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Some Investigations on Friction & Wear Properties of Different Steel Materials

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ABSTRACT

In this paper frictional coefficient and wear rate of different steel materials are investigated and compared. Experiments are carried out on a pin-on-disc apparatus, on different types of pin materials such as stainless steel SS 304 , stainless steel SS 316 and mild steel sliding against EN-31 disc. The experiments has been performed on a group of specimens for duration of 10 minutes and load of 0.5 Kg, 1 Kg , 1.5 Kg , 2 Kg, 2.5 Kg & 3 Kg with speed 480 rpm. Results show that friction coefficient varies with duration of rubbing, normal load and sliding velocity. In general, friction coefficient increases for a certain duration of rubbing and after that it remains constant for the rest of the experimental time. The obtained results reveal that friction coefficient decreases with the increase in normal load for all the tested pairs. Wear rate increases with the increase in normal load. At identical operating condition, the magnitudes of friction coefficient and wear rate are different for different materials depending on normal load. The wear performance of steel significantly governed by the chemical composition of material. Results have also shown that wear of carbon steel is significantly reduced by adding more carbon to it.

Keywords— **Friction coefficient; Wear rate; Normal load; Sliding velocity; Duration of rubbing.**

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I. INTRODUCTION

It was observed by several research scholar's that the variation of friction depends on interfacial conditions such as normal load, sliding velocity, surface roughness of the rubbing surfaces, type of material, system rigidity, temperature, relative humidity, lubrication. Among these factors normal load and sliding velocity are the two major factors that play significant role for the variation of friction. Friction coefficient and wear rate of metals and alloys shows different behaviour under different operating conditions [1-2]. It was observed that the coefficient of friction may be very low for very smooth surfaces and/or at loads down to micro to nano- newton range [3,4]. In spite of these findings, the effects of normal load and sliding velocity on friction coefficient of different types steel materials, particularly SS 304, SS 316 and mild steel , sliding against EN-31 are yet to investigated.

Research Objectives

1. To study the friction and wear characteristics of SS 316, SS 304 and mild steel under dry condition.
2. Development of required experimental set up.
3. To perform trials to compare different parameters.
4. Investigate the wear behaviour of carbon steels having varying carbon percentage.

Research Methodology

The experiments are to be performed on a pin on disc machine under conditions of dry sliding conditions. The friction coefficient and wear rate of the given different steel materials i.e., SS 304, SS 316 and mild steel sliding against EN-31 are to be investigated under given atmospheric conditions.

Test Method

Standard test method for wear testing with a Pin-on-Disk Apparatus Designation: G 99 .Test Standards ASTM G99-05 (2010) American Society for Testing and Materials is followed. [2]

Composition of Pin Material

All steels samples were tested for chemical composition at Metasys Testing and Calibration Laboratories LLP Bhosari , Pune, India. The results were tabulated as follows

Table 1: Composition of Steels tested

	C%	Cr%	Ni%	Mo%	Mn %	Si%	N%	S%	P%	Fe%
SS304	0.08	18-20	8	0	2	1	0	0.03	0.05	Bal.
SS316	0.03	18	14	3	0	0.8	0.1	0.03	0.05	Bal.
M.S.	0.18	0	0	0	0.90	0.4	0	0.04	0.04	Bal.

Disc

The disk diameters range from 30 to 100 mm and have a thickness in the range of 2 to 10 mm. Material used is EN-31 hardened to 60 HRC ground to 1.6 Ra surface roughness. Wear track diameter is adjustable in between 50 mm to 100 mm in steps of 1mm. Disc can be rotated with minimum speed of 200 rpm to max. 2000 rpm in the step of 1 rpm.

Sample Preparation

Pins are made up of above selected steel materials and machined with sizes φ 10 mm & 30 mm long are hold in clamping collects during conducting test. The materials being tested are fulfils all norms of G 99 like , dimensions, surface finish, material type, form, composition, microstructure, processing treatments, and indentation hardness.

Load

Experiments are to be conducted at normal load carrying from 0.5 Kg to 20Kg and at sliding velocity varying from 1 m/s to 2 m/s. At different normal loads and sliding velocities, variations of friction coefficient with the duration of rubbing are to be investigated.

II. Experimental Set up

The experimental set-up is comprises of a pin and a circular rotating disk which is placed at a perpendicular with respect to the pin surface shown in Fig. 1. The diameter of the pin is 10 mm and the length is 30mm.The disk is made of hardened steel EN-31 on which the pin is held with a jaw in the apparatus and rotation is provided to disk which causes wear of the pin on a fixed path on disk. The pin is pressed against the surface of the disk with load being applied with the arm attachment provided to the apparatus. Machine is attached with a data acquisition system and WINDUCOM 2010 software which gives result values and graphs.

Fig.1 Experimental Set up

Machine Specifications

Table 2: Machine Specifications DUCOM

Description	Specifications
Disc Speed	200-2000rpm
Normal Load	0 -20 Kg
Wear rate	+/- 2 mm
Temp. – Pin heating	400° c
Temp. Chamber Heating	400° c
Wear track Diameter	Min 50 mm Max. 100 mm
Sliding Speed	Min 0.5 m/s to Max 10 m/s
Water cooling	Water jacket protected for spindle , water inlet from domestic tap.

III. Wear Test

The pin specimen was tested in Pin on disc apparatus as shown in fig (2). 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 1.0 Kg, 1.5 Kg, 2.0 Kg and 2.5 Kg. Specimens from all the four materials were tested with loads from 0.5 Kg to 2.5 Kg to know the effect of load on the wear of materials. To know the effect of carbon content on the wear; specimens from materials were tested with fixed load of 2.5 Kg. Timer was set for ten minutes. The readings were taken and compared.

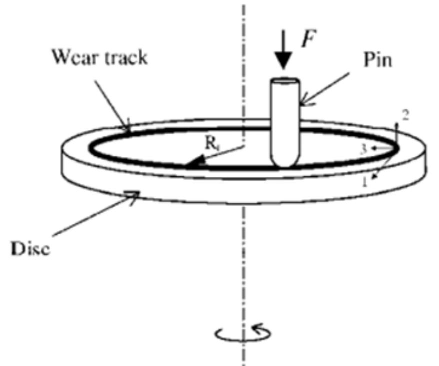

Fig. 2 Pin on Disc Wear Test

IV. Results & Discussions:-

Fig. 3 shows the variation of friction coefficient with the duration of rubbing at different normal loads for mild steel. During experiment, the sliding velocity was 1.256 m/s. Curve 1 of this figure is drawn for normal load 2 Kg. From this curve, it is observed that at the initial duration of rubbing, the value of friction coefficient is 0.473 and then increases very steadily up to 0.523 over a duration of 4 minutes of rubbing and after that it remains constant for the rest of the experimental time. At the initial stage of rubbing, friction is low and the factors responsible for this low friction are due to the presence of a layer of foreign material on the disc surface. The trends of these results are similar to the results of Chowdhury and Helali [5-6].

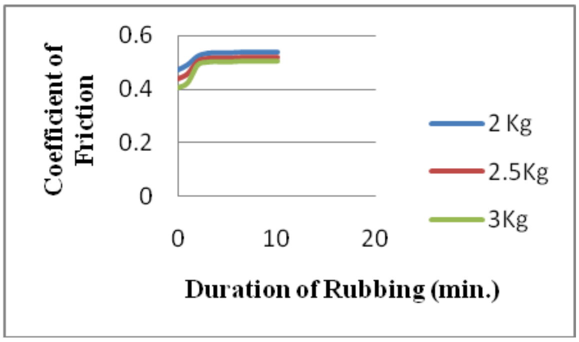

Fig. 3 Frictional Coefficient as a Function of duration of rubbing at different normal loads. Test sample Pin Mild Steel and disc EN -31

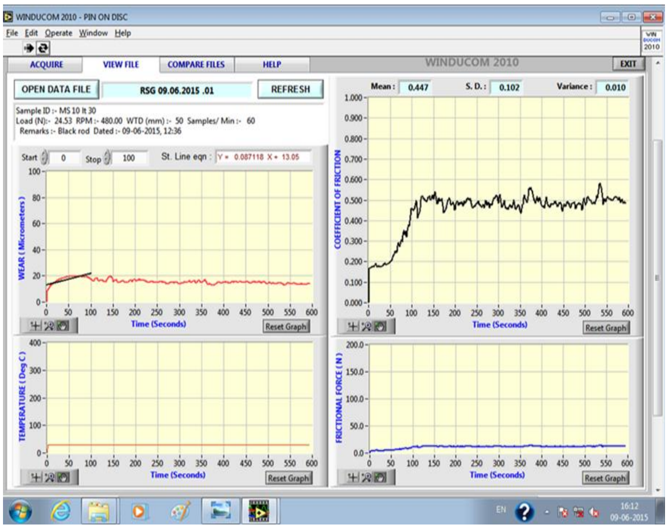

Fig. 4 Wear, Coefficient of friction, Frictional force of Mild steel Vs Time in Second.

Curves 2 and 3 of this fig. are drawn for normal load 2.5 Kg and 3 Kg respectively and show similar trends as that of curve 1. From these curves, it is also observed that time to reach steady state value is different for different normal loads. Results show that at normal load 2, 2.5 and 3Kg, M.S. takes 4, 3 and 2 minutes respectively to reach steady friction. It indicates that the higher the normal load, the time to reach steady friction is less. This is because the surface roughness and other parameter attain a steady level at a shorter period of time with the increase in normal load. Figure 4 shows wear, coefficient of friction & frictional force verses time , of mild steel sliding against EN-31 material.

Figure 5 shows the effect of the duration of rubbing on friction coefficient at different normal loads for SS 316 at velocity of 1.256 m/s Curve 1 of this figure drawn for normal load 2 Kg, shows that during initial rubbing, the value of friction coefficient is 0.32 which rises for few minutes to a value of 0.38 and then it becomes steady for the rest of the experimental time. Almost similar trends of variation are observed in curves 2 and 3 which are drawn for load 2.5 and 3 Kg respectively. From these curves, it is found that time to reach steady friction is different for different normal loads. At normal loads 2, 2.5 and 3 kg , SS 316 takes 5, 3 and 2 minutes respectively to reach steady friction. It means that higher the normal load, SS 316 takes less time to stabilize.

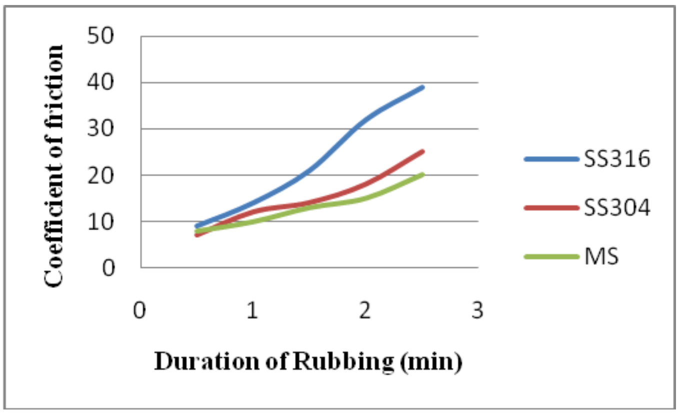

Fig.5 Frictional Coefficient as a function of duration of rubbing at different normal loads. Test sample Pin SS 316 and disc EN -31

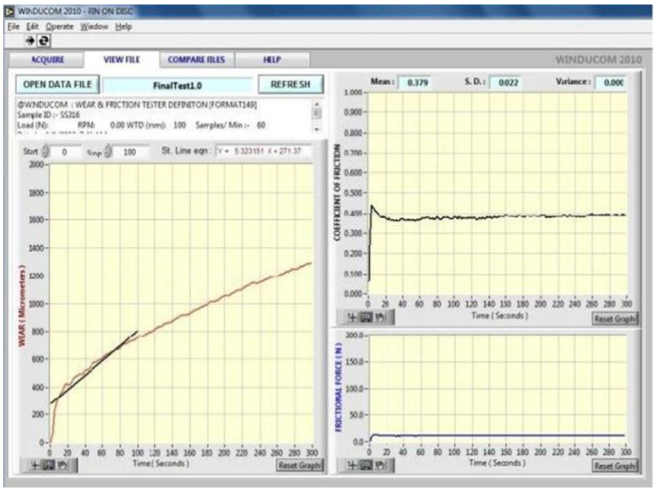

Fig.6 Wear, Coefficient of friction, Frictional force of SS 316 Vs time in second.

Fig. 6 shows relationship between wear, coefficient of friction & frictional force verses time of SS -316 against EN- 31 material.

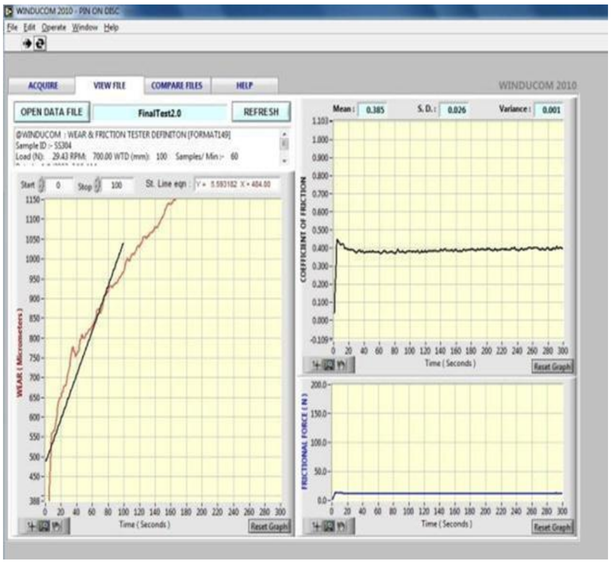

Fig. 7 Shows relationship between wear, coefficient of friction & frictional force verses time of SS -304 against EN- 31 material.

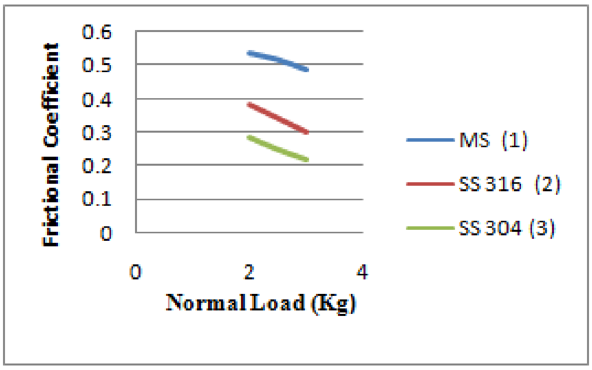

Fig. 8 Variation of frictional coefficient with variation of normal load for different materials

Fig. 8 shows the comparison of the variation of friction coefficient with normal load and curves of this figure are drawn for SS 304, SS 316 and mild steel. These results are obtained from the steady values of friction coefficient. It is shown that friction coefficient varies from 0.284 to 0.229, 0.382 to 0.302 and 0.538 to 0.486 with the variation of normal load from 2 to 3 Kg for SS 304, SS 316 and mild steel respectively. All of these results show that friction coefficient decreases with the increase in normal load. Increased surface roughening and a large quantity of wear debris are believed to be responsible for the decrease in friction [7,8] with the increase in normal load.

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 [10]. In well-designed tribological systems, the removal of material is usually a very slow process but it is very steady and continuous [11].

Pin on disc type wear tests for the specimen with 0.03% C , 0.08 % C and 0.17 % C steel in contact with EN-31 hardened steel disc were conducted under un-lubricated conditions of varying load with step wise changes between low and high levels on SS 316, SS 304 and mild steel respectively.

Table 3: Wear at different Load

Grade		0.5 Kg	1Kg	1.5Kg	2Kg	2.5Kg
SS316	Wear	9	14	21	32	35
SS304	Wear	7	12	13	18	24
MS	Wear	8	10	13	15	19

The wear behaviour of all above three material tested at different loads has been shown in the graphs (fig 9).The relation between carbon content in specimen and wear of specimen has been shown in figure 10. It has been noticed that wear increases with the increase in applied normal load [9]

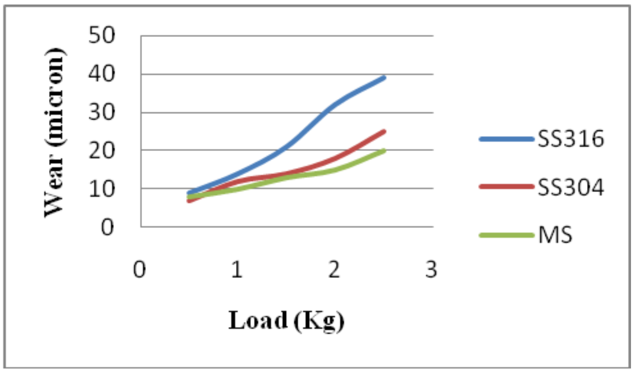

Fig. 9 Comparative Wear Behaviour

Table 4: Wear at Constant Load 2.5 Kg

Steel Grade	SS 316	SS 304	MS
Carbon	0.03	0.1	0.17

Content (%)			
Wear in Microns	35	24	19

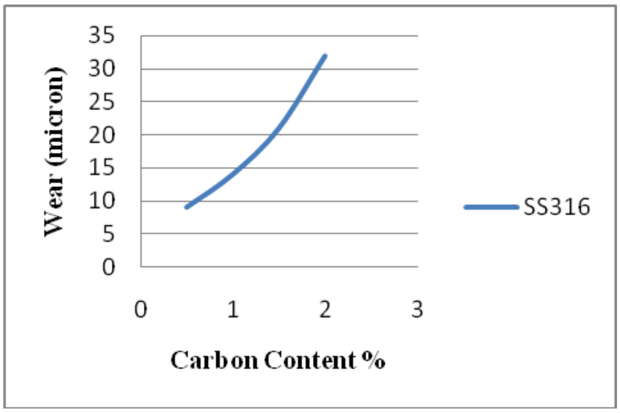

Fig. 10 Relationship of Wear and carbon content in steel

V. CONCLUSIONS

In general, friction coefficient increases for a certain duration of rubbing and after that it remains constant for the rest of the experimental time. The obtained results reveal that friction coefficient decreases with the increase in normal load for all the tested materials. Wear rate increases with the increase in normal load and sliding velocity for SS 316, SS 304 and mild steel. In addition, at identical operating condition, the magnitudes of friction coefficient and wear rate are different for different materials depending on sliding velocity and normal load.

Pin on disc type wear tests for the specimen with 0.03% C , 0.08 % C and 0.17 % C steel in contact with EN-31 hardened steel disc were conducted under un-lubricated conditions of varying load with step wise changes between low and high levels on SS 316, SS 304 and mild steel respectively. 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) The wear performance of steel significantly governed by the chemical composition of material.

Results have also shown that wear of carbon steel is significantly reduced by adding more carbon to it.

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