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Research Article

Tribological Analysis of SAE 4140 Steel

C.K.Patil*, S.P.Shisode, G.D.Shrigandhi and N.T.Dhokane

Mechanical Engineering Department, MAEER's MIT College of Engineering, Pune-38, India

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Abstract

Wearing has direct influence on the efficiency, finishing and quality of products. Therefore, this is critical point, when considered the aspects of tool components recovery, occurrences of tool fractures and undesirable production line stops. Moreover, the industry production growing speeds push the search for higher efficiency level of manufacturing. One of the main causes of wearing is the friction between contact surfaces by relative sliding in general, with some exceptions as for braking, the wear coefficient and pressure must be as low as possible to reduce wearing. The aim of this paper is to find wear behavior of bare SAE 4140 steel material. This work involves Chemical Composition testing of substrate steel material to get exact composition of SAE 4140 steel and it is used for wear as well as fatigue testing. This paper work also involves wear test on Pin-on-Disc set up. The study uses ANSYS WORKBENCH-12 software to derive the finite element model of the standard specimen. Based on this model, Von-misses stresses & displacements are found.

Keywords: *FEM, Static structural analysis, Wear*

1. Introduction

Wearing has direct influence on the efficiency, finishing and quality of products. Therefore this is critical point for any component. Moreover, the industry production growing speeds push the search for higher efficiency level of manufacturing. One of the main causes of tool wearing is the friction between contact surfaces by relative sliding. The mechanical forming industry is continually investing on the development of wear resistant materials. The targets are the improvement of materials properties and new materials development. New materials have been developed and upgraded for different applications.

Metal Fatigue is a phenomenon which results in the sudden fracture of a component after a period of cyclic loading in the elastic regime. Failure is the end result of a process involving the initiation and growth of a crack, usually at the site of a stress concentration on the surface. Occasionally a crack may initiate at a fault just below the surface. Eventually the cross sectional area is so reduced that the component ruptures under a normal service load, but one at a level which has been satisfactorily withstood on many previous occasions before the crack propagated. The final fracture may occur in a ductile or brittle mode depending on the characteristics of the material. Fatigue fractures have a characteristic appearance which reflects the initiation site and the progressive development of the crack front, culminating in an area of final overload fracture.

Nitriding and Physical Vapor Deposition (P.V.D.) coating techniques have been used for some time and are still on development. These processes have been extensively used to change any component surface strength. Coating materials deposited in the surface of metals has been extensively used in aerospace, automotive and oils fields, in order to improve the corrosion and wear resistance.

Wear

Damage occurring when two bodies are in contact and in relative motion, produces debris. Wear is produced when this debris is removed from the contact. The rate of expulsion of the debris depends on the contact geometry. Confined or conforming contact will not allow debris to displace. The wear particles may act as weak layers which reduce friction, i.e. as lubricants. They have a much more complex effect such as making the counterpart smoother. The contact zone is seen as having changing morphology, structure, chemistry, particle size and aspect ratio. It will be stretched, compacted and rolled by the repeated deformations in the contact.

2. Wear Consideration in Design

The wear is erosion or sideways displacement of material from its derivative and original position on a solidsurface performed by the action of another surface.Wear is related to interactions between surfaces and more specifically the removal and deformation of material on a surface as a result of

*Corresponding author: **C.K.Patil**

mechanical action of the opposite surface. The need for relative motion between two surfaces and initial mechanical contact between asperities is an important distinction between mechanical wear compared to other processes with similar outcomes.

The definition of wear may include loss of dimension from plastic deformation if it's originated at the interface between two sliding surfaces. However, plastic deformation such as yield stress is excluded from the wear definition if it doesn't incorporates a relative sliding motion and contact against another surface despite the possibility for material removal, because it then lacks the relative sliding action another surface. Impact wear is in reality a short sliding motion where two solid bodies interact at an exceptional short time interval.

Aspects of the working environment which affect wear include loads and features such as unidirectional sliding, reciprocating, rolling, and impact loads, speed, temperature, but also different types of counter-bodies such as solid, liquid or gas and type of contact ranging between single phase or multiphase, in which the last multiphase may combine liquid with solid particles and gas bubbles.

3. Mechanism of wear

According to the former DIN 50320, wear mechanisms are divided into four basic categories under the headings of adhesion, abrasion, and surface fatigue and tribochemical reactions. These are presented in table no.1

Table 1 Wear Mechanisms According To Former DIN 50320

Wear mechanism	
Adhesion	Formation and breaking of interfacial adhesive bonds
Abrasion	Removal of material due to scratching
Surface fatigue	Fatigue and formation of cracks in surface regions due to tribological stress cycles that result in the separation of material
Tribochemical reactions	Formation of chemical reaction products as a result of chemical interactions between the elements of a tribosystem initiated by tribological action

3.1. Stages of Wear

Under normal mechanical and practical procedures, the wear-rate normally changes through three different stages:

1. Primary stage: Primary stage or early run-in period, where surfaces adapt to each other and the wear-rate might vary between high and low.
2. Secondary stage: Secondary stage or mid-age process, where a steady rate of ageing is in motion. Most of the components operational life is comprised in this stage.
3. Tertiary stage: Tertiary stage or old-age period, where the components are subjected to rapid failure due to a high rate of ageing.

The secondary stage is shortened with increasing severity of environmental conditions such as higher temperatures, strain rates, stress and sliding velocities etc.

In explicit wear tests simulating industrial conditions between metallic surfaces, there are no clear chronological distinction between different wear-stages due to big overlaps and symbiotic relations between various friction mechanisms. Surface engineering and treatments are used to minimize wear and extend the components working life.

Table.2 Material Properties of AISI 4140

Material	Chemical Composition
% C	0.39
% Mn	0.86
% Cr	0.95
% Mo	0.20
% Si	0.20
% S	0.003
% P	0.014

4. Pin-On-Disc Machine

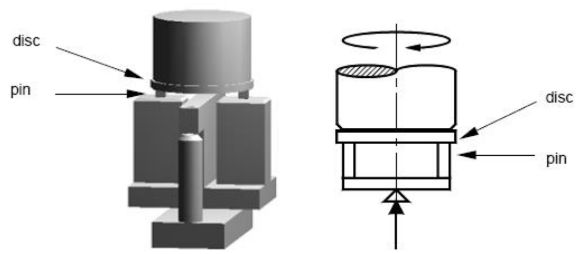
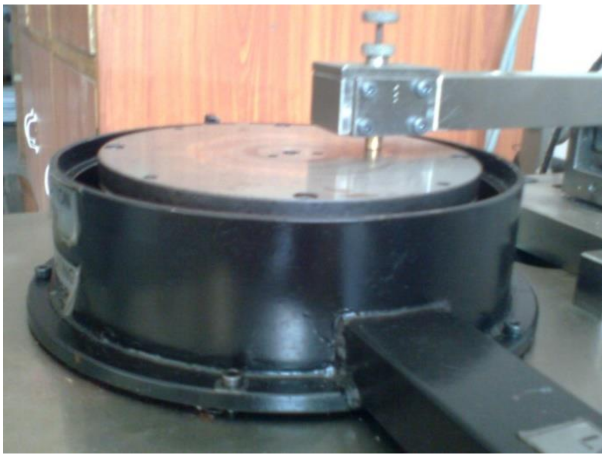


Fig.1 Pin-on Disc

The pin-on-disc configuration consists of a fixed 2-pins holder continuously sliding against a rotating disc. The rotation is transmitted via a rotary vacuum feed through to a shaft with the sample disc at the lower end. Loading is established by pressurized He-gas acting on a piston which presses a lever with the sample holder upwards against the lower face of the rotating disc. Polymer composites were cut into pins. In order to reduce the time of the running-in period, specimens were pre-worn with grinding paper (Grid 800) against the disc counterpart and then carefully cleaned with ethanol.

5. Experimental Result

(a)



(b)

Fig.2 Pin and disc set up

Working conditions taken during test are as follows:

Rotations of disc =700 RPM
Normal load applied in steps = 20N, 30N, 40N, 50N, 60N.
Duration considered = 3 Minutes

A. Performances Characteristics Wear Verses Load

Wear verses load characteristic is drawn for different load conditions for the duration of 3 minutes and plotted on the graph to interpret. Load conditions taken for bare material SAE 4140 are 20N, 30N, 40N, 50N, 60N.

B. Performances Characteristics Coefficient Of Friction Verses Load

Keeping above working conditions this performance is plotted. Wear behavior against time is also observed and plotted as shown in figure 5. Coefficient of friction against time is also observed and plotted as shown in figure 6.

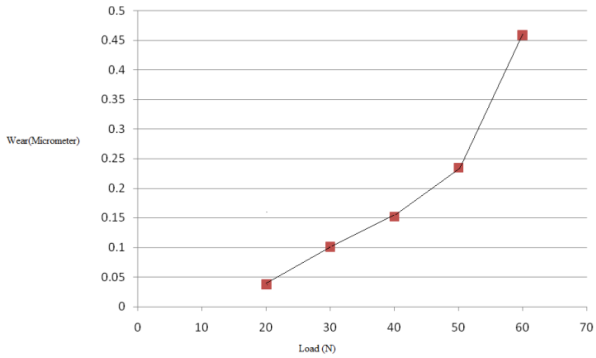


Fig. 3 Load Vs Wear

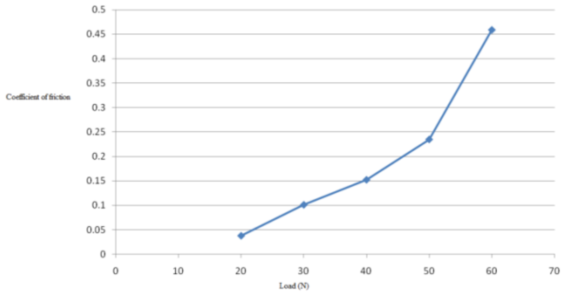


Fig. 4 Load Vs Coefficient of Friction

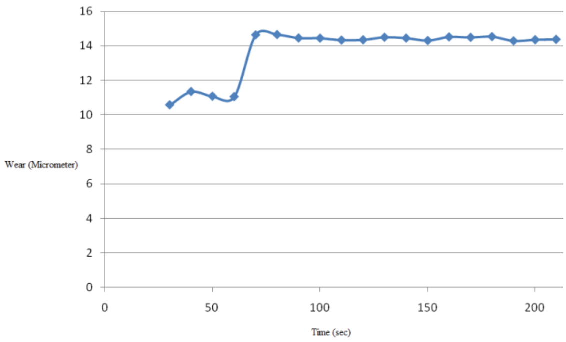


Fig. 5 Wear Vs Time

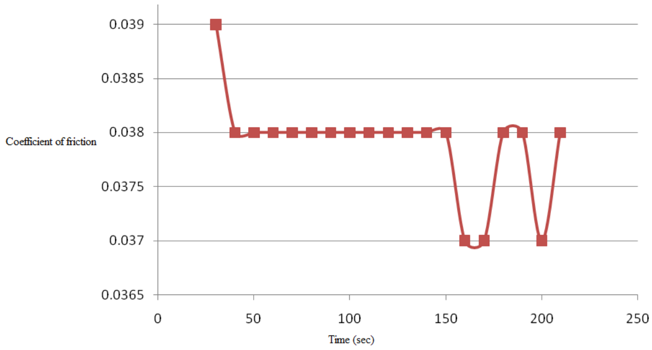


Fig.6 Coefficient of Friction Vs Time

6 Experimental Set-Up

The tribometer uses a pin-on-disk system to measure wear. The unit consists of a gimbaled arm to which the pin is attached, a fixture which accommodates disks up to 165 mm in diameter & 8 mm thick, an electronic force sensor for measuring the friction force, and a computer software (on Lab view platform) for displaying the parameters, printing, or storing data for analysis. The motor driven turntable produces up to 700 rpm.

Fig. 7 Wear and friction monitor

Wear is quantified by measuring the wear groove with a profilometer (to be ordered separately) and measuring the amount of material removed. Users simply specify the turntable speed, the load, and any other desired test variables such as friction limit and number of rotations. Designed for unattended use, a user need only place the test material into turntable fixture and specify the test variables.

A pre-determined Hertzian pressure is automatically applied to the pin using a system of weights. Rotating the turntable while applying this force to the pin includes sliding wear as well as a friction force. Since pins can be fabricated from a wide range of materials virtually any combination of metal, glass, plastic, composite, or ceramic substrates can be tested.

Software included with this model provides for quick calculation of the Hertzian pressure between the pin and disk.

7. Experimental Equipment

Different equipments are used to measure Wear rate & coefficient of friction with respect load & time. They are,

A. Pin: The circular pin is used having diameter 8 mm and length 30 mm. The suitable clamping arrangement is provided for making surface contact between pin and rotating disc. The pin is made up of steel material. The following fig.8 shows the different pins.

Fig.8 Pins

B. Circular disc: The disc is always in contact with face of pin for measurement of wear rate. The diameter of a disc is 165 mm and thickness is 8 mm.The following fig.9 shows the sample of rotating disc.

Fig.9. Rotating disc

C. Dead Weights: There are different weights used for measurement of wear rate and coefficient of friction. These dead weights are available in several categories such as 1Kg, 2Kg, and 5Kg.

D. Wear and friction controller: The following fig.10 shows the wear and friction controller. With the help of controller different input parameter is set such as frictional force, wear, temperature, RPM indicator and On-off option. According to this input parameter software generates the wear graph, so from that graphs, user can get useful information relating to the tribological properties of material such as coefficient of friction and wear.

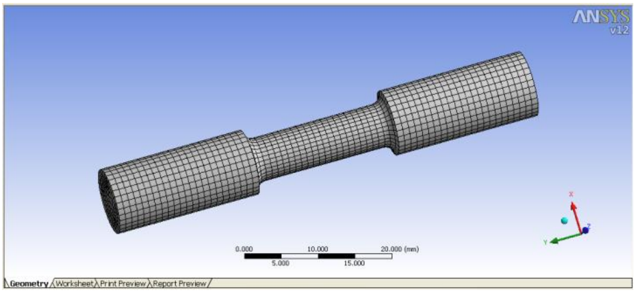
Fig.10. Wear and friction controller

E. Display Unit: A computer with the control software is used to monitor the signal; here all the data can be stored in the computer for future references. This is mainly in the form of PC (Laptop) when the wear occurs then the signals transferred to the software and after conversion comes in graphical form through the software. Generally, the data includes graphs of wear vs. time, coefficient of friction vs. time. Megview Software is used as tribological software for generating the following graphs:

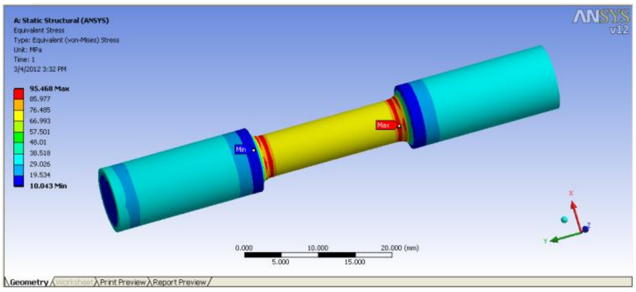
A) Performances characteristic of wear verses load.
B)Performances characteristic of coefficient of friction verses load.
C)Performances characteristic of wear verses time.
D)Performances characteristic of coefficient of friction verses time.

8. Static Structural Analysis of Standard Specimen

The solid model of standard specimen for axial fatigue testing is made with the help of ANSYS WORKBENCH -12 software. Static structural analysis of standard specimen is carried with the help of ANSYS WORKBENCH -12 software. The static structural analysis module is selected for evaluating maximum stress induced in the specimen.



(a)



(b)

Fig.11 Static structural analysis of specimen

Fig. 11 shows the static structural analysis of standard specimen. In this analysis, the standard specimen is meshed with the help of Quad element. The numbers of nodes are 34,261& numbers of elements are 7,632.The different boundary conditions are used such as applying axial pressure at one end and applying fixed support at other end. Von-misses stress is selected the output of structural module. The output results shows that maximum value of stress induced at neck region of specimen is 96 N/mm^2 and it is lower than the allowable strength of material i.e. 326 N/mm^2. Hence specimen is safe against failure at 2000 N.

Conclusions

From the study and wear testing we conclude that the wear and coefficient of friction are increases with increase in load. From the results of wear test it is concluded that wear is increasing initially up to 70 seconds and becoming nearly constant for further duration. Coefficient of friction decreases significantly initially up to 50 seconds and remains nearly constant for further duration. From static structural analysis, we conclude that specimen is safe against failure for static loading condition.

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