An Experimental Investigation of the Effect of Carbon Content on the Wear Behavior of Plain Carbon Steel

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Abstract: ***Wear behaviour of various carbon steels used in different industries has a direct impact on the performance of mechanical systems. In the present investigation the wear behaviour of carbon steels having varying carbon percentage has been studied, utilizing a pin-on disc sliding tribometer. Experiments were carried out under dry condition. Normal load applied was 5 – 25 N at a fixed rotational speed of 480 rpm. Results indicate that the wear performance of steel significantly governed by the chemical composition of material. Results have also shown that wear of carbon steel is markedly reduced by adding more carbon to it. Results obtained from experimental procedure shown by different graphs.***

Keywords: carbon steel, friction, wear, pins on disc.

1. Introduction

Steels represent the most important group of engineering materials as they have the widest diversity of applications of any of the engineering materials. Generally, carbon is the most important element profoundly affecting the mechanical properties of the steels. Increasing the carbon content of steels increases the hardness and strength. More-over, plain carbon steels have moderate strengths and can resist satisfactorily ordinary temperatures and atmospheres and also are available in large quantities, in quite large variations of shapes and sizes with a much lower cost.Among many failure modes associated with steel components, wear presents a unique challenge to the designer and the developer of mechanical components. Wear characteristics of steel components and their real life performance under various working environments have been the subject of numerous investigations, because so many variables are involved, such as load, sliding speed, test geometry, composition, hardness, environment etc [1].

Wear is the removal of material from one or both of two solid surfaces in a solid-state contact. It occurs when solid surfaces are in a sliding, rolling, or impact motion relative to one another. Wear occurs through surface interactions at asperities, and components may need replacement after a relatively small amount of material has been removed or if the surface is unduly roughened [2]. In well-designed tribological systems, the removal of material is usually a very slow process but it is very steady and continuous [3]. Actually wear refers to the progressive removal of material from a surface and plastic deformation of material on a surface due to the mechanical action of the other surface. The necessity for relative motion between the operating surfaces and initial mechanical contact between asperities leads an important role between mechanical wear compared to other processes with similar outcomes [4]. The sliding wear behaviour of various steels is a vast subject which has received much attention in recent years. Tribological behaviour of metals which are in sliding contact depends on the many variables such as normal Load applied on the material, sliding speed, sliding distance, surface geometry, surface hardness, roughness of operating surface, working environment, etc., which affect the wear mechanism and results in change of wear rate [5]. For most of the cases wear rate is proportional to the normal load applied [6]. The sliding speed and normal load indeed affects the friction force and wear rate considerably. The values of friction coefficient decrease with the increase of sliding speed and normal load. The wear rates, on the other hand, increase with the increase of sliding speed [7].

2. Experimental details

2.1. Machine Used

A pin on disc wear apparatus ED-201(DUCOM, Bangalore, India) was used for experiments. This machine facilitates study of friction and wear characteristics in sliding contact under desired conditions. Sliding occurs between the stationary pin on a rotating disc. Normal load and wear track diameter can be varied to suit the test conditions. Tangential friction force and wear are monitored with electronic sensors and displayed on front panel.

Figure 1: Pin on Disk apparatus

2.2 Material and specimens

2.2.1 Disc

The disc used for experiments is the one which is supplied with the apparatus by DUCOM India. This is a hardened wear disc made of EN-31 steel. The diameter of disc is 100 mm and thickness of disc is 6 mm.

2.2.2 Pin

The materials tested were all low carbon steels, chosen so as to give the complete range of carbon content of low carbon steel. Many carbon steels were tested for chemical composition at Kailtech test & research centre pvt. Ltd. Indore, India. Three materials were marked for experiments; their chemical composition is given in table 1. The pin specimen is a cylinder of 6 mm in diameter and 30 mm in length.

Mark	C %	Si %	Mn %	P %	S %
A	0.131	0.215	0.457	0.008	0.028
B	0.246	0.170	0.514	0.008	0.031
C	0.358	0.339	0.583	0.010	0.061

Table 1: Composition of steels tested

2.2.3 Specification of Machine

Parameters	*Unit*	*Min*	*Max*
Pin size	mm	6	6
Disc size	mm	100X6	100X6
Wear track diameter	mm	20	80
Disc rotation	rpm	480	480
Normal load	N	5	30
Wear	Micrometer	0	2000

2.3 Measurement System

a. Wear Measurement

The plunger movement as in indication of wear rate is sensed by LVTD.As wear occurs its plunger lifts up and this movement is displayed as wear on controller. The least count of LVTD is 1 micrometer, the initial position of plunger measurement is kept at mid of to have both +ve & –ve wear readings. The maximum wear rate measurement possible is +/- 2mm. In addition to wear as indicated by LVTD, the wear on specimens may also be computed by measuring the initial & final length of specimen using digital vernier calliper or micrometer.

b. Frictional Force Measurement

A beam type load cell with capacity of 3kg is mounted over sliding plate to measure frictional Force from 0.1N to 30N.This is a strain gauge type of load cell, it is primarily a column of corrosion resistant super alloy of high tensile strength steel that deforms very minutely under load. This deformation is sensed by Foil type strain gauges bounded on to the column and connected to form balanced wheat Stones Bridge. The electrical output from wheat stones Bridge is proportional to load acting on column. The extremely rugged and hermetically sealed construction makes them the ideal choice for this application.

2.4 Wear Test

First of all three materials were chosen based upon carbon content in their chemical composition.pin specimen were made from these materials namely A, B and C. The pin specimen were tested in Pin on disc apparatus .To perform the test specimen was clamped in jaw. Wear track diameter was fixed at 50 mm. The rotational speed of disc was fixed at 480 rpm. Timer was set for three minutes for each set of loads. Initially each specimen was tested with the normal load of 0.5 Kg. Apparatus was run for three minutes; readings were taken from the digital display. Then normal load was increased to 1.0kg, 1.5kg, 2.0kg and 2.5kg. Specimens from all the three materials were tested with loads from 0.5kg to 2.5kg to know the effect of load on the wear of materials. To know the effect of carbon content on the wear; specimens from materials A, B, and C were tested with fixed load of 2.5kg. Timer was set for three minutes. The readings were taken and compared.

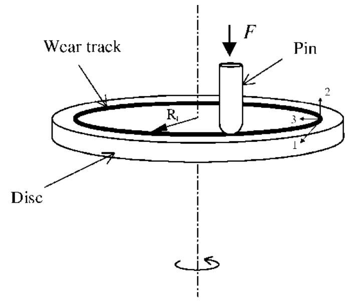

Figure 2: Schematic diagram of pin on disc wear test

Results and Discussion

The wear behaviour of all three material tested at different loads has been shown in the graphs (fig 3).The relation between carbon content in specimen and wear of specimen has been shown in figure 4. It has been noticed that wear increases with the increase in applied normal load.

For specimen A (0.131% carbon) increase in the wear was almost linear. The increase in wear was not very much when load was increased from 0.5 kg to 1.0 kg, but after that slope got steeper. For specimen B(0.246% carbon) slope of wear curve was small up to 1.5 kg of load but when the load was increased from 1.5kg to 2.5 kg and then 2.5kg,the slope of curve got bigger. For specimen C (0.358% carbon) wear was increased very rapidly when the load was increased from 0.5 kg to 1.0kg.It was noticed that slope of the wear curve got smaller when load was increased from 1.0kg to 1.5 kg and then went with higher slope for the load of 2.0kg and 2.5kg.The effect of carbon content on wear behaviour of plain carbon steel has been shown in the fig.4. Tendency of the wear curve has been found to be decreasing with the increase in carbon content. Wear falls quite rapidly with the increase in carbon content from 0.131% to 0.246% and follows the trend for further increase in carbon content to 0.358%.

Table 2: Wear at constant load of 2.5 Kg

S. No	Material Mark	C (%)	Load(kg)	Wear(mm)
1	A	0.131	2.5	35
2	B	0.246	2.5	28
3	C	0.358	2.5	24

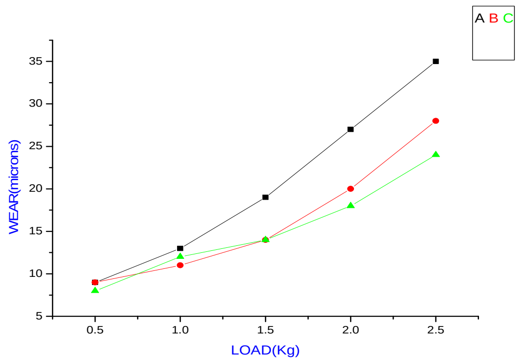

Figure 3: Comparative wear behaviour

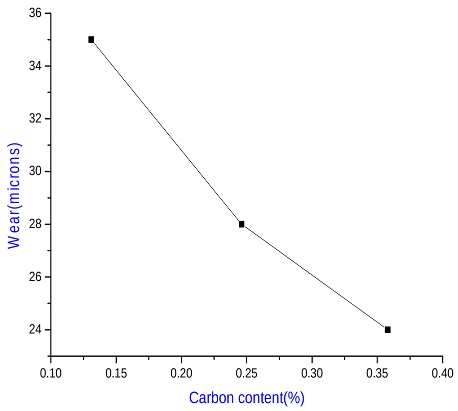

Figure 4: The relationship of wear and carbon content in steel

Conclusions

Pin on disc type wear tests for the specimen with 0.131% C, 0.246% C and 0.358% C steel in contact with EN-31 hardened steel were conducted under un-lubricated conditions of varying load with step wise changes between low and high levels. The main results are summarized as follows:

(1)Wear resistance of steel is affected by the load. Wear of steel is linearly related to the load.
(2)Steel with lower carbon content have less friction and wear characteristics.

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[8] Increase in the carbon content in plain carbon steel produce marked reduction in the wear.