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Analysis on of mechanical properties of low carbon steel by carburization process

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Abstract

The heat treatment and carburization has been acknowledged by some means of improving the various properties of metals and alloys. In the present investigation the mechanical and wear behaviors of AISI 1020 carbon steels carburized at different temperature range of 850, 900 and 950^{0}C have been studied and it is found that the simple heat treatment greatly improves the hardness, tensile strength and wears resistance of the AISI 1020 carbon steels. The aim has been to examine the effects of these different carburization temperatures and conditions on the mechanical and wear properties of the carburized AISI 1020 carbon steels. For above purpose firstly the AISI 1020 carbon steels are carburized under the different temperature range as stated above and then it is tempered at 200^0 C for half an hour after this the carburized and tempered AISI 1020 carbon steels are subjected for different kind of test such as hardness test, tensile test and the toughness test. The results of these experiment shows that the process of carburization greatly improves the mechanical and wear properties like hardness, tensile strength and wear resistance and these properties increases with increase in the carburization temperature but apart from this the toughness property decreases and it is further decreases with increase in carburization temperature. The experimental results also shows that the AISI 1020 carbon steels carburized under different temperature range as stated above, with in which the AISI 1020 carbon steels carburized at the temperature of 950^{0}C gives the best results for the different kinds of mechanical and wear properties because at this temperature it gives highest tensile strength, hardness and wear resistance, so it must be preferred for the required applications.

Introduction

Carburizing steel is widely used as a material of automobiles, form implements, machines, gears, springs and high strength wires etc. which are required to have the excellent strength, toughness, hardness and wear resistance, etc because these parts are generally subjected to high load and impact. Such mechanical properties and wear resistance can be obtained from the carburization and quenching processes. This manufacturing process can be characterized by the key points such as: it is applied to low carbon work are in contact with high carbon gas, liquid or solid, it produces hard work piece surface, work piece cores retain soft.

Carbon steel is a category of steel, which contain 0.12 to 2% carbon. This steel category gains hardness and strength with heat treatment when the percentage of carbon content increases, but the ductility is reduced. AISI 1020 carbon steel is a commonly used plain carbon steel. It has a good combination of strength and ductility and can be hardened or carburized.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, untempering, 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 predetermined depth below the surface to a sufficient level to allow subsequent quench hardening.

2.0 Experimental Method and Methodology

2.1 Materials Selection

AISI 1020 steels of the required dimensions were purchased from the local market and the test specimens were prepared from it. The chemical composition of mild steel by (wt %) is given as follows C-0.16, Si-0.03, Mn-0.32, S-0.05, P-0.2, Ni- 0.01, Cu-0.01, Cr-0.01 and Fe.

Preparation of test specimens

The test specimen for analysis of different mechanical and wear properties like toughness, tensile strength and hardness were prepared as per ASTM standard and its description is given below.

1. **Specimen for hardness test:-** The hardness isdetermined from the same specimen. A standard specimen of dimensions (5.5cm x 2.0cm x 2.0cm) of AISI 1020 steel is prepared for the same purpose.

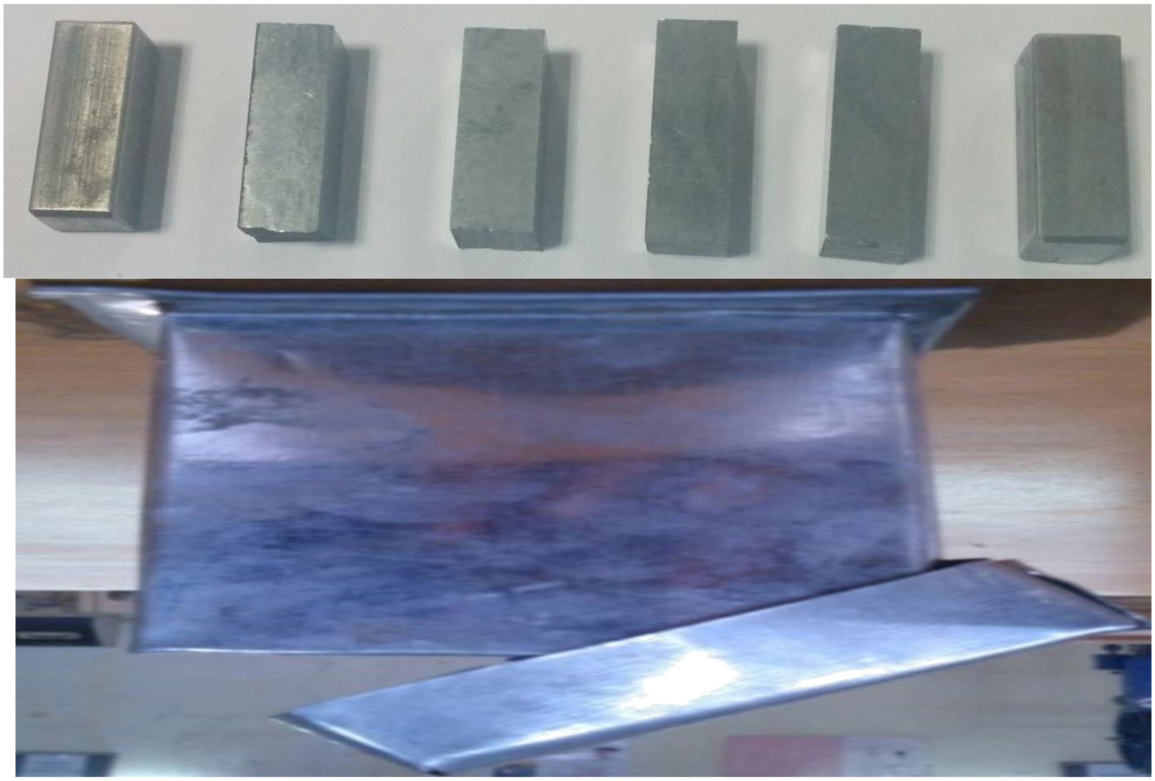

Fig 2 Prepared mild steel samples Carburizing of mild steel and AISI 1020 samples

The test specimens from AISI 1020 steel were subjected to pack carburizing treatment. For this purpose, closed containers were fabricated, galvanized steel sheet was used for making container. The AISI 1020 steel samples were packed in thick bed of wood charcoal kept in a container and the top of the container was covered by the lid. Carburizing process was done at three different temperatures i.e. 850^{0}C, 900 ^{0}C and 950^{0}C. After maintaining the muffle furnace at required temperature, the packed containers were put inside the muffle furnace for given soaking time i.e. 2 and 5 hours. After soaking at a particular temperature for one particular soaking time the muffle furnace was switched off. The container was left inside the furnace for slow cooling. After 24 hours, the container was taken out from the furnace. The carburized steel samples are shown in fig 2.2

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FIG. 2.1 Muffle furnace used for carburizing mild steel samples

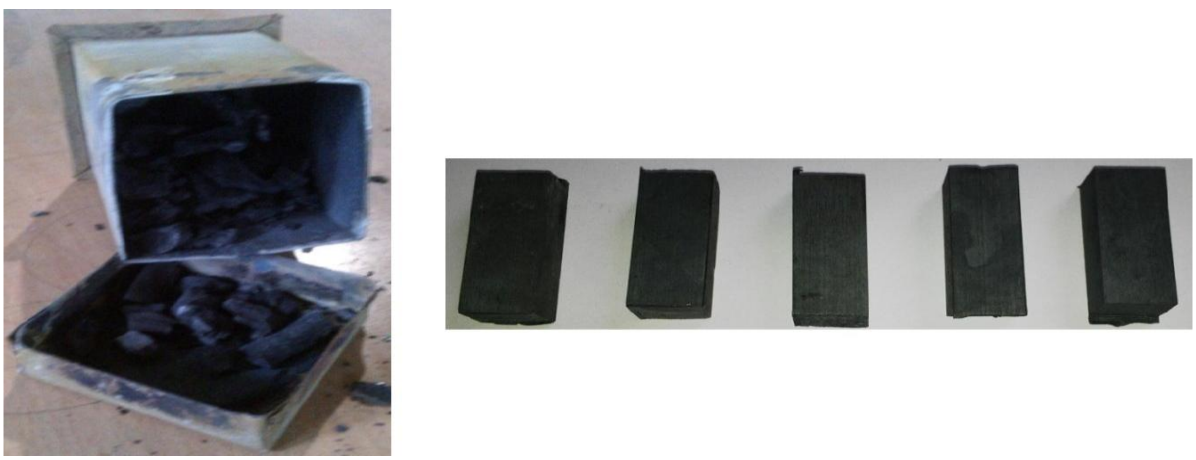

Fig 2.2 the carburized steel samples

3.3 Post carburizing Heat treatment

After carburizing the steel is often becomes harder than the required value. It becomes too brittle for most practical uses. But in our case, the steel samples became softer than original when they were kept within the packing of charcoal for 24 hours. Thus to improve the hardness the carburized samples were again treated for improving the hardness. The carburized steel samples were heated for 30 minutes at 850^{0}C. Some samples were kept inside the furnace to be annealed and some were quenched in water. Due to the rapid cooling severe internal stresses were developed. To relieve the internal stresses induced and to reduce brittleness, tempering process was done on hardened carburized steel samples at 150^0C for 30 minutes, and then cooled in air. The hardness was measured at each stage to know the difference in hardness.

2.3 Tempering of carburized AISI 1020 steel samples

After the carburization process, the steel is often harder than needed and is too brittle for most practical uses. Also, severe internal stresses are set up during the rapid cooling from the hardening temperature. To relieve the internal stresses and reduce brittleness, we should temper the steel after it is hardened. So in this tempering process the carburized steel samples were heated at the temperature of 200^0C for duration of 0.5 hours and then cooling it usually in the still air. The carburized and tempered AISI 1020 steel specimens are then subjected to various kind of mechanical and wear test.

2.4 Heat Treatment of AISI 1020 sample

Nine samples were taken in a batch. The samples were kept inside the muffle furnace for four hours at 850^0C.

The first medium for quenching was taken as plain water at room temperature as shown in fig 3.5.

Fig. 3.5 Water as quenching medium

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2.5 Hardness test

Rockwell hardness testing is the most popular method for measuring the bulk hardness of metals. Although hardness testing does not give a direct measurement of any performance properties, hardness correlates with strength, wear resistance, and other properties. Hardness testing is widely used for material evaluation due to its simplicity and low cost relative to direct measurement of many properties. This method works on the principle that the depth of penetration varies with hardness of material. For measuring the hardness, it uses the diamond cone or hardened steel ball indenter according to the soft or hard material. The indenter is forced into the test material under a preliminary minor load usually of 10 kg. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. In addition to the minor load major load of usually 100 kg or 150kg is applied with resulting increase in penetration. After reaching equilibrium condition, the additional the Major load is removed but preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number. In present experimental work Rockwell hardness was measured on carburized and tempered AISI 1020 steel samples which are carburized in the temperature range of 850,900 and 950^{0}C by the help of the steel ball indenter and by applying a major load of 100 kg which gave the Rockwell hardness value in B scale i.e. RHB. For each of the sample, test was conducted for 5 times and the average of all the tests was taken as the observed values in each case. The Rockwell testing machine is shown in fig 3.8.

Fig. 2.4 Rockwell hardness testing machine

2.6Toughness (charpy impact) test

The test is conducted for the nine different samples carburized under the three different temperatures of 850, 900 and 950^{0}C. The test consist of measuring the energy absorbed in breaking a ASTM standard U – notched specimen by giving a single blow by swinging hammer. The specimen is simply supported at its ends. As the velocity of striking body is changed, there must occur a transfer of energy; work is done on the parts receiving the blow. The mechanics of impact involves not only the question of stresses induced, but also a consideration of energy transfer and of energy absorption and dissipation. The ability of material to absorbed energy and deform plastically before fracture is called "toughness". It is usually measured by the energy absorbed in a notched impact test like charpy or izard tests. In present work for each of the sample, test was conducted for 9 times and the average of all the samples was taken as the observed values in each case.

3.8 Machine specifications: - The specification of charpy machine used for the toughness test of present work is as follows.

Weight of the hammer 18.75kg

Striking of hammer 5cm / s to 5.5 cm / s

Angle of hammer striking edge 30^0

Radius of curvature of striking edge 2mm

Swing Of hammer both ways 0 - 160^0

Fig 2.7 Charpy impact tester for toughness test

TENSILE TEST

The tensile strength is measured by tensile test which is carried out on an Intron 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

Important parameter are the gauge length L_0 and the cross sectional area A_0 then a uniformly increasing load is applied on the specimen. As the load increases the specimen initially gets elastically elongated. On further elongation, the specimen starts necking at some points when the material goes beyond the elastic range. The reduced width of specimen would further be reduced under the force of the load and finally develops fractures when the test is completed. It can be observed that there is a limit up to which the applied stress is directly proportional to the induced strain, the end of this linear portion is the yield point of the material above which the material starts plastically deforming and when the force applied load goes beyond the limit that can borne by the material, the specimen breaks. The stress at elastic limit is called yield strength. The maximum stress reached in a material before the fracture is termed as the ultimate tensile strength.

In present experiment the tensile test was carried out on carburized and tempered AISI 1020 steel samples which are treated under different temperature range of 850, 900 and 950^0C and the following condition were taken during tensile test machine.

Machine parameter:

Sample type	:	ASTM
Sample rate (pts/sec)	:	9.103
Cross head speed (mm/min)	:	2.000
Full scale loading range (KN)	:	50.00
Humidity (%)	:	50
Temperature (0F)	:	73

Dimensions parameters of specimen for tensiletest:-

Width - 7 mm
Thickness - 5 mm
Gauge length - 34 mm
Grip distance - 100 mm

Fig. 2.8 Instron 1195 machine for tensile test

3.0 Result Analysis

The AISI 1020 steel samples were carburized and tempered under the different condition and temperature and then tested for various kinds of test like tensile strength test, toughness test and hardness test. The results result of Rockwell hardness test at 150 kg load is recorded in Table – 2. Similarly the result of toughness test and tensile strength test is recorded in Table – 3 and 4 respectively. The proximate analysis of Vasundhara coal is also done which is used as a carburized and its value is shown in Table – 1.

Results of proximate analysis of Vasundhara coal

The results of proximate analysis of vasundhara coal is shown in Table – 1, this analysis is performed to find out the percentage (wt %) of moisture, volatile matter, ash and carbon content 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.

Mechanical Properties results (tensile strength, toughness and hardness test results)

In general heat treatment and carburization of AISI 1020 carbon steel resulted in an increase in hardness, tensile strength and wear resistance and decreases the weight loss

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during abrasion and toughness values. The tests results of different mechanical characteristics like tensile strength, toughness and hardness under the different carburization temperature of 850, 900 and 950^{0}C is shown in Table 3 – 4 and summarized under the following points.

1. The tensile strength is varied between the ranges of 6155MPa – 5950MPa (Table – 4) and is highest for the AISI 1020 carbon steel carburized at temperature of 950^{0}C and lowest for the uncarburized simple AISI 1020 carbon steel. This results shows that the carburization greatly improved the tensile strength of AISI 1020 steels.

2. For taking the case of carburized AISI 1020 carbon steels only, the tensile strength is highest for the AISI 1020 steel carburized at the temperature of 950^{0}C and is lowest for the AISI 1020 carbon steel carburized at temperature of 850^{0}C, that's leads to the conclusion that with the increase in the carburization temperature, the tensile strength of carburized AISI 1020 carbon steel increases. This result is also shown graphically.

3. From the results of the toughness test(Table – 3) it is analyses that the toughness is varied between the range of 258 – 234 and it is highest for the uncarburized AISI 1020 carbon steel and lowest for the AISI 1020 carbon steel carburized at temperature of 950^{0}C. So it is concluded that the carburization process decreases the toughness of the AISI 1020 carbon steel. This results is expected and it is also supported from the literature [21]

4. It is also obtained from the toughness test results that. As the carburization temperature increases from value of 850 – 950^{0}C, there is a little decrease in the toughness values from 258 – 234, so it is concluded from the results that with increase of carburization temperature, the toughness values decreases.

5. The hardness values varied between range of 46 Rc – 60 Rc and it is highest for the AISI 1020 carbon steel carburized at temperature of 950^{0}C and is lowest for the AISI 1020 steel carburized at 850C, so with increase of carburization temperature the hardness values increases. This is also shown graphically. From the hardness test experiment it is also noted that the hardness values of uncarburized simple AISI 1020 carbon steel is unable to calculate in Rc scale because of its very less hardness values.

6. Finally the net results is that the AISI 1020 carbon steel carburized at 950^{0}C is giving

the best results for the mechanical and wear properties like tensile strength, hardness and wear resistance except the case of toughness test.

Effect of carburization temperature on weight loss of carburized AISI 1020 steel

The variation of carburization temperature with weight loss due to abrasion is shown in *the Table 3 – 4 and it is also graphically. From these* results we found that the weight loss due to abrasion is highest for the AISI 1020 carbon steel carburized at temperature of 850^0C and it is lowest for the AISI 1020 carbon steel carburized at temperature of 950^0C. From the graph it is shown that the weight loss curve decreases gradually with increase in the carburization temperature. This result is expected because as the carburization temperature increases, the hardness of carburized AISI 1020 carbon steel is also increases and due to increase in the hardness the weight loss due to abrasion is decreases.

Effect of load on the weight loss of carburized mild AISI 1020 steel

The abrasive wear test is conducted for the three different load of 14.7 N, 29.4 N and 49N for the carburized AISI 1020 carbon steel and the results is shown in the Table 3 – 4 and it is found that the weight loss due to abrasion is greatly affected with increase in applied load, the weight loss due to abrasion is highest for the load of 49 N and it is lowest for the load of 14.7 N. The result shows that, with the increase in the applied load the weight loss due to abrasion is also increases, this is because of the increase in the force, the friction increases which causes the weight loss. Where it shows that weight loss due to abrasion is highest for the load curve of 49 N and it is above other two curves.

Effect of carburization temperature on wear resistance of carburized AISI 1020 carbon steel

The effect of carburization temperature on wear resistance of carburized AISI 1020 carbon steel for the three different temperatures of 850, 900 and 950^0C is shown in the Table 3 – 4 . where it is shown that wear resistance varies directly with the carburization temperature, it means with increase of carburization temperature the wear resistance also increases and the wear resistance is maximum for the AISI 1020 carbon steel carburized at temperature of 950C and it is minimum for the AISI 1020 carbon steel carburized at temperature of 850^0C. So the AISI 1020 carbon steel carburized at temperature of 950C are giving the best results and it is preferred.

Effect of hardness on the weight loss of carburized AISI 1020 carbon steel

The variation between hardness and weight loss due to abrasion is represented graphically. Where it is found that the weight loss due to abrasion is highly influenced by the hardness and it varies inversely relationship with the hardness this means with increase in the hardness values of carburized AISI 1020 carbon steel the weight loss due to abrasion is decreases. Or in other words for the carburized AISI 1020 carbon steel having higher weight loss due to abrasion, its hardness must be less. That is because of the hard material having the greater abrasive wear resistance, so the less wear occurs in the carburized AISI 1020 carbon steel and the weight loss decreases.

Effect of carburization temperature on tensile strength of carburized AISI 1020 carbon steel

The effect of carburization temperature on tensile strength of carburized AISI 1020 carbon steel is shown in the Table – 4 and it is also represented graphically. The results of tensile strength shows that the carburization process greatly improve the tensile strength of AISI 1020 carbon steel. The results explain that the tensile strength varied directly with the carburization temperature. This concluded that with the increase in the carburization temperature, the tensile strength increases linearly and comparing the carburization temperature of 850, 900 and 950^{0}C, the tensile strength is highest for the AISI 1020 carbon steel carburized at 950^{0}C, and lowest for 850^{0}C. So the AISI 1020 carbon steel carburized at 950^{0}C is giving the best results and it must be preferred.

Effect of carburization temperature on toughness of carburized AISI 1020 carbon steel

The toughness properties of AISI carbon steel is highly influenced by the carburization process the Table – 3 shows the toughness results of carburized and uncarburized AISI 1020 carbon steel where it is found that the toughness values of uncarburized AISI 1020 carbon steel is higher than that of carburized AISI 1020 carbon steel and toughness values decreases with increase in carburization temperature, so the process of carburization decreases the toughness of AISI 1020 carbon steel. This result is also shown graphically. Which shows that with increase in the carburization temperature the toughness of carburized AISI 1020 carbon steel decreases. This result is also supported from the literature [21].

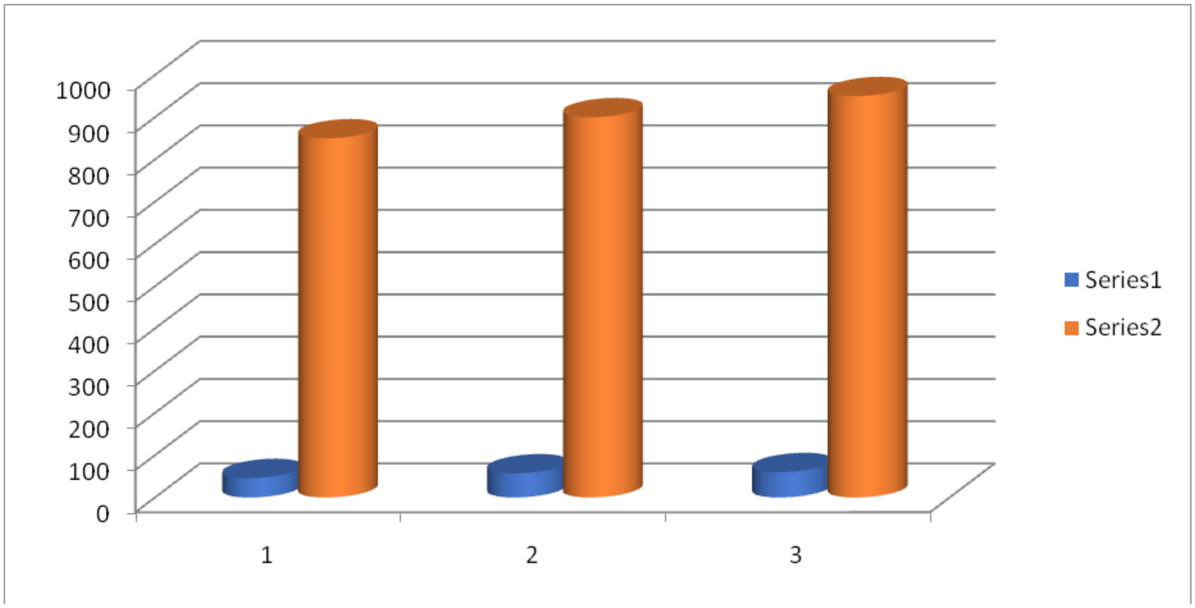

Fig. 3.1 Rockwell hardness of low carbon steel at load 150kg:

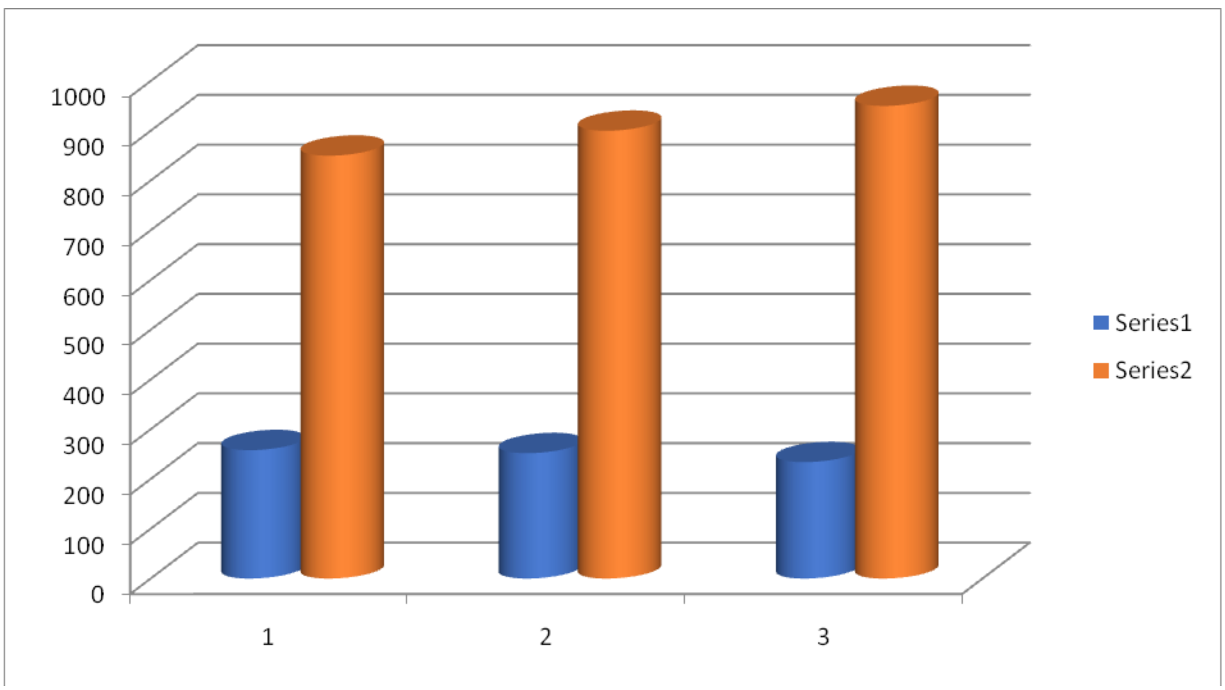

Fig. 3.2 Result of toughness test of carburized low carbon steel

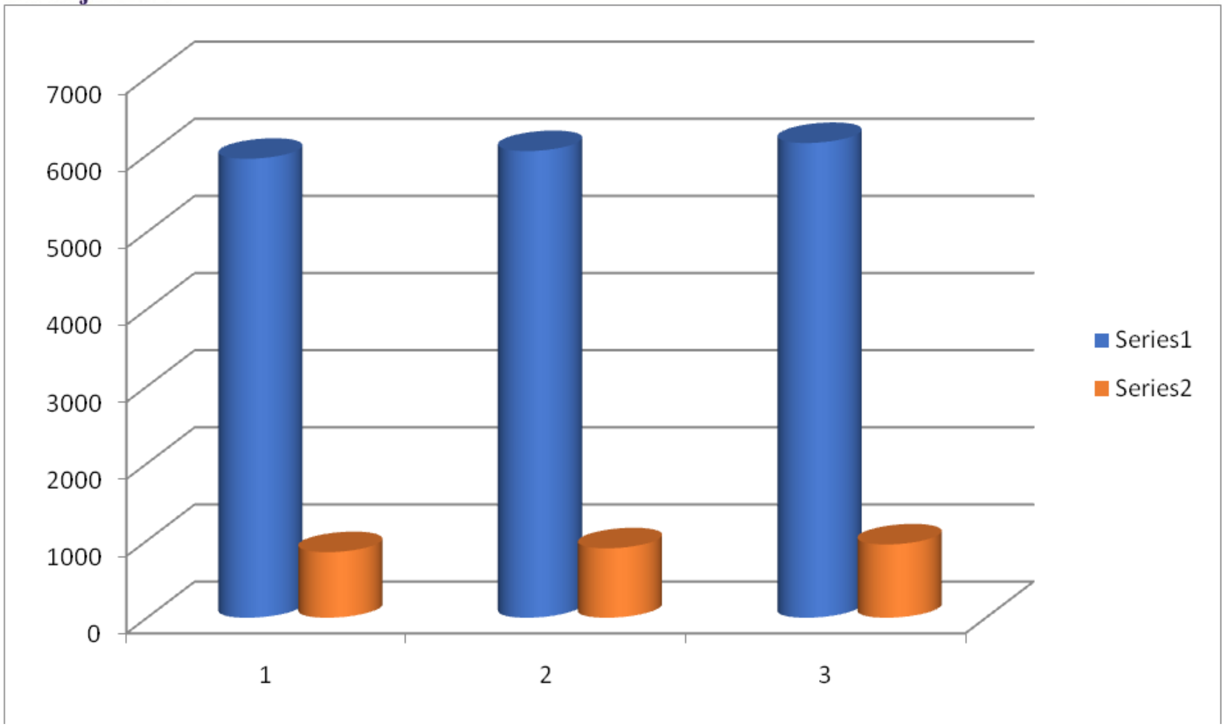

Fig. 3.3 Tensile strength of low carbon steel:

Conclusion

From the present studies on "mechanical and wear properties of carburized mild steels sample" the following conclusion have been drawn.

1. The mechanical and wear properties of AISI 1020 steels were found to be strongly influenced by the process of carburization and carburizing temperature.
2. The carburization treatment followed by the water quenching appreciably improved the hardness, wear resistance and tensile strength of AISI 1020.
3. The weight loss due abrasion, wear volume and wear rate increases with the increase in the applied load.
4. The carburization process decreases the toughness of the AISI 1020 steel. And the toughness is decreases with increase in the carburization temperature.
5. Hardness, wear resistance and tensile strength increases with increases in the carburization temperature.
6. Weight loss due to abrasion, wear volume, wear rate and toughness decreases with

increase in the carburization temperature.

7. Post carburizing heat treatment processes strongly influenced the hardness of AISI 1020.
8. With increase in the hardness the wear resistance increases, but there is decrease in weight loss due to abrasion and wear rate.
9. As comparing for different carburization temperature. The AISI 1020 steel carburized at the temperature of 950^{0}C shows the best combination of higher hardness, higher tensile strength and higher wear resistance with low weight loss and less wear rate.
10. Finally the net conclusion is that the mild steel carburized under the different temperature range of 850, 900, 9500C with in which the mild steel carburized at the temperature of 950^{0}C is giving the best results for the mechanical and wear properties like hardness and wear resistance.

Suggestion for the future work:-

After studying the Mechanical and wear properties of carburized steel sample under the different carburization temperature of 850, 900 and 950^{0}C. 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.

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