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Determination of wear characteristics of Aluminum based Silicon Carbide refractory bricks reinforced with Red mud extracts for Torpedo Type of Ladle Refractory Lining.

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ABSTRACT : *In this paper we discussed the wear behavior of red mud which can be used to prepare effective refractories to torpedo cars. The present trend in the steel industries runs on bauxite based refractories. The red mud can effectively replaces the bauxite in the make of refractories to with stand very high temperatures. Red mud or red sludge is a solid waste product of the Bayer process, the principal industrial means of refining bauxite in order to provide alumina as raw material for the electrolysis of aluminum by the Hall–Heroult process.A typical plant produces one to two times as much red mud as alumina. This ratio is dependent on the type of bauxite used in the refining process. One third of our global energy consumption is consumed wastefully in friction. In addition to this primary saving of energy, very significant additional economics can be made by the reduction of the cost involved in the manufacture and replacement of prematurely worn out components. The dissipation of energy by wear impairs strongly the national economy and the life style of most of people. So, the effective decrease and control of wear of metals are always desired.*

Keywords –*Red mud, Wear test, Pin-on-Disc, XRD Analysis, Sliding Distance, microstructure.*

I. INTRODUCTION

Wear of metals is probably the most important yet at least understood aspects of tribology. It is certainly the youngest of the tri of topics, friction, lubrication and wear, to attract scientific attention, although its practical significance has been recognizes throughout the ages. The findings of Guillaume Amontons in 1699 [2] establishing scientific studies of friction are almost of 300 years age, while Petrov [1], Tower [3] and Reynolds [4] brought enlightenment to the subject of lubrication a century ago in the hectic 1880s. Substantial Studies of wear can be associated only with the five decades that have elapsed since R.Holm [5] explored the fundamental aspects of surface interactions encountered in electrical contacts.

Wear causes an enormous annual expenditure by industry and consumers. Most of this is replacing or repairing equipment that has worn to the extent that it no longer performs a useful function. For many machine components this occurs after a very small percentage of the total volume has been worn away. For some industries, such as agriculture, as many as 40% of the components replaced on equipment have failed by abrasive wear. Other major sources of expenditure are losses production consequential upon lower efficiency and plant shutdown, the need to invest more frequently in capital equipment and increased energy consumption as equipment wears. Estimates of direct cost of abrasive wear to industrial nations vary from 1 to 4 % of gross national product and Rigney [7] has estimated that about 10% of all energy generated by man is dissipated in various friction processes.

Wear is not an intrinsic material property but characteristics of the engineering system which depend on load, speed, temperature, hardness, presence of foreign material and the environmental condition [8]. Widely varied wearing conditions causes wear of materials. It may be due to surface damage or removal of material from one or both of two solid surfaces in a sliding, rolling or impact motion relative to one another. In most cases wear occurs through surface interactions at asperities. During relative motion, material on contacting surface may be removed from a surface, may result in the transfer to the mating surface, or may break loose as a wear particle. The wear resistance of materials is related to its microstructure may take place during the wear process and hence, it seems that in wear research emphasis is placed on microstructure [9]. Wear of metals depends on many variables, so wear research programs must be planned systematically. Therefore researchers have normalized some of the data to make them more useful. The wear map proposed by Lim and Ashby [8] is very much useful in this regard to understand the wear mechanism in sliding wear, with or without lubrication.

II. TYPESOF WEAR

In most basic wear studies where the problems of wear have been a primary concern, the so-called dry friction has been investigated to avoid the influences of fluid lubricants. Dry friction' is defined as friction under not intentionally lubricated conditions but it is well known that it is friction under lubrication by atmospheric gases, especially by oxygen [10].

A fundamental scheme to classify wear was first outlined by Burwell and Strang [11]. Later Burwell [12] modified the classification to include five distinct types of wear, namely (1) Abrasive (2) Adhesive (3) Erosive (4) Surface fatigue (5) Corrosive.

Abrasive wear can be defined as wear that occurs when a hard surface slides against and cuts groove from a softer surface. It can be account for most failures in practice. Hard particles or asperities that cut or groove one of the rubbing surfaces produce abrasive wear. This hard material may be originated from one of the two rubbing surfaces.

In sliding mechanisms, abrasion can arise from the existing asperities on one surface (if it is harder than the other), from the generation of wear fragments which are repeatedly deformed and hence get work hardened for oxidized until they became harder than either or both of the sliding surfaces, or from the adventitious entry of hard particles, such as dirt from outside the system.According to the recent tribological survey, abrasive wear is responsible for the largest amount of material loss in industrial practice.

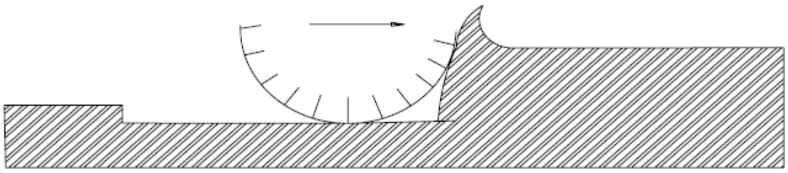

Fig. 1. Schematic representations of the abrasion wear mechanism

Adhesive wear can be defined as wear due to localized bonding between contacting solid surfaces leading to material transfer between the two surfaces or the loss from either surface. For adhesive wear to occur it is necessary for the surfaces to be in intimate contact with each other. Surfaces, which are held apart by lubricating films, oxide films etc. reduce the tendency for adhesion to occur.

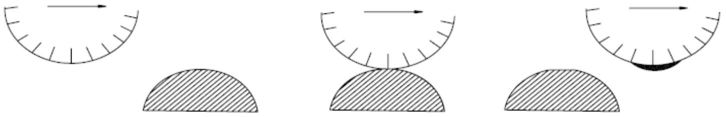

Fig. 2. Schematic representations of the adhesive wear mechanism

Erosive wear can be defined as the process of metal removal due to impingement of solid particles on a surface. Erosion is caused by a gas or a liquid, which may or may not carry, entrained solid particles, impinging on a surface. When the angle of impingement is small, the wear produced is closely analogous to abrasion. When the angle of impingement is normal to the surface, material is displaced by plastic flow or is dislodged by brittle failure.

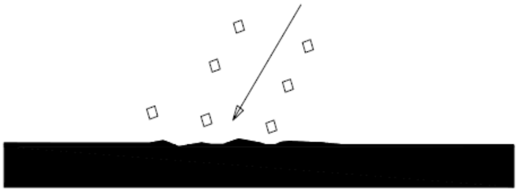

Fig. 3. Schematic representations of the erosive wear mechanism

Wear of a solid surface caused by fracture arising from material fatigue. The term 'fatigue' is broadly applied to the failure phenomenon where a solid is subjected to cyclic loading involving tension and compression above a certain critical stress. Repeated loading causes the generation of micro cracks, usually below the surface, at the site of a pre-existing point of weakness. On subsequent loading and unloading, the micro crack propagates. Once the crack reaches the critical size, it changes its direction to emerge at the surface, and thus flat sheet like particles is detached during wearing. The number of stress cycles required to cause such failure decreases as the corresponding magnitude of stress increases. Vibration is a common cause of fatigue wear.

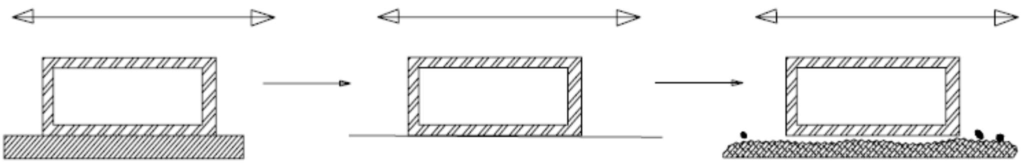

Fig. 4. Schematic representations of the surface fatigue wear mechanism

Most metals are thermodynamically unstable in air and react with oxygen toform an oxide, which usually develop layer or scales on the surface of metal or alloyswhen their interfacial bonds are poor. Corrosion wear is the gradual eating away ordeterioration of unprotected metal surfaces by the effects of the atmosphere, acids, gases,alkalis, etc. This type of wear creates pits and perforations and may eventually dissolvemetal parts.

III. PIN-ON-DISC WEAR TESTING MACHINE

Experiments have been conducted in the Pin-on-disc type Friction and Wearmonitor (DUCOM; TL-20) with data acquisition system, (Fig. 5&6) which was used toevaluate the wear behaviour of the composite, against hardened ground steel disc having hardness 65 HRC and surface roughness (R_a) 0.5 µm. It is versatile equipmentdesigned to study wear under sliding condition only. Sliding generally occurs between astationary Pin and a rotating disc. The disc rotates with the help of a D.C. motor; havingspeed range 0-2000 rev/min with wear track diameter 50 mm-180 mm, which could yieldsliding speed 0 to 10 m/sec. Load is to be applied on pin (specimen) by dead weightthrough pulley string arrangement. The system has a maximum loading capacity of 200N.

Fig. 5. Pin-on-Disc

Fig. 6. Loading Panel

IV. MATERIALS USED FOR WEAR TEST

Commercially pure aluminium of IE–07 grades from National AluminiumCompany (NALCO), Angul of Orissa was collected and was used for experimentalpurpose. The composition analysis along with other test results such as hardness, density,& tensile strength are presented in table-1 and 2.

Si	Fe	Ti	V	Cu	Mn	Al
0.08	0.15	0.001	0.007	0.001	0.003	99.76

Table 1.Compositional analysis of Aluminium

Density	2.7 gm/cc
Hardness	40.8 VHN
Tensile Strength	67 MPa

Table 2.Density, Hardness & Tensile Strength of Aluminium

The red mud used for the present investigation was brought from thealuminum refinery of NALCO located at Damanjodi, Koraput, and Orissa. Dust was prepared manually. The size of the dust was measured by using a sieve. As per this analysis the average size of the dust was 150 micron. Red mud dust was subjected to XRD, and chemical analysis. The presence of different elements as confirmed by chemical analysis is presented in table 3.

Constituents	% (wt)	Constituents	% (wt)
Al_2O_3	**15.0**	**Fe_2O_3**	**54.8**
TiO_2	**3.7**	**SiO_2**	**8.44**
Na_2O	**4.8**	**CaO**	**2.5**
P_2O_5	**0.67**	**V_2O_5**	**0.38**
Ga_2O_3	**0.096**	**Mn**	**1.1**
Zn	**0.018**	**Mg**	**0.056**
Organic C	**0.88**	**L.O.I**	**Balance**

Table 3. Chemical (dry) analysis of Red mud

V. XRD ANALYSIS OF RED MUD

XRD analysis was done to detect the presence of different elements in the red mud. XRD work was carried out on a Philips X-ray diffractometer. The X-ray diffractograms are taken using Cu Kα radiation at scan speed of 30 / min. Fig.7 shows the XRD analysis of red mud particles. The large peak found are of Al_2O_3 particles, whereas small peaks indicates the presence of Fe_2O_3 in red mud. The noisy peaks indicate the presence of other trace elements like SiO_2, Al_3Fe etc.

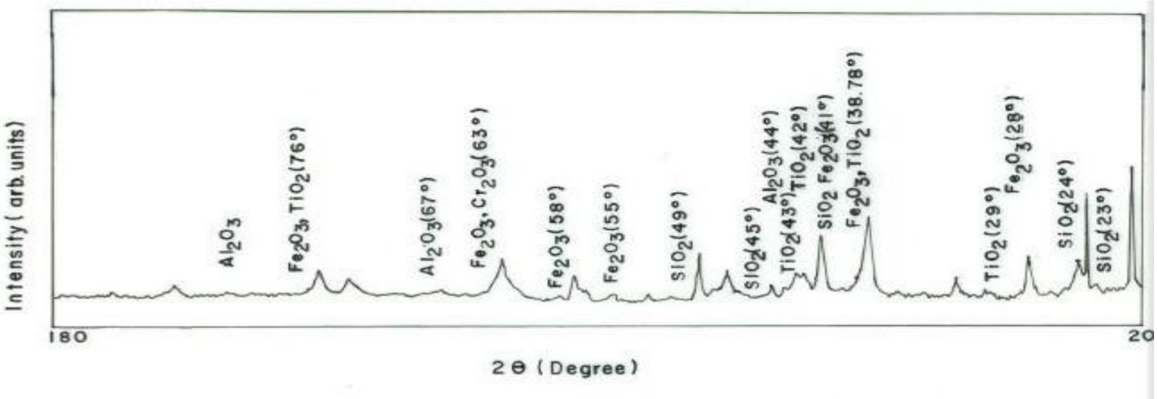

Fig. 7. XRD pattern of NALCO red mud

The selected 20% red mud added sample has been analyzed by x-ray diffraction analysis. The composites were produced under different conditions to identify the different phases in it; the study was made on the analysis chart, which is shown in the diffractogram Fig.8. The large peaks found are of Al_2O_3 particles, whereas small peaks indicate the presence of FeO, and Al_3Fe in MMC. The noisy peaks indicate the presence of other trace elements like SiO_2 in the diagram and confirm the presence of red mud particles in the composites. The other particles presents in MMCs are very small peaks.

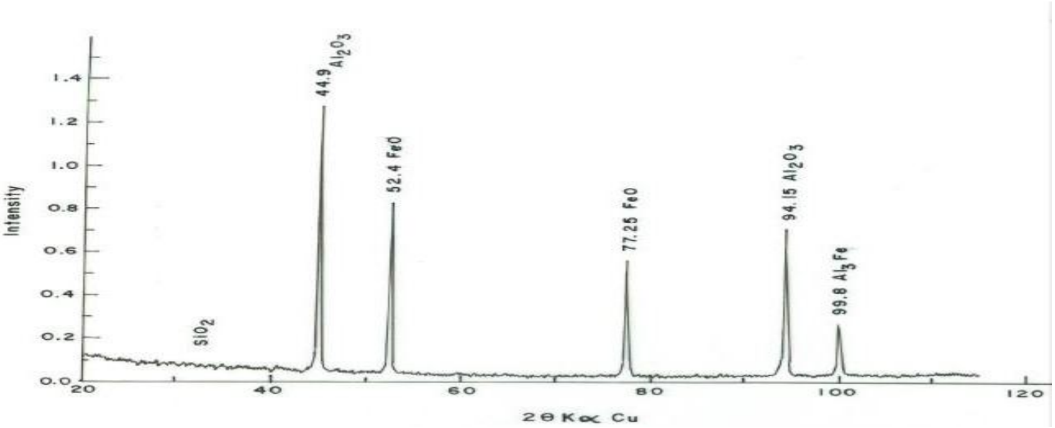

Fig. 8. XRD pattern of 20% red mud composite

VI. DETERMINATION OF THE AMOUNT OF WEAR

Before conducting the test, the pin and the disc surfaces were polished with emery papers, so that the contact will be a smooth one. All the wear tests were carried out as per ASTM G-99 standard under unlubricated condition in a normal laboratory atmosphere at 50-60% relative humidity and a temperature of 28-320C. Each test was carried out for 6 hrs run. The mass loss in the specimen after each test was estimated by measuring the weight of the specimen before and after each test using an electronic weighing machine having accuracy up to 0.01mg. Care has been taken that the specimens under test are continuously cleaned with woolen cloth to avoid the entrapment of wear debris and to achieve uniformly in experiential procedure. The test pieces are cleaned with tetra-chloro-ethylene solution prior and after each test.

Wear rate was estimated by measuring the mass loss in the specimen after each test and mass loss, Δm in the specimen was obtained. Cares have been taken after each test to avoid entrapment of wear debris in the specimen. Wear rate which relates to the mass loss to sliding distance (L) was calculated using the expression,

$$W_r = \Delta m / L \qquad (1)$$

The volumetric wear rate W_v of the composite is relate to density (ρ) and the abrading time (t), was calculated using the expression,

$$W_v = \Delta m / \rho\, t \qquad (2)$$

The friction force was measured for each pass and then averaged over the total number of passes for each wear test. The average value of co-efficient of friction, μ of composite was calculated from the expression,

$$\mu = F_f / F_n \qquad (3)$$

Where F_f is the average friction force and F_n is the applied load.

For characterization of the abrasive wear behaviour of the composite, the specific wear rate is employed. This is defined as the volume loss of the composite per unit sliding distance and per unit applied normal load. Often the inverse of specific wear rate expresses in terms of the volumetric wear rate as

$$W_s = W_v / V_s F_n \qquad (4)$$

where V_s is the sliding velocity.

VII. EXPERIMENTAL RESULTS OF WEAR TEST

Experimental results of the wear test of different test pieces (20 and 30 % by weight of red mud) at different test conditions are tabulated and presented in table 4, 5 and 6.

m1 (gm)	m2 (gm)	Δm (gm)	t (sec)	F_f (kg)	μ	R.D × 10^3 (m)	W_r ×10^{-6} (N/m)	W_v × 10^{-12} (m^3/sec)	W_s × 10^{-13} (m^3/N-m)
8.25	8.18	0.07	3600	0.33	0.33	4.53	0.15175	7.4215	6.018
8.25	8.12	0.13	7200	0.33	0.33	9.06	0.14091	6.8914	5.5886
8.25	8.04	0.21	10800	0.29	0.29	13.59	0.15175	7.4215	6.0185
8.25	7.97	0.28	14400	0.33	0.33	18.12	0.15175	7.4215	6.0185
8.25	7.92	0.33	18000	0.30	0.30	22.65	0.14308	6.997	5.674
8.25	7.87	0.38	21600	0.33	0.33	27.18	0.1373	6.714	5.444

Table 4. Wear test results ofpure aluminium at: load=10N, ρ=2.62 x 10^3 kg/m^3, RPM=200, V_s=1.257 m/sec

m1 (gm)	m2 (gm)	Δm (gm)	t (sec)	F_f (kg)	μ	R.D × 10^3 (m)	W_r ×10^{-6} (N/m)	W_v × 10^{-12} (m^3/sec)	W_s × 10^{-13} (m^3/N-m)
8.47	8.43	0.04	3600	0.36	0.36	4.53	0.0867	4.41	3.576
8.47	8.39	0.08	7200	0.34	0.34	9.06	0.0867	4.41	3.576
8.47	8.35	0.12	10800	0.36	0.36	13.59	0.0867	4.41	3.576
8.47	8.32	0.15	14400	0.26	0.26	18.12	0.0813	4.1336	3.352
8.47	8.30	0.17	18000	0.36	0.36	22.65	0.0737	3.7478	3.04
8.47	8.27	0.20	21600	0.37	0.37	27.18	0.0723	3.6743	2.98

Table 5. Wear test results of Al+20% red mud at: load=10N, ρ=2.527 x 10^3 kg/m^3, RPM=200, V_s=1.257 m/sec

m1 (gm)	m2 (gm)	Δm (gm)	t (sec)	F_f (kg)	μ	R.D × 10^3 (m)	W_r ×10^{-6} (N/m)	W_v × 10^{-12} (m^3/sec)	W_s × 10^{-13} (m^3/N-m)
7.80	**7.65**	**0.15**	**3600**	**0.36**	**0.36**	**11.309**	**0.130**	**16.339**	**5.303**
7.80	**7.56**	**0.24**	**7200**	**0.34**	**0.34**	**22.618**	**0.1041**	**13.071**	**4.242**
7.80	**7.43**	**0.37**	**10800**	**0.36**	**0.36**	**33.927**	**0.1069**	**13.435**	**4.36**
7.80	**7.27**	**0.53**	**14400**	**0.26**	**0.26**	**45.236**	**0.114**	**14.433**	**4.684**
7.80	**7.18**	**0.62**	**18000**	**0.36**	**0.36**	**56.545**	**0.1075**	**13.507**	**4.383**
7.80	**7.08**	**0.72**	**21600**	**0.37**	**0.37**	**67.854**	**0.1041**	**13.071**	**4.242**

Table 6. Wear test results of Al+30% red mud at: load=10N, $\rho=2.55 \times 10^3$ kg/m^3, RPM=400, V_s=3.141 m/sec

Based on the tabulated results, various graphs are plotted for different percentage of reinforcement under different test conditions. Fig.9 shows the variation of wear rate with sliding distance for different loads (10N, 20N, 30N) at 200 rpm.

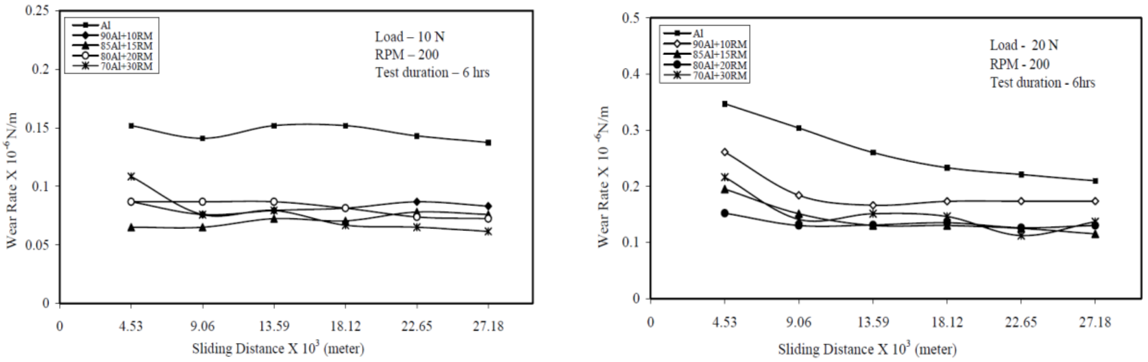

Fig. 9. Variation of wear rate with sliding distance

It is seen from the plots that with addition of red mud particles the wear rate of the composite is decreasing. Also as the sliding distance increases the wear rate first decreases and then almost remains same for the entire test period. Since the trend for 300 and 400 rpm remains same as 200 rpm, it has not been presented here. The micrographs of red mud distribution in the composite for different volumes are shown in fig.10.

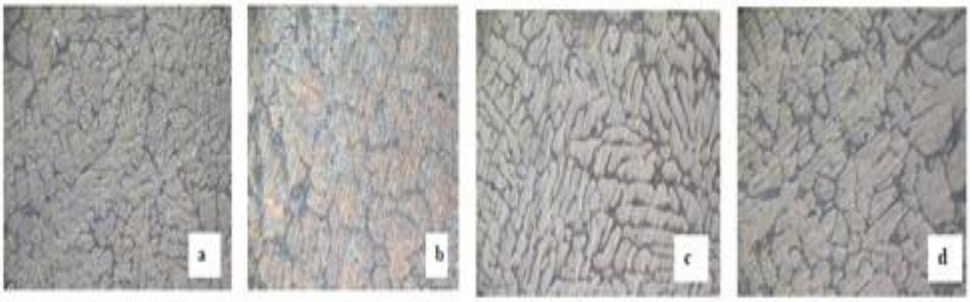

Fig. 10. Micrographs showing red mud distribution in the composites of different Volume fractions (a) 10% (b)15% (c) 20% and (d) 30% at (200 X)

VIII. CONCLUSION

Aluminium matrix composites have been successfully fabricated with fairly uniform distribution of red mud particles. Dispersion of red mud particles in aluminium matrix improves the hardness of the matrix material and also the wear behaviour of the composite. The effect is the increase in interfacial area between aluminium matrix and red mud particles leading to the increase in strength appreciably. Co-efficient of friction decreases as the load increases. At higher load and higher speed specific wear rate decreases with increases in Red mud content. Wear co-efficient tends to decrease with increasing particle volume content. It also indicates that red mud addition is beneficial in reducing wear of the aluminium red mud composite. Wear resistance of the composite increases due to addition of red mud particles. However there exists an optimum filler volume friction which gives maximum wear resistance to the composite.

REFERENCES

[1]. N.P.Petrov, “Friction in machines and the effect of the lubricant”, Inzh.Ah, 1893, pp 71-140, Vol. 2, 1983, pp 227-279.

[2]. G. Amontons, Mem. Acad. T. , Ser. A, 1699, pp 257-282.

[3]. B.Tower, “First report on friction experiments”, Proc., Inst. Mech. Eng., London, Nov. 1983, pp 632-659.

[4]. O.Renolds, “On the theory of lubrication and it’s application to Mr. Beauchamp Tower’s experiments”, Plilos. Trans. T. Soc. London, Vol. 177, 1886, pp. 157-234.

[5]. R. Holm, “The frictional force over the real area of Contact”, Wiss. Vereoff.Siemens Werken, Vol. 17 (4), 1938, pp. 38-42.

[6]. Peterson.M. B, “Advanced in tribo-materials I Achievements in Tribology”, Amer,Soc, Mech. Eng., Vol.1, New York, 1990, pp. 91-109.

[7]. D.A.Rigney, “Fundamentals of Friction and wear of materials”, American Societyfor Metals, Metal park, Ohio.

[8]. M.F.Ashby and S.C.Lim, ‘Wear-mechanism maps’, Scripta Metallurgical et Materialia, Vol.24, 1990, pp. 805-810.

[9]. Y. Wang, T.C. lei and C.Q. Gao, ‘Influence of isothermal hardening on the sliding wear behaviour of 52100 bearing steel’, Tribology International, 1990, Vol. 23(1), pp. 47-53.

[10]. N.Soda, ‘Wear of some F.F.C metals during unlubricated sliding part-1. Effects of load, velocity and atmospheric pressure on wear’. Wear 33 (1975) 1-16.

[11]. Burwell J.T. and Strang C.D, ‘Metallic wear’, Proc.Soc (London), 212A May1953, pp 470-477.

[12]. Burwell J.T., ‘Survey of possible wear mechanisms’, Wear 1, 1957/58, pp119-141.

[13]. K.H.Zumgahr, ‘Microstructure and wear of materials’ Elsevier, Amsterdam, 1987.