

# Study of Abrasive Wear Characteristics, Mechanical and Wear Properties of Carburized Mild Steel Samples

Mehul Kumar<sup>1</sup> Ashok Sharma<sup>2</sup>

<sup>1,2</sup>Department of Mechanical Engineering

<sup>1,2</sup>Shri Shankaracharya Institute of Technology and Management Junwani Bhilai-490020, India

**Abstract**— The Heat treatment and carburization has been recognized by certain methods for improving the different properties of metals and combinations. In the present examination the mechanical and wear practices of gentle steels carburized at various temperature scope of 850, 900 and 950°C have been contemplated and it is discovered that the basic warmth treatment significantly improves the hardness, elasticity and wear opposition of the mellow steels. The point has been to look at the impacts of these distinctive temperature of carburization s and conditions on the mechanical and wear properties of the carburized gentle steels. For above reason initially the mellow steels are carburized under the diverse temperature go as expressed above and afterward it is tempered at 2000 C for thirty minutes after this the carburized and tempered gentle steels are oppressed for various sort of test, for example, rough wear test, hardness test, elastic test and the durability test. The aftereffects of these test demonstrates that the procedure of carburization significantly improves the mechanical and wear properties like hardness, elasticity and wear obstruction and these properties increments with increment in the temperature of carburization yet separated from this the durability property diminishes and it is further reductions with increment in temperature of carburization . The trial results likewise demonstrates that the mellow steels carburized under various temperature extend as expressed above, with in which the gentle steels carburized at the temperature of 950°C gives the best outcomes for the various types of mechanical and wear properties on the grounds that at this temperature it gives most astounding elasticity, hardness and wear opposition, so it must be favored for the required applications.  
**Keywords:** Mild Steel, Carburization, Plasma and Salt Bath Carburization

## I. INTRODUCTION

The carburization gives a progressive change in carbon substance and volume of carbide from the surface to the mass, bringing about a slow modification of mechanical and wear properties. The treatment of heat and carburization expands the mechanical and wear opposition. Carburizing is the expansion of carbon to the external of low-carbon steels at temperatures for the most part somewhere in the range of 850 and 950°C (1560 and 1740°F), at which austenite, with its high solvency for carbon, is the steady precious stone structure. Solidifying is practiced when the high-carbon surface layer is extinguished to shape martensite so a high-carbon martensitic case with great wear and weakness opposition is superimposed on an extreme, low-carbon steel center. Carburizing of steels for case solidifying ordinarily have base-carbon substance of about 0.2%, with the carbon substance of the carburized layer for the most part being controlled at somewhere in the range of 0.8 and 1% C. Be that as it may, surface carbon is frequently constrained to 0.9% in

light of the fact that too high a carbon substance can bring about held austenite and fragile martensite. During agricultural operations (either dry or wet ) the farm implements undergo abrasion by the scratching actions of sand and stone particles present in the soil and it is the most common cause of their quick failure and damage. It is therefore necessary to minimize wear. Due to limited resources and unavailability of economically feasible technology, agro industries have not been able to substantially get better the mechanical properties and wear resistance of these steels. The attempt have been made by researchers to improve the resistance of wear of steel materials, but very little attention has been paid in reducing the wear of farm implements materials. Thus, there is an imperative need to substantially upgrade the mechanical properties and resistance of wear of low carbon and mild steels in actual soil conditions. The present work aims to improve the wear resistance and mechanical properties of mild steel by developing an economically feasible carburization technique. Also the present work is applicable not only for the farm implements but also for the applications like material of automobiles, machines, gears, springs and high strength wires etc.

### A. Ferrous Materials:

The word “ferrous” usually refers to the materials that have a lot of iron in them. It is common for these materials to be strongly magnetic but not all of them are. Different type of iron and steel are more or less magnetic. High-chromium stainless steel is nearly non-magnetic, while unadulterated iron tend to form magnets simply. Iron with impurity usually stays attractive better than pure iron.

These ferrous materials are mainly classified in the two different types.

- 1) Steels: - Carbon contain up to 2%
  - a) Plain carbonsteel
  - b) Alloysteel
- 2) Cast iron: - Carbon contain above 2% to 6.67%
  - a) Grey cast iron
  - b) White cast iron
  - c) Malleable cast iron
  - d) Ductile cast iron

### B. Plain Carbon Steels:

The plain steels are generally classified in following 3 types.

#### 1) Low carbon steel:

up to 0.30% of carbon. Mild steel is the majority common form of steel as its cost is relatively low while it provides material properties that are acceptable for many applications. Low carbon steel have approximately 0.05–0.15% carbon and mild steel contains 0.16–0.30% carbon. Mild steel has a relatively little tensile strength, but it is low-priced and malleable; hardness of surface can be improved through

carburizing. It is used where ductility or softness are important.

#### 2) Medium carbon steel:

From 0.30 to 0.60% of carbon. These are less ductile but harder and have greater tensile strength than low carbon steel. It balances ductility and strength and has good wear resistance. They have also better machining qualities. Properties: Harder, better tensile strength, good wear resistance.

#### 3) High carbon steel:

From 0.60 to 1.70% of carbon. They have higher tensile strength and harder than other plain carbon steels. They also readily respond to heat treatment. These steels can be tempered to incredible hardness. Utilized for specific purposes like (non-mechanical reason) blades, axles or punches.

#### C. Case hardening:

Case hardening is a simple method of hardening of steel. This procedure is utilized for steels with a low carbon content. Carbon is added to the external surface of the steel, to a profundity of around 0.03mm. This solidifying procedure incorporates a wide assortment of systems is utilized to improve the mechanical properties and wear opposition of parts without influencing the gentler, extreme inside of the part. One bit of leeway of this technique for solidifying steel is that the inward center is left immaculate so still procedures properties, for example, adaptability is still moderately delicate.

## II. TYPES OF CARBURIZATION

There are following types of carburization processes exist

- 1) Solidcarburization
- 2) Gaseouscarburization
- 3) Vacuumcarburization
- 4) Plasmacarburization
- 5) Salt bathcarburization

#### A. Solidcarburization:

The strong or pack carburization includes warming the steels parts installed in fine blend of 85% coal and 15% BaCO<sub>3</sub> at a temperature in range 900-950 degree Celsius. The remaining air in the case joins with carbon to deliver CO gas. Carbon monoxide gas is unsteady at the procedure temperature and in this manner decays after reaching the iron surface by response  $2CO = C + CO_2$  The atomic carbon enters the steel through the following reaction.  $Fe + 2CO = Fe(C) + CO_2$

The addition of BaCO<sub>3</sub> enhances the carburizing effect. BaCO<sub>3</sub> decompose and evolves CO<sub>2</sub> which retort with coal to form carbon monoxide.  $C + CO_2 = 2CO$ . Typical carburizing time to obtain a case depth of 1-2 mm is around 6-8 hours. Higher speed can be obtained by carburizing in gaseous medium.

#### B. Gaseous carburization:

The vaporous carburization is completed at temperature in range 900-950 degree Celsius. Carbon monoxide and different hydrocarbon are utilized as a carburizers. They break down at the procedure temperature and structure nuclear carbon as per the accompanying response.  $2CO = C +$

$CO_2$ .  $C_n + H_m = nC + mH$ . It is fundamental to precisely control the organization and stream pace of carburizing gas. Gas carburization is the fundamental procedure in large scale manufacturing, while the more straightforward strong carburization is financially increasingly powerful in little scale generation

#### C. Vacuum carburization:

In endeavors required to rearrange the air, carburizing in a sans oxygen condition at low weight (vacuum carburizing) has been investigated and formed into a practical and significant option. In spite of the fact that the heater fenced in area in certain regards turns out to be progressively mind boggling, the air is incredibly improved. A solitary segment climate comprising exclusively of a basic vaporous hydrocarbon, for instance methane, might be utilized. Besides, on the grounds that the parts are warmed in a sans oxygen condition, the carburizing temperature might be expanded generously without the danger of surface or grain-limit oxidation. The higher temperature allowed increments not just the strong solvency of carbon in the austenite yet additionally its pace of dissemination, with the goal that the time required to accomplish the case profundity wanted is diminished.

#### D. Plasma and Salt Bathcarburization:

A method that overcome both of these main problems yet retain the enviable features of a simple atmosphere and permissible operating temperature is plasma or ion carburizing.

These methods begin carbon by the use of gas (atmospheric-gas, plasma, and vacuum carburizing), liquids (salt bath carburizing), or solid compounds (pack carburizing). All of these methods have restrictions and advantages, but gas carburizing is used the common frequently for comprehensive production because it can be accurately controlled and involves a minimum of special handling. Vacuum carburizing and plasma carburizing have found applications because of the lack of oxygen in the kiln atmosphere. Salt bath and set carburizing arc still done rarely, but have modest commercial significance today.

#### E. Nitriding:

Nitriding is a process of surface-hardening treatment of heat that introduces nitrogen into the surface of steel at a temperature range (500 to 600°C) while it is in the ferrite condition. Thus, nitriding is like to carburizing in that surface composition is altered, but different in that nitrogen is added into ferrite in its place of austenite. Because nitriding does not engage heating into the austenite stage field and a succeeding satisfy to form martensite, nitriding can be accomplished with a minimum of distortion and with admirable dimensional control. In this process pure ammonia dissociates by there action  $NH_3 = 3H + N$ . The atomic nitrogen thus produced diffuses into the steel. In addition to only if outstanding wear resistance,

#### F. Carbonitriding and cyaniding:

Carbonitriding is a modified form of gas carburizing, at a temperature range between 750 - 9000 C. The change consists of introducing ammonia into the gas carburizing atmosphere

to add nitrogen to the carburized case as it is creature produced. Nascent nitrogen forms at the work surface by the dissociation of ammonia in the furnace atmosphere; the nitrogen diffuses into the steel simultaneously with carbon. Typically, carbonitriding is carried out at a lower temperature and for a shorter time than is gas carburizing, producing a shallower case than is usual in production carburizing. In its effects on steel, carbonitriding is similar to liquid cyaniding. Because of problems in disposing of cyanide-bearing wastes, carbonitriding is often ideal over liquid cyaniding. In terms of case characteristics, carbonitriding differs from carburizing and nitriding in that carburized cases normally do not contain nitrogen, and nitride cases contain nitrogen primarily, whereas carbonitrided cases include both.

#### G. Flame hardening:

This is the simplest form of heat treatment process. The workpiece is heated by means of a gas torch (oxy-acetylene flame) followed by a water spray on the heated parts. The heat from the torch penetrates only to small depth on the surface and consequently the steel in the outer layers gets quenched to martensite and bainite. Case depth up to 3mm can be achieved by this process. This process can be followed by heating to about 200 °C for the purpose of stress relieving. The hardness of surface is not appreciably affected by these reheating operations. This process is suitable for any shape of complex of component such as crank shaft, large gears, cam, etc. with carbon percentage ranging from 0.3 to 0.6%. Though high carbon steel can also be flame hardened, greater care is needed to avoid surface cracking.

#### H. Induction hardening:

This is like fire solidifying procedure where the warming of segment surface is accomplished by the electromagnetic enlistment. The workpiece, for example, wrench shaft is encased in the attractive field of an exchanging (10 kHz to 2MHz) current conductor to get case profundity of the request for 0.25 to 1.5 mm. This causes enlistment warming of the workpiece, The warmed workpiece at that point extinguished by water splash. The enlistment warmth infiltrates just external surface of the workpiece accordingly just the skin gets solidified by the extinguishing procedure. The entire procedure is quick (5s to 4 minutes) and result in hard external surface (50 to 60 Rc) which is wear safe.

#### I. Tempering:

After the solidifying treatment is connected, steel is frequently harder than required and is unreasonably weak for most handy employments. Additionally, extreme inner anxieties are set up during the quick cooling from the solidifying temperature.

##### 1) Factors affecting of wear of metallic materials:

The wear rate can be influenced by a number of factors as given below:-

- 1) Physico concoction properties of materials, for example, piece, microstructure, hardness, work solidifying qualities, consumption opposition, wear quality, and so forth.
- 2) Wear conditions, for example, contact territories, load connected, temperature, nearness of greases, level of oil,

rotational/sliding pace, stream pace of fluid or gas, nature of condition, span of wear and so forth.

- 3) Characteristics of grating including hardness, shape and size.
- 4) Design properties including transmission of burden, kind of movement, test geometry and so on.

#### J. Objectives of the present work:

The main purpose of present work is to get better the mechanical properties and wear resistance of the mild steels by using Vasundhara coal as a carburizer and a smaller amount energy consuming carburization technique. In this connection the following studies were aimed to be carried out.

- 1) Proximate analysis of the Vasundhara coal.
- 2) Carburization of mild steel samples under various conditions and various temperatures by using less energy consuming techniques.
- 3) Tempering of these carburized mild steel samples at an exact temperature for a particular period of time.
- 4) Determination of mechanical properties like hardness, toughness and tensile strength of these carburized and tempered mild steel samples.
- 5) Study of abrasive wear characteristics of these carburized and tempered mild steel samples.
- 6) Analysis of the results obtained.

### III. LITERATURE REVIEW

The investigation on the mechanical and wear properties of iron and steel component under different condition have been made by a number of workers. Most of these investigation had been made on analysis of wear properties a very few studies were made including both the mechanical and wear properties under the same parameters and conditions.

Luo et al [10] studied the impacts of microstructure on the grating wear conduct of spheroidal cast iron and detailed that the wear obstruction of spheroidal dim cast iron was second rate compared to that of steel with a comparative lattice. Extinguished structures were more impervious to scraped area than the austempered structures. Likewise, the wear execution of extinguished iron and steel tests were accounted for to be superior to austenized at higher temperature.

Celik et al [7] studied considered the high temperature grating wear conduct of an as-cast malleable iron and revealed that the high temperature ductile properties were influenced by unique strain maturing. Serrated stream was seen in the temperature extend somewhere in the range of 100 and 300 °C. In this temperature system, rigidity esteems were practically perpetual. Over 400 °C, increment of temperature diminished the elasticity. Least malleability was seen at 500 °C. At 600 °C, higher malleability was seen than that of 500 °C. he additionally presumed that after the expansion in wear obstruction at 50–100 °C, grating wear opposition diminished with expanding temperature. Dynamic strain maturing caused improvement of scraped area opposition. The most astounding protection from rough wear is seen at temperature go somewhere in the range of 50 and 100 °C. At this temperature extend malleable iron showed over 15% higher scraped area opposition than room temperature.

Izciler and Tabur [8] on his investigation of rough wear conduct of various case profundity gas carburized AISI 8620 apparatus steel presumed that in regard with microstructures, tests exposed to longer times of gas carburizing display more noteworthy case profundity. The examples having more prominent case profundity and hardness of surface are more wear safe than that with low case profundity. The hardness of the abrasives in connection with the connected loads and wear. Separations had influenced the wear resistance significantly. Comparing Al<sub>2</sub>O<sub>3</sub> and SiC abrasive papers, Al<sub>2</sub>O<sub>3</sub> abrasive papers lose their sharpness more than SiC papers do, especially under higher loads.

Khusid et al [9] on his work contemplated the Wear of carburized high chromium steels and detailed that Carburization raises the rough wear obstruction and permits noteworthy concealment of the attachment marvels under dry sliding. The outcomes acquired decide the system of surface solidifying of high chromium steels required to create the ideal blend of wear obstruction and mass quality properties.

The aftereffects of an exploratory examination did by Akdemir et al [11] on Impact durability and microstructure of consistent steel wire-strengthened cast iron composite and detailed that ingested vitality of the dark cast iron increments essentially with including the flexible support. Likewise assimilated vitality of the composite reductions with diminishing test temperature since the steel wire in the composite loses its pliability and carries on as a fragile material as the test temperature was diminished. He additionally announced that Impact durability of the dark cast iron was not improved with the expanding standardization temperature since there is no adjustment in the morphology of graphite drops in the dim cast iron with normalizing heat treatment. Normalizing heat treatment does not influence sway sturdiness of the cast composite altogether, on the grounds that the halfway broken down district is restricted because of deficient volume division for the present work condition.

Baldissera and Delprete [12] contemplated impacts of profound cryogenic treatment (DCT) on static mechanical properties of 18NiCrMo5 carburized steel and reasoned that The drenching time parameter demonstrates a solid effect on the hardness increment instigated by the pre-hardening DCT and, under the presumption that the microstructural instrument includes the whole procedure further enhancements could be conceivable with a drawn out DCT presentation. The unaltered elasticity of the pre-hardening DCT gatherings could be identified with a remuneration impacts because of the misfortune in lingering worry, as it is accounted for by writing.

Kayali et al [13] on his work of high Temperature Tensile and Abrasive Wear Characteristics of As-cast Ductile Irons announced that at whole temperature run pearlitic malleable iron showed higher quality and lower pliability than ferritic pliable iron. High temperature tractable testing caused serrated stream in the temperature go somewhere in the range of 100 and 300°C. In this temperature system, elasticity estimations of both pliable irons were practically constant. Above 400°C, increment of temperature diminished both elasticity and pliability drastically. Be that as it may, ferritic pliable iron displayed fundamentally higher pliability at 600 than 500°C.

Wang and Lei [17] saw that wear opposition expanded in following request: spheroidized carbide, martensite, bainite and lamellar pearlite. The outcome additionally demonstrated that the distinction in wear opposition of different microstructures were brought about by the distinctions in their warm steadiness, protection from misshapening, protection from nucleation and proliferation of smaller scale breaks and so on.

In arrangement of investigations, Kumar and Gupta [14, 15] completed broad examinations on low pressure grating wear attributes of carburized gentle steels, and warmth tried medium carbon and composite steels. The creators found that the hardness and scraped spot obstruction of carburized mellow steels expanded significantly with increment of temperature of carburization and drench time; utilization of coaltar pitch and extinguishing oil on gentle steel surface and its resulting carburization in charcoal incredibly Improved the wear opposition of carburized gentle steel; the most noteworthy scraped area obstruction was seen in the steel tests carburized in part consumed charcoal and the hardness and wear obstruction estimations of gentle steels carburized by utilizing coaltar pitch were similar with those of warmth treated high carbon low Cr steels.

Bepari et al [16] examined the impacts of Cr and Ni expansion on the structure and properties of carburized low carbon steels and found that both Cr and Ni advance the arrangement of held austenite in carburized and solidified steel, Cr being increasingly compelling. Both were found to refine the martensite platelets, with Ni being progressively viable the hardenability was found to increment with increment of austenite grain size and with degree of carbon entrance in carburized steel.

#### IV. EXPERIMENTAL DETAILS (MATERIALS AND METHODS)

##### A. Materials Selection:

Mild steels of the required measurements were acquired from the neighborhood showcase and the test examples were set up from it. The compound piece of mellow steel by (wt %) is given as pursues C-0.16, Si-0.03, Mn-0.32, S-0.05, P-0.02, Ni-0.01, Cu-0.01, Cr-0.01 and Fe.

##### B. Preparation of Test Specimens:

The test example for examination of various mechanical and wear properties like grating wear, durability, elasticity and hardness were set up according to ASTM standard and its portrayal is given beneath.

##### 1) Specimen for Abrasive Wear and Hardness Test:

The grating wear and hardness is resolved from a similar example. A standard example of measurements (4cm x 2.5cm x 0.5cm) of gentle steel is set up for a similar reason.



Fig. 2: Specimen for abrasive wear and hardness test

2) *Specimen for toughness test:*

A sturdiness test specimen as per ASTM standard is primed for the same purpose having the following dimensions. Length – 5.5 cm Width – 1 cm Thickness – 1 cm Notch depth – 0.5 cm

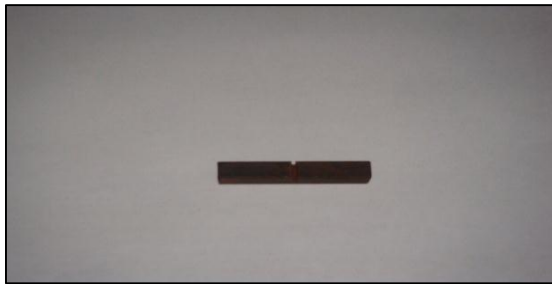


Fig. 3: specimen for toughness test

3) *Specimen for tensile strength test:*

A tensile test specimen as per ASTM standard is prepared for this purpose is based on the following equation.

$$L_0 = 5.65 \sqrt{A_0}$$

Where,  $L_0$  = Gauge length

$A_0$  = Cross sectional area



Fig. 4: Specimen for tensile strength test

C. *Coal selection and preparation:*

The vasundhara coal is taken for this reason and it is squashed into - 52 work size with the assistance of smasher and test sifter, around 4 kg of coal is set up for this reason and this coal is utilized for the pack carburization of gentle steel tests.

1) *Proximate analysis of vasundhara coal:*

Analysis for moisture, volatile matter, ash and fixed carbon contents in vasundhara coal (Table) were carried out on Samples ground to pass through -72 mess B.S. test sieve by the method given below.

2) *Moisture determination:*

One gram of air dried coal powdered example of size - 72mess was taken in a borosil glass cauldron and after that kept noticeable all around stove kept up at the temperature 110°C. The example was drenched at this temperature for one hour and afterward taken out from the heater and cooled. Reduction of weight was recorded utilizing an electronic parity. The rate misfortune in weight gave the rate dampness content in the example.

3) *Volatile matter determination:*

One gram of air dried coal powdered example of size - 72 wreckage was taken in an unstable issue cauldron (made of silica) and kept in the suppress heater kept up at the required temperature of 925°C. The example was drenched at this temperature for seven minutes and afterward pot was taken Out from the heater and cooled in air. Reduction of weight in the example was recorded by utilizing an electronic parity.

4) *Ash determination:*

One gram of air dried powdered example of size - 72mess was taken in a shallow silica plate and kept in the suppress heater kept up at the temperature of 775-800°C.

5) *Fixed carbon determination:*

The fixed content of carbon in the sample was determined by using the following formula: Fixed Content of carbon (Wt. %) = 100 - Wt % (Moisture + Volatile matter + Ash)

6) *Carburization of mild steel samples:*

The different test example tests prepared up of mellow steel for mechanical and wear properties testing were exposed to pack carburization treatment. In this procedure the gentle steel tests were put on the thick bed of carburizer kept in a tempered steel compartment and completely secured from all sides, the highest point of the holder was secured with a steel plate. The compartment was then brought into the suppress heater and afterward kept up at distinctive required carburization



Fig. 5: Muffle furnace for carburization of mild steel samples temperatures of 850, 900 and 9500C with the splash time of 2 hours by along these lines the mellow steel tests gets carburized and afterward they were extinguished in water for example the solidifying was affected following carburization. By this carburization procedure the mechanical and wear properties of mellow steel tests expanded extensively. The carburized steel tests were then tempered for a specific temperature and time and afterward it prepared for the diverse sort of mechanical and wear test.

7) *Tempering of carburized mild steel samples:*

After the carburization procedure, the steel is regularly harder than required and is unreasonably fragile for most pragmatic employments. Likewise, extreme inward burdens are set up during the quick cooling from the solidifying temperature. To diminish the inside burdens and decrease fragility, we should temper the steel after it is solidified. So in this treating procedure the carburized steel tests were warmed at the temperature of 2000C for span of 0.5 hours and after that cooling it more often than not in the still air. The carburized and tempered mellow steel examples are then exposed to different sort of mechanical and wear test.

8) *Abrasive wear test:*

The materials considered for this investigation is carburized gentle steel tests which is carburized under various temperature scope of 850, 900 and 9500C with measurements 4.0cm x2.5 cm x 0.5 cm. The test was led on a machine called Pin on circle machine (make: SD logical enterprises) as appeared in fig. The example was mounted oppositely on a stationary bad habit with the end goal that its one of the face is compelled to press against the grating that is fixed on the spinning plate. Henceforth it is the rough paper that will in general wear the outside of the examples. At the point when the circle turns for a specific timeframe, the example can stacked at the top to press against the plate with the assistance

of a switch system. In this experiment the test can be conducted with the following parameters (1) Load (2) Speed (3) Time

In the present experimental work, speed and time wear kept constant while the load was varied from 14.7 N to 49 N. Parameters that remained constant throughout all the experiments.

|                        |                      |
|------------------------|----------------------|
| RPM                    | 300                  |
| Time                   | 5 minute             |
| Type of abrasive paper | Emery, 80 grade size |

For every one of the example, test was directed for multiple times and the normal of the considerable number of tests was taken as the watched qualities for each situation.

When the parameter is set and work piece is mounted, the test is carried on for the ideal time. The wear track so framed on the turning plate is a circle. After each test just the mass loss of the example was considered as the wear. The wear pace of each example was determined from the weight reduction, the measure of wear is dictated by gauging the example when the test utilizing precession electronic gauging machine. Since the mass misfortune is estimated it is changed over to volume misfortune utilizing the thickness of the example. Consequently wear volume, wear rate and wear opposition can be determined as pursues. Density of the specimen. Hence wear volume, rate of wear and wear resistance can be calculated as follows.

1) wear volume:

$$\text{Wear volume} = \frac{\text{weight loss}}{\text{density}} \quad \text{Density of specimen} = 7.86 \text{ g/cm}^3$$

2) wear rate:

It is defined as wear volume per unit distance travelled  
Wear rate = wear volume / sliding distance (s)

Sliding distance (s) can be calculated as  
Sliding distance (s) =  $V \times \text{time}$

$$= (2 \pi R N / 60) \times \text{time}$$

Where, R = radius of abrasive wheel (7.25cm)

N = R.P.M (300)

$\Pi = 3.14$  (constant) Time = 5 minute = 300 S

3) wear resistance:

wear resistance is a reciprocal of wear rate  
wear resistance =  $1 / \text{wearrate}$



Fig. 6: Pin on disc machine for abrasive wear testing.

9) Hardness test:

Rockwell hardness testing is a general strategy for estimating the mass hardness of metallic Table 1 Parameter taken constant in abrasive wear test and polymer materials. Despite the fact that hardness testing does not give an immediate estimation of any exhibition properties, hardness associates with quality, wear obstruction, and different properties.

Hardness testing is broadly utilized for material assessment because of its effortlessness and ease in respect to coordinate estimation of numerous properties. In present exploratory work Rockwell hardness was estimated on carburized and tempered mellow steel tests which are carburized under various temperature scope of 850, 900 and 9500C. For every one of the example, test was directed for multiple times and the normal of the considerable number of tests was taken as the watched qualities for each situation



Fig. 7: Rockwell hardness tester

10) Tensile test:

The tensile strength is measured by tensile test which is carried out on an Instron 1195 machine. This involves the preparation of a test specimen as per ASTM standard as shown in fig.4 and this test specimen is based on following relation.

$$L_0 = 5.65 \sqrt{A_0}$$

Where,  $L_0$  = Gauge length

$A_0$  = Cross sectional area

Here the significant parameter are the check length  $L_0$  and the cross sectional territory  $A_0$  then a consistently expanding burden is connected on the example. As the heap builds the example at first gets flexibly prolonged. On further stretching, the example begins necking at certain focuses when the material goes past the flexible range. The diminished width of example would further be decreased under the power of the heap lastly creates breaks when the test is finished It very well may be seen that there is a limit up to which the connected pressure is straightforwardly relative to the prompted strain, the finish of this direct segment is the yield purpose of the material above which the material begins plastically twisting and when the power connected burden goes past the point of confinement that can borne by the material, the example breaks. The worry at versatile farthest point is called yield quality. The most extreme pressure came to in a material before the crack is named as a definitive elasticity.

In present trial the ductile test was completed on carburized and tempered gentle steel tests which are treated under various temperature scope of 850, 900 and 9500C and the accompanying condition were taken during elastic test in Instron 1195 machine.

11) Machine parameter of Instron 1195 tensiletest:

Samplotype : ASTM

Samplerate(pts/sec) : 9.103

Cross headspeed(mm/min) : 2.000

Full scale loadingrange(KN) : 50.00

Humidity(%) : 50

Temperature(0F) : 73

Dimensions parameters of specimen for Instron 1195 tensile test:-  
Width - 7 mm  
Thickness - 5 mm  
Gaugelength -34 mm  
Grip distance - 100 mm



Fig. 8: Instron 1195 machine for tensile test

#### 12) Toughness (Charpy impact) test:

The test is directed for the three distinct examples carburized under the three unique temperatures of 850, 900 and 9500C. The test comprise of estimating the vitality consumed in breaking an ASTM standard U – indented example by giving a solitary pass up swinging mallet. The example is essentially upheld at its finishes. As the speed of striking body is changed, there must happen an exchange of vitality; work is done on the parts accepting the blow. The mechanics of effect includes the subject of stresses instigated, yet in addition a thought of vitality move and of vitality ingestion and dissemination. The capacity of material to retained vitality and disfigure plastically before crack is designated "strength". It is typically estimated by the vitality ingested in an indented effect test like charpy or izod tests. In present work for every one of the example, test was directed for 3times and the normal of the considerable number of tests was taken as the watched qualities for each situation.

#### 13) Machine Specifications:

The specification of charpy machine used for the toughness test of present work is as follows.

Weight of hammer 18.75 kg  
Striking of hammer 5 cm / s to 5.5 cm / s  
Angle of hammer striking edge 300  
Radius of curvature of striking edge 2 mm Swing of hammer both ways 0 -1600

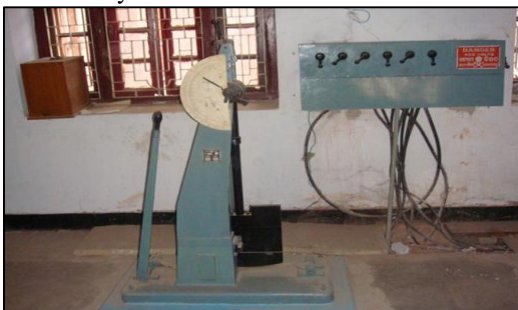


Fig. 9: Charpy impact tester for toughness testing.

## V. RESULTS AND DISCUSSION

The diverse kind of mild steel samples were carburized and tempered under the different condition and temperature and then tested for various types of test like abrasive wear test, tensile strength test, toughness test and hardness test. The

results of abrasive wear test as received for different load (i.e.14.7 N, 29.4 N and 49 N) is recorded in Table 3 – 5, the result of Rockwell hardness test at 150 kg load is recorded in Table – 6. Similarly the result of toughness test and tensile strength test is recorded in Table – 7 and 8 respectively. The close investigation of Vasundhara coal is also done which is used as a carburized and its value is shown in Table – 2.

#### A. Results of proximate analysis of Vasundhara coal:

The results of proximate analysis of vasundhara coal is shown in Table – 2, this analysis is performed to find out the percentage (wt %) of moisture, volatile matter, ash and content of carbon in the given coal sample. From the analysis we found that vasundhara coal content 31% of carbon, 5% of moisture, 29% of volatile matter and 35% of ash.

#### B. Results of abrasive wear test:-The abrasion characteristics of carburized mildsteels:

The results shows rough wear trial of carburized gentle steels, carburized at various temperature of 850, 900 and 9500C is appeared in Table 3 – 5. The reduction of weight bend as an element of hardness for these steels is appeared in Fig.22 – 25, generally, the reduction of weight during scraped spot of all these carburized steels diminishes directly with the expansion of hardness and temperature of carburization. From the exploratory consequences of grating wear test (Table 3 – 5), the accompanying regularities can be found. The weight loss during abrasion is maximum for uncarburized simple mild steel and is lowest for the mild steel carburized at temperature of 9500C.

- 1) As looking at the instance of carburized gentle just, the reduction of weight during scraped spot is most astounding for the mellow steel carburized at temperature of 8500C and is least for the mellow steel carburized at temperature of 9500C, that is a direct result of nearly low content of carbon at lower temperature of carburization . So it is inferred that, as the temperature of carburization builds the reduction of weight during scraped area is diminishes.
- 2) The scraped area test is directed under three unique heaps of 14.7 N, 29.4 N and 49 N and it is gotten from the test that the reduction of weight during the scraped spot is most astounding for the heap of 49 N and is least for the heap of 14.7 N, so it is finished up from the test that, as the heap builds the reduction of weight during scraped spot is likewise increments
- 3) The wear rate is most astounding for uncarburized basic gentle steel and is least for the mellow steel carburized at temperature of 9500C and this wear rate is continuously diminishes with increment in temperature of carburization. This is because of the way that the reduction of weight during scraped spot is legitimately corresponding to the wear rate, so as the temperature of carburization expands the reduction of weight during scraped spot diminishes and all the while there is the abatement in the wear rate.
- 4) The wear rate is additionally load subordinate and the scraped spot test outcomes demonstrated that the wear rate increments bit by bit while expanding the connected burden, so the wear rate is most elevated for the heap of 49 N and it is least for the heap of 14.7 N.

- 5) The wear obstruction is most elevated for the mellow steel carburized at the temperature of 9500C and it is least for the uncarburized gentle steel. For taking the instance of just carburized gentle steels additionally the wear obstruction is most elevated for the mellow steel carburized at the temperature of 9500C and is least for mellow steels carburized at temperature of 8500C. Henceforth the scraped spot results clarify that the wear obstruction is legitimately relative to the temperature of carburization, as the temperature of carburization expands the wear opposition increments.
- 6) The net outcomes is that the mellow steel carburized at temperature of 9500C giving the best outcomes, as it has having the most elevated wear opposition, least reduction of weight because of scraped spot and most minimal wear rate.

*C. Mechanical properties results (tensile strength, toughness and hardness test results):*

In general heat treatment and carburization of mellow steels brought about an expansion in hardness, rigidity and wear obstruction and diminishes the reduction of weight during scraped spot and sturdiness esteems. The tests aftereffects of various mechanical attributes like rigidity, sturdiness and hardness under the distinctive temperature of carburization of 850, 900 and 9500C is appeared in Table 6 – 8 and condensed under the accompanying focuses.

- 1) The rigidity is changed between the scopes of 441MPa – 1960 MPa (Table – 8) and is most noteworthy for the mellow steel carburized at temperature of 9500C and least for the uncarburized straightforward gentle steel. This outcomes demonstrates that the carburization significantly improved the elasticity of gentle steels.
- 2) For taking the instance of carburized mellow steels just, the rigidity is most elevated for the gentle steels carburized at the temperature of 9500C and is least for the gentle steels carburized at temperature of 8500C, that is prompts the end that with the expansion in the temperature of carburization, the elasticity of carburized gentle steels increments.
- 3) From the consequences of the durability test (Table – 7) it is examinations that the sturdiness is changed between the scope of 54J – 32J and it is most astounding for the uncarburized mellow steels and least for the gentle steels carburized at temperature of 9500C. So it is reasoned that the carburization procedure diminishes the strength of the gentle steels. This outcomes is normal and it is likewise bolstered from the literature [21]
- 4) It is additionally acquired from the durability test outcomes that. As the temperature of carburization increments from estimation of 850 – 9500C, there is a little decline in the strength esteems from 37J – 32 J, so it is closed from the outcomes that with increment of temperature of carburization, the sturdiness esteems diminishes.
- 5) The hardness esteems differed between scope of 51 Rc – 57 Rc and it is most astounding for the gentle steel carburized at temperature of 9500C and is least for the mellow steels carburized at 8500C, so with increment of temperature of carburization the hardness esteems increments. From the hardness test try it is additionally

noticed that the hardness estimations of uncarburized straightforward mellow steel can't compute in Rc scale as a result of its less hardness esteems.

- 6) Finally the net outcomes is that the mellow steels carburized at 9500C is giving the best outcomes for the mechanical and wear properties like rigidity, hardness and wear obstruction with the exception of the instance of strength test.

*D. Effect of temperature of carburization on weight loss of carburized mild steels:*

The variation of temperature of carburization with wear due to scuff is shown in the Table 3 – 5 and it is also graphically represented in the Fig.10 – 13. From these results we found that the weight loss due to abrasion is highest for the mild steel carburized at temperature of 8500C and it is lowest for the mild steel carburized at temperature of 9500C. From the graph it is shown that the weight loss curve decreases gradually with increase in the temperature of carburization. This result is expected because as the temperature of carburization increases, the hardness of carburized mild steel is also increases and due to increase in the hardness the weight loss due to abrasion is decreases.

*E. Effect of load on the weight loss of carburized mild steels:*

The abrasive wear test is performed for the three kinds load of 14.7 N, 29.4 N and 49N for the carburized of mild steels and the results is shown in the Table 3 – 5 and it is found that the weight loss due to abrasion is greatly affected with increase in practical load, the weight loss due to abrasion is highest for the load of 49 N

*F. Effect of temperature of carburization on wear resistance of carburized mildsteels:*

The impact of temperature on carburization on wear opposition of carburized gentle steels for the three distinct temperatures of 850, 900 and 9500C is appeared in the Table 3 – 5 and it is plotted graphically in the Fig.18 – 21. where it is demonstrated that wear opposition differs straightforwardly with the temperature of carburization, it implies with increment of temperature of carburization the wear obstruction additionally increments and the wear obstruction is most extreme for the gentle steels carburized at temperature of 9500C and it is least for the mellow steels carburized at temperature of 8500C. So the gentle steels carburized at temperature of 9500C is giving the best outcomes and it is liked.

*G. Effect of hardness on the weight loss of carburized mild steels:*

The variety among hardness and reduction of weight because of scraped spot. Where it is discovered that the reduction of weight because of scraped area is exceptionally impacted by the hardness and it fluctuates contrarily association with the hardness this implies with increment in the hardness estimations of carburized mellow steels the reduction of weight because of scraped spot is diminishes. Or then again at the end of the day for the carburized mellow steels having higher reduction of weight because of scraped area, its hardness must be less. That is a direct result of the hard material having the more noteworthy rough wear obstruction,

so the less wear happens in the carburized gentle steels and the reduction of weight diminishes.

**H. Effect of temperature of carburization on tensile strength of carburized mildsteels:**

The impact of temperature of carburization on rigidity of carburized gentle steels is appeared in the Table – 8 and it is likewise spoken to graphically in the Fig.26. The aftereffects of rigidity demonstrates that the carburization procedure extraordinarily improve the elasticity of mellow steels. The outcomes clarify that the elasticity changed straightforwardly with the temperature of carburization. This inferred with the expansion in the temperature of carburization, the elasticity builds directly and looking at the temperature of carburization of 850, 900 and 9500C, the rigidity is most elevated for the gentle steel carburized at 9500C, and least for 8500C. So the gentle steels carburized at 9500C is giving the best outcomes and it must be liked.

**I. Effect of temperature of carburization on sturdiness of carburized mellow steels:**

The sturdiness properties of mellow steels is exceptionally impacted by the carburization procedure the Table – 7 demonstrates the durability consequences of carburized and uncarburized gentle steels where it is discovered that the strength estimations of uncarburized mellow steels is higher than that of carburized gentle steels and durability esteems diminishes with increment in temperature of carburization, so the procedure of carburization diminishes the strength of mellow steels. This outcome is likewise demonstrated graphically in the Fig.27. Which demonstrates that with increment in the temperature of carburization the strength of carburized gentle steels diminishes. This outcomes is additionally bolstered from the literature[21].

**VI. CONCLUSION AND SUGGESTIONS FOR FUTURE WORK**

**A. Conclusions:**

From the present studies on “Mechanical and wear properties of carburized of mild steels samples” the following conclusion have been drawn.

- 1) The mechanical and wear properties of mellow steels were observed to be unequivocally affected by the procedure of carburization and carburizing temperature.
- 2) The carburization treatment pursued by the water extinguishing apparently improved the hardness, wear opposition and elasticity of gentle steels.
- 3) The carburization procedure diminishes the durability of the mellow steels. What's more, the sturdiness is diminishes with increment in the temperature of carburization.
- 4) The reduction of weight due scraped spot, wear volume and wear rate increments with the expansion in the connected burden.
- 5) Hardness, wear obstruction and elasticity increments with increment in the temperature of carburization.
- 6) Weight misfortune because of scraped spot, wear volume, wear rate and strength diminishes with increment in the temperature of carburization.

- 7) With increment in the hardness the wear opposition increments, yet there is decline in reduction of weight because of scraped area and wear rate.
- 8) As looking at for changed temperature of carburization. The gentle steels carburized at the temperature of 9500C demonstrates the best blend of higher hardness, higher elasticity and higher wear obstruction with low reduction of weight and less wear rate.
- 9) Finally the net end is that the gentle steel carburized under the distinctive temperature scope of 850, 900, and 9500C with in which the mellow steel carburized at the temperature of 9500C is giving the best outcomes for the mechanical and wear properties like elasticity, hardness and wear obstruction.

**B. Suggestions for the future work:**

After studying the Mechanical and wear properties of carburized steel sample under the different temperature of carburization of 850, 900 and 9500C. The following works are suggested to be carried out in the future.

- 1) The similar studies can be made for other types of wear like adhesive wear, erosive wear, corrosive wear etc.
- 2) The studies on abrasive wear can also be performed by varying its rotational speed and time.
- 3) The similar studies can also be made for other types of mechanical properties like elasticity, plasticity, compressive strength, ductility, brittleness and malleability etc.
- 4) The similar studies can be performed by changing the carburization temperature.
- 5) The similar studies can also be made by changing the soak time and the tempering temperature.
- 6) The similar studies can be performed for the heat treated medium carbon steels.
- 7) The similar studies can also be performed by changing its quenching medium.
- 8) The similar studies can also be performed for other type of heat treatment process like nitriding, cyaniding, carbonitriding etc.

| Coal            | Proximate analysis (Wt %) |                 |     |              |
|-----------------|---------------------------|-----------------|-----|--------------|
|                 | Moisture                  | Volatile matter | Ash | Fixed carbon |
| Vasundhara coal | 4.999                     | 28.999          | 35  | 31           |

Table 2: Proximate analysis of Vasundhara coal

| Carburization condition |                | Tempering condition |                 | Weight loss, g | Wear Volume cm <sup>3</sup> x10 <sup>-2</sup> | Wear rate, cm <sup>3</sup> x10 <sup>-7</sup> | Wear resistance, cm <sup>3</sup> x10 <sup>7</sup> |
|-------------------------|----------------|---------------------|-----------------|----------------|---|--|---|
| Temp (°C)               | Soak time(Hrs) | Temp(°C)            | Soak time (Hrs) |                |   |  |   |
| Simple mild steel       | -              | -                   | -               | 0.211          | 2.68  | 3.93   | 0.254   |
| 850°C                   | 2              | 200°C               | 0.5             | 0.134          | 1.68  | 2.49   | 0.404   |
| 900°C                   | 2              | 200°C               | 0.5             | 0.119          | 1.49  | 2.21   | 0.456   |
| 950°C                   | 2              | 200°C               | 0.5             | 0.108          | 1.39  | 2.099  | 0.496   |

Table 3: Result of abrasive wear test for carburized mild steel, at load 14.7N

| Carburization condition     |                | Tempering condition        |                 | Weight loss, g | Wear volume, $\text{cm}^3 \times 10^{-2}$ | Wear rate, $\text{cm}^3 \times 10^{-7}$ | Wear resistance $\text{cm}^2 \times 10^7$ |
|-----------------------------|----------------|----------------------------|-----------------|----------------|---|---|---|
| Temp ( $^{\circ}\text{C}$ ) | Soak time(Hrs) | Temp( $^{\circ}\text{C}$ ) | Soak time (Hrs) |                |   |   |   |
| Simple mild steel           | -              | -                          | -               | 0.254          | 3.22                                      | 4.709                                   | 0.212                                     |
| 850 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 0.159          | 2.00                                      | 2.929                                   | 0.3139                                    |
| 900 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 0.139          | 1.749                                     | 2.569                                   | 0.3889                                    |
| 950 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 0.1249         | 1.549                                     | 2.329                                   | 0.4289                                    |

Table 4: Result of abrasive wear test for carburized mild steel, at load 29.4 N

| Carburization condition     |                | Tempering condition        |                 | Weight loss, g | Wear volume, $\text{cm}^3 \times 10^{-2}$ | Wear rate, $\text{cm}^3 \times 10^{-7}$ | Wear resistance, $\text{cm}^2 \times 10^7$ |
|-----------------------------|----------------|----------------------------|-----------------|----------------|---|---|--|
| Temp ( $^{\circ}\text{C}$ ) | Soak time(Hrs) | Temp( $^{\circ}\text{C}$ ) | Soak time (Hrs) |                |   |   |  |
| Simple mild steel           | -              | -                          | -               | 0.309          | 3.92                                      | 5.75                                    | 0.175                                      |
| 850 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 0.191          | 2.42                                      | 3.54                                    | 0.284                                      |
| 900 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 0.169          | 2.14                                      | 3.13                                    | 0.321                                      |
| 950 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 0.152          | 1.93                                      | 2.82                                    | 0.356                                      |

Table 5: Result of abrasive wear test for carburized mild steel, at load 49 N

| Carburization condition     |                | Tempering condition        |                 | Hardness(R <sub>c</sub> ) |
|-----------------------------|----------------|----------------------------|-----------------|---------------------------|
| Temp ( $^{\circ}\text{C}$ ) | Soak time(Hrs) | Temp( $^{\circ}\text{C}$ ) | Soak time (Hrs) |                           |
| Simple mild steel           | -              | -                          | -               | -                         |
| 850 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 50.999                    |
| 900 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 54.999                    |
| 950 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 56.999                    |

Table 5: Rockwell hardness of carburized mild steel, at load 150 kg

| Carburization condition     |                | Tempering condition        |                 | Toughness, Joule(Nm) |
|-----------------------------|----------------|----------------------------|-----------------|----------------------|
| Temp ( $^{\circ}\text{C}$ ) | Soak time(Hrs) | Temp( $^{\circ}\text{C}$ ) | Soak time (Hrs) |                      |
| Simple mild steel           | -              | -                          | -               | 54                   |
| 850 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 36.999               |
| 900 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 34.999               |
| 950 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 31.999               |

Table 7: Result of toughness test of carburized mild steel

| Carburization condition     |                | Tempering condition        |                 | Tensile strength(mpa) |
|-----------------------------|----------------|----------------------------|-----------------|-----------------------|
| Temp ( $^{\circ}\text{C}$ ) | Soak time(Hrs) | Temp( $^{\circ}\text{C}$ ) | Soak time (Hrs) |                       |
| Simple mild steel           | -              | -                          | -               | 441                   |
| 850 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 1871.999              |
| 900 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 1924.999              |
| 950 $^{\circ}\text{C}$      | 2              | 200 $^{\circ}\text{C}$     | 0.5             | 1959.999              |

Table 8: Tensile Strength of carburized mild steel

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