

An Experimental Study on Characteristics of Journal Bearing Material by Friction & Wear

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ABSTRACT: The aim of this research study was to determine the Coefficient of Friction ($\mu = F/W$) by studying the characteristics of bearing material. Force in journal bearings under realistic operating conditions. The testing of each specimen is carried out in three different conditions namely, fully lubricated condition, semi dry condition and dry condition. In the lubricated test, the bearings are tested using SAE 10 lubricating oil. In the semidry test, after running-in, the bearings and the shaft are thoroughly cleaned with acetone and dried to remove traces of oil from the surface. The bearings are then tested without any further lubrication. In dry test, the bearings were tested in completely dry condition without any lubrication.

KEYWORDS: Journal bearing, Zn- Al- Cu Alloy, Friction and Wear, Lubrication conditions and EDXS.

I. INTRODUCTION

Friction is the natural phenomenon of resistance to motion between moving surfaces. Although friction is an essential requirement in our daily lives, a 1/3-1/2 of world's output of energy is lost in overcoming the effects of friction. In mechanical systems, friction is sought to be minimized by use of bearings, which provide for a rotating or sliding contact between surfaces and which constitute one of the most important groups of engineering components used in industries. Bearings are classified into "Rolling Element bearings and Journal or Bush bearings" based on the type of motion employed. Cast metal bearing industry is an ancient technology which has been functioning in an organized basis for more than two centuries, and therefore is very mature and well entrenched. Traditionally a large number of bearing material has been available to the designers which, between themselves, offered a wide range of properties. Copper base alloys such as tin bronzes, lead bronzes and aluminium bronzes have always been synonymous with cast bearings. However copper, tin and lead have been declared as scarce materials by most countries. India especially is very deficient in its availability of copper and tin. On the other hand, Zn and Al are being substantially indigenously produced. Besides, Zn-Al alloys are lighter and their cost is lower than copper base alloys. Hence the use of Zinc-Aluminium alloys is justified on the basis of cost (30-40% of copper alloys), weight reduction and more importantly, on the basis of strategic consideration.

II. MATERIALS AND METHODS

Three zinc-aluminium based (Zn-Al-Cu) alloys were prepared by permanent mould casting process. In order to prepare Zn-Al-Cu alloys, aluminium and copper additions were made as aluminium-copper (46.5% Al) master alloy. The master Al-Cu alloy was prepared in the laboratory. The purity of metals used to prepare the master and Zn-Al alloys was 99.99% for zinc and copper, 99.97% for aluminium. The melting process was carried out in the temperature controlled electrical crucible furnace. The melted alloys were then cast into steel moulds preheated at a temperature of 2000C. In view of the above discussion, an attempt has been made to study the influence of copper on bearing characteristics of a conventional Zinc-aluminium die cast ZA20 alloy contains copper in the range from 1 to 3 wt.%. In this study, coefficient of friction of ZA radial bearings has been determined and effects of copper content and load on bearings have been examined in dry, semi dry and lubricated conditions. The chemical composition shown in table (1), alloy composition for wear shown in table (2) below.

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(An ISO 3297: 2007 Certified Organization)

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Alloy	Elements										
	Al	Cu	Mg	Sn	Cd	Fe	Sb	Ti	Pb	Mn	Zn
ZA200	19.46	0.003	0.005	0.01	0.0013	0.049	0.0021	0.0003	0.0014	0.0022	Balance
ZA201	19.2	0.91	0.104	0.0092	0.0011	0.088	0.005	0.0003	0.0010	0.0082	Balance
ZA202	18.99	1.85	0.112	0.0089	0.0016	0.089	0.0049	0.0004	0.0025	0.0099	Balance
ZA203	18.88	2.9	0.111	0.009	0.0014	0.009	0.0048	0.0004	0.0019	0.0090	Balance

Table (1): Chemical Composition Analysis

Alloy	Al wt%	Cu wt%	Mg wt%	Fe wt%	Pb wt%	Cd wt%	Sn wt%	Zn wt%
ZA 200	10.80-11.50	0.50-1.20	0.02-0.03	max. 0.075	max. 0.006	max. 0.006	max. 0.003	Rem.
ZA 201	25.00-28.00	2.00-2.50	0.02-0.03	max. 0.075	max. 0.006	max. 0.006	max. 0.003	Rem.
ZA 202	--	76.50-79.50	--	max. 0.35	14.00-17.70	--	5.30-7.00	max. 1.50

Table (2): Alloy Composition for Wear

III. EXPERIMENTAL SET UP

WEAR TEST: Dry sliding wear tests were conducted using a pin-on-disc wear test apparatus on cylindrical pin specimens of 6 mm diameter, 25 mm long against an EN 25 steel counter face (0.3% C, 0.7% Cr, 2.5% Ni, 0.5% Mo, remainder Fe) having HRC 62 hardness. Velocity on the test specimens were varied in each case in steps until prior sliding distance of 1000 m is reached. The wear rates of the specimens were computed by the weight loss technique. A high precision digital balance was used for weighing the specimens. Temperature rise near the specimen surface was monitored as a function of test duration by inserting a Chromel- Alumel thermocouple in a holes are made at a distance of 1.5 mm and 3 mm from the mating surface of the specimen respectively. Wear test specimens having diameter of 6mm and 25mm long were machined and holes are drilled as previously explained to assess the temperature. The test was carried out according to the ASTM G-99 standards, as shown in figure (1).



Fig (1): Journal bearing Test equipment used for the testing of bearing under different lubrications

Specifications: Radial load: up to 15 000 N
Tilting torque: 5000 Nm

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Rotational speed: 0 – 4000 rpm
Journal diameter of tested bearings: 30 - 100 mm
Separated unit of lubrication of the tested bearing (water, oil etc.)

IV. EXPERIMENTAL RESULTS

The chemical compositions of the alloys were determined by the atomic absorption method and also chemistry of the same alloy was quantified by EDAX analysis. The results were tabulated in Table (3). All resulted graphs are shown.

Alloys	ZA-200		ZA-201		ZA-202	
Pressure MPa	Wear resistance X 10 ⁻⁶ , mm ³ /Nm	Friction coefficient	Wear resistance X 10 ⁻⁶ , mm ³ /Nm	Friction coefficient	Wear resistance X 10 ⁻⁶ , mm ³ /Nm	Friction coefficient
3	11.0	0.108	49.33	0.118	20.6	0.115
5	10.6	0.100	31.08	0.119	17.7	0.105
Average	10.8	0.104	40.205	0.1185	19.3	0.110

Table (3): Wear resistance of tested alloys



Fig (2). Energy Dispersive X-ray Spectroscope control Area (EDXS) used in the experiment

The Stribeck curve is the graph of coefficient of friction (μ) of the alloy plotted against the bearing parameter under lubricated test conditions. The values shown in the graphs are arithmetic mean of three tests. It was found that ZA200&

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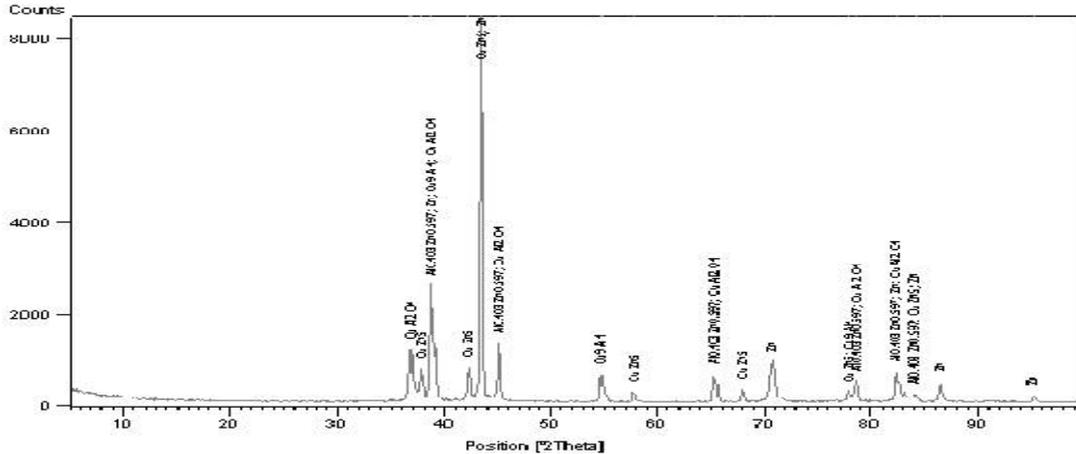


Fig (5): X-ray spectra of ZA202 containing 2 wt. % Cu alloy

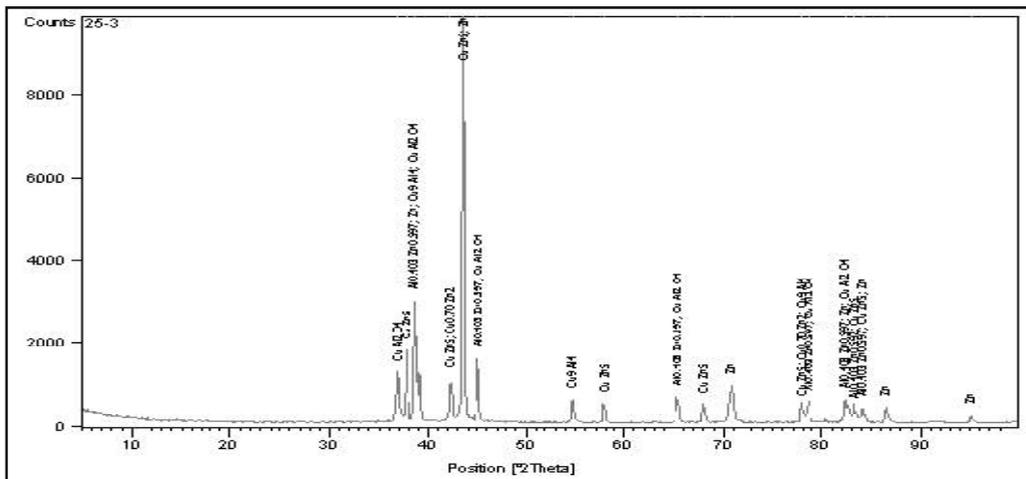


Fig (6): X-ray spectra of ZA203 containing 3 wt. % Cu

The graphs of coefficient of friction (μ) of the alloy plotted against load applied under semi dry and dry test conditions respectively. It was found that ZA202 exhibited visually observable stick–slip and even seizure at the higher loads. The remaining alloys showed a decrease in μ value but an increase with increase in load. It is interesting to note that all ZA alloy bearings studied in this work showed almost identical bearing characteristics.

In the present work, the μ value increases for the alloy ZA200 (without copper) and ZA202 (2wt% copper), in the first case the increase in μ value is due to absence of copper (copper addition strengthens the alloy) and in later case due to segregation of intermetallic compounds from the matrix results in weakening of matrix material hence the higher values of coefficient of friction.

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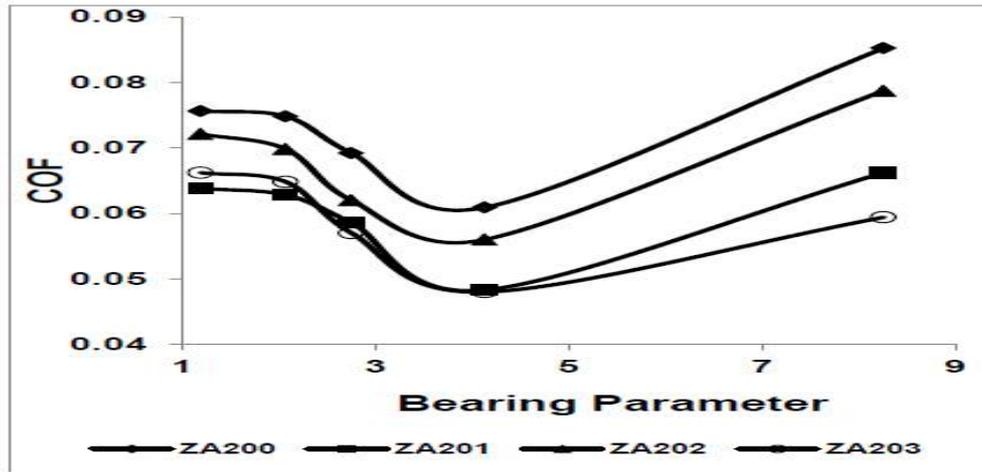


Fig (7): COF vs. bearing parameter (By EDXS)

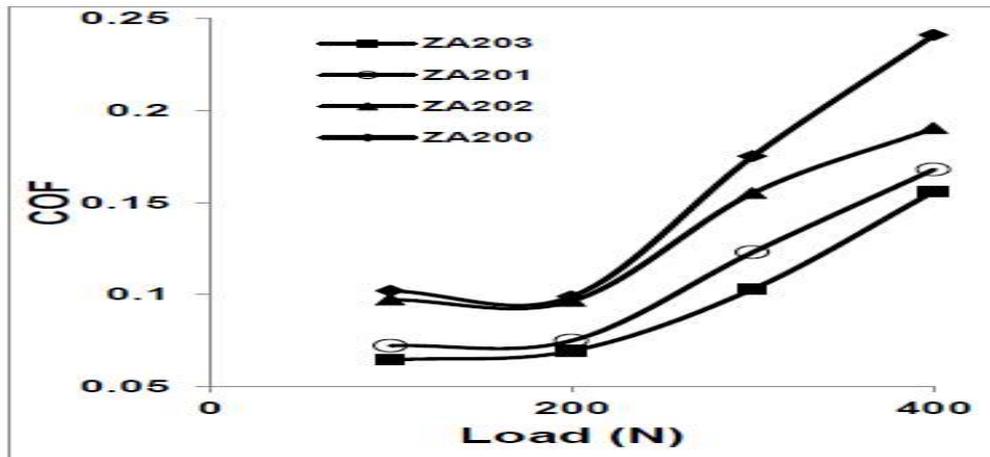


Fig (8): COF vs Load (By EDXS)

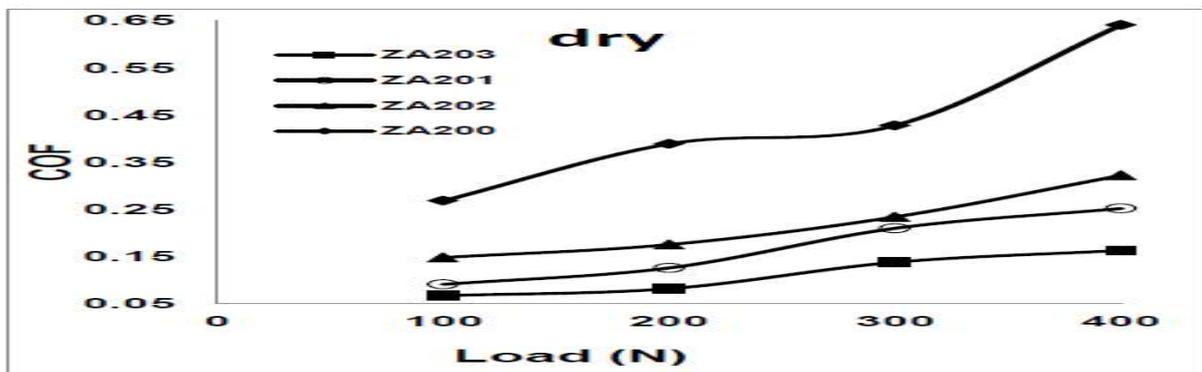


Fig (9): COF vs Load for dry condition

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Final roughness was obtained at the end of the experiments and initial roughness was measured from bearings after the running-in period. The surface finish of the bush was smoother after the test due to metal to metal contact with the shaft for approximately 2½ hours, during this period the shaft has completed; about 1500 revolutions and had traversed a linear distance of 284 meters, the work results are shown in the following figures (10), (11).

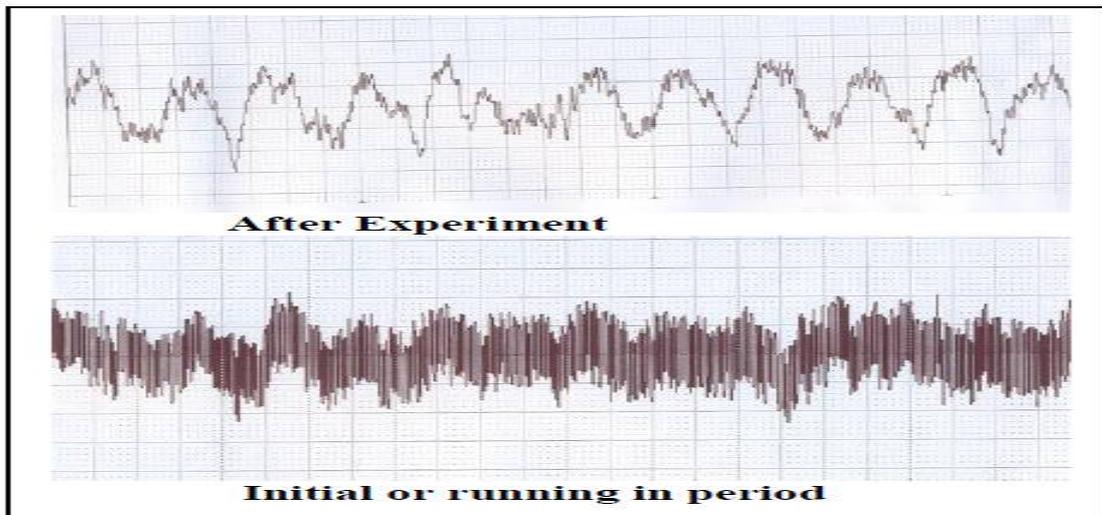


Fig (10): Surface Roughness

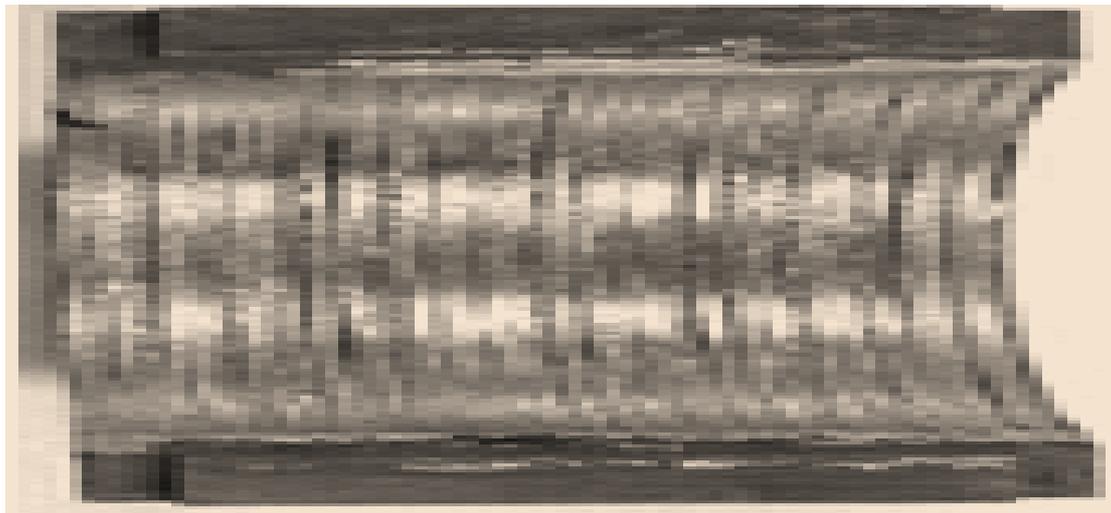


Fig (11): Worn out surface of bearing half sleeve

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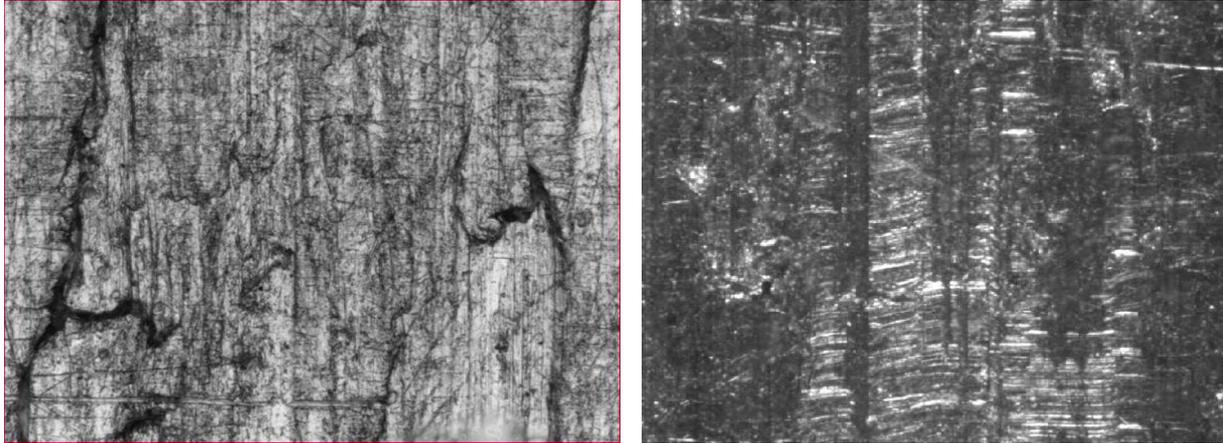


Fig (12): (a) Worn out surface for 400N load (b) Worn out surface of bearing

Composition	ZA200		ZA201		ZA202	
	Ingot	Casting	Ingot	Casting	Ingot	Casting
Al	.020-.030	.015-.030	.020-.030	.015-.030	.012-.020	.010-.020
Mg	0.8-1.3	0.8-1.3	0.5-1.2	0.5-1.2	2.0-2.5	2.0-2.5
Cu	0.8-1.3	0.8-1.3	0.5-1.2	0.5-1.2	2.0-2.5	2.0-2.5
Fe (max)	.065	.075	.065	.075	.072	.075
Pb (max)	.005	.006	.005	.006	.005	.006
Cd	.005	.006	.005	.006	.005	.006
Sn (max)	.002	.003	.002	.003	.002	.003
Zn	Bal	Bal	Bal	Bal	Bal	Bal
Color Code	Blue	Blue	Orange	Orange	Purple	Purple

Table (4): Chemical Specification of ZA alloy (per ASTM) (% by Weight)

Mechanical properties	ZA200		ZA201		ZA202	
	Sand cast	Permanent mold	Sand cast	Permanent mold	Sand cast	Permanent mold
Ultimate tensile strength [ksi (MPa)]	38 (263)	32-37 (221-255)	40-46 (276-317)	45-50 (310-345)	58-64 (400-441)	45-47 (310-324)
Yield strength - 0.2% offset [ksi (MPa)]	29 (200)	30 (206)	31 (214)	39 (269)	54 (372)	37 (255)
Elongation [% in 2'']	1-2	1-2	1-3	1-3	3-6	8-11
Shear strength [ksi (MPa)]	-	35 (241)	37 (255)	-	42 (290)	33 (228)
Hardness [Brinell]	85	85-90	89-105	89-105	110-120	90-110

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Impact strength [ft·lbf (J)]	156 (20)	-	193 (25)	-	353 (47)	433 (58)
Fatigue strength rotary bend in 5x10⁸ cycles [ksi (MPa)]	-	7.5 (52)	15 (103)	-	25 (172)	15 (103)
Compressive yield strength 0.1% offset [ksi (MPa)]	29 (199)	31 (214)	33 (227)	34 (234)	48 (331)	37 (255)
Modulus of elasticity [psi x 10⁶ (MPa x 10³)]	12.4 (85.5)	12.47 (85.5)	12.07 (82.7)	12.07 (82.7)	11.37 (77.9)	11.37 (77.9)
Poisson's ratio	0.29	0.29	0.30	0.30	0.32	0.32

Table (5): Properties of various zinc aluminium alloys

Roughness (µm)	CuSn10	CuZn30	ZnAl Alloy	AlCuMg2	SnPbCuSb
Before wear	1.61	2.5	1.01	3.51	1.33
After wear	1.83	1.85	1.12	5.21	2.62

Table (6): Roughness of bearing materials.

Alloy	Fully lubricated (µ)	Semi dry (µ)	Dry (µ)	Minimum Load 100N (µ)	Maximum Load 400N (µ)	Wear Range In (µm)	Hardness range	predictions
Babbitt	0.29- 0.41	0.34-0.46	0.41-0.60	0.19-0.24	0.38-0.52	0.12-0.18	58-64	IN USE
ZAC	0.09-0.19	0.11-0.21	0.19-0.28	0.08-0.11	0.19-0.23	0.07-0.11	56-62	SUGGESTED

Table (7): Experimental results Comparison for Co- efficient of friction (µ) between BABBITT materials and ZAC alloy material of journal bearings.

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V. CONCLUSION

Fly ash and Graphite particulate obtained are representing an attractive dispersion to provide low cost MMCs. The graphite and fly ash particle reinforced exhibited reduced dry wear loss than the unreinforced alloy. The wear loss decreased with increasing in fly ash and Graphite content. The dry wear loss of composites as well as the matrix alloy increased with the increase in load applied. The friction coefficient of zinc-aluminium alloy metal matrix composite decreases with increase in percentage of reinforcement. An average value of coefficient of friction in lubricated test is low as compared to dry test. The better performance of the ZA bearing is mainly attributed to different phases like α phase which acts as load bearing phase and deformability characteristics while η of Zn solid lubrication by smearing on the contacting surfaces. Formation zinc-di- thiophosphate film at the interface. This zinc base organic product improves the conformability and embedability of the bearings so they can perform better under severe running conditions and low rates of lubrication. Thick lubricant film was formed in hydrodynamic region that is reason why μ increases. Rubbing-in patches were observed in all the bushes at the inner surface, corresponding to the zone where the journal was in contact with the bearing. The shaft was also roughened at the corresponding area. This is due to the presence of loose wear particles lodged at the interface.

REFERENCES

- [1] Alex de Kraker, Ron A.J. van Ostayen "Calculation of Stribeck curves for (water) lubricated journal bearings" Tribology International 40, 459-469 (2007).
- [2] J. P. O'Donoghue and W. B. Rowe "Hydrostatic bearing design" Tribology November, 225-232, 1969.
- [3] Haoran Geng "Friction and wear of Al-Zn-Pb bearings" Wear 169, 201-207 (1993).
- [4] Bo Jacobson "The Stribeck memorial lecture" Tribology International 36, 781 (2003).
- [5] A. W. J. De Gee "Selection of materials for lubricated journal bearings - determination of the critical roughness parameter" Wear, 42, 251 - 261-1977.
- [7] P. Fornallaz, J. Gehrig "Test rig for the automatic analysis of friction and wear in journal bearings under unlubricated friction conditions" Wear, 41, 63 - 69- 1977.
- [8] A. W. J. De Gee "Selection of materials for lubricated journal bearings" Wear, 36, 33 - 61(1976).
- [9] Kenneth Unklesbay, Glenn E. Staats and Donald L. Creighton "Optimal design of journal bearings" Int. J. Engg Sci., Vol. 11,973-983, 1973.
- [10]. Sharma, S. C., Sathish, B. M., Girish, B. M., Kamath, R., Asanuma, H. Dry Sliding Wear of Short Fiber Reinforced Zinc-Aluminium Composites Wear 31: 183 - 189, 1998.
- [11]. Sharma, S. C., Girish, B. M., Kamath, R., Sathish, B. M. Effect of SiC Particles Reinforcement in Al6065 Alloy .Journal of Material Science 315 : 298 - 305: 1999.
- [12]. Sharma, S. C., Girish, B. M., Somashekar, D. R., Satish, B. M., Kamath, R. Sliding Wear Behaviour of Zircon Particles Reinforced ZA-27 Alloy Composite Materials Wear 224: 89 - 94: 1999.
- [13]. Dutt, I., Allan, S. M., Hafley, J. L. Wear Behaviour of Zinc-Aluminium/SiCp MMCs Journal of Metallurgical and Material Transactions A 22:2553- 1991.
- [14]. Mitra, R., Rama Rao, V. V., Mahajan, Y. R. Dry Sliding Wear Behaviour of ZA-27/ Alumina Particle MMCs Mat.Sci. and Tech. 13: 415, 1997.
- [15]. Prasad, B. K. A.K.Patwardhan, A.H.Yegneswaran "Dry sliding wear Characteristics of some Zinc-Aluminium alloys: a comparative study with a conventional bearing bronze at a slow speed", Wear 199, 142-151(1996).
- [16]. Samuel Murphy., Temel Savaskan. "Comparative Wear Behaviour of Zn-Al-Based alloys in automotive engine applications". Wear 98: 151-161- 1984.