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Mechanical and Wear Properties of Carburized Low Carbon Steel Samples

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Abstract

The heat treatment and carburization is used to improve the mechanical and wear properties of different metals and alloys. The mechanical and wear properties of mild steels were found to be strongly influenced by the process of carburization. The experimental results also shows that the mild steels carburized under different temperatures (850^{0}C, 900^0 C and 950^{0}C) out of which the mild 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.

Keywords: *Mechanical properties, Wear properties, low carbon steel, carburization etc.*

1. Introduction

Carburizing is one of the most widely used surface hardening technique. The process involves diffusing carbon in to low carbon steel alloy to form a high carbon steel surface. Carburizing steel is widely used as a material of machines, gears, springs, automobiles and wires which are required to have high strength, toughness, hardness and wear resistance. These mechanical properties and wear properties can be obtained from the carburization and quenching processes.

The carburization provides a gradual change in carbon content and carbide volume from the surface to the bulk, resulting in a gradual change of mechanical and wear properties. The heat treatment and carburization increases the mechanical properties and wear resistance.

Carburization is the addition of carbon to the surface of low carbon steels at temperatures generally between 850^{0}c and 950^{0}c, at which Austenite, with its high solubility for carbon, is the stable crystal structure.

Hardening is accomplished when the high carbon surface layer is quenched to form Martensite so that a high carbon Martensitic case with good wear and fatigue resistance is superimposed on a tough, low carbon steel core. Carburizing steels for case hardening usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at between 0.8 and 1%C. However surface carbon is often limited to 0.9% because too high carbon content can result in a retained austenite and brittle martensite.

Plain carbon steel contains up to 0.30% carbon and having the properties malleability and ductility. Case Hardening is used for hardening the steel. Carbon is added to the outer surface of steel; to a depth of about 0.03mm.The surface hardening of steel has an advantage over other hardening process because of less expensive carbon and easier process.

Carburization is defined as the addition of carbon to the surface of low carbon steels at temperatures between 850-950^{0}C.Here carbon is added to the surface at austenite.

Nitriding is a surface-hardening process that introduces Nitrogen in to the surface of a steel at a temperature range (500-600^{0}C) while it is in the ferrite condition.

Severe internal stresses are induced during rapid cooling from the hardening temperature. To relieve the internal stresses and reduce brittleness, tempering the steel is necessary.

Wear is commonly defined as the undesirable deterioration of a component by the removal of materials from its surface. It occurs by displacement and detachment of particles from its surface. The mechanical properties of steel are sharply reduced due to wear. These are of different types, such as- abrasive wear, adhesive wear or metal to metal wear, erosive wear, corrosive wear, Fatigue wear.

2. Objectives of this work

Here “Vashundhra” coal is used as carburizer. In this connection the following studies were aimed to be carried out. Proximate analysis of the "vasundhara" coal. Carburization of mild steel samples under various conditions and various temperatures by using less energy consuming techniques. Tempering of these carburized mild steel samples at a definite temperature for a particular period of interval. To find out mechanical properties like hardness, toughness and tensile strength of these carburized and tempered low carbon steel samples

3. Experimental Details

Material selection- Mild 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 in wt. % is given as follows C-0.15, Si-0.04, Mn-0.32, S-0.05, P-0.2, Ni- 0.01, Cu-0.01, Cr-0.01 and Fe. The specimens are prepared as per ASTM standard.

Specimen for abrasive wear and hardness test:-

Dimensions (4cm x 2.5cm x 0.5cm)
Specimen for toughness test: - As per ASTM standard
Length-5.5 cm
Width-1cm
Thickness-1cm
Notch depth-0.5cm

Fig 1-Toughness test specimen

Specimen for tensile strength test-

L_0=5.65cm=gauge length
A_0=Cross sectional area

Fig 2-Tensile strength test specimen

Coal selection and preparation-Vashundhara coal is crushed in to 52 mesh size with help of crusher and test sieve.wt. of the coal is 4kg.
Proximate analysis of "Vashundhara" coal-Analysis for moisture, volatile matter, ash and carbon content is required. It is done by -72 meshes B.S.testsieve.
Moisture determination: One gram of air dried coal powdered sample of size-72mess was taken in a borosil glass crucible and then kept in air oven at temperature 110^0C.The sample was soaked at this temperature for 1hour and then taken out from the furnace and then cooled. Weight loss was recorded by an electronic balance. The percentage loss in weight gave the percentage of moisture was present in it.
Volatile matter determination: One gram of air dried coal powered sample of size-72mess was taken in a volatile matter crucible and kept in muffle furnace and maintained at temperature 925^0C.Then the sample was soaked for 7minutes and crucible was taken out from the furnace and cooled in air. Weight loss in sample was taken by an electronic balance. The percentage loss in weight minus moisture present in the sample gives the volatile matter present in the sample.
Ash Determination: One gram of air dried coal powdered sample of size-72mesh was taken in a shallow silica disc and kept in the muffle furnace at temperature 779^0C.The sample was allowed for complete burning and then ash weight is measured.
Fixed Carbon Determination: Fixed carbon percentage=100-sum of weight percentage of ash, volatile substance and moisture.
Carburization of low carbon steel samples- The samples are kept at different temperatures like 850, 900, 950^0C for 3 hours.

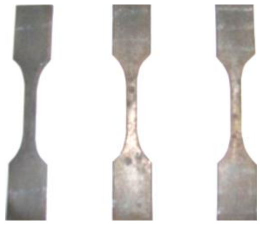

Fig 3- Carburization of low carbon steel samples

Table 1 Proximate Analysis of coal

	Proximate analysis(Wt.%)			
Coal	Moisture	Volatile matter	Ash	Fixed carbon
"Vasundhara"	6	28	35	31

Fig 4-Muffle furnace

Fig 5-Abrasive wear testing machine

Tempering of carburized mild steel samples

After carburization process to remove the hardness, tempering is done. The carburized sample is kept at temperature of 200^0C for 2hours and then to cool it in still air.

Abrasive test

In this experiment test following parameters are taken such as-Load, speed and time.
Wear volume=wt. loss/density
Density specimen=7.87 g/cm^3
Wear rate=wear volume/sliding distance(s)
Sliding distance= (2π RN/60) X time
R=radius of abrasive wheel=7.25 cm
N=300 rpm
Time=300s
Wear resistance=1/wear rate

Table-2 Result of abrasive wear test at 14.7N

Carburization condition	Temp (^{0}c)	Mild Steel	850	900	950
	Soak time(Hr)	-	2	2	2
Tempering condition	Temp (^{0}c)	-	200	200	200
	Soak time (hr)	-	0.5	0.5	0.5
Wt. loss(g)		0.21	0.133	0.118	0.109
Wear volume Cm^{3}x10^{-2}		2.67	1.69	1.5	1.38
Wear rate Cm^{2}x10^{-2}		3.9	2.4	2.2	2
Wear resistance cm^{-2}x10^7		0.255	0.403	0.455	0.495

Table-3 Result of abrasive wear test at 29.4 N

Carburization condition	Temp (^{0}c)	Mild steel	850	900	950
	Soak	-	2	2	2
Tempering condition	Temp (^{0}c)	-	200	200	200
	Soak time (hr)	-	0.5	0.5	0.5
Wt. loss(g)		0.253	0.158	0.138	0.125
Wear volume Cm^{3}x10^{-2}		3.21	2	1.75	1.59
Wear rate Cm^{2}x10^{-2}		4.7	2.93	2.5	2.33
Wear resistance cm^{-2}x10^7		0.212	0.314	0.389	0.429

Hardness test

The test was carried out by Rockwell hardness tester

Fig.6- Hardness Tester

Fig.7- Tensile Tester

Table- 4 Rockwell hardness of mild steel at 150 kg

Carburization condition		Tempering condition		Hardness(Rc)
Temp (^{0}C)	Soak time(Hrs)	Temp (^{0}C)	Soak time (Hrs)	
Simple mild steel	–	–	–	–
850	2	200	0.5	51
900	2	200	0.5	55
950	2	200	0.5	57

Tensile test

Machine parameter of Instron 1195 tensile test:

Sample- ASTM
Cross head speed (mm/min) - 2.000
Full scale loading (KN) Range- 50.00
Humidity (%) - 50
Temperature (^{0}F) - 73

Dimension parameter of instron 1195 tensile test-

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

Table-5 Tensile test results

Carburization condition		Tempering condition		Tensile strength(mpa)
Temp (^{0}C)	Soak time(Hrs)	Temp(^{0}C)	Soak time	
Simple mild steel	–	–	–	441
8500C	2	200	0.5	1872
9000C	2	200	0.5	1925
9500C	2	200	0.5	1960

Toughness test

Specifications-

Wt. of hammer 18.75 kg
Radius of curvature of striking edge- 2mm

Fig. 8- Charpy impact tester machine

Table-6 Toughness test results

Carburization condition		Tempering condition		Toughness ,Joule(Nm)
Temp (^{0}C)	Soak time(Hrs)	Temp(^{0}C)	Soak time (Hrs)	
Simple mild steel	–	–	–	54
850	2	200	0.5	37
900	2	200	0.5	35
950	2	200	0.5	32

Results of mechanical properties

From the above tensile test tensile strength varies from 441 Mpa-1960Mpa.Here carburized steel is having highest strength at 950^{0}C.The uncarburized steel is having least strength i.e 441Mpa.So carburization improves the tensile strength.

Results of toughness test

From the toughness test table we got carburized steel is having least toughness (32J), and uncarburized steel is having highest toughness (54J).This result was required and that is also satisfying literature review.

Results of hardness test

From the above table we got hardness is increasing for carburized mild steel from 850-950^{0}C.This is also our requirement. It is highest for carburized steel at 950^{0}c i.e 57Rc and lowest for 850^{0}C i.e. 51 Rc.

Results of abrasive wear test

From the above table at different load we have concluded that carburized steel at 950^{0}C is also giving better wear properties.

Effect of carburization temperature on weight loss carburized mild steels

The variation of carburization temperature with weight loss due to abrasion is given in the table 2 and 3.

Effect of carburization temperature on tensile strength of carburized mild steels

The variation of carburization temperature with weight loss due to abrasion is given in the table 5.

Effect of carburization temperature on toughness of carburized mild steels
The toughness properties is influenced by carburization technique in table 6.

Conclusions and future work

From above experimental studies we have concluded that

Mechanical and wear properties of low carbon steel is strongly influenced by carburization temperature and carburization process.

The toughness property decreases due to carburization and toughness decreases with increase in carburizing temperature.

Finally we got carburized steel at temperature 950^{0}C gives better mechanical and wear properties.

Similarly further study can be done for other mechanical and wear properties at different temperature and different conditions.

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