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Effect of Soaking Time And Applied Load On Wear Behavior of Carburized Mild Steel

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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. For this investigation before heat treated , heat treated and carburized mild steel were selected. Three Heat Treatment process namely Quenching, Carburizing and Tempering were done. In the present investigation the Mechanical and Wear behaviours of mild steels Carburized at 860^0 C different Soaking time 2 hour(120min), 2 hour 30 minutes(150min) and 3 hour(180min). The aim has been to examine the effects of these different Soaking Time and conditions on the Mechanical and Wear properties of the Carburized mild steels. For above purpose firstly the mild steels are carburized at 860^0C temperature and then it is Tempered at 200^0C for 1 hour after this the Carburized and Tempered mild steels are subjected for different kind of test such as Abrasive Wear Test, Hardness Test and Tensile Test. Abrasive Wear behaviour of these mild steels was investigated by using the Dry Sand Abrasion Test Rig (TR-50) Machine. This paper further examines the effect of soaking time, applied load and abrasive wear behavior of carburized mild steel have been studied in detailed

Key Words: *Abrasive Wear, Carburizing, Heat Treatment, Mild Steel, Soaking Time*

I. INTRODUCTION:

Steels are alloys of iron and carbon together with other alloying any other elements. The steel is being separated as low carbon steel, high carbon steel, medium carbon steel. The controlled heating and cooling processes used to change the structure of a material and alter its physical and mechanical properties. The purpose of heat treatment is to soften the metal, to change the grain size, to modify the structure of the material and to relieve the stress set up in the material after hot and cold working. Heat treatment is generally employed for the purpose such as to improve mechanical properties like tensile strength, hardness, ductility, yield strength and so on. The heat treatment and carburization increases the mechanical and wear resistance. Carburizing is the addition of carbon to the surface. The heating of a metal at a constant temperature for a suitable duration of time is called soaking time. Mechanical properties of mild steels were found to be strongly influenced by the carburizing temperature and soaking time at carburizing temperature. The mechanical properties of mild steel were found to be strongly influenced by the process of carburization, carburizing temperature and soaking time at carburizing temperature [1]

II. EXPERIMENTAL:

The part deals with various experimental procedures involved in carrying out the present investigation. It include sample preparation, heat treatment of samples, abrasive wear tests, hardness test, tensile test, micro-structural characterization of heat treated samples. Specimens of 75 × 25 × 7 mm were prepared as shown in figure 1.

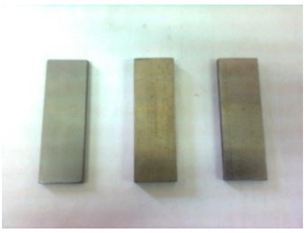

Figure 1. Test Samples

2.1 Heat Treatment:

The samples were heat treated at Indo-German tool room, Indore, using electric furnaces. The heat treatment processes carried out are Carburizing, hardening& Tempering and the sequence of operations followed are given below.

2.2 Carburization of Mild Steel Samples:

The different test specimen samples made up of mild steel for mechanical and wear properties testing were subjected to pack carburization treatment. In this process the mild steel samples were placed on the thick bed of carburizer kept in a stainless steel container and fully covered from all sides, the top of the container was covered with a steel plate. The container was then introduced into the furnace and then maintained at the required carburization temperature of 860^0C with the different soaking time of 2 hours, 2 hours and 30 minutes, and 3 hours. Various intensive quenching applications to significant reduce the required diffusion times of carburizing processes [2].

2.3 Tempering of Carburized Mild Steel Samples:

After the carburization process, the steel is often harder than needed and is too brittle for most practical uses. 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 1 hour. The disadvantage of austempering is it can only be used on few steels, and it requires a special salt bath [5].

2.4 Quenching of Carburized Mild Steel Samples:

In this process, the heated steel is suddenly dipped onto a cooling medium bath. In this experiment oil are used. The hardness in steel depends essentially on its quenching rate. Quenching is necessary to harden low and medium plain carbon steel. Certain alloys can be hardened at a too low rate of cooling. For high carbon steel and alloy steels, oil and various commercial oils is generally used as quenching medium. They have different cooling effect and impart different hardness on quenching.

Figure 2. Samples after Heat Treatment

III. ABRASIVE TEST:

Abrasive wear occurs when a hard rough surface slides across a softer surface. A hard material is more resistant to wear and abrasion compared to a soft material. The heat treated high C low Cr steel and mild steel carburized by using coal tar pitch provide the best hardness and abrasion resistance and thus appear to be the most suitable materials for making agricultural tools [3]. The test was conducted on a machine called Dry Sand Abrasion Test Rig TR-50. The photographic views of the test apparatus is shown in Figure 3, 4 and 5. Specimen is weighed before and after the test, and the loss in mass is recorded. Hence wear volume, wear rate and wear resistance can be calculated as follows-

3.1. Wear Volume:-

Wear Volume = weight loss / density

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

= (2 π R N / 60) x time

where, R = radius of Abrasive Wheel (11cm)

N = R.P.M (225)

Π = 3.14 (constant)

3.3. Wear Resistance: - wear resistance is a reciprocal of wear rate

Wear Resistance = 1 / Wear Rate

Figure 3.Dry Sand Abrasion Test Rig TR-50

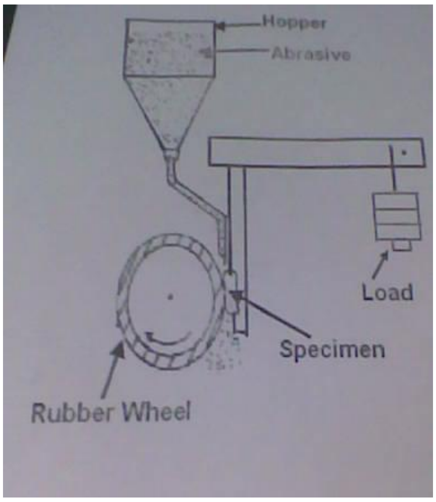

Figure 4. Line diagram of Dry Sand Abrasion Test

Figure 5. Close View of Rubber Wheel and Sample

3.4 Effect of Sliding Distance on the Wear Behaviour of Untreated and Heat Treated Mild Steel at Different load and Different Soaking Time:

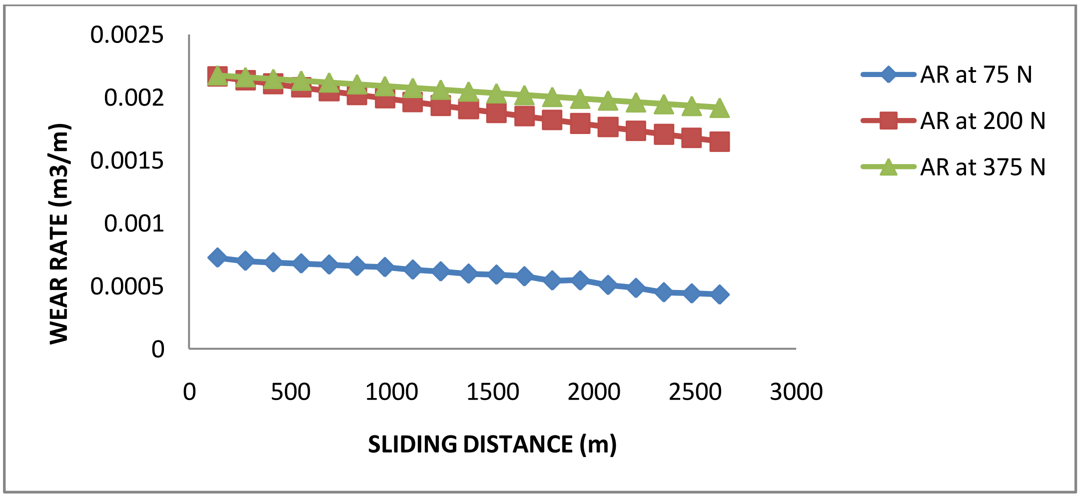

Figure 6. Graph between Wear Rate and Sliding Distance at different load

In this fig.6 Shown variation of wear rate with sliding distance. At load 75N wear rate is minimum and at load 375N wear rate is maximum. We can say that wear rate is increases when load also increases. Wear rate is initially more and then decreases with increase in sliding distance because at higher load, the pressure between the specimen and rubber wheel is higher and it increases the penetration of sand particles in the specimen surface.

3.5. Effect of Sliding Distance on the Wear Behaviour of Carburized Mild Steel at load 75 N and Different Soaking Time(ST) -

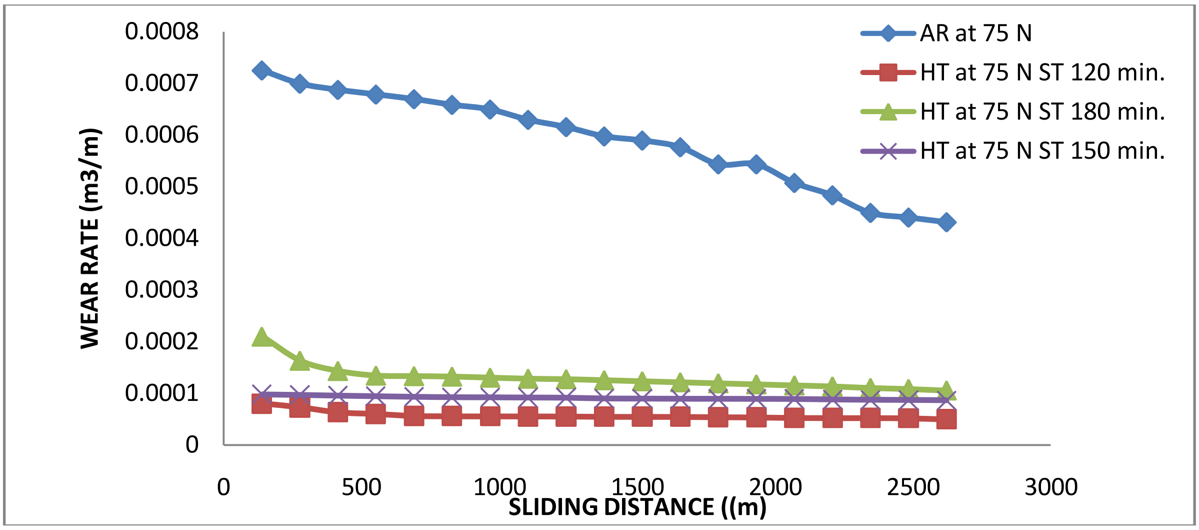

Figure 7. Effect of ST on Wear Rate of Mild Steel Carburized at 860^{0}C and Tested at 75N

In this graph as without heat treated samples or as received (AR) higher wear rate as compared with heat treated (HT) samples. Load is constant and soaking time is different i.e., 120 minutes, 150 minutes and 180 minutes. Without heat treated samples shown higher wear rate, the minimum wear rate at 2 hour (120 min) soaking time is due to more hardness or the specimen. At lower soaking time the specimen shows more hardness and toughness which leads to improvement in wear resistance of carburized mild steel.

3.6. Effect of Sliding Distance on the Wear Behaviour of Carburized Mild Steel at load 200 N and Different Soaking Time-

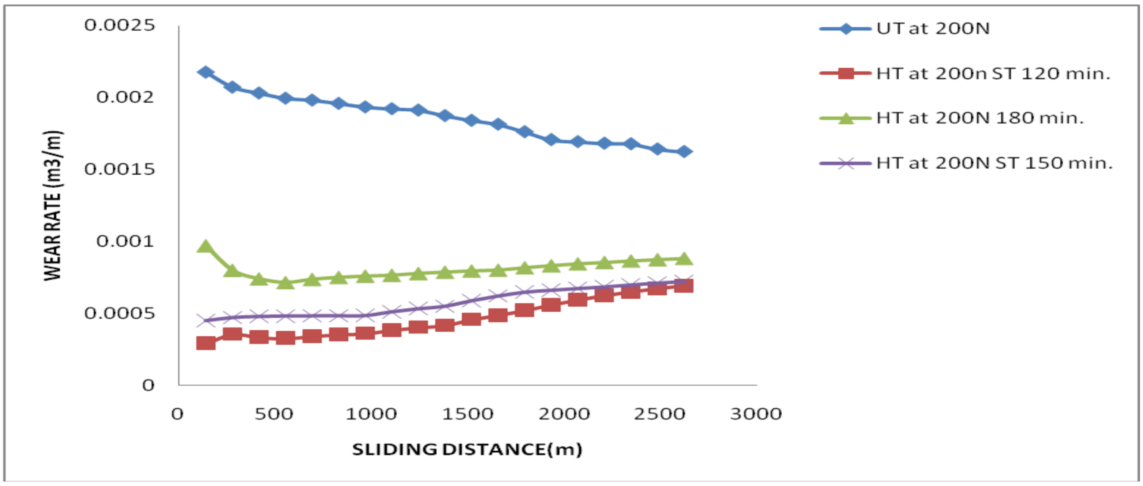

Figure 8. Effect of ST on Wear Rate of Mild Steel Carburized at 860^{0}C and Tested at 200N

The variation of the wear rate with sliding distance at 200N applied load in different soaking time (ST) condition are presented in figure 3.8. Untreated (UT) or without heat treated sample gives higher wear rate as compared with carburized mild steel. Load is constant and soaking time is different i.e. 2 hour, 2 hour30 min. and

3 hours (120 min, 150 min and 180 min). Untreated samples shown higher wear rate and heat treated samples 2 hour soaking time shown minimum wear rate.

3.7 . Effect of Sliding Distance on the Wear Behaviour of Carburized Mild Steel at load 375 N and Different Soaking Time-

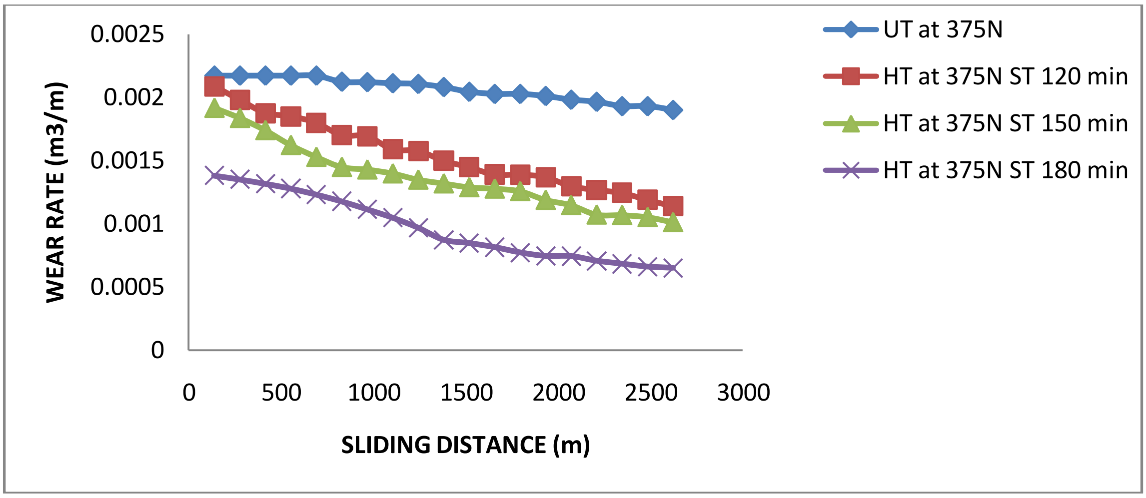

Figure 9. Effect of ST on Wear Rate of Mild Steel Carburized at 860^{0}C and Tested at 375N

Untreated samples shown higher wear rate and heat treated samples 3 hour (180 min) soaking time shown minimum wear rate. Because soaking time is more and carbide particles are more uniformly distributed and at higher load (375N) it may maintain the properties (hardness and toughness) even at high properties which Leeds to lower wear rate.

3.5.1.8 . Effect of Sliding at Distance on the Wear Behaviour of Carburized Mild Steel Constant Soaking Time of 2 hour (120 min) at Different load-

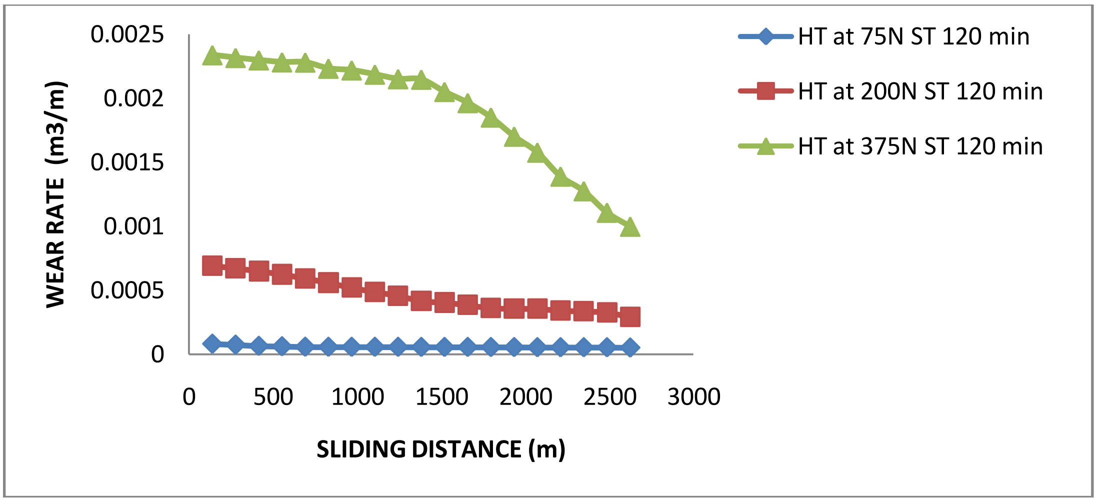

Figure 3.10 Graph showing Different load and Soaking Time 2:00 hour

Figure 3.10 shown constant soaking time (ST) and different load i.e. 75N, 200 N and 375N. Figure 3.10 represents the variation of wear rate at different sliding distance for the carburized mild steel sample at constant soaking time 2 hour (120 min) and different load at 75 N, 200 N and 375 N. The graph were drawn between wear rate (in m^3/m) and sliding distance (in meter) at constant soaking time and different load at 75 N, 200N and 375 N and it is marked from the figure 3.10 that the wear rate reduces with sliding distance and finally approaches to a constant value.

3.5.1.9 . Effect of Sliding Distance on the Wear Behaviour of Carburized Mild Steel at Constant Soaking Time of 2 hour and 30 minutes(150 min) at Different load-

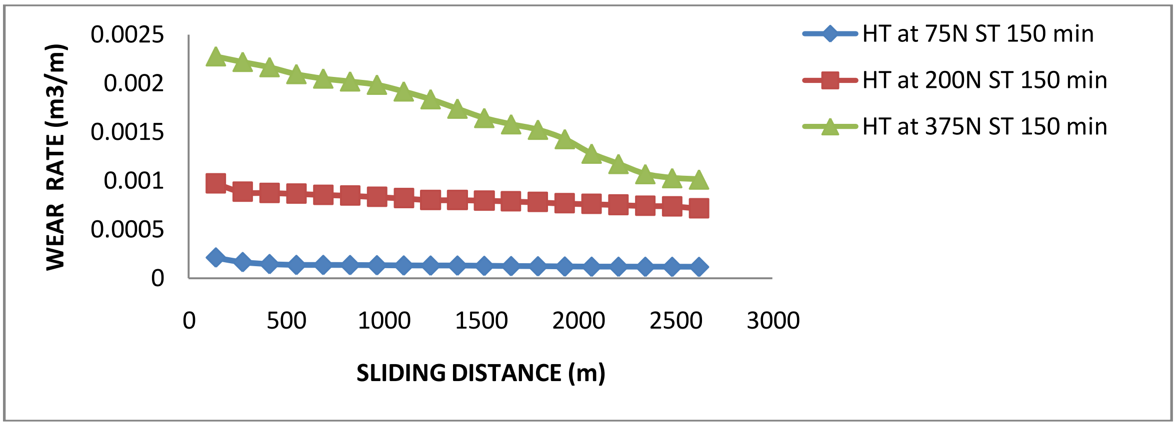

Figure 3.11 Graph showing Different load and soaking time is 2 hour and 30 minutes

This figure shows that the variation in wear rate is more in initial stages of the wear. As the sliding distance increases the wear rate of steel tested at higher load (375N) reduces drastically due to more work hardening at higher applied load and because of removal of decarburized surface material in initial stages.

3.5.1.10 . Effect of Sliding Distance on the Wear Behaviour of Carburized Mild Steel at Constant Soaking Time of 3 hour (180 min) at Different load-

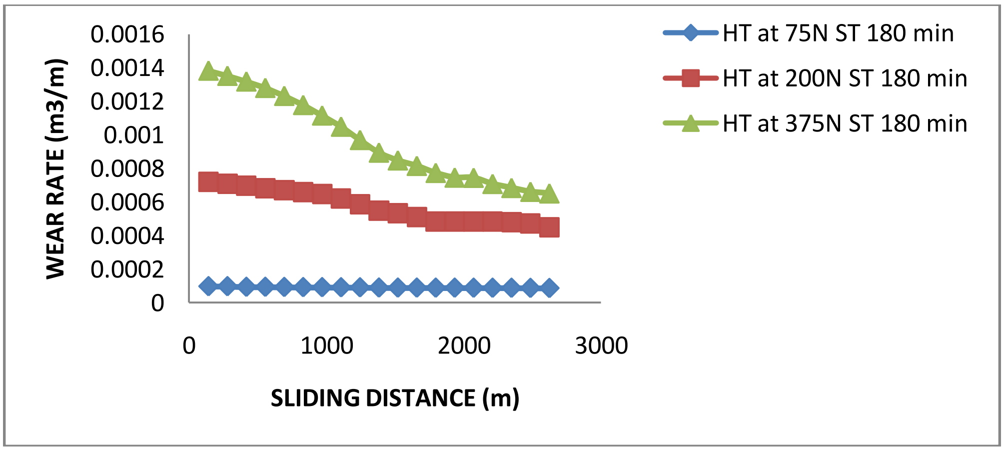

Figure 3.12 Graph showing Different load and Soaking Time is 3:00 hour

Figure 3.12 shown constant soaking time (ST) 3 hour (150min) and different load i.e. 75N,200N and 375N. Figure 3.12 represents the variation of wear rate at different sliding distance for the carburized mild steel sample at constant soaking time 3 hours and different load at 75 N, 200 N and 375 N. The graph were drawn between wear rate (in m^3/m) and sliding distance (in meter) at constant soaking time and different load at 75 N, 200N and 375 N.

3.5.2. Hardness Test:

Heat-treated mild steel samples were tested on Rockwell hardness tester (fig 3.13) at Indo German Tool Room, Indore. In present experimental work Rockwell hardness was measured on carburized and tempered mild steel samples which are carburized 860^0 C and different soaking time (i.e., 2 hour, 2 hour 30 minutes and 3 hour). For each of the sample, test was conducted for 5 times and the average of all the samples was taken as the observed values in each case. The variation of wear rate with heat treatment schedules is attributed to the variation in microstructures and micro constituents which finally varies the hardness and toughness of the material [4].

Figure 3.13 Rockwell Hardness Tester

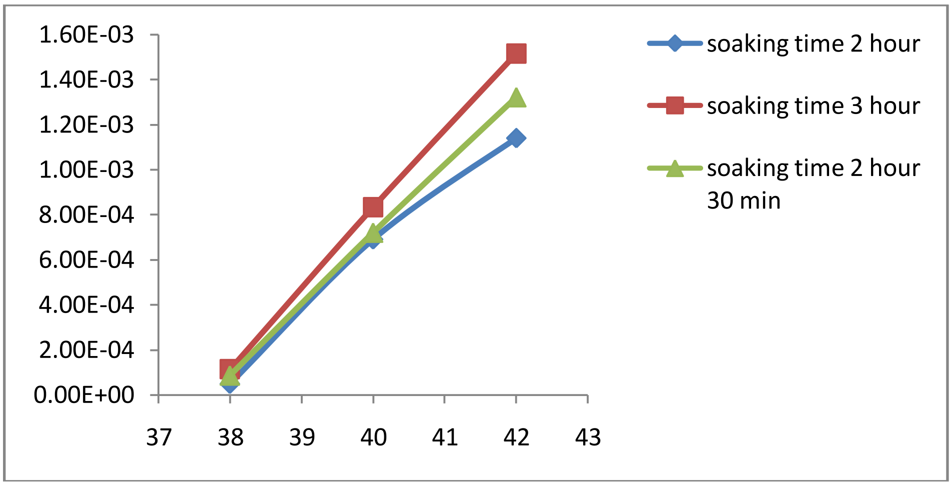

Figure 3.14 Wear Rate Vs Hardness

The variation between hardness and weight loss due to abrasion is represented graphically in the Fig.3.14. Where it is found that the weight loss due to abrasion is highly influenced by the hardness. Or in other words for the carburized mild steels 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 mild steels and the weight loss decreases. Hardness increases with soaking time i.e. 3 hour (180 minutes) that is gives best result. The hardness values varied between range of 38 HRc – 42 HRc and carburized at temperature of 860^0C and tempering temperature is 200^0C soaking time 1 hour, so with increase of soaking time the hardness values increases. Shown in table 4.2.

3.5.3. Tensile Test:-

As the load increases the specimen initially gets elastically elongated. On further elongation, the specimen (fig. 3.15) starts necking at some points when the material goes beyond the elastic range.

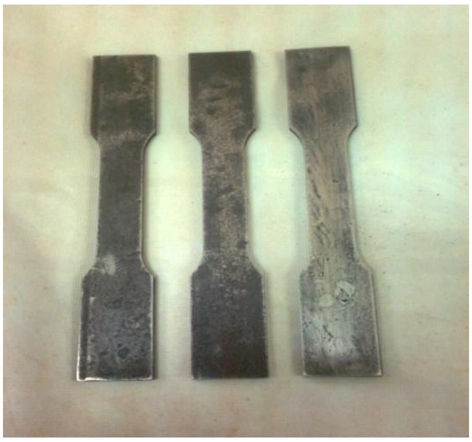

Figure 3.15 Samples for Tensile Test

3.5.3.1. Effect of Tensile Test-

Heat treated sample carburized at 860^0C and different soaking time i.e. 2 hour (120min), 2 hour 30 minutes (150min) and 3 hour (180min). Maximum soaking time gives maximum breaking point and minimum soaking time gives minimum breaking point.3 hour soaking time gives higher breaking point due to more Soaking Time. From the figure 3.16 it is clear that the Yield strength (YS), Ultimate tensile strength (UTS) and Breaking point (BP) is increases with the increment in the Soaking Time. Shown in table 4.2.

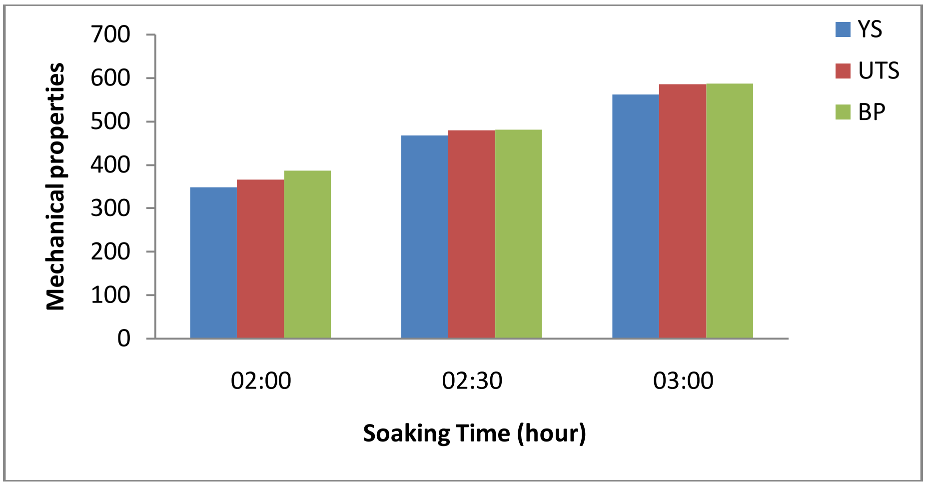

Figure 3.16 Graph between Mechanical Properties and Soaking Time

IV. RESULT AND DISCUSSION:

The different kind of mild steel samples were carburized and tempered for the different soaking time and temperature and then tested for various kinds of test like abrasive wear test, tensile test, and hardness test. Cooling rate influenced the stability of C-Cr associate. The mechanical property of CLAM steel subjected to different heat treatment [6].

1. The abrasion test is conducted under three different loads of 75 N, 200 N and 375 N and it is obtain from the test that the weight loss during the abrasion is highest for the load of 375 N and is lowest for the load of 75 N. so it is concluded from the test that, as the load increases the weight loss during abrasion is also increases because at higher load, the pressure between the specimen and rubber wheel is higher and it increases the penetration of sand particles in the specimen which leads to more abrasion at the specimen surface and this results is also shown graphically in the Fig 3.6.
2. The weight loss during abrasion is highest for uncarburized mild steel and is lowest for the mild steel carburized at temperature of 860^0C, because uncarburized mild steel is having low mechanical properties like hardness and toughness at lower hardness the penetration of sand particles is more, the pressure of cracks and induced stresses further increases the wear rate. Formation of tempered martensite structure during carburizing. Significantly increase the hardness and toughness that leads to reduction in wear rate.
3. The wear rate is highest for untreated samples and is lowest for the mild steel carburized at temperature of 860^0C and this wear rate is gradually decreases with increase in sliding distance because this reduction in wear rate with sliding distance is due to work hardening effect and refinement in micro structure due to very high temperature at the point of contact (sand particles and specimen) more wear rate in initial stage also due to surface defects due to burning of surface carbon in the presence of atmospheric air while shifting the specimen from high temperature furnace to cooling medium sometimes there may be small cracks or Pitts or due scaling effect these results shown graphically.
4. The tensile strength is varied between the ranges of 385 to 586 mpa and it is highest for the mild steel carburized at temperature of 860^0C and soaking time 3 hour and lowest for the As received mild steel. From this results obtained, we can conclude that the soaking time improved the tensile strength of mild steels.
5. The hardness values varied between range of 38 HRc to 42 HRc and it is highest for the mild steel carburized at temperature of 860^0C and soaking time 3 hour and is lowest for the mild steels carburized at 860^0C and soaking time 2 hour, so with increase the soaking time hardness values increases. This is also shown in the figure 3.14.
6. Finally the net results is that the mild steels carburized at 860^0C and soaking time 3 hour is giving the best results for the mechanical and wear properties like tensile strength, hardness and wear resistance .

Table 4.1
Rockwell Hardness of Carburized Mild Steel

Carburization condition		Temperature condition		Hardness (Rc)
Temperature (□C)	Soak Time (min)	Temperature (□C)	Soak Time (min)	
860 □C	120	200 □C	60	38
860 □C	150	200 □C	60	40
860 □C	180	200 □C	60	42

Table 4.2
Tensile Strength of Carburized Mild Steel

Carburization condition		Temperature condition		Tensile strength (mpa)
Temperature (□C)	Soak Time (min)	Temperature (□C)	Soak Time (min)	
860 □C	120	200 □C	60	385
860 □C	150	200 □C	60	480
860 □C	180	200 □C	60	586

Table 4.3
Result of Abrasive Wear Test for Carburized Mild Steel, at load 75 N

Carburization Data		Tempering Data		Weight loss gm
Temperature (□C)	Soak Time (min)	Temperature (□C)	Soak Time (min)	
Untreated Sample				1.2
860 □C	120	200 □C	60	0.142
860 □C	150	200 □C	60	0.230
860 □C	180	200 □C	60	0.297

Table 4.4
Result of Abrasive Wear Test for Carburized Mild Steel, at load 200 N

Carburization Data		Tempering Data		Weight loss gm
Temperature(˚C)	Soak Time (min)	Temperature (˚C)	Soak Time (min)	
Untreated Sample				4.5
860 □C	120	200 □C	60	1.808
860 □C	150	200 □C	60	2.019
860 □C	180	200 □C	60	2.316

Table 4.5
Result of Abrasive Wear Test for Carburized Mild Steel, at load 375 N

Carburization Data		**Tempering Data**		**Weight loss gm**
Temperature (°C)	**Soak Time (min)**	**Temperature (°C)**	**Soak Time (min)**	
Untreated Sample				**5.2**
860 °C	**120**	**200 °C**	**60**	**3.626**
860 °C	**150**	**200 °C**	**60**	**5.843**
860 °C	**180**	**200 °C**	**60**	**5.979**

V. CONCLUSION:-

From the present studies on **"Effect of Soaking Time and Applied load on Wear Behaviour of Carburized Mild Steel**" the following conclusion have been drawn**.**

1. The wear rate of heat treated samples is less than the untreated samples. However, heat treated mild steel exhibits higher wear resistance as compared to untreated mild steel.
2. The carburization treatment improved the hardness, wear resistance and tensile strength of mild steel.
3. The weight loses due to abrasion, while wear rate increases with the increase in the applied load.
4. Hardness and tensile strength increases with the increases in the soaking time.
5. The mild steel carburized at 860^0C temperature and 3hour (180 minutes) soaking time showed the best result of higher hardness.
6. 3 hour soaking time gives best result of higher tensile strength.
7. Mild steel soaked at 2hour, gives less wear rate whereas, 3 hour soaked, gave higher wear rate.

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