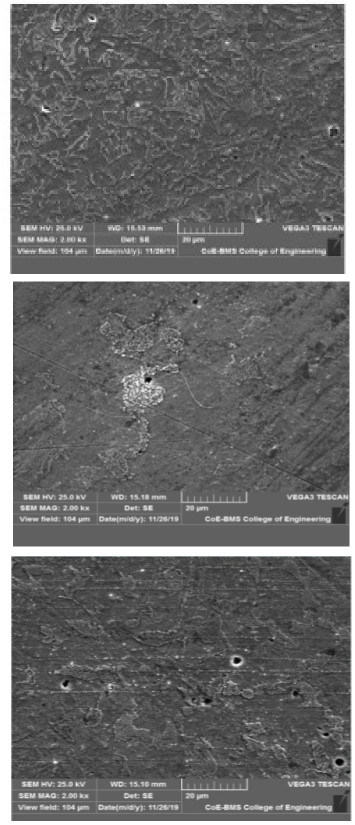


Figure 5 (b) SEM images of 900Q,700Q,500Q at 20 µm of 2000x

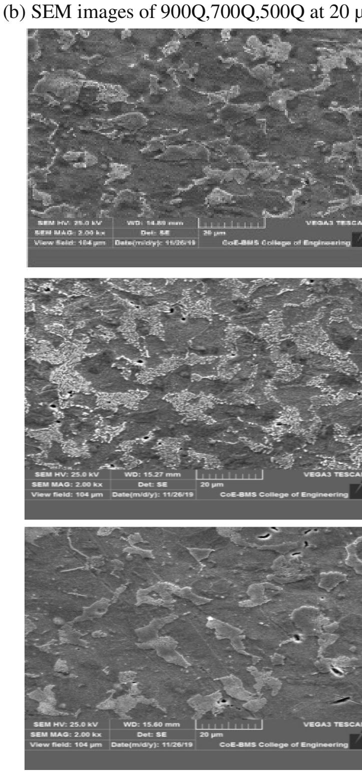


Figure 5 (c) SEM images of 900N,700N,500N at 20 μm of 2000x

Figure 5(a) shows that the microstructure of HCS specimen primarily consist ferrite and cementite(Fe3) and the transformation takes as pearlite. It is observed that the ultra-fine grains of white patches indicate ferrite and discontinuous proeutectoid carbide particles these steel are super plastic .Figure 5(b,c) shows the microstructures of 900Q, 700Q,500Q and 900N,700N,500N respectively. It shows that the specimen mainly consists ferrite, pearlite, cementite and austenite due to heating and fast cooling and austenite transformation due to Fe into martensite. Conventional HCS has some properties with high carbon content, ultra-fine grains of white patches indicate ferrite and discontinuous pro eutectoid carbide particles with high hardness and strength, wear resistance and improves the toughness. Similarly other specimens carried out heat treatment at different temperature to study the effect of quenching and normalizing process .during quenching process is uniform and fast cooling rate behave super plastic characteristic with %C reduce gradually the hyper to hypoeutectic particles so modifying size of grain structure with non-homogeneous arrangement of grains so this process will remove the residual stresses to re-crystallization. Increases hardness and resistance of material from deformation. normalizing process is non uniform and slow cooling rate behave super elastic characteristic based on %C reduce gradually the hyper to hypoeutectic particles so refine size of grain structure with homogeneous arrangement of grains and observed so it has changed from brittle to ductility ,improve mach inability, increased hardness and improve internal stress of material improves life of specimen. based on this microstructure mechanical performance improvised with increase in temperature with high hardness,% elongation,% reduction, very good wear resistance and decreases tensile ,yield strength, ductility, toughness and young's modulus, improve mach inability, improve internal stress of material improves life of specimen. Similarly vice-versa for performance decrease as temperature reduces.

VI. CONCLUSION

In this work, heat treatment of high carbon steel was carried out to study the effect of quenching and normalizing on the properties of high carbon steel. From this work, we observed that the Compression strength is is higher in quenching in oil as compared to quenching in open air. when we observed that the medium hardness value. shear strength value is observed that the ultimate shear stress and ultimate load of quenched specimen is higher than the normalized specimen. It is also reported in the literature that the effect of specimen quenching in oil on mechanical properties like ultimate shear stress and ultimate load has been increased , while hardness decreases respectively compare to others and normal HCS respectively.Wear rate by volume, time and specific wear rate has been with respective different load and different speed which depends on the hardness of the specimen.Wear rate by volume,time and specific wear rate increases at 900 deg c of normalizing process and 700 deg c of quenching process for different speed and load for 20N at 400rpm and 40N at 600rpm but for 60N at 800 rpmincreases at 700 deg c of normalizing process and 500 deg c of quenching process compare to others and normal HCS respectively Microstructure base metal with high carbon content, with high hardness and strength, improves resistance value from deformation, will remove the residual stresses to re-crystallization with respective % of c .But heat treated specimen at different temperature changes its physical ,chemical, and mechanical properties for both normalizing and quenching process. So modifying size of grain structure, better elastic characteristic with non-homogeneous arrangement of grains which has superplastic characteristic, has changed from brittle to ductility ,improve machinability, increased hardness and improve internal stress of material improves life of specimen.

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REFERENCES

[1] Mahyar Mohammadnezhad, Vahid Javaheri *2012*" The effects of heat treatment on the mechanical properties of wear resistant Cr-Mo Steel" *International Conference on Materials Heat Treatment, Islamic Azad University, Isfahan, Iran.*

[2] Uttam B. Kalwane, Yuwaraj M. Ghugal and Ajay G. Dahak *2016* "Shear strength of polymer modified steel fiber reinforced concrete" *The Indian Concrete Journal*.

[3] Rumana Hossain, Farshid Pahlevani and Veena Sahaj Walla *2018* "Evolution of Microstructure and Hardness of High Carbon Steel under Different Compressive Strain Rates" *Centre for Sustainable Materials Research and Technology and The University of New South Wales, Sydney.*

[4] Ezio Cadoni, Daniele Forni, Roman Gieleta and Leopold Kruszka, *2018* "Tensile and compressive behaviour of S355mild steel in a wide range of strain rates" *Faculty of Civil Engineering and Geodesy, Military University of Technology,00-908 Warsaw, Poland and University of Applied Sciences of Southern Switzerland, Canobbio, Switzerland*

[5] Minjung Kang, In-Hwan Jeon, Heung Nam Han and Cheolhee Kim, *2018* "Tensile–Shear Fracture Behaviour Prediction of High-Strength Steel Laser Overlap Welds" *Department of Materials Science and Engineering and RIAM, Seoul National University, Seoul 08826, Korea*

[6] Hossain, R.; Pahlevani, F.; Quadir, M.; Shahjalal's *2016* "Stability of retained austenite in high carbon steel under compressive stress" *An investigation from macro to nano scale.*

