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A Project Report On Heat Treatment of Low Carbon Steel

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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 harness 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.

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I. INTRODUCTION:-

As we know there is a little bit of steel in everybody life. Steel has many practical applications in every aspects of life. Steel with favorable properties are the best among the goods. The steel is being divided as low carbon steel, high carbon steel, medium carbon steel, high carbon steel on the basis of carbon content.

Low carbon steel has carbon content of 0.15% to 0.45%. Low carbon steel is the most common form of steel as it's provides material properties that are acceptable for many applications. It is neither externally brittle nor ductile due to its lower carbon content. It has lower tensile strength and malleable. Steel with low carbon steel has properties similar to iron. As the carbon content increases, the metal becomes harder and stronger but less ductile and more difficult to weld.

The process heat treatment is carried out first by heating the metal and then cooling it in water, oil and brine water. The purpose of heat treatment is to soften the metal, to change the grain size, to modify the structure of the material and relive the stress set up in the material. The various heat treatment process are annealing, normalizing, hardening, austempering, mar tempering, tempering and surface hardening.

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, ball bearings, railway wheels.

As my project concerned it is basically concentrate on carburizing which is a case hardening process. It is a process of adding carbon to surface. These are done by exposing the part to carbon rich atmosphere at the elevated temperature (near melting point) and allow diffusion to transfer the carbon atoms into the steel. This diffusion work on the principle of differential concentration.

But it is not easy to go through all the carburizing process like gas carburizing, vacuum carburizing, plasma carburizing and salt bath carburizing.

So we go through pack carburizing which can easily done in experimental setup. In this process the part that is to be carburized is placed in a steel container, so that it is completely surrounded by granules of charcoal which is activated by barium carbonate. The carburizing process does not harden the steel it only increases the carbon content to some pre determined depth below the surface to a sufficient level to allow subsequent quench hardening.

The most important heat treatments and their purposes are:
Stress relieving - a low-temperature treatment, to reduce or relieve Internal stressesremaining after casting
Annealing - to improve ductility and toughness, to reduce hardness and to removecarbides
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 significantductility and good wear resistance.

Surface hardening - by induction, flame, or laser to produce a local wear resistanthard surface.
Boronizing is one of the methods used on steels and iron to improve their surface properties Boronized steel parts exhibit excellent performance in various tribological applications in mechanical engineering and in the automotive sector In the past 40 years, boronizing has become an increasingly better surface protection method Boronizing of steels is used against adhesive, sliding and abrasive wear and is recognized as an effective method to combat these effects The most widely known boronizing procedure is forming iron borides on the steel surface Boronizing is one of the most widely used methods in many tribological applications where wear and friction control are paramount.

The boronizing process is a chemical heat treatment that aims to form borides with the substrate metal by diffusing the boron atoms into the sample surface Boron is a metal that can form many minerals and compounds Because it is a relatively small element, the process may be applied to many types of materials such as ferrous and non-ferrous metals , nickel and cobalt alloys, metal bound carbides, refractory alloys and some super alloys. Boronizing of ferrous products is usually conducted between 840 and 1050 °C There are several techniques available for surface boron enrichment process.The process can be carried out employing any of the solid, liquid, gaseous state,plasma andion implantation environments Pack boronizing mixtures comprise 5% B_4C as the source, 5% KBF_4 as activator and 90% SiC as the diluting agent During the boronizing process, the sample is put inside a sealed container packed with powder mix and sealed. The container is heated up to desired temperature and kept at that temperature for the prescribed time, and finally cooled.

With the diffusion of boron into the steel, iron borides (FeB, Fe_2B) form and the thickness of the boride layer is determined by the process temperature and time The crystal structure of both layers exhibit columnar shapes oriented along the diffusion axis Generally, saw-tooth shaped single phase (Fe_2B) layer formation is preferred over a layer with both FeB and Fe_2B The boron-rich FeB phase that has approximately 16.23 wt% B is not preferred because it is more brittle compare to the Fe_2B phase that has 8.83 wt% B Boride layers adhere to the substrate material more strongly because of the saw-tooth morphology. Brittleness of the boronized layer increases with the layer thickness Also, since the FeB and Fe_2B phases have different thermal expansion constants (TEC; $\alpha_{FeB} = 23 \times 10^{-6}\ ^{\circ}C^{-1}$, $\alpha_{Fe\ B} = 7.85 \times 10^{-6}\ ^{\circ}C^{-1}$), crack formations are frequently found on the FeB/Fe_2B phase interfaces in two phase layers. These cracks frequently cause spalling and scaling under a mechanical load By controlling the boronizing parameters, that is the boronizing powder composition, temperature and process time, the pack boronizing method can reliably produce the Fe_2B phase.

Steels surface treated using boronizing heat treatment methods are widely used in industry. It is known that the boride layers can exhibit surface hardness over 2000 HV and provide good abrasive and adhesive wear resistance Comparison of steels used in industry treated with other surface hardening treatments such as carburizing and nitriding with boronizing shows that the boronized steels have superior tribological characteristics Boronized iron and steel surfaces exhibit high hardness, excellent wear and corrosion resistance and strong chemical stability.

Habig reports that the abrasive wear resistance of boronized steels is higher against alumina abrasives than against silicon carbide abrasives. Habig concludes that this is because of relative hardness of these materials. Richardson similarly reports that in case the hardness H value of the material subjected to wear is higher than the hardness H_a of the abrasive material or more appropriately in case $H > 0.8H_a$, wear resistance significantly decreases.

A very hard surface layer, a very low coefficient of friction, no requirement of heat treatment after the boronizing process and a very significant resistance against some acids, bases, metal solutions and high temperature oxidizing are among the advantages of boronizing over other surface hardening methods Hardness, shape and size or roughness of abrasive material, angle of contact, normal load applied, sliding speed and fracture toughness of the material are all among important factors in wear mechanisms One of the most important reasons for the machinery parts to suffer damage and fail is wear. Abrasive wear, most important type of wear for the industrial machine parts, is important as it may cause rapid failure in the system. Because of these, this study focuses on the effects of boronizing treatments carried out at different temperatures and with different process durations on abrasive wear resistance.

Today in this modern era high mechanical properties can be easily achieved by heat treatment process. The medium carbon steel has high fatigue strength, has high yield strength and high proportional limit. There is various heat treatment processes out of which Annealing, Hardening, Normalizing, Tempering are the most suited one for improving the microstructure of the engineering material such as steel.

In normalizing process the material is heated to austenitic temperature range and then air cooling is done.In hardening process the steel is heated to such a temperature that it can support the formation of austenite ,and it is held in temperature up to carbon has dissolved or quenched in water or oil. Steel is the alloy of iron which has carbon % around 0.15- 1.5% [1] plain carbon are those which has % around 0.1-0.25 The main two reason that steel is so used because.

The application of this steel is that it is used in trains, railroad, beams of building support structure reinforcing rods in concrete, construction of ship, tubes for boiler in power generating plants, car radiator, oil and gas lines.

II. LITERATURE REVIEW

2.1. Carbon steel:

Carbon steel (plain carbon steel) is steel which contain main alloying element is carbon. Here we find maximum up to 1.5% carbon and other alloying elements like copper, manganese, silicon. Most of the steel produced now-a-days is plain carbon steel. It is divided into the following types depending upon the carbon content.

1. Dead or mild steel (up to 0.15% carbon)
2. Low carbon steel (0.15%-0.45% carbon)
3. Medium carbon steel(0.45%-0.8% carbon)
4. High carbon steel (0.8%-1.5% carbon)

Steel with low carbon content has properties similar to iron. As the carbon content increases the metal becomes harder and stronger but less ductile and more difficult to weld. Higher carbon content lowers the melting point and its temperature resistance carbon content cannot alter yield strength of material.

2.1.1. LOW CARBON STEEL:-

Low carbon steel has carbon content of 1.5% to 4.5%. Low carbon steel is the most common type of steel as its price is relatively low while its provides material properties that are acceptable for many applications. It is neither externally brittle nor ductile due to its low carbon content. It has lower tensile strength and malleable.

2.2. HEAT TREATMENT:-

The process of heat treatment is carried out first by heating the material and then cooling it in the brine, water and oil. The purpose of heat treatment is to soften the metal, to change the grain size, to modify the structure of the materialand to relieve the stress set up in the material after hot and cold working.

The various heat treatment processes commonly employed in engineeringpractice as follows:-

2.2.1. ANNEALING:-

Spherodizing:-

Spherodite forms when carbon steel is heated to approximately 700 for over 30 hours. The purpose is to soften higher carbon steel and allow more formability. This is the softest and most ductile form of steel. Here cementite is present.

Full annealing:-

Carbon steel is heated to approximately above the upper critical temperature (550-650) for 1 hour. Here all the ferrite transforms into austenite. The steel must then cooled in the realm of 38 per hour. This results in a coarse pearlite structure. Full annealed steel is soft and ductilewith no internal stress.

Process annealing:-

The steel is heated to a temperature below or close to the lower critical temperature (550-650), held at this temperature for some time and then cooled slowly. The purpose is to relive stress in a cold worked carbon steel with less than 0.3%wt c.

Diffusion annealing:-

The process consists of heating the steel to high temperature (1100- 1200). It is held at this temperature for 3 hours to 20 hours and then cooled to 800-850 inside the furnace for a period of about 6 to 8 hours. It is further cooled in the air to room temperature. This process is mainly used for ingots and large casting. It is also called isothermal annealing.

2.2.2. NORMALISING:-

The process of normalizing consist of heating the metal to a temperature of 30 to 50 c above the upper critical temperature for hypo-eutectoid steels and by the same temperature above the lower critical temperature for hyper-eutectoid steel. It is held at this temperature for a considerable time and then quenched in suitable cooling medium. The purpose of normalizing is to refine grain structure, improve machinibility and improve tensile strength, to remove strain and to remove dislocation.

2.2.3. HARDENING:-

The process of hardening consist of heating the metal to a temperature of 30-50 c above the upper critical point for hypo-eutectoid steels and by the same temperature above the lower critical temperature for hyper-eutectoid steels. It is held this temperature for some time and then quenched. The purposes of hardening are to increase the hardness of the metal and to make suitable cutting tools.

2.2.4. AUSTEMPERING:-

It is a hardening process. it is also known as isothermal quenching. In this process, the steel is heated above the upper critical temperature at about 875 c where the structure consists entirely of austenite. It is then suddenly cooled by quenching it in a salt bath maintained at a temperature of about 250 c to 525 c.

2.2.5. MARTEMPERING:-

This process is also known as steeped quenching or interrupted quenching. It consists of heating steel above the upper critical temperature and quenching itin a salt bath kept at a suitable temperature.

2.2.6. TEMPERING:-

This process consists of reheating the hardened steel to some temperature below the lower critical temperature, followed by any desired rate of cooling. The purpose is to relive internal stress, to reduce brittleness and to make steel tough to resist shock and fatigue.

2.3. SURFACE HARDENING:-

In many engineering applications, it is desirable that steel being used should have a hardened surface to resist wear and tear. At this time, it should have soft and tough interior or core so that it can absorb any shocks. Case hardening isthe process of hardening the surface of metal, often a low carbon steel by infusing elements into the metal surface forming a hard, wear resistance skin but preserving a tough and ductile interior. This type of treatment is applied to gears, ball bearings, railway wheels. The various case hardening processes are as follows:-

A. Carburizing
B. Cyaniding
C. Nitriding
D. Carbonitriding
E. Flame/induction hardening

2.3.1. FLAME AND INDUCTION HARDENING:-

Flame or induction hardening are process in which the surfaces of the steel is heated to a high temperature (by direct application of flame or by induction heating), then cooled rapidly using water this creates a case of martensite on the surfaces. A carbon content of 0.4%-0.6%wt c is needed for this type of hardening.

Typically uses are shackles of a lock, where the outer layer is hardened to be file resistant and mechanical gears, where hard gear mesh surface are needed to maintain a long service life.

2.3.2. NITRIDING:-

This process heats the steel part to 482-621 c in an atmosphere of ammonia gas and dissociated ammonia. The hardness is achieved by formation of nitrides. Theadvantage of this process is it causes little distortion.

2.3.4. CYANIDING:-

The part is heated to 1600 -1750 c in a bath of sodium cyanide and then quenched and rinsed in water and oil to remove any residual cyanide. This process produces a thin, hard shell (between 0.010 and 0.030 inches) that is harder than the one produced by carburizing and can be completed in 20 to 30 minutes. It is typically used on small parts such as bolts, nuts, screw and small gears. The major disadvantage of cyaniding is that cyanide salts are poisonous.

2.3.5. CARBONITRIDING:-

Carbonitriding is a case hardening process in which steel is heated in a gaseous atmosphere of such composition that carbon and nitrogen are absorbed simultaneously. The term carbonitriding is misleading because it implies a modified nitriding process. Actually carbonitriding is a modification of carburizing, and the name “nitro carburizing” would be more descriptive. The process is also known as dry cyaniding, gas cyaniding, and nicarbing. The atmosphere used in carbonitriding generally comprises a mixture of carrier gas, and ammonia. The carrier gas is usually a mixture of nitrogen, hydrogen, and carbon monoxide produced in an endothermic generator, as in gas carburizing.

The presence of nitrogen in the austenite accounts for the major differences between carbonitriding and carburizing. Carbon nitrogen austenite is stable at lower temperatures the plain carbon austenite and transforms more slowly on cooling. Carbonitriding therefore can be carried out at lower temperatures and permits slower cooling rates than carburizing in the hardening operation because ofthe lower temperature treatment.

2.3.6. CARBURIZING:-

As my project concerned “heat treatment of low carbon steel” is an experimental project which mostly deals with carburizing process.

The traditional method of applying the carbon to the surfaces of the iron involved packing the iron in a mixture of ground bone or charcoal or a combination of leathers, hooves, salt and urine, all inside a well sealed box. The resulting package is then heated to a high temperature, but still under the melting point of the iron and left at that temperature for a length of time. The longer the package is held at the high temperature, deeper carbon will diffuse into the surface, the resulting case hardened part may show a distinct correlation on the surface.

Carburizing is a process of adding carbon to surface. This is done by exposing the part to carbon rich atmosphere at the elevated temp (nearly melting point) and allows diffusion to transfer the carbon atoms in the steel. This diffusion work on the principle of differential concentration.

$2CO \leftrightarrow C \text{ (in Fe)} + CO_2$

And

$CO+H_2 \leftrightarrow C \text{ (in Fe)} + H_2O$

2.4. TYPES OF CARBURIZING PROCESS:-

1) Gas carburizing
2) Liquid carburizing
3) Vacuum carburizing
4) Plasma(ion) carburizing
5) Salt bath carburizing
6) Pack carburizing

2.4.1. GAS CARBURIZING:-

Gas carburizing has become the most popular method of carburizing in the last two decades. The main carburizing agent in this process is any carbonaceous gas such as methane,propane or natural gas. In this process it is necessary that the hydrocarbon gases should be diluted with a carrier gas to avoid heavy soot formation. Carrier gas can be made by controlled combustion of hydrocarbon gas. Methane can be burnt in air to methane ratio 2.5 and reacts as:

$2CH_4+O_2 \leftrightarrow 2CO+2H_2$

And the common endothermic carrier gas has the composition (vol. %)N_2=39.8%; CO=20.7%; H_2=38.7%; CH_4=0.8%

The important chemical reaction occurring during gas carburizing is:$CH_4+Fe \leftrightarrow Fe(C) +2H_2$ (1)

$2CO+Fe \leftrightarrow Fe(C) +CO_2$ (2)

$CO+H_2+Fe \leftrightarrow Fe(C) +H_2O$ (3)

Where Fe(C) indicates carbon dissolved in austenite.$CH_4+CO_2 \rightarrow 2CO+2H_2$ (4)

$CH_4+H_20 \rightarrow CO+3H_2$ (5)

The H_2 and CO as regenerated by reaction(4) and (5), react with steel surface according to the reaction (2) and (3) to cause enrichment of surface by carbon. It is thus obvious that the ultimate source of carbon in gas carburizing is CH_4.

ADVANTAGES OF GAS CARBURIZATION:

1) In gas carburization, the surface carbon content as well as the case depth canbe accurately controlled.
2) It gives more uniform case depth.
3) It is much cleaner and more efficient method than pack carburizing.
4) Total time of carburization is much less than the pack carburization as theboxes and the solid carburizer are not to be heated.

DISADVANTAGES OF GAS CARBURIZING:-

1) Furnace and gas generator are expensive.
2) Trays are expensive.
3) Greater degree of operating skill is required.
4) Handling of fire hazards and toxic gases is difficult.

Since gas carburizing is more expensive process than pack carburizing that is why the later one is preferred in the present work.

2.4.2. LIQUID CARBURIZING:-

Liquid carburizing is a method of case hardening steel by placing it in a bath of molten cyanide so that carbon will diffuse from the bath in to the metal and produce a case comparable to the one resulting from pack or gas carburizing. Liquid carburizing may be distinguished from cyaniding by the character and composition of the case produced. The cyanide case is higher in nitrogen and lower in carbon the reverse is true of liquid carburized cases. Low temperature salt baths (lights case) usually contain a cyanide content of 20 percent and operate between 1550 °F and 1650° F. High temperature salt baths (deep case) usually have cyanide content of 10 percent and operate between 1650°F and 1750° F.

ADVNTAGES OF LIQUID CARBURIZING:

1) Freedom from oxidation and sooting problems.

2) Uniform case depth and carbon content.
3) A rapid rate of penetration.
4) The fact that the bath provides high thermal conductivity, thereby reducingthe time required for the steel to reach the carburizing temperature.

DISADVNTAGES OF LIQUID CARBURIZING:

1) Parts must be thoroughly washed after heat treatment to prevent rusting.
2) Regular checking and adjustment of the bath.
3) Proper composition is necessary to obtain uniform case depth.
4) Some shapes cannot be handled because they either float or will causeexcessive drag out of salt.
5) Cyanide salts are poisonous and require careful attention to satisfy.

2.4.3. PACK CARBURIZING:-

In this process, the part that is to be carburized is packed in a steel container, so that it is completely surrounded by granules of charcoal. The charcoal is treated with an alternating chemical such as barium carbonate (BaBo3) that promotes the formation of carbon dioxide (CO2). This gas in turns reacts with the excess carbon in the charcoal to produce carbon monoxide (CO) .carbon monoxide reacts with low carbon steel surface to form atomic carbon which diffuses into the steel. Carbon monoxide supplies the carbon gradient that is necessary for diffusion. The car bruising process does not harden the steel. It only increases the carbon content to some predetermined depth below the surface to a sufficient level to allow subsequent quench hardening.

$CO2+C \rightarrow 2CO$

$\downarrow$

$2CO+3Fe \rightarrow Fe3C+CO2$

The oxygen of the entrapped air (in the carburizing box) initially reacts with the carbon of the carburizing medium as follows:

$C+O2 \rightarrow CO2$ (1)

$2C+O2 \rightarrow 2CO$ (2)

As the temperature rises the following reactions take place and the equilibrium shifts towards right that is gas becomes progressively richer in CO. at high temperature (> 800°c) the boudoirs reaction occurs as follows

$CO2+C \leftrightarrow 2CO$ ……… (3)

At the steel surface the decomposition of CO gas occurs as follows:$2C+O2 \rightarrow CO2+C$ (atomic)

$Fe+C$ (atomic) $\rightarrow Fe(C)$

Where Fe(C) is carbon dissolved in austenite.

This atomic and nascent carbon is radially absorbed by the steel surface, and subsequently it diffuses towards the centre of steel sample. CO2 thus formed react with the carbon (C) of the carburizing medium (reaction 3) to produce CO, and thus, the cycle of the reaction continues. Charcoal is the basic source of carbon during pack carburization. As entrapped air inside the box may be less to produce enough CO2 (reaction 1) particularly in the beginning of the carburization, it is thus it is common practice to add energizer (usually BaCO3) which decomposes during the heating up period as:

$BaCO3 \rightarrow BaO+CO2CO2+C \rightarrow 2CO$

The CO2 thus formed then react with the carbon of the carburizer to produce CO gas. Thus BaCO3 makes CO2 available at an early stage of carburization andhence it is called energizer.

The case depth increases with rise in carburization temperature and time. The best carburizing temperature is 900°c, the steel surface absorbs carbon at a faster rate and the rate at which it can diffuse inside, thus producing super saturated case which may produce cracks during quenching. In pack carburization it is difficult to control exactly the case depth because of many factors affecting it, such as density of packing amount of air present inside the box, reactivity of carburizer, etc….

ADVANTAGES OF PACK CARBURIZING:-

1) It is a cheap and simple method if only few parts are to be carburized.
2) Very large and massive parts which are too large for gas or salt carburization can be carburized if a furnace of that size is available. Pack carburization can be done in large variety of furnaces if these are having uniformity of the temperature.
3) In comparison to liquid and gas carburization, this method carburization involves less capital investment.
4) No atmosphere-controlled furnace is required.
5) No poisonous cyanide or gas is used in this process.

6) It can be done any workshop. DISADVANTAGES OF PACK CARBURIZING:-

1) Carburizing time is very long, as carburizing boxes as well as bad heatconducting carburizing materials need to be heated.
2) It is difficult to control the surface carbon and the carbon gradient.
3) It is difficult to control the case depth exactly.
4) Handling carburizing material and packing is dirty and dusty job.
5) In pack carburization it is difficult to quench the carburized parts.

2.5. APPLICATION:

The possible applications of low carbon steel are very wide. The properties aresuch As to extend the field of usefulness of mild steel and enable it.

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Some popular uses of Low carbon steel for various engineering application are for:

1. Support bracket for agricultural tractor.
2. Gear teeth profile
3. Crane wheels.
4. Crane cable drum.
5. Gear wheel and pinion blanks and brake drum.
6. Machines worm steel.
7. Flywheel.
8. Ball bearing.
9. Railway wheels.
10. Crankshaft.
11. Shackles of lock.
12. Bevel wheel.
13. Hydraulic clutch on diesel engine for heavy vehicle.
14. Fittings overhead electric transmission lines.
15. Boiler mountings, etc.

III. LITERATURE SURVEY:

Basak and chakroborty (1983) developed Cr-Mn-Cu white cast iron for application in mining, farm machinery; etcrequiringerosive and corrosive wear resistance properties. They found that the addition of Cu improves the corrosion resistance of Cr-Mn iron and hence reduced the rate of corrosive wear of high copper, chromium and manganese cast iron.

Kuma and Gupta(1990) studied the abrasive wear behavior of mild, medium carbon, leaf and high carbon, low Cr. Steel by means of a dry stand rubber wheel abrasion apparatus. They found that the heat treated high carbon low Cr. Steel and mild steel carburized by their own technique to be the best abrasion resistance materials. The abrasive wear resistance values of the two materials wear found to be very much comparable with each other.

They also studied the abrasive wear of carburized mild steel. They investigated the influence of carburization conditions (e.g., temperature, time, properties of carbonaceous material etc.) on the abrasive wear loss. During the study, Kumar developed a cheaper method of carburizing producing better wear resistance. Inthis technique, mild steel samples are carburized under two conditions such as;

1. Carburization in as received charcoal granules +BaCO3 mixtures with a thickcoating (2mm approx.) of a coal tar pitch on steel sample.
2. Carburization in used charcoal +BaCO3 mixture with cold tar pitches coating onthe steel sample.

In both the cases carburization was carried out at a temperature 930c for two hours (optimum).All the quenched carburized steel samples were tempered at 150c for 15min.

As outlined by them, the nature and reactivity of carbon used greatly affect the mechanical properties and abrasion resistance of carburized mild steel specimens. The result obtained by their carburization technique was found to be much superior to those obtained by conventional technique. The tribological properties of carbon graphite have been widely documented in the literature. This carbonization technique not only gives very high hardness and abrasion resistance (equivalent to those of high carbon steel) but also result in the following other advantages.

1) Reduction in the requirements of charcoal and BaCO3.
2) Saving of carburization time and elimination of rehardening elements.
3) Utilization of waste material.
4) Saving in the composition of electricity.

Lancaster(1989) has suggested that graphite crystallite are embedded into the surface valley aspirates and acts as nuclei as a for lubrication film building and thus reduced the effectiveness of of abrasive wear of aspirates physically.

Stevenson and hutchengs(1994) , have reported that sinter particles wear cause to ease gross fracture of the carbide and so those materials with a high volume fraction of carbide shared the greatest resistance to erosive wear.

IV. EXPERIMENTAL PROCEDURE:

The experimental procedure for the project work can be listed as :

1) Specimen preparation
2) Heat treatment
3) Harden measurement
4) Mechanical property study
5) Microstructure study

4.1. SPECIMEN PREPARATION:

The first and foremost job for the experiment is the specimen preparation. The specimen size should be compatible to the machine specifications:

We got the sample from mild steel trader. The sample that we got was

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 asspecified below. So we can also say that it is basically a pearlitic/ferritic matrix.

4.2. HEAT TREATMENT

Low Carbon Steel are primarily heat treated to create matrix microstructures and associated mechanical properties not readily obtained in the as-cast condition. As- cast matrix microstructures usually consist of ferrite or pearlite or combinations of both, depending on cast section size and/or alloy composition The principle objective of the project is to carry out the heat treatment of Low carbon steel and then to compare the mechanical properties. There are various types of heat treatment processes we had adopted.

4.2.1. ANNEALING

a) The specimen was heated to a temperature of 900 deg Celsius
b) At 900 deg Celsius the specimen was held for 2 hour
c) Then the furnace was switched off so that the specimen temperature willdecrease with the same rate as that of the furnace

The objective of keeping the specimen at 900 deg Celsius for 2 hrs is to homogenize the specimen. The temperature 900 deg Celsius lies above Ac1 temperature. So that the specimen at that temperature gets sufficient time to get properly homogenized .The specimen was taken out of the furnace after 2 days when the furnace temperature had already reached the room temperature

4.2.2. NORMALIZING:

a) At the very beginning the specimen was heated to the temperature of 900 degCelsius.
b) There the specimen was 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 Ac1 is called normalizing.

4.2.3. QUENCHING:

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

a) The specimen was heated to the temp of around 900 deg Celsius and were allowed to homogenize at that temp for 2 hour.
b) An oil bath was maintained at a constant temperature in which the specimen hadto be put.
c) After 2 hour the specimen was taken out of the furnace and directly quenched inthe oil bath.
d) After around half an hour the specimen was taken out of the bath and cleanedproperly.
e) Now the specimen attains the liquid bath temp within few minutes. But the rateof cooling is very fast because the liquid doesn’t release heat readily.

4.2.4. TEMPERING:

This is the one of the important experiment carried out with the objective of theexperiment 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 thenquenched in the oil bath maintained at room temp.

b) Among the 4 specimen 2 were heated to 250 deg Celsius. But for different timeperiod of 1 hour, 1and half hour and 2 hour respectively.
c) Now 3 more specimens were heated to 450 deg Celsius and for the timeperiod of 1 hour, 1and a half hour and 2 hour respectively.
d) The remaining specimens were heated to 650 deg Celsius for same timeinterval 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.

4.2.5. AUSTEMPERING:

This is the most important experiment carried out for the project work. Theobjective was to develop all round property in the material.

a) The specimen was heated to the temperature of 900 degree Celsius and sufficient time was allowed at that temperature, so that the specimen got properlyhomogenized.

b) A salt bath was prepared by taking 50% NaN03 and 50 % KnO3 salt mixture. The objective behind using NaNO3 and KNO3 is though the individual melting points are high the mixture of them in the bath with 1:1 properties from an eutectic mixture this eutectic reaction brings down the melting point of the mixture to 290 deg Celsius. The salt remains in the liquid state in the temp range of 290-550 deg Celsius whereas the salt bath needed for the experiment should be at molten stateat 350 deg Celsius

c) After the specimen getting properly homogenized it was taken out of the furnace and put in another furnace where the container with the salt mixture waskept at 350d deg Celsius.

d) At that temp of 350 degree the specimen was held for 2 hrs In this time the austenite gets converted to bainite. The objective behind choosing the temperature of 350 deg Celsius is that at this temperature will give upper bainite which has fine grains so that the properties developed in the materialsare excellent.
e) An oil bath also maintained so that the specimen can be quenched.

f) So after sufficient time of 2 hr the salt bath was taken out of the furnace and thespecimen were quenched in the oil bath.

g) An oil bath is also maintained so that specimen can be quenched. Now the specimens of each heat treatment are ready at room temperature. But during quenching in a salt bath, or oil bath or cooling due to slight oxidation of the surface of cast iron, there are every possibility of scale formation on this surface if the specimens are sent for testing with the scales in the surface then the hardness value will vary and the specimen will also not be gripped properly in the UTS .To avoid this difficulties the specimens were ground with the help of belt grinder to remove the scales from the surface. After the scale removal the Specimens are ready for the further experimentations.

4.3. STUDY OF MECHANICAL PROPERTIES:

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

4.3.1. 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 to100kg.
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 b y using the standard converter chart.

4.3.2. 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 lengthof 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. RESULTS AND DISCUSSION:

5.1.1. TABULATION FOR HARDNESS TESTING:

Table.1

SPECIMEN SPECIFICATION	TIME	HARDNESS
Quenched from 900 and temperedat 250 degree Celsius	1 hour	45
	1 ½ hour	39
	2 hour	34
Quenched from 900 and temperedAt 450 degree Celsius	1 hour	38
	1 ½ hour	34
	2 hour	29
Quenched from 900 and tempered at 650 degreeCelsius	1 hour	31
	1 ½ Hour	27
	2 hour	24
Austempered 350 degree celsius	1 hour	29
	2 hour	29
As Received		22

different hardness values in Rc scale for various heat treated low carbon steelspecimen

Table.2

Specimen Specification	Time(in hours)	Hardness
Quenched from 900 andtempered at 250 degree celsius	1 hour	43
Quenched from 900 andtempered At 450 degree celsius	1 hour	36
Quenched from 900 andtempered at 650 degree celsius	1 hour	33

Hardness vs. tempering temperature for constant tempering timeof 1 hour

Table.3

Specimen Specification	Time(in hours)	Hardness
Quenched from 900 andtempered at 250 degree celsius	1 ½ hour	39
Quenched from 900 andtempered At 450 degree celsius	1 ½ hour	34
Quenched from 900 andtempered at 650 degree celsius	1 ½ hour	28

Hardness vs. tempering temperature for constant tempering timeof 1 ½ hour

Table.4

Specimen Specification	Time(in hours)	Hardness
Quenched from 900 andtempered at 250 degree celsius	2 hour	34
Quenched from 900 andtempered At 450 degree celsius	2 hour	29
Quenched from 900 andtempered at 650 degree celsius	2 hour	22

Hardness vs. tempering temperature for constant tempering timeof 2 hour

5.1.2. TABULATION FOR ULTIMATE TENSILE STRENGTHTESTING:

Table.5

Specimen Specification	Time(inhours)	UTS(inMpa)	Yield Strength(in Mpa)	Elongation%
Quenched from 900andtempered at 250 degreecentigrade	1	548	334	9.654
Quenched from 900 and tempered at 450 degreecentigrade	1	497	297	14.369
Quenchedfrom 900 and tempered at 650 degree	1	318	234	20.476

Tensile properties for different tempering temperature for 1 hourtempering time

Table.6

Specimen Specification	Time(inhours)	UTS(inMpa)	Yield Strength(in Mpa)	Elongation%
Quenchedfrom 900 andtempered at 250 degree centigrade	1 ½	543	331	12.269
Quenchedfrom 900 andtempered at 450 degree centigrade	1 ½	313	284	18.345
Quenchedfrom 900 andtempered at 650 degree centigrade	1 ½	487	238	24.856

Tensile properties for different tempering temperature for 1 ½ anhour tempering time

Table.7

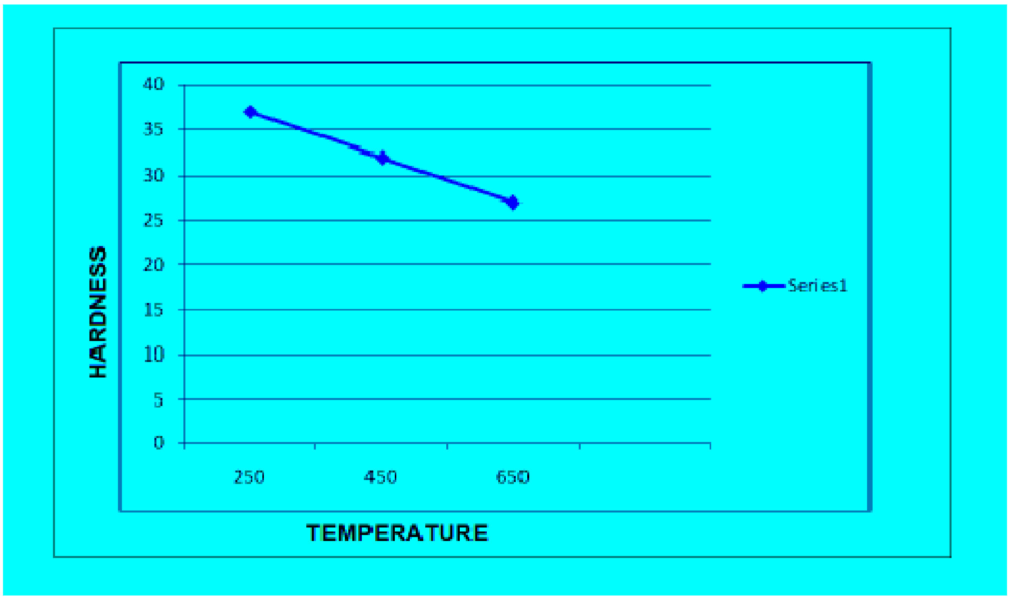
Specimen Specification	Time(inhours)	UTS(inMpa)	Yield Strength(inMpa)	Elongation%
Quenchedfrom 900 andtempered at 250 degree centigrade	2	412	267.5	22.821
Quenchedfrom 900 andtempered at 450 degree centigrade	2	382	254.6	27.514
Quenchedfrom 900 andtempered				

at 650 degree centigrade	2	251	198	27.729

Tensile properties for different tempering temperature for 2 hourtempering time

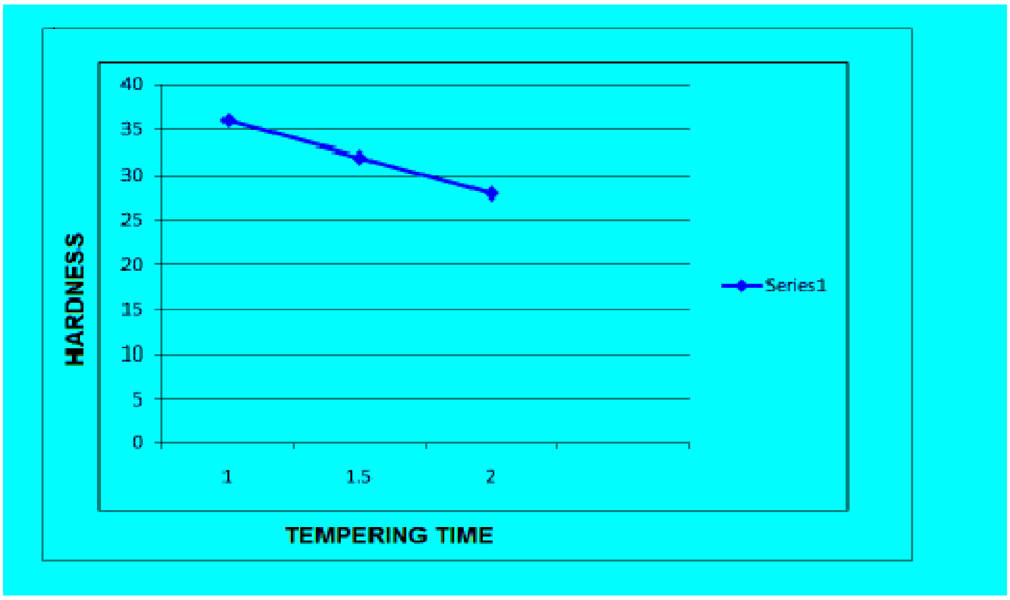
5.2. GRAPHS:

1.



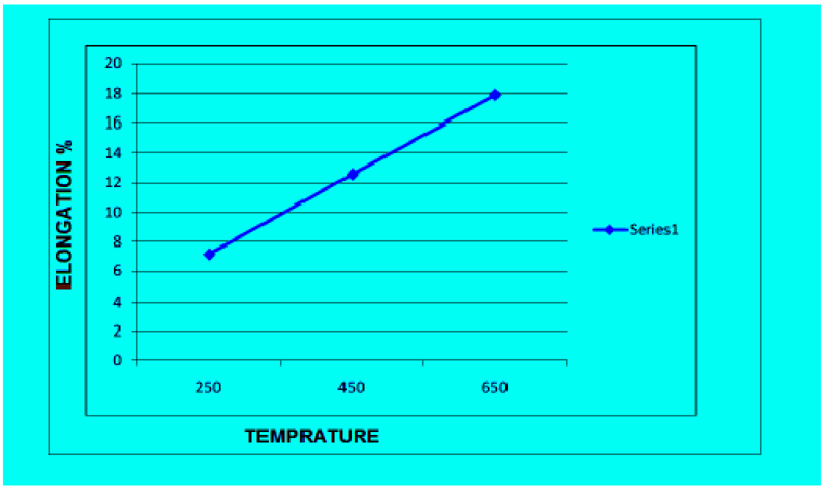
Hardness for different tempering temperature (in degreecentigrade)

2.



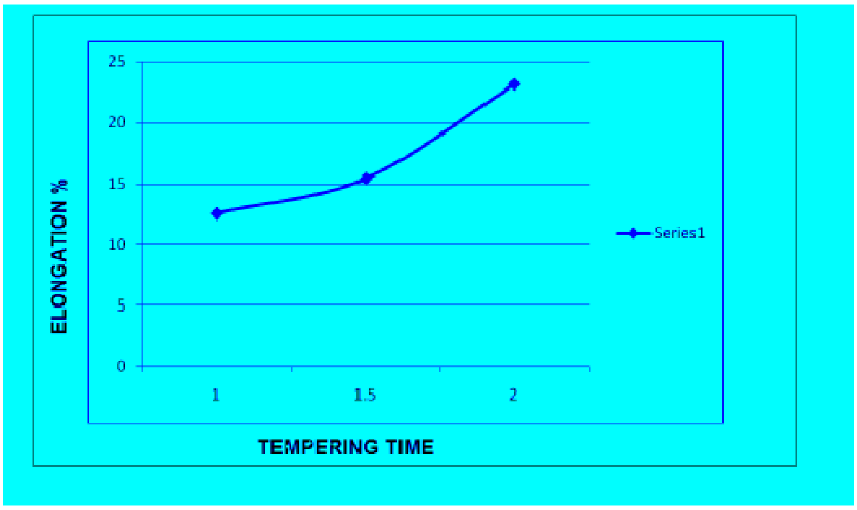
Variation in Hardness for different tempering time

3.



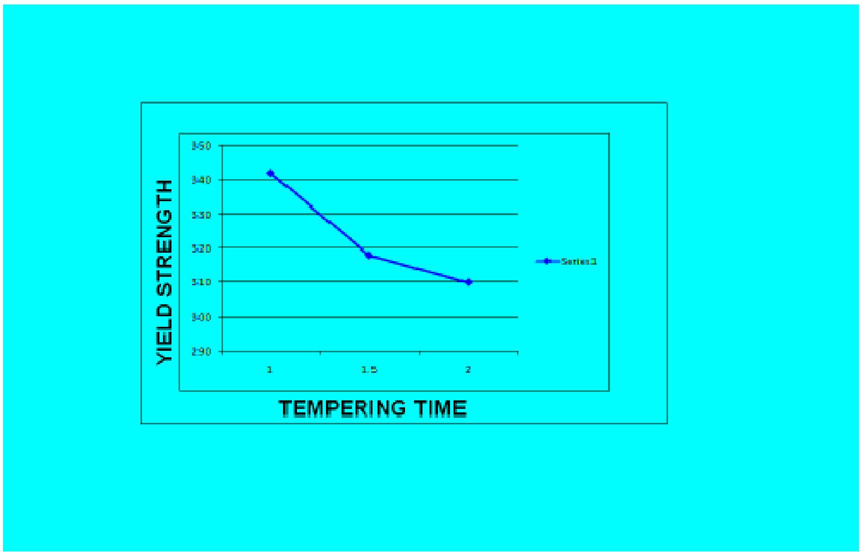
Variation of % elongation with different tempering temperature(in degree centigrade)

4.



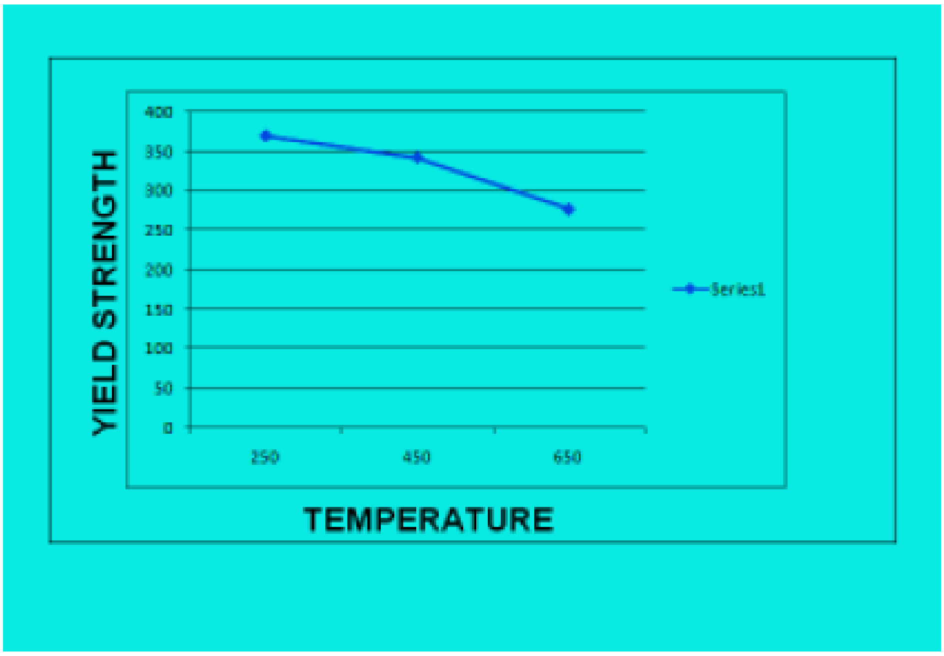
Variation of % elongation with different tempering time

5.



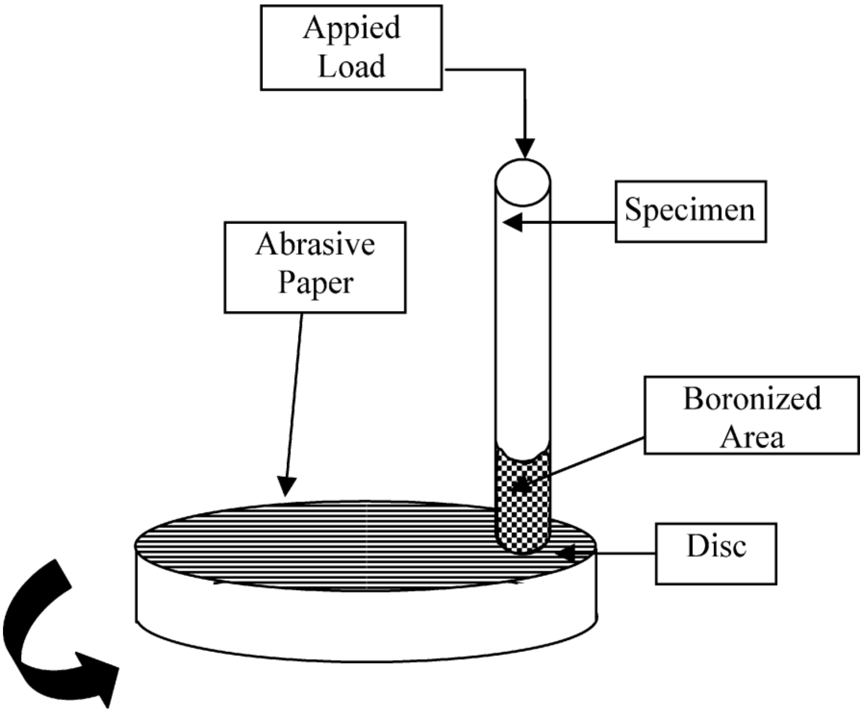
Variation of yield strength with different tempering time

6.



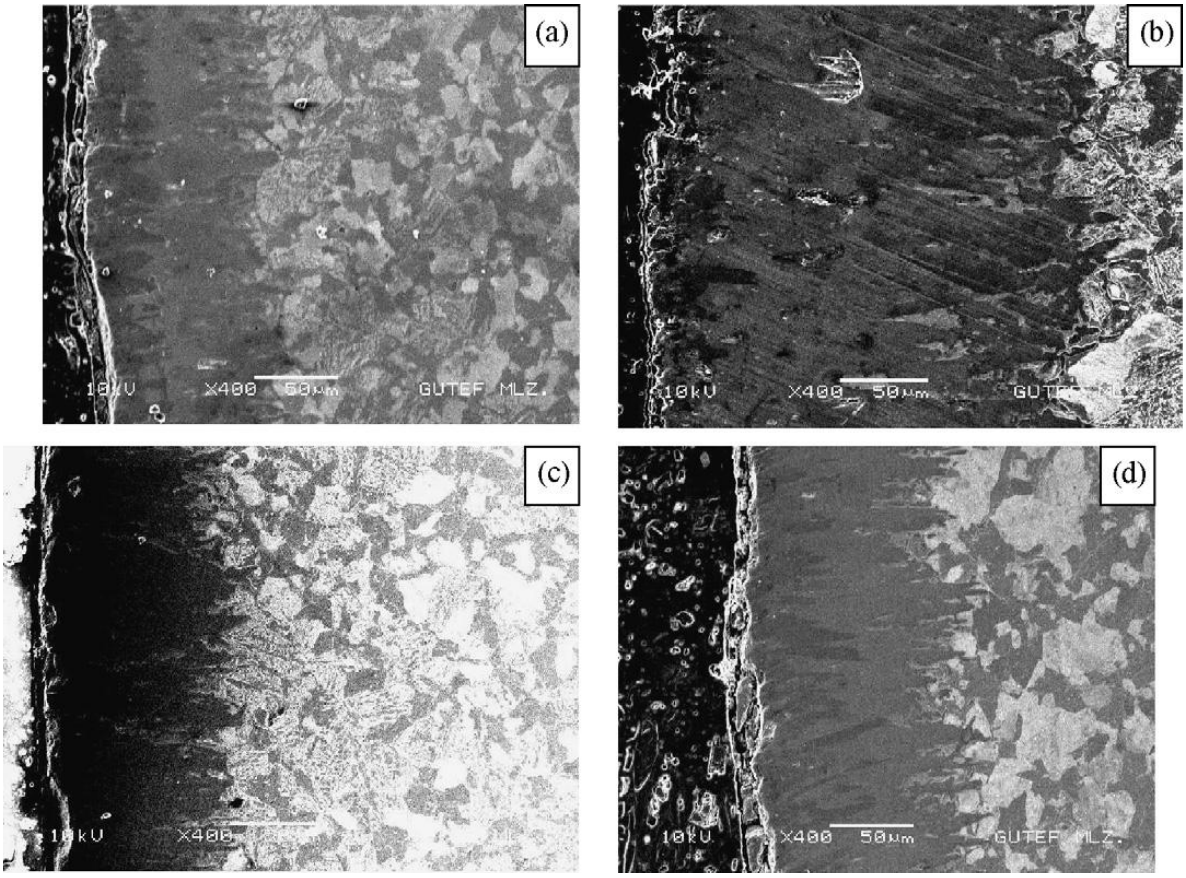
Variation of yield strength with tempering temperature (in Microstructure

5.2.1MICROSTUCTURE:



Scanning electro microscopy (SEM) examinations of the boronized steels revealed that the borides on the surfaces of these samples have smooth branched morphology. It was observed that the thickness of the boride layer increased with boronizing time and temperature [9,17]. Boronized surfaces had three distinguishable zones. These are (i) layer with FeB and Fe_2B borides, (ii) diffusion zone beneath the boride layer where boron makes a solid state solu- tion with the steel and which has lower hardness than the borides but higher hardness than the steel, and (iii) steel matrix free of boron [14] (Fig. 2 (a)–(d)).

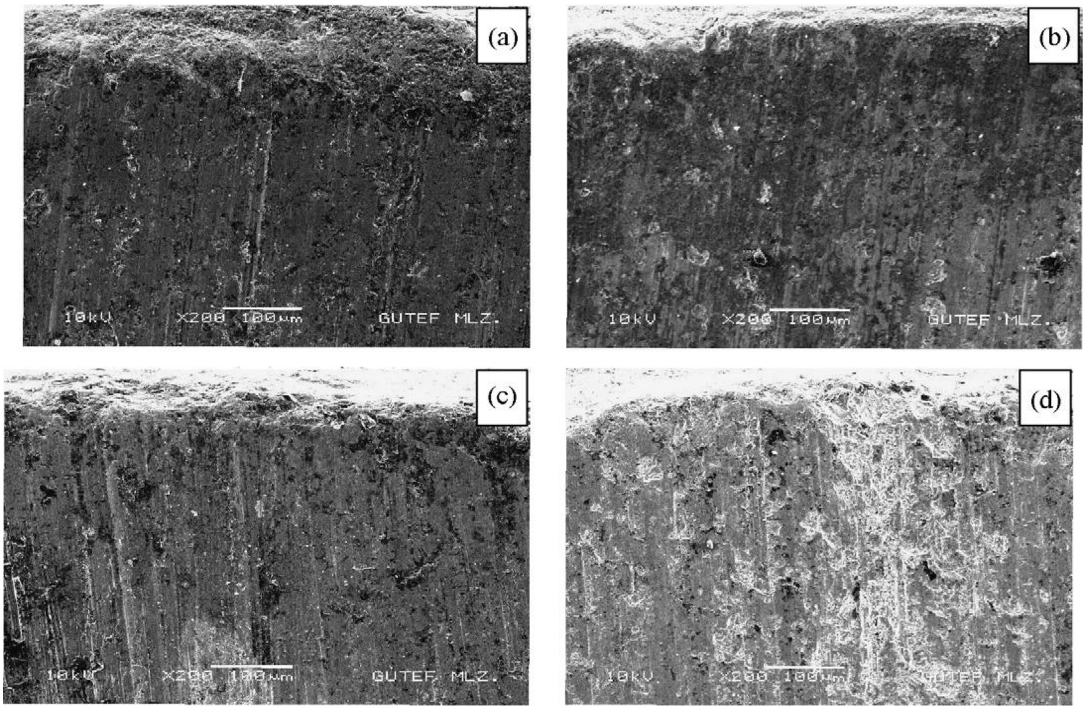
Change in the hardness of the AISI 8620 steel with distance from the surface is shown in Fig. 4. Hardness of the unboronized AISI 8620 steel was found to be 220 HVN0.1. Vickers hardness values of the boride layer and the matrix of the boronized samples are 1650 and 220 HVN0.1, respectively. As can be seen on the hardness curves, hardness values of the borides are much higher than those of the matrix. Hardness decreases with distance into the matrix. This may be explained by grain growth in matrix with temperature and treatment duration. The boride layer hardness of the sample

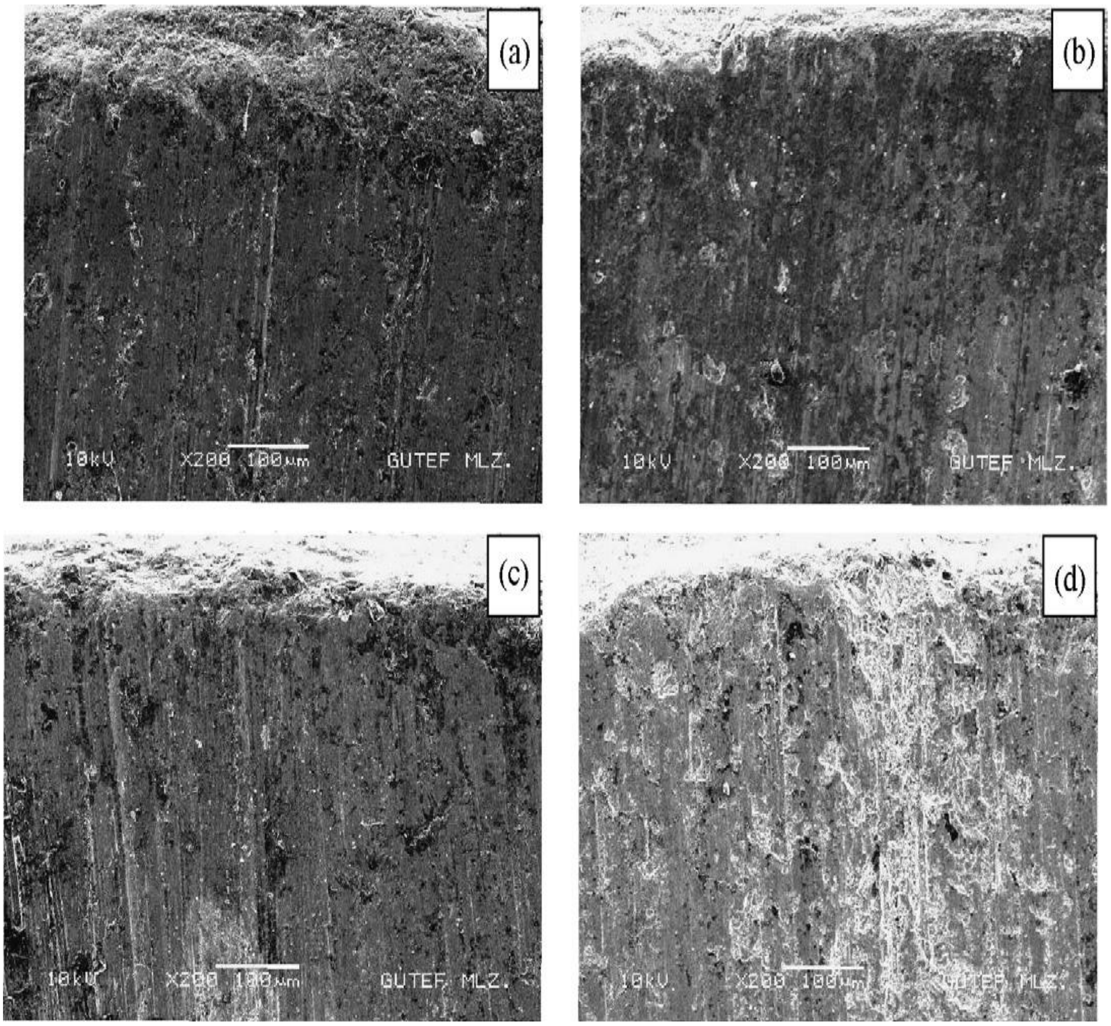


5.2.2.Wear behavior:

Wear mechanism is defined as the physical and chemical phe- nomena that take place during wear. Abrasive wear refers to the mechanism where two bodies rubbing against each other break off pieces from each other. Hardness, shape and size or roughness of abrasive material, angle of contact, normal load applied, slid- ing speed and fracture toughness of the material are all among important factors in wear mechanisms

Wear ratios of the samples are given in Fig. 4. Accordingly, largest wear was exhibited by the sample boronized at 950 °C for 2 h while smallest wear was exhibited by the sample boronized at 850 °C for 6 h. This is because the FeB layer formed on the sample boronized for a longer time has a brittle and crisp structure. The decrease in wear on the sample boronized for 6 h at 850 °C is explained by the thickness of the boride level is increased at the same temperature with the extension of the boronizing duration. As seen in Fig. 2(a) and (d) the thickness of the FeB layer increases at higher boronizing temperatures, leading to increased wear mea- sured in samples boronized at higher temperatures. For this reason, it is advantageous to boronize for longer durations at lower temperatures. Great care was taken to decrease the sliding distance to determine the effects of these layers on wear resistance. Mar- tini et al. in their study, “Adhesive and Abrasive Wear Behavior of


(a)
10kV X200 100µm GUTEF MLZ.
(b)
10kV X200 100µm GUTEF MLZ.
(c)
10kV X200 100µm GUTEF MLZ.
(d)
10kV X200 100µm GUTEF MLZ.


(a)
10kV X200 100µm GUTEF MLZ.
(b)
10kV X200 100µm GUTEF MLZ.
(c)
10kV X200 100µm GUTEF MLZ.
(d)
10kV X200 100µm GUTEF MLZ.

5.3. 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.

VI. 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.

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