Effect of Various Heat Treatment On The Mechanical Properties of Steel Alloy EN31

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Abstract

Steel has widely used in industries because of its geometric properties, such as hardness, high flexibility and ability to resist static and dynamic loads. In this project a sample of steel alloy type EN-31 is selected where various heat treatments like annealing, quenching and normalizing are carried out for improving its mechanical properties. After that heat treated samples are used for different mechanical tests like tensile, hardness etc. From the project procedure which heat treatment's better for improving material properties will be investigated.
Keywords: Heat treatment, Hardness, Tensile strength, Material Properties

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I. INTRODUCTION

Welding, cutting, or even grinding on metal produces heat, which in turn has an effect on the structure of the metal. As a Steelworker, you need to understand the effect that heat treatment has on metals so you can attain the desired properties for a particular metal. You also need to know what methods can be used to restore a metal to its original condition. Heat treatment is the process of heating (but never allowing the metal to reach the molten state) and cooling a metal in a series of specific operations which changes or restores its mechanical properties. Heat treatment makes a metal more useful by making it stronger and more resistant to impact, or alternatively, making it more malleable and ductile. However, no heat-treating procedure can produce all of these characteristics in one operation; some properties are improved at the expense of others. For example, hardening a metal may make it brittle, or annealing it may make it too soft.

All heat-treating processes are similar because they all involve the heating and cooling of metals. However, there are differences in the methods used, such as the heating temperatures, cooling rates, and quenching media necessary to achieve the desired properties. The heat treatment of ferrous metals (metals with iron) usually consists of annealing, normalizing, hardening, and/or tempering. Most nonferrous metals can be annealed, but never tempered, normalized, or case hardened. To successfully heat treat a metal, you need to have the proper equipment with close control over all factors relevant to the heating and cooling. For example, the furnace must be the proper size and type with the temperatures controlled and kept within the prescribed limits for each operation, and you must have the appropriate quenching media to cool the metal at the correct rate. The furnace atmosphere itself affects the condition of the metal being heat treated. This atmosphere consists of the gases in the furnaces heating chamber that circulate and surround the metal being heated. In an electric furnace, the atmosphere is either air or a controlled mixture of gases. In a fuel-red furnace, the atmosphere is a mixture of gases and air. Air combines with gases released by the fuels combustion resulting in various proportions of Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrogen (H), Nitrogen (N), Oxygen (O), water vapour (H_2O), and other various Hydrocarbons (nCH_2). When you vary the proportions of air and fuel in a fuel- fired furnace, you can provide three distinct atmospheres: oxidizing, reducing, and neutral. You accomplish heat treatment in three major stages:

- Stage l Heat the metal slowly to ensure a uniform temperature.
- Stage 2 Soak (hold) the metal at a given temperature for a given time.
- Stage 3 Cool the metal to room temperature.

A. Application of the EN-31 material

EN-353 steel is an easily available and cheap material that is acceptable for heavy duty applications. Heat treatment on EN-353 steel is improved the hardness and relive internal stress in the material.

B. Chemical composition of EN-31 material

Table – 1
Chemical composition of EN -31 material

Sr. No.	*C %*	*Si %*	*Mn %*	*Cr %*	*S %*
1.	*0.9 to 1.2*	*0.1 to 0.35*	*0.3 to 0.6*	*1.0 to 1.6*	*0.04*

II. OBJECTIVE OF STUDY

EN-31 steel has carbon content of 1% the most common form of steel as it's provides material properties that are acceptable for the manufacture of parts such as general purpose axles and shafts, gears, bolts and studs. It is neither externally brittle due to its higher carbon content and higher hardness. As the carbon content increases, the metal becomes harder and stronger. To increase the hardness of the material and increase the life of the material against the failure occurs due to high loading on the axles, gears, bolts and studs we are going to use heat treatment on the material at different temperature and through different quenching media.

III. LITERATURE REVIEW

Mainly low carbon containing Material are commonly used in the Gear, axle, shaft, bolt and studs. There are some impact load on the heavy duty gears and axles so there is wear and tear of the components so we are going to study about to investigate the heat treatment effect on the hardness and tensile strength of the materials so we have studied some research papers and review papers which are mentioned below.

1) D.A.Fadare, T.G.Fadare and O.Y.Akanbi researched that the effect of heat treatment on the microstructure and some selected mechanical properties of NST 37-2 steel were studied. Sample of steel was purchased from local market and the spectrometry analysis was carried out. The mechanical properties (tensile yield strength, ultimate tensile strength, Young's modulus, percentage reduction, percentage elongation, toughness and hardness) of the treated and untreated samples were determined using standard methods and the microstructure of the samples was examined using metallographic microscope equipped with camera. Results showed that the mechanical properties of NST 37-2 steel can be changed and improved by various heat treatments for a particular application.
2) T. Senthilkumarand T. K. Ajiboye researched that the heat treatment database was developed to optimize the development of heat treatment parts and manufacturing conditions. Data related to carburize and induction hardened gears was input to construct the database. The analysis speed of computer simulation of heat treatment quality has been dramatically increased, allowing analysis of large scale models such as entire shapes of gears using a personal computer. Benchmark simulation currently undertaken as an industry-academia joint project was carried out and the accuracy of simulation analysis was evaluated. The fluctuation range of hardness of carburized gears of construction equipment manufactured in full-scale production was estimated using the database and simulation.
3) Grazyna Mrowka, Jan Sieniawski and Andrzej Nowotnik investigated that the effect of heat treatment parameters (temperature and time) on the tensile properties and fracture toughness of 6082 aluminium alloy. Design/methodology/approach: Tensile strength - Rm, yield strength - Rp0.2 and elongation - A of the 6082 aluminium alloy was determined by uni axial tensile test at room temperature. Furthermore, the aged alloy was tested in tension in order to evaluate its fracture toughness. Therefore, according to ASTM standard tests were performed on fatigue pre cracked compact tension (KIc) and sharp-notched specimens in both the longitudinal and transverse orientation with respect to the rolling direction. Findings: The results show that the microstructure, mechanical properties and fracture toughness changes during artificial aging due to the precipitation strengthening process. Practical implications: This paper is the part of previous authors' investigations which results in modification of the heat treatment parameters that may lead to the most favourable mechanical properties and fracture toughness of 6082 alloy. Originality/value: Paper contains a broad spectrum of experimental data including uniaxial tensile test and fracture toughness investigation based on two various technique and as well as a new ideas concerning aging parameters and their effect on the mechanical properties and ductility of the 6082 alloy.
4) Vinod Joshi, Sohit Singh, Saurabh Bohra, Saurabh Kumar and Shahzad Ali researched that the effect of heat treatment process on micro grain structure of steel in different electrical furnaces at different temperature levels and varying the holding time and heat treatment mediums. This study shows the effect of heat treatment process (annealing, normalizing, hardening, and tempering) on micro grain structure of steel. By heat treating the steel the material properties like ductility, toughness, hardness, tensile strength can easily be changed which would suit our design. This study summaries the alteration of mechanical property of steel undergoing various heat treatment process in comparison to untreated samples.

5) KushalKhera, Anmol Bhatia, Sanjay Kumar and Mehul Bhatia researched that the effect of heat treatments on microstructure and mechanical properties of EN -31 and EN-08 carbon steel are being studied. Further both the carbon steels are compared on the basis of their mechanical properties as well as the rate of corrosion, then the hardness of both the carbon steel are noted before and after the heat treatment processes. The heat treatment processes i.e. Annealing, Tempering & Oil quenching (hardening) are done. The hardening temperature for EN-31 varies from 8200C - 8600C whereas the hardening temperature for EN-08 varies from 7500C – 9000C. The mechanical properties such as the hardness and tensile strength among three processes, the oil quenching sample posses highest hardness and the annealed sample posses highest elongation. That is how heat treatment plays an important role in the mechanical properties and corrosion resistance of the experimental steel.
6) Sathish Kumar, B.Shiva, V. Nachimuthu concerned basically on "To study the heat treatment on the structure and properties of automobile gears, which consist of hardening and carburizing process which is a case hardening process". Case hardening is the process of hardening the surface of metal, often low carbon steel by infusing elements into the metal surface forming a hard, wear resistance skin but preserving a tough and ductile applied to gears. The hardening treatment for most steels consists of heating the steel to a set temperature and then cooling it rapidly by plunging it into oil, water. EN-08 and EN-353 steel is an easily available and cheap material that is acceptable for heavy duty applications. Heat treatment on EN-08 and EN-353 steel is improved the hardness and relive internal stress in the material. The experimental results of hardness and microstructure are done to get idea about heat treated materials. It is found that the hardness of the materials is improved after the heat treatment and the microstructure is changed from austenite to marten site.
7) Amit Kumar Tanwerthe author has studied about the mechanical properties like Tensile strength, yield stress and elongation for different steels such as low carbon steel and stainless steel and find out the effect of various heat treatments like annealing, quenching and normalizing on material properties through testing on samples using UTM. First of all, Metal rods are machined on lathe machine as per drawing of samples. Drawing is based for testing of samples on Universal Testing Machine (UTM) then Heat treatments processes are done in muffle furnace on 9000 C and holding time is 2 hrs. Than cooled as per different heat treatment. After that heat treated samples are used for testing of different material properties. Result shows which heat treatment will be better for improving material properties of mild steel and stainless steel

IV. EXPERIMENTAL WORKS

A. Annealing for EN-31 material

Annealing will be done to remove the relieve stress from the material EN-31 and following steps are conducted.

1) An annealing will be conducted at 670 degree Celsius.
2) At 670 degree Celsius material will be cooled for around 2 hours to be get homogenized.
3) The heating will be carried out in three steps:
   - In the first step the material will be heated up to 200 degree Celsius and hold for 30 minute.
   - In the second step the material will be again heated from 200 degree Celsius to 350 degree Celsius and again hold there for 30 minute.
   - Now in the third step material will be heated from 350 degree Celsius to 670 degree Celsius and hold there for 1.5 hour.
4) Now going to do a furnace cooling.

B. Hardening of EN-31 Material

Hardening will be conducted to increase the hardness of material EN-31 and following steps are conducted.

1) Hardening will be done at a three different austenization temperature:
   - At 750 degree Celsius
   - At 800 degree Celsius
   - At 850 degree Celsius
2) After annealing an austenization temperature Quenching will be done on a material EN-31.Quenching will be carried out in three quenching medium:
   - Water quenching
   - Oil quenching
   - Air quenching
3) After doing a quenching of a material, Tempering will be done on the material EN-31 and a tempering will be done at three temperature i.e.
   - At 200 degree Celsius
   - At 300 degree Celsius
   - At 400 degree Celsius

V. EXPERIMENTAL SETUP

A. Light weight muffle furnace

Table – 2
Specification of light weight muffle furnace

	NAME	SPECIFICATION
1.	Construction	CRC sheet-powder coated
2.	Insulation	Fibre wool insulation
3.	Max. temperature	1200 degree Celsius
4.	Working temperature	1150 degree Celsius
5.	Temperature control	Digital temperature indicator cum controller with K type sensor
6.	Operation	220/230 volts AC single phase
7.	Working size	225 D X 100 W X 100 H mm.

B. Rockwell Hardness Tester

Table – 3
Specification of a Rockwell hardness testing machine

	NAME	SPECIFICATION
1.	Loads	60,100,150,187.5,200 kgf
2.	Initial load	10 kgf
3.	Max. test height	230 mm
4.	Depth of throat	133 mm

VI. RESULT AND DISCUSSION

A. Result Table for Hardness of EN-31 Steel Material

Table – 4
Result Table for Hardness of EN-31 Steel Material

Test case	Austenization temperature	Quenching media	Tempering temperature	Hardness value measured before tempering in HRC	Hardness value measured after tempering in HRC
1	750	Water	150	68	56
2	750	Oil	150	55	48
3	750	Air	150	24	21
4	750	Water	200	66	55
5	750	Oil	200	54	45
6	750	Air	200	27	20
7	750	Water	250	66	57
8	750	Oil	250	55	46
9	750	Air	250	23	20
10	800	Water	150	70	58
11	800	Oil	150	58	50
12	800	Air	150	27	23
13	800	Water	200	69	57
14	800	Oil	200	60	49
15	800	Air	200	28	22
16	800	Water	250	71	61
17	800	Oil	250	58	47
18	800	Air	250	27	25
19	850	Water	150	72	62
20	850	Oil	150	61	57
21	850	Air	150	29	24
22	850	Water	200	71	63
23	850	Oil	200	59	52
24	850	Air	200	28	25
25	850	Water	250	72	62
26	850	Oil	250	64	54
27	850	Air	250	31	28

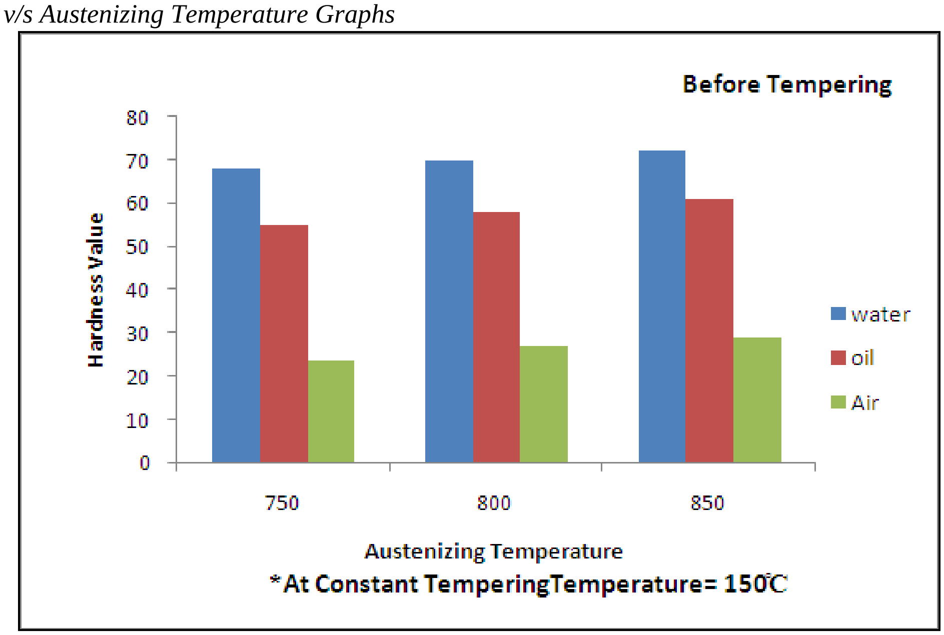
B. Result Table for Tensile Strength of EN-31 Steel Material

Table – 5
Result Table for Tensile Strength of EN-31 Steel Material

Test case	*Austenization temperature*	*Quenching media*	*Tempering temperature*	*Yield Tensile strength measured in N/mm^2*	*Ultimate Tensile strength measured in N/mm^2*
1	*750*	*Water*	*150*	*722.73*	*1396.10*
2	*750*	*Oil*	*150*	*661.03*	*1256.37*
3	*750*	*Air*	*150*	*579.61*	*1164.61*
4	*750*	*Water*	*200*	*678.54*	*1358.47*
5	*750*	*Oil*	*200*	*575.44*	*1170.58*
6	*750*	*Air*	*200*	*507.76*	*1106.88*
7	*750*	*Water*	*250*	*653.06*	*1302.74*
8	*750*	*Oil*	*250*	*517.52*	*1118.23*
9	*750*	*Air*	*250*	*480.69*	*1045.38*
10	*800*	*Water*	*150*	*744.63*	*1399.48*
11	*800*	*Oil*	*150*	*699.04*	*1283.24*
12	*800*	*Air*	*150*	*640.52*	*1214.17*
13	*800*	*Water*	*200*	*688.10*	*1386.34*
14	*800*	*Oil*	*200*	*619.82*	*1205.60*
15	*800*	*Air*	*200*	*591.36*	*1145.30*
16	*800*	*Water*	*250*	*667.19*	*1349.72*
17	*800*	*Oil*	*250*	*568.07*	*1178.54*
18	*800*	*Air*	*250*	*545.58*	*1100.91*
19	*850*	*Water*	*150*	*788.41*	*1460.39*
20	*850*	*Oil*	*150*	*730.69*	*1296.17*
21	*850*	*Air*	*150*	*621.21*	*1237.66*
22	*850*	*Water*	*200*	*699.04*	*1416.20*
23	*850*	*Oil*	*200*	*640.52*	*1271.30*
24	*850*	*Air*	*200*	*580.21*	*1192.47*
25	*850*	*Water*	*250*	*690.88*	*1407.84*
26	*850*	*Oil*	*250*	*603.30*	*1218.35*
27	*850*	*Air*	*250*	*545.58*	*1150.07*

C. *Graphical representation of a Hardness of EN-31 Steel Material*

1) *Hardness value v/s Austenizing Temperature Graphs*



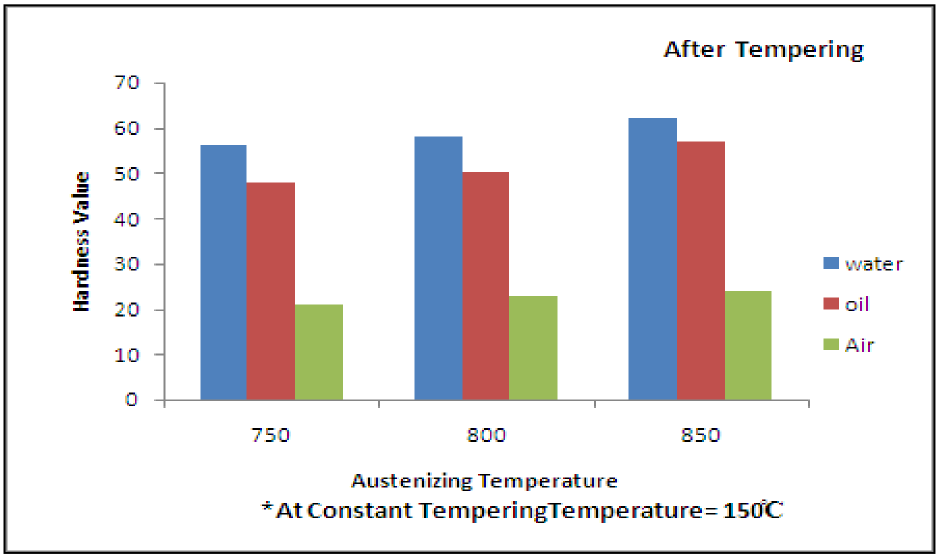


Fig. 1: For constant tempering temperature 150°

Above chart indicates that we can find max hardness value in water quenching and min hardness value in Air quenching. It also indicates that as Austenizing temperature increases the Hardness value also increases.

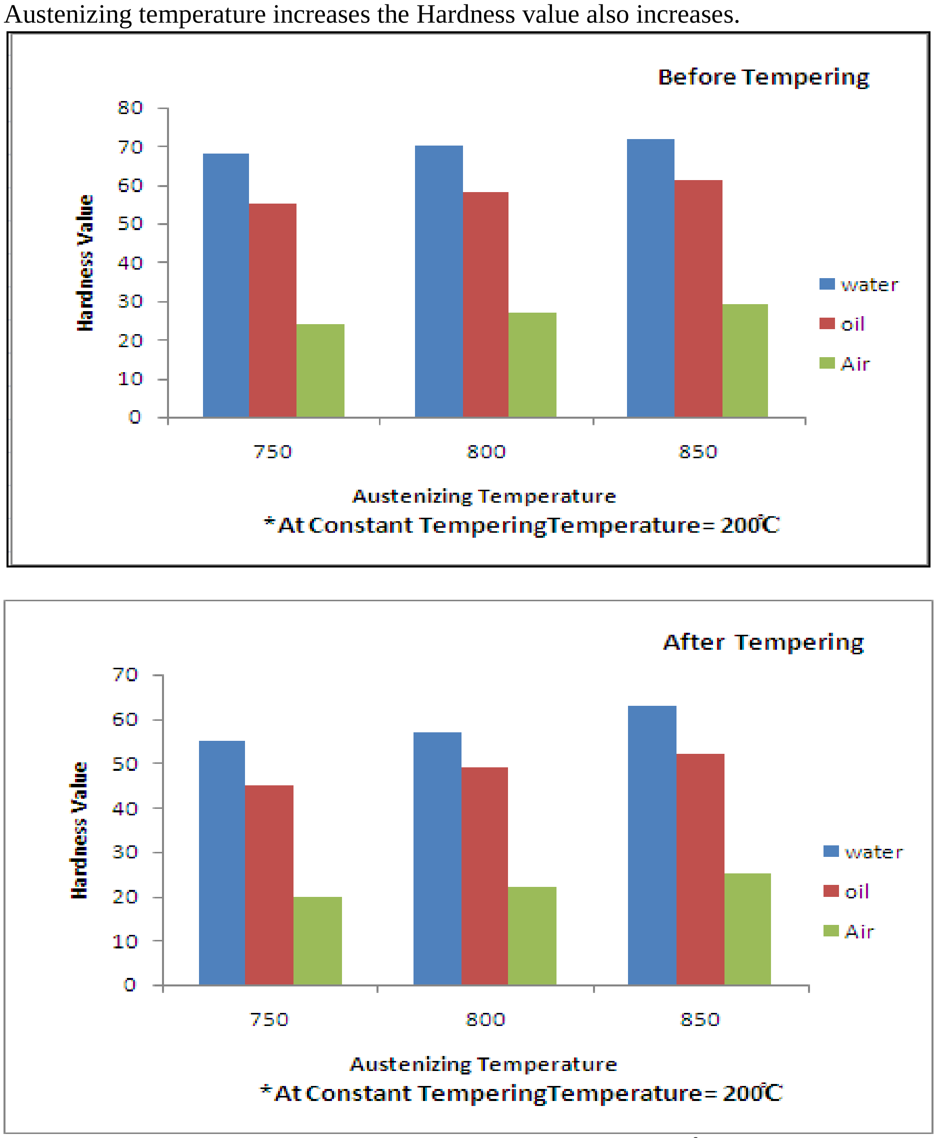
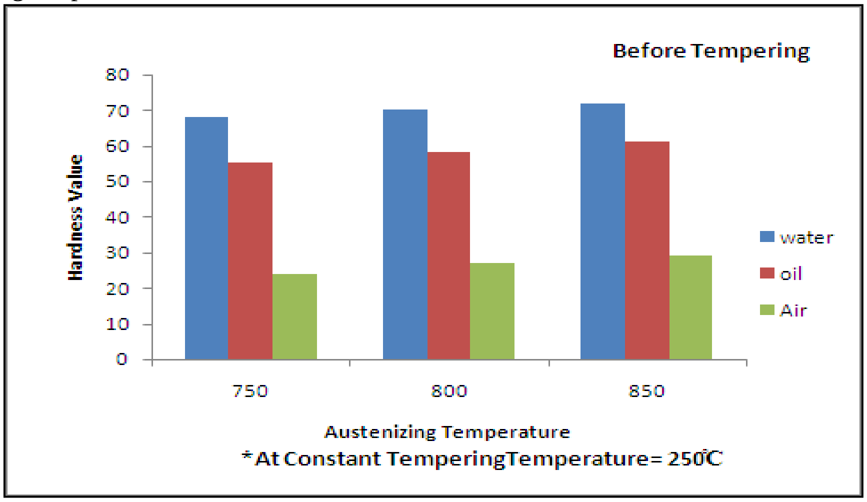


Fig. 2: For constant tempering temperature 200^0

Above chart indicates the value of Hardness decreases compare to Constant tempering temperature 150^0 in All the Quenching media. As the Austenizing temperature increases the value of Hardness also increases.



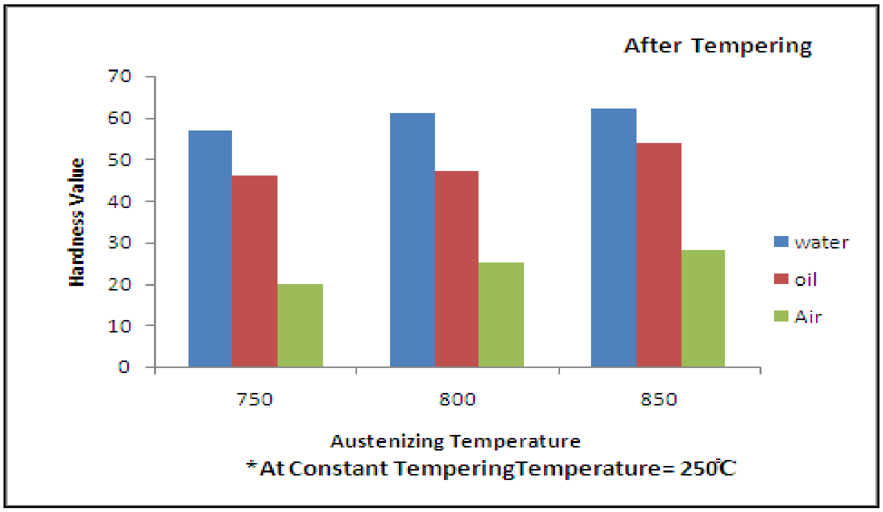
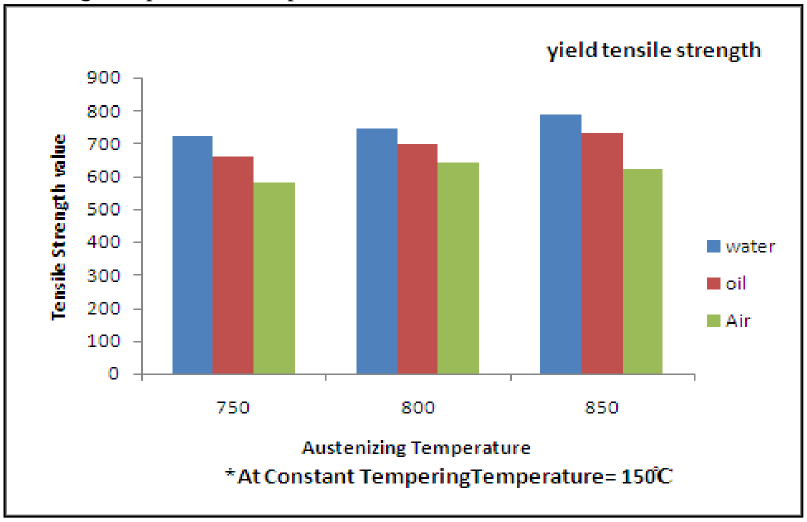


Fig. 3: For constant tempering temperature 250^0

Above chart indicates that as tempering temperature increases the Hardness value decreases in all three Quenching media. Same like above two charts as Austenizing temperature increases the value of Hardness also increases.

D. Graphical representation of a Tensile Strength of EN-31 Steel Material

1) Tensile Strength v/s Austenizing Temperature Graphs



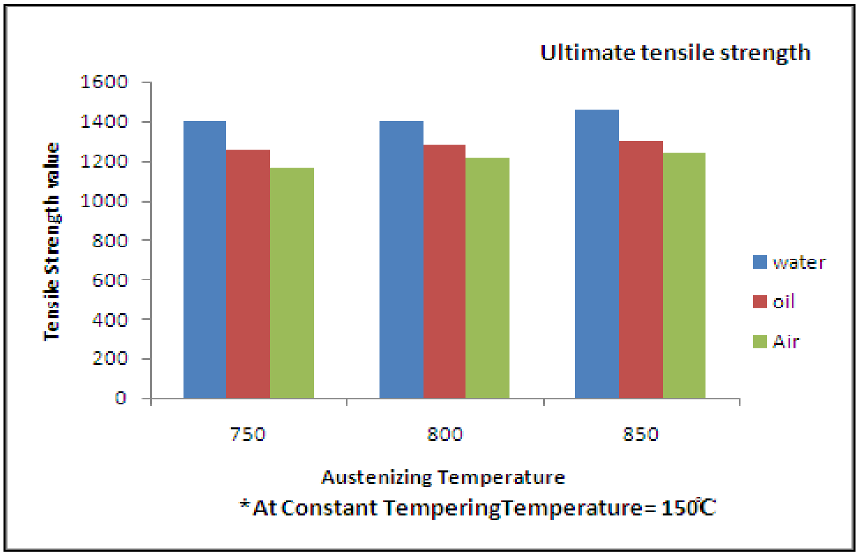
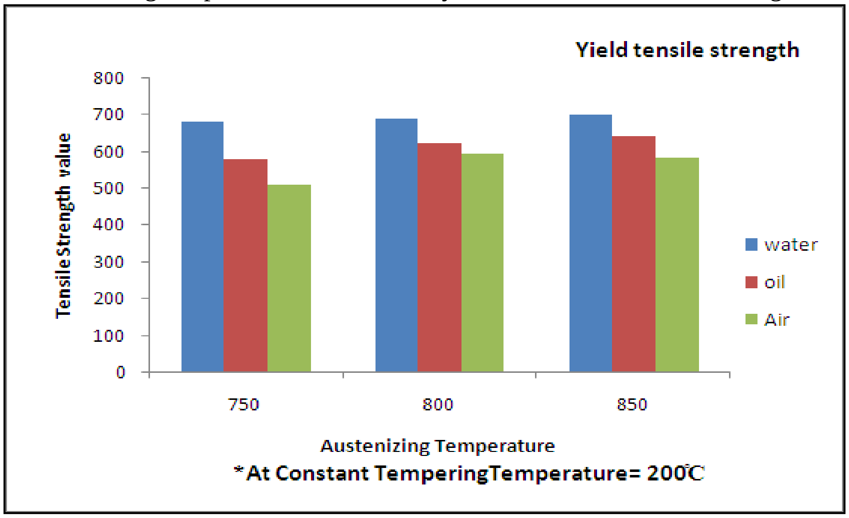


Fig. 4: For constant tempering temperature 150^0

Above graphs shows that as austenizing temperature increases the yield and ultimate tensile strength also increases.



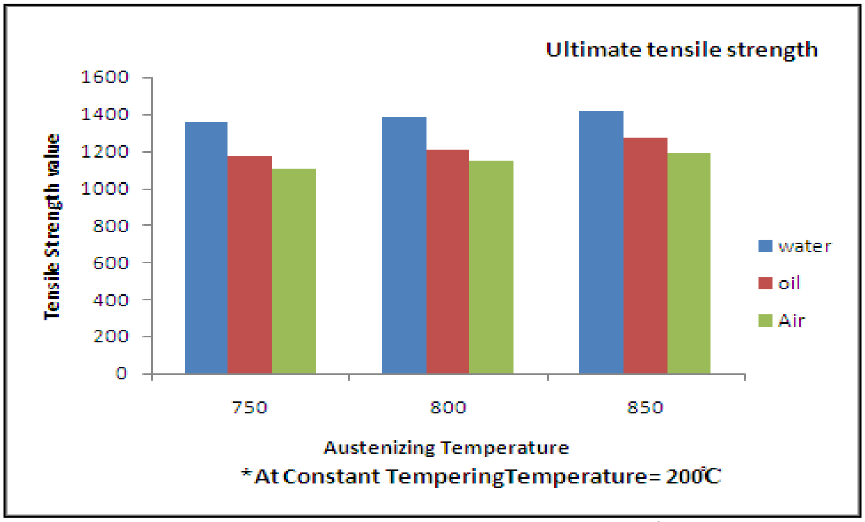
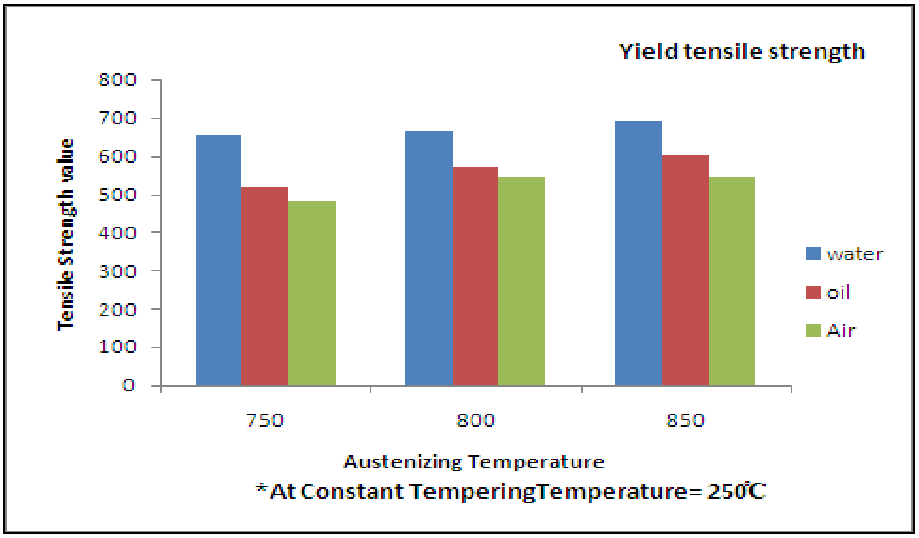


Fig. 5: For constant tempering temperature 200^0

As the tempering temperature increase the tensile strength reduces so as compare to 150^{0}C tempering temperature at 200^{0}C tensile strength is low.



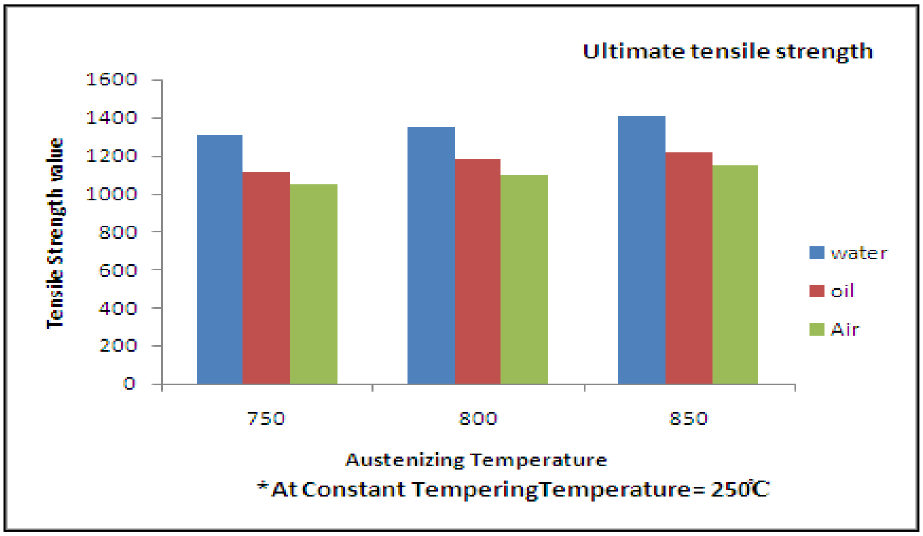


Fig. 6: For constant tempering temperature 250^0

Above chart indicates that as tempering temperature increases the Tensile Strength and Ultimate tensile strength value decreases in all three Quenching media.

VII. CONCLUSION

After performing experiments we can conclude that as austenizing temperature increases the value of hardness also increases and as tempering temperature increases and the hardness value decreases in respective quenching media. We are getting maximum value of hardness at austenizing temperature is 850^0 C, Quenching medium is water, Tempering temperature is 150^0 C and the value is 62 HRC measured in Rockwell hardness tester. Also we came to conclude that as Austenizing temperature increases the tensile strength also increases and as tempering temperature increases the tensile strength decreases compare to the tensile strength of the material before tempering. We can find the maximum yield tensile strength and ultimate tensile strength at austenizing temperature 850^0 C, Quenching medium is water and tempering temperature 150^0 C we get 788.41 N/mm^2 and 1460.39 N/mm^2.

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