Effect of Load & Speed on Mechanical & Tribological Properties of High Manganese Hadfield steel at Room Temperature

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Abstract- **Hadfield's Manganese steel is a very useful engineering material due to its high toughness, ductility, high work-hardening capacity and good resistance to wear. The original austenitic manganese steel, containing about 1.2% C and 13% Mn, was invented by Sir Robert Hadfield in 1882. In the present study slight chromium was added for better work hardening effects, especially used in rail road crossings. Wear characteristics of hadfield steel under different operational conditions like wear pressures of 0.12490480, 0.24980970, 0.40590890, 0.49961930, 0.72320020, 0.87433381; 1.0403642MPa and sliding speeds of 2, 3, 4, 5, 6,7and8 m/s were monitored on a standard pin-on-disc wear and friction monitor (TR20L) testing equipment under dry sliding. Weight loss of the specimen was measured after the wear tests to obtain wear rate. The variations were observed in wear rate and specific wear rate with wear pressures under different sliding speeds for the fixed sliding distance of 10,000 meters. The results indicated almost constant specific wear rate under all the operational conditions. Low wear rate at the sliding speed of 4 m/s for all the wear pressures was observed. Sliding speed of 4 m/s can be considered as critical sliding speed for the hadfield steel. The depth of work hardening under dry sliding is more at lower sliding speed. The occurrence of wear mechanisms are governed by the combined effects of wear pressure and sliding speed. The wear mechanisms found to be primarily abrasive wear followed by pitting, gauging, adhesive, delaminative, oxidative, impact, scuffing, laminative, fretting and fatigue wear with respect to the wear pressure and sliding speed.**

Index Terms- **Austenite,Hadfieldsteel, Work hardening, Hardenability,Frictionalforce.**

I INTRODUCTION

Wear is one of the important subjects under tribology which is a complex phenomenon **[1].** Wear is the major cause of material wastage and loss of mechanical performance and reduction in wear can result in considerable savings, which can be made by improved friction control. The one third of the world's energy resources in present use is needed to overcome friction in one or another form. Lubrication is an effective means of controlling wear and reducing friction. The process of wear can be defined as the volume loss per unit distance sl. It occurs whenever surfaces come into sliding contact even in the presence of a lubricant. Wear can also be defined by the American Society for Testing and Materials (ASTM) as 'Damage to a solid surface' generally involving the progressive loss of material due to relative motion between that surface and a contacting substance or substances **[2]**. Wear is one of the major phenomena reducing the effectiveness of mechanical components, directly or indirectly impact the nation financially in terms of material loss, associated equipment down time for repairing and finally replacement of worn and corroded components **[3]**. Wear of machine parts means replacement and this by itself is very expensive. Wear is a system response and it is not a material property. Interface wear is strongly dominated by operating conditions. Therefore, it is required to design the machine parts for a minimum amount of wear. In general, the wear rate 'W_r' depends on the bearing pressure W/A (where W is the load carried by the contact and A is its nominal area in contect), on the sliding speed S, and on material properties and the surface geometry.

W_r=f(W/A,S,MaterialProperties, Geometry)………………. **[1]**

Although it has been widely accepted that friction and wear are system properties **[4]**, the tribological behavior is also influenced by some basic physical and mechanical properties **[5]**. Industry has long been involved in the development of processing techniques capable of selectively modifying the surface properties of metal parts

Friction and wear are not the intrinsic material properties. They are dependent on both the working conditions and the properties of materials. Widely varied wearing conditions cause wear of materials by various mechanisms. Small changes of speed, wear pressure, frictional temperature or properties of the materials including microstructures cause remarkable changes in the wear of contact surfaces. The main difficulty with wear studies is that, in most practical situations the conditions at the sliding interface are very complex and difficult to study. The wear resistance of a material is related to its microstructures as changes of microstructures may take place during the wear process and hence, it seems that in wear research, emphasis should be placed on microstructures **[6].** Therefore the basic way to study the wear of metals is by combining the wear phenomenon of friction and wear with the in-situ micro structural changes of metals. This approach certainly contributes to the selection and development of wear resistant materials and their treatment methods.

In the present investigation hadfield steel material is considered to know the various its behavior and to study the work hardening effects. Almost all the railway tracks at the junctions, the commonly used material is Hadfield's Austenite Manganese steel (AMS) which is a very useful engineering material due to its high toughness, ductility, high work-hardening capacity and good resistance to wear. It is particularly useful for severe service that combines abrasion and heavy impact as in railway frogs and crossings, in power shovel loader, bucket teeth, rockcrusher, etc. The original austenitic manganese steel containing about 1.2% Carbon and 13% Manganese, was invented by Sir Robert Hadfield in 1882 **[7]**. Many variations of the original austenitic manganese steel have been proposed, often in unexploited patents, but only a few have been adopted as significant improvements. These usually involve variations of carbon and manganese, with or without additional alloys such as chromium, nickel, molybdenum, vanadium, titanium, and bismuth. In the present study the high manganese low carbon austenitic steel has 1.09%C and 12.5% Mn and 1.12% Cr is added for better work hardening effects, especially used in rail road crossings. The material is heat treated at temperature 1040^0C and quenched to get the austenite state. The wear behavior of metals depend on various factors such as wear pressure, sliding speed, frictional temperature, hardness, surface roughness and microstructure etc. The wear mechanisms of this metal and its study are very important factor. The main aim of the present work is to study the wear mechanisms at different sliding speeds and wear pressures and also to study the work hardening effects and hardenability at subsurface. Most forms of wear are the result of events occurring at asperity contacts. It has been postulated by Archard that the total volume is proportional to the real contact area times the sliding distance, a wear coefficient or Archard coefficient used as an index of wear severity **[8]**. However the same term, the wear coefficient used to describe the specific wear rate k' by Gwidon W Stachowiak and Andrew.W.Batchlor, which is expressed as the ratio of wear volume to the load acting and sliding distance.

$k' = V / W*L$ m^3/Nm. ---------- ***(2)***

The objective is to study the effects of sliding distance on wear of hadfield steel, to understand the wear rate, Frictional force and wear coefficient of hadfield steel at different sliding speeds and wear pressures under dry sliding condition. To study the dominant wear mechanisms under wide ranges of sliding speeds and wear pressures of hadfield steel. To study the work hardening effects after wear of hadfield steel.

II EXPERIMENTAL PROCEDURE

The wear test experiments have been conducted on pin on disc TR 20L wear and friction monitor to determine volumetric wear rate at room temperature for different load, speed conditions. Wear tests are conducted with a pin on disc type wear and Friction monitor machine which employs essentially the basic 'tribometer', one of the most frequently used test rigs. The end of a wear pin rides on the flat surface of the disc. A flat – ended wear pin riding on a flat surface provides an ostensibly constant area of contact.

The wear volume of the pin specimen is determined from weight loss measurements by considering the density. Frictional force generated on the specimen is monitored through the use of a sensor attached to the pivoting arm and the same is measured in Kef. The contact frictional temperature in the ambient temperature of room temperature is measured by the thermocouple embedded in the wear pin very close to the wearing surface. This PoD tribometer works on WinDucom software. This software has four parts – machine control, data acquisition, analysis and display. Test plan and sample related information is entered in the machine control module before the start of a test. Soft- ware controls test parameters like speed, load, temperature and duration. Various outputs like friction force, coefficient of friction, wear, temperature are acquired. Coefficient of friction and volume loss are estimated and displayed online. Acquired data can be presented in several ways. Graphs of individual test can be printed . Results of different tests can be superimposed for comparative viewing. Acquired data can be exported to other software in ASCII format

Fig 2: Specimen weighing machine

Fig.1: Wear and friction monitor (TR-20LE)

Fig3:DisplyUnit

Chemical compositions of the experimental alloys are listed in Table 1.

Table 1

Parameter	C	Mn	Si	S	P	Cr	Ni	Mo
Observed values %age	1.089	12.446	0.890	0.001	0.087	1.123	0.111	0.075

In the present research, one of the commonest and simplest methods to test for wear rate was by using a pin-on-disc wear tester (Model: TR-20, LE) as per ASTM: G99 – 05. The counterpart disc was made of quenched and tempered EN-32 steel having a surface hardness of 65 HRC. The specimens of size Ø10×33 mm were machined out from all the specimens. The specimens were also polished and then cleaned with acetone before conducting the test.

During study, one of the common and simplest methods to test for wear rate is by using a pin-on-disc wear tester at ambient room temperature. Weight loss of the pin was measured after the wear test. Wear is usually expressed as worn volume per unit sliding distance. The wear volume of the pin specimen was determined from weight loss measurements by considering the density. Frictional force generated on the specimen was monitored through the use of a sensor attached to the pivoting arm and the same was measured in Newton (N).. Sliding speed (2, 3, 4, 5, 6,7and8m/s) Normal Pressure (0.12490480,0.24980970,0.40590890,0.49961930, 0.72320020,0.87433381;1.0403642MPa) between the size of the junctions produced during sliding and the size of the wear particles formed from those junctions.

There are many factors that influence the rate and mechanism of wear when the materials rub against one another.

1. Volumetric wear rate (K_v)

K_v = Volume of layer removed / sliding distance = mm^3/mm

Wear rate (Wr) = [Weight loss / Density] / Sliding distance m^3/m--(6)

Wear coefficient k = (V H / W L)-----(7)

= Volume of material removed x Hardness / Load applied x sliding distance = $((mm^3 * N/mm^2) / (N * mm))$

Estimated the volumetric wear rate, frictional force, and coefficient of friction

III RESULTS AND DISCUSSIONS:

1] Wear rate, volumetric wear rate, Co-efficient of friction, were calculated with known formula

Sliding distance 10,000 meters

Estimation of sliding speed and time:

The disc wear track diameter was set at 100 mm. The sliding speeds 2, 3, 4 5, 6,7 and 8 m/sec were selected and pin diameter of 10 mm was selected as per the standards of ASTM G99. The rotational speed of the disc was calculated from the below mentioned equations.

S = π * D*N/1000*60 (m/sec) ----- **(3)**

D= Diameter of the wear track (mm)

S= Sliding speed (m/s)

N= Rotational speed of wear disc (RPM)

N= S*1000*60/π*D (rpm) --------- **(4)**

In the present investigation, sliding distance (L) of 10,000 m was considered for optimum values of the results (steady state) for wear study. Time required to cover a sliding distance of 10,000 metres for different sliding speeds was calculated from the following equation:

L= π* D*N*T/1000 metres ----------- **(5)**

T= Time in min

L= 10,000 metres

The wear measurements give information about the surface interaction based on the premise that an intimate connection exists

2] Hardness of the specimen before and after the wear test is determined using Rockwell hardness testing equipment

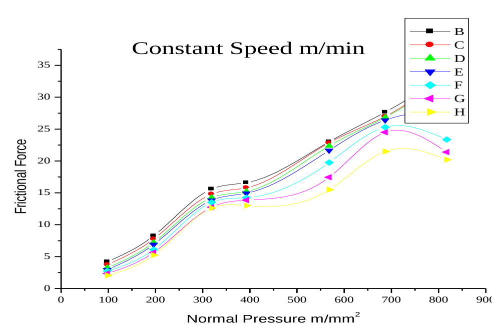
3] Response table were generated for wear rate, volumetric wear rate, coefficient4] Following graphs were drawn

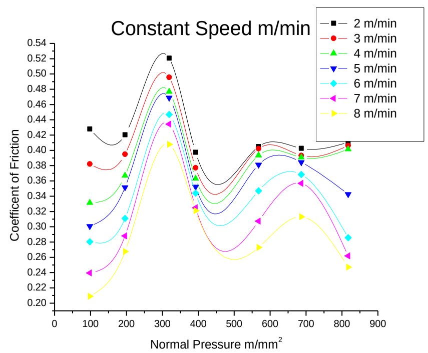
1] Volumetric wear rate v/s Normal Pressure

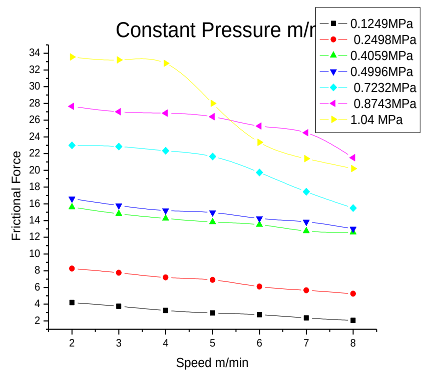
2] Frictional Force v/s Normal Pressure

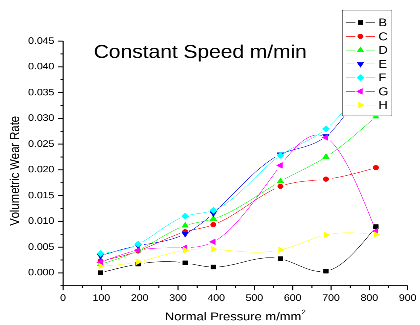
3] Coefficient Friction v/s Normal Pressure

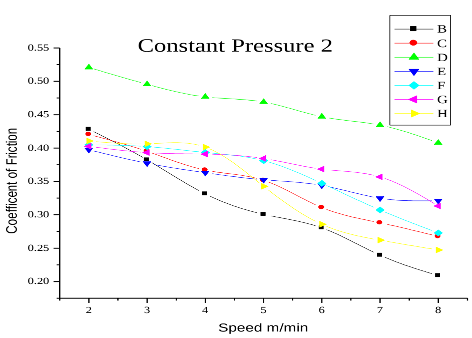
5] The result were analyzed using result table and graphs to investigate effect of parameters considered for the study

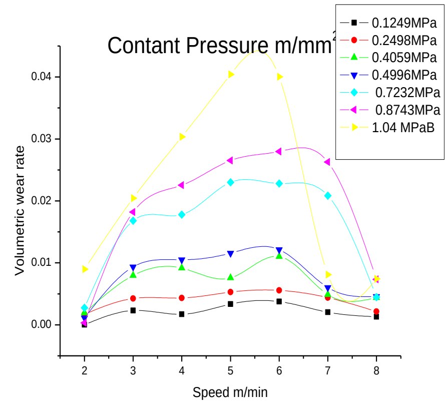












IV CONCLUSIONS

1] At constant normal pressure for the Hadfield specimen shows volumetric wear rate remains same for all sliding speeds at lower pressure on the other hand it increases with increase in higher pressure with increase in the sliding speed.

2] At constant normal pressure for the Hadfield specimen shows Frictional Force is remains same all the sliding speed but as the frictional force decreases due with increase in normal pressure

3] At constant normal pressure for the Hadfield specimen shows coefficient of friction decreases with increase in the sliding speed but as coefficient of friction increase as normal pressure increases

4] At constant speed hadfield steel shows the volumetric wear rate increases with increase in normal pressure at all sliding speeds

5] At constant speed hadfield steel shows the Frictional Force increases with increase in normal pressure.

6] At constant speed coefficient of friction increases at initial stage up to normal pressure up to 300 m/mm^2 their after it decreases up to 500 m/mm^2 and again slightly increases for further Increases in higher pressure. Above all coefficient of friction also decreases with increase in speed

7] As the volumetric wear rate increases at higher normal pressure ,which reveals that it is best wear resistant material

8] As the coefficient of friction increases as normal pressure increases ,which reveals that it is better wear resistant material under sliding conditions

9] With increase in sliding speed, the actual asperity contect area will decrease due to less residential time between wearing surface with the sliding disc,hence coefficient of friction is decrease

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