AN EXPERIMENTAL STUDY OF EFFECTS OF VARIOUS HEAT TREATMENT PROCESSES ON HARDNESS AND ULTIMATE TENSILE STRENGTH OF MILD STEEL PRODUCT AFTER CASTING

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Abstract- *Low carbon steel is easily available and cheap having all material properties that are acceptable for many applications. Heat treatment on low carbon steel is to improve ductility, to improve toughness, strength, hardness and tensile strength and to relive internal stress developed in the material. Here basically the experiment of hardness and ultimate tensile strength is done to get idea about heat treated low carbon steel, which has extensive uses in all industrial and scientific fields.*

Keywords- Heat treatment ,Normalizing , Quenching, Tempering, Hardness, Toughness, Tempering.

I. INTRODUCTION

The process of heating and cooling of material is Heat treatment . It is possible to obtain the desirable mechanical properties for steel or alloys by heat treatment. In heat treatment temperature variation with time is basic parameter to alter mechanical property of the component. If this variation is proper so that phase transformation is according to part application requirement, because the basic requirement of mechanical properties is different for different environment.

In this paper a grade of steel AISI8620 has been taken for experiment purpose in highly stressed application and number of heat treatment processes has been carried out which impart the optimum value of mechanical properties. In these heat treatment processes a variation is made over temperature and time and optimum value has been selected. The most important heat treatments are Stress relieving, Annealing, Normalizing, Hardening and Tempering.

The most important heat treatments and their purposes are:
Stress relieving - a low temperature treatment, to reduce or relieve Internal stresses remaining after casting.
Annealing - to improve ductility and toughness, to reduce hardness and to remove carbides .
Normalizing - to improve strength with some ductility.
Hardening and tempering - to increase hardness or to give improved Strength and higher proof stress ratio.
Austempering - to yield bainitic structures of high strength, with significant ductility and good wear resistance.
Surface hardening - by induction, flame, or laser to produce a local wear resistant hard surface.

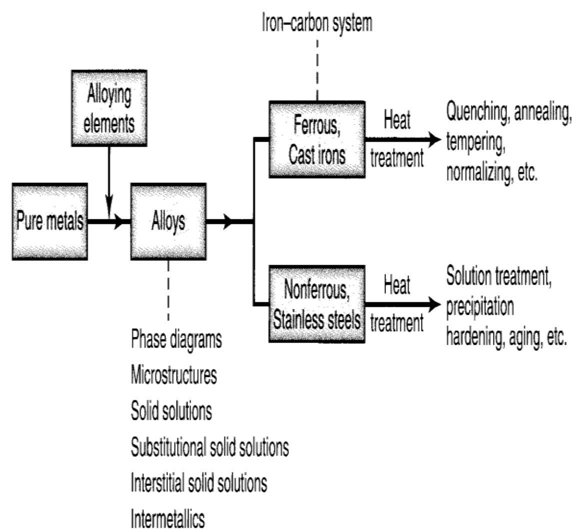


Fig.1. An outline of various Heat treatment processes for various materials.[1]

II. MATERIAL DETAILS

Mild steel. AISI8620: It is one of the American standard specifications of the mild steel having the pearlitic matrix (up to70%) with relatively less amount of ferrite (30-40%). And so it has high hardness with moderate ductility and high strength as specified below. So we can also say that it is basically a pearlitic/ferritic matrix.

III. HEAT TREATMENT OPERATION

1. ANNEALING

a) The specimen was heated up to a temperature of 950°C.
b) At temperature 950°C the specimen was held for 2 hour.
c) Then the furnace was switched off so that the specimen temperature will decrease with the same rate as that of the furnace the objective of keeping the specimen at 950°C for 2 hrs is to homogenize the specimen. The temperature 950° C lies above re-crystallization temperature. So that the specimen at that temperature gets sufficient time to get properly homogenized .The specimen was taken out of the furnace after 1 day when the furnace temperature had already reached the room temperature.[2]

2. NORMALIZING

a) At the very beginning the specimen was heated to the temperature of 900°C.
b) There the specimen was again kept for 2 hour.
c) Then the furnace was switched off and the specimen was taken out.
d) Now the specimen is allowed to cool in the ordinary environment i.e. the specimen is air cooled to room temperature. The process of air cooling of specimen heated above re-crystallization is called normalizing.

3. QUENCHING

This experiment was performed to harden the AISI8620. The process involved putting the red hot specimen directly in to a liquid medium.

a) The specimen was heated to the temp of around 900° C and was allowed to homogenize at that temp for 2 hour.
b) An oil bath was maintained at a constant temperature in which the specimen had to be put.
c) After 2 hour the specimen was taken out of the furnace and directly quenched in the oil bath.
d) After around half an hour the specimen was taken out of the bath and cleaned properly.
e) Now the specimen attains the liquid bath temp within few minutes. But the rate of cooling is very fast because the liquid doesn't release heat readily.[3]

4. TEMPERING

This is the one of the important experiment carried out with the objective of the experiment being to induce some amount of softness in the material by heating to a moderate temperature range.

a) First the '4' specimen were heated to 900 deg Celsius for 2 hour and then quenched in the oil bath maintained at room temp.
b) Among the 4 specimen 2 were heated to 250 deg Celsius. But for different time period of 1 hour, 1 and half hour and 2 hour respectively.
c) Now 3 more specimens were heated to 450 deg Celsius and for the time period of 1 hour, 1and a half hour and 2 hour respectively.
d) The remaining specimens were heated to 650 deg Celsius for same time interval of 1 hour. 1 and half and 2 hour respectively.

After the specimens got heated to a particular temperature for a particular time period, they were air cooled. The heat treatment of tempering at different temp for different time periods develops variety of properties within them.[3]

IV. STUDY OF MECHANICAL PROPERTIES

As the objective of the project is to compare the mechanical properties of various heat treated mild steel specimens, now the specimens were sent to hardness testing and tensile testing.

HARDNESS TESTING

The heat treated specimens hardness were measured by means of Rockwell hardness tester. The procedure adopted can be listed as follows:

1. First the brale indenter was inserted in the machine; the load is adjusted to100 kg.
2. The minor load of a 10 kg was first applied to seat of the specimen.
3. Now the major load applied and the depth of indentation is automatically recorded on a dial gage in terms of arbitrary hardness numbers. The dial contains 100 divisions. Each division corresponds to a penetration of .002 mm. The dial is reversed so that a high hardness, which results in small penetration, results in a high hardness number. The hardness value thus obtained was converted into C scale by using the standard converter chart.

ULTIMATE TENSILE STRENGTH TESTING

The heat treated specimens were treated in UTS Machine for obtaining the % elongation, Ultimate Tensile Strength, yield Strength. The procedures for obtaining these values can be listed as follows;

1) At first the cross section area of the specimen was measured by means of an electronic slide caliper and then the gauge length was calculated.
2) Now the distance between the jaws of the UTS was fixed to the gauge length of the specimen.
3) The specimen was gripped by the jaws of the holder.
4) The maximum load was set at 150 KN.
5) The specimen was loaded till it fails.
6) The corresponding Load vs. Displacement diagrams were plotted by using the software. From the data obtained the % elongation, yield strength and ultimate tensile strength were calculated by using the following formulae: -

% elongation = (change in gauge length of specimen/initial gauge length of the specimen.) *100

Yield strength = load at 0.2% offset yield/ initial cross section area Ultimate tensile strength = maximum load/ initial cross section area

V. RESULT AND DISCUSSION

TABULATION FOR HARDNESS TESTING

The purpose of hardness testing is to evaluate the hardness of mild steel in sequential manner of Heat treatment A specification for hardness testing of mild steel specimen are given in the following table (a):

SPECIMEN SPECIFICATION	TIME	HARDNESS
Quenched from 900 and tempered at 250 degree Celsius	1 hour	45
	1½ hour	39
	2 hour	34
Quenched from 900 and tempered At 450 degree Celsius	1 hour	38
	1½ hour	34
	2 hour	29
Quenched from 900 and tempered at 650 degree Celsius	1 hour	31
	1½ hour	27
	2 hour	24
As Received	-----------	-----------------

Table (a) Different hardness values in Rc scale for various heat treated low carbon steel specimen

SPECIMEN SPECIFICATION	TIME	HARDNESS
Quenched from 900 and tempered at 250 degree Celsius	1 hour	43
Quenched from 900 and tempered At 450 degree Celsius	1 hour	36
Quenched from 900 and tempered at 650 degree Celsius	1 hour	33

Table (b) Hardness vs. tempering temperature for constant tempering time of 1 hour

SPECIMEN SPECIFICATION	TIME	HARDNESS
Quenched from 900 and tempered at 250 degree Celsius	1 ½ hour	39
Quenched from 900 and tempered At 450 degree Celsius	1 ½ hour	34
Quenched from 900 and tempered at 650 degree Celsius	1 ½ hour	28

Table (c) Hardness vs. tempering temperature for constant tempering time of 1 ½ hour

SPECIMEN SPECIFICATION	TIME	HARDNESS
Quenched from 900 and tempered at 250 degree Celsius	2 hour	34
Quenched from 900 and tempered At 450 degree Celsius	2 hour	29
Quenched from 900 and tempered at 650 degree Celsius	2 hour	22

Table (d) Hardness vs. tempering temperature for constant tempering time of 1 hour

V.B. TABULATION FOR ULTIMATE TENSILE STRENGTH TESTING

SPECIMEN SPECIFICATION	TIME	UTS (in Mpa)	Yield Strength (in Mpa)	Elong-ation%
Quenched from 900 and tempered at 250 degree Celsius	1 hour	548	334	9.654

Quenched from 900 and tempered At 450 degree Celsius	1 hour	497	297	14.369
Quenched from 900 and tempered at 650 degree Celsius	1 hour	318	234	20.476

Table (e) Tensile properties for different tempering temperature for 1 hour tempering time

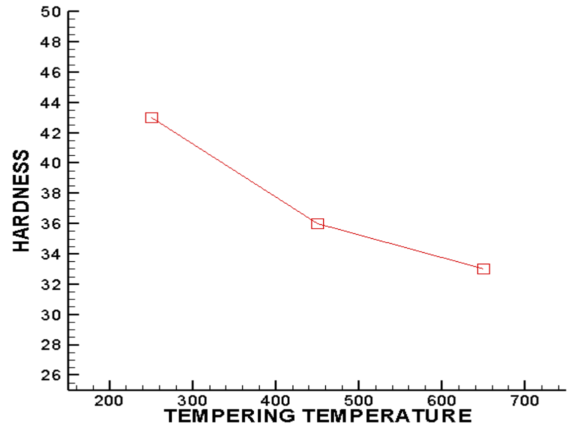
SPECIMEN SPECIFICATION	TIME	UTS (in Mpa)	Yield Stren gth(in Mpa)	Elong-ation%
Quenched from 900 and tempered at 250 degree Celsius	1½ hour	543	331	12.269
Quenched from 900 and tempered At 450 degree Celsius	1½ hour	313	284	18.345
Quenched from 900 and tempered at 650 degree Celsius	1½ hour	487	238	24.856

Table (f) Tensile properties for different tempering temperature for 1 ½ an hour tempering time

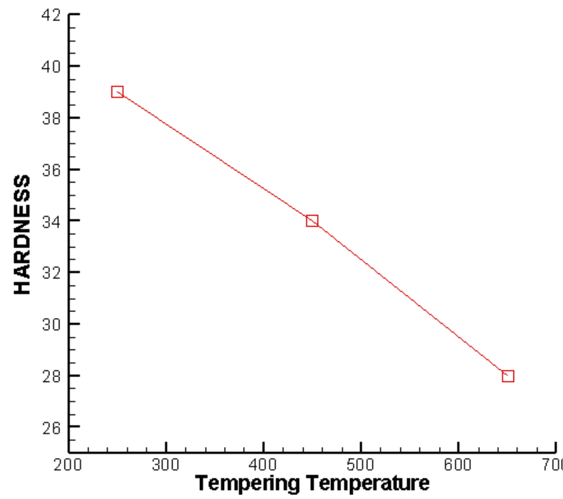
SPECIMEN SPECIFICATIO N	TIM E	UTS (in Mpa)	Yield Strengt h(in Mpa)	Elong - ation %
Quenched from 900 and tempered at 250 degree Celsius	2 hour	412	267.5	22.82 1
Quenched from 900 and tempered At 450 degree Celsius	2 hour	382	254.6	27.51 4
Quenched from 900 and tempered at 650 degree Celsius	2 hour	251	198	27.72 9

Table (g) Tensile properties for different tempering temperature for 2 hour tempering time

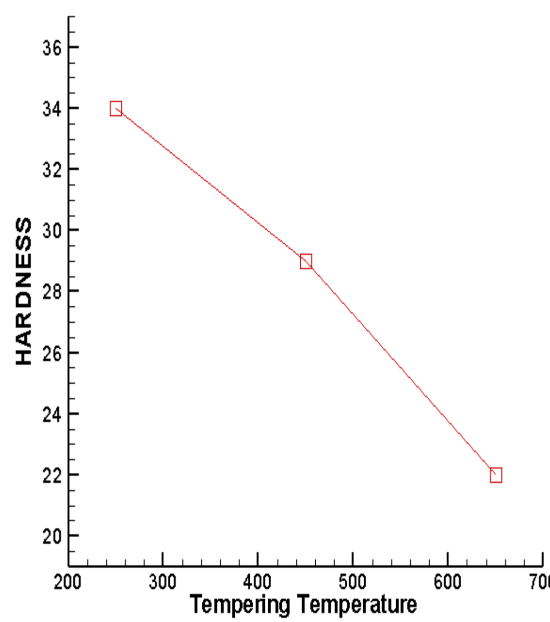
GRAPHS FOR HARDNESS MEASUREMENT



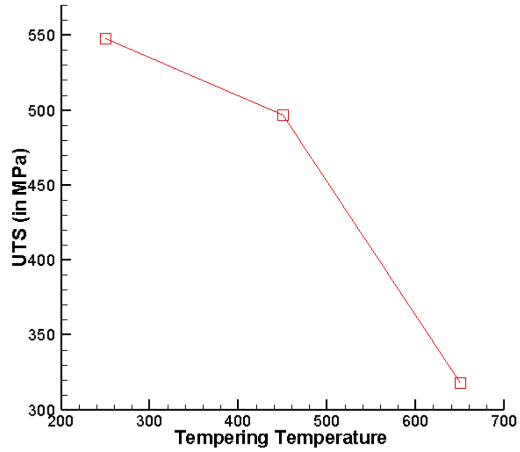
Graph (a) Hardness for different tempering temperature (in degree centigrade) for 1 hour



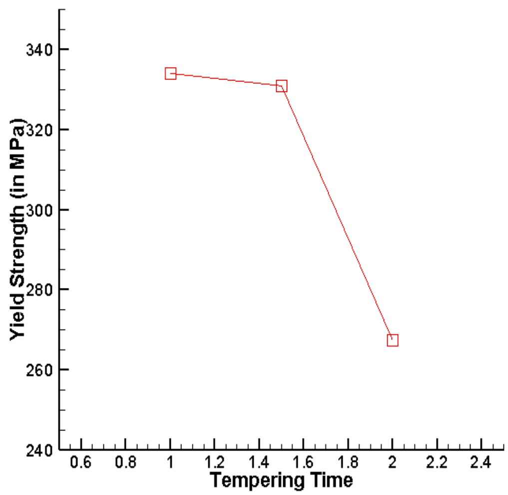
Graph (b) Hardness for different tempering temperature (in degree centigrade) for 1 ½ hour



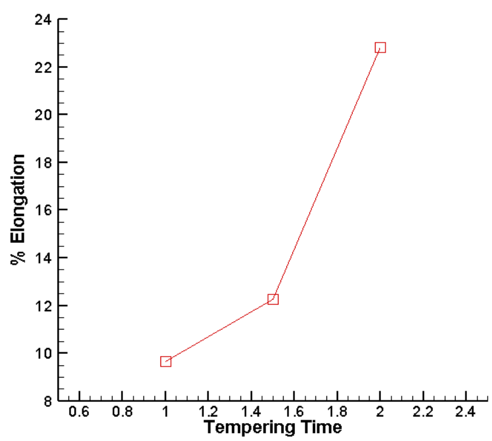
Graph (c) Hardness for different tempering temperature (in degree centigrade) for 2 hour



Graph (d) UTS for different tempering temperature (in degree centigrade) for 1 hour



Graph (e) Yield Strength (in MPa) for different tempering time (in Hour)



Graph (f) % Elongation for different tempering time (in Hour)

VII. RESULT AND DISCUSSION

From the various experiments carried out following observations and inferences were made. It was seen that the various tensile properties followed a particular sequence:

1) More is the tempering temperature, less is the hardness or more is the softness (ductility) induced in the quenched specimen. (ductility) induced in the quenched specimen.
2) Microstructure photographs taken by SEM and metallurgical inspections indicated that the surfaces of heat treated samples are martensitic.
3) Case depth can be increased by longer cycle of carburization. Case depth can be increased exponentially by increasing carburization temperature.
4) The samples having greater case depth and surface hardness are more wear resistant than that with low case depth and low surface hardness.
5) More is the tempering time (keeping the tempering temperature constant), more is the ductility induced in the specimen.
6) This clearly implies that the UTS and also to some extent the yield strength decreases with increase in tempering time where as the ductility (% elongation) increases.
7) For a given tempering time, an increase in the tempering temperature decreases the UTS value and the yield strength of the specimen where as on the other hand increasing the % elongation and hence the ductility.

VIII. CONCLUSION

From the various results obtained during the project work it can be concluded that the mechanical properties vary depending upon the various heat treatment processes. Hence depending upon the properties and applications required we should go for a suitable heat treatment processes. When ductility is the only criteria tempering at high temperature for 2 hours gives the best result among all tempering experiments however it is simply the hardness of the low carbon steel that is desired than we should go for low temperature tempering for 1 hour or so.

However if strength is also desired along with hardness, this should not be done. It is seen that annealing causes a Tremendous increase in % elongation (ductility). It can be clearly seen comparing all the heat treatment processes, optimum Combination of UTS, Yield Strength, % Elongation as well as hardness can be Obtained through austempering only.

FUTURE SCOPE

The present method adopted to solve the optimization problem of heat treatment process is simple enough and is flexible in selection of objective functions for such manufacturing processes. During the solution of the problem, it has been found that the results obtained by the heat treatment method towards the exact solutions.Then this method will be able to show its importance in real life complex manufacturing problem solution.

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