Open Access Scientific Reports

Kumar and Rajavel, 1:2
http://dx.doi.org/10.4172/scientificreports.177

Research Article Open Access

Different Hardness Sol-gel Surface Treatment of A390 Aluminium Alloy and its Tribological Effects

John Presin Kumar[1] and R. Rajavel[2]

[1]*Mechanical Engineering Department, Singhania University, Pacheri Bari, Distt, Jhunjhunu (Rajasthan), India*

[2]*Mechanical Engineering Department, International City, Manipal University, Dubai-345050, UAE*

Abstract

In this work, the suitability of aluminium A390 for bearing application is analyzed by means of sol-gel surface coating of Chromium nitrate $Cr(NO_3)_3$ of different hardness values. A380 is better known for its application as aluminium bearing material but it is little more costlier than A390. Therefore the ways in which A390 can be improved in properties like A380 is worked out in this work and sol-gel treatment technology associated with dip coating is utilized as the surface treatment technique. Wear loss and Specific Wear Rate analysis are done for these materials for comparing A390 with A380. In terms of specific wear rate, it is found that A390 hardened to 55 HRC has equivalent properties to A380 and cost effective.

Keywords: Sol-gel; SEM; EDAX; XRD; AFM; Pin-on-disc

Introduction

Aluminium alloys should possess better wear resistance and anti friction properties especially those used for bearing applications. Where is the removal of the material from the surface of a solid body as a result of mechanical action of the counter body. A380 and A390 are important aluminium related bearing alloys which finds many conventional usage for the same. Chromium nitrate Cr(NO3)3 is selected as the coating material for A390 alloy because of its anti-wear properties. In sol-gel technology, the coating material is first synthesized and then coated on the material using dip-coating for different hardness values such as 55HRC, 65 HRC etc using variations in heat treatment furnace temperature, aging time duration etc. Wear test is done using pin-on-disc apparatus and the specific wear rate results are compared for both the alloys (Table 1).

Methodology

Aluminium alloys A390 and A380 are compared for tribological behavior after surface modifications using different hardness sol-gel treatment.

Wear testing

The pin-on-disc apparatus wear tests are done in three trials in order to incorporate the various changes in heat treatment furnace temperature, aging time duration etc. These tests were carried out at a constant load of 3 kg and a sliding velocity of 3 m/s with different sliding distances of 250 m, 500 m and 1000 m keeping other parameters constant and the results are presented in the tables below. Secondly wear tests were carried out for a constant sliding distance of 1000 m with a sliding velocity of 2 m/s and under various load conditions of 2.5 kg, 5 kg and 10 kg.

Wear test nature	Symbol
Sliding Distance of 250m with a Sliding Speed of 3m/S and applied load of 3kg.	WearTest1
Sliding Distance of 500m with a Sliding Speed of 3m/S and Applied Load of 3kg.	WearTest2
Sliding Distance of 1000m with a Sliding Speed of 3m/S and Applied Load of 3kg.	WearTest3
Sliding Distance of 1000m with a Sliding Speed of 2m/S and Applied Load of 2.5kg.	WearTest4
Sliding Distance of 1000m with a Sliding Speed of 2m/S and Applied Load of 5kg.	WearTest5
Sliding Distance of 1000m with a Sliding Speed of 2m/S and Applied Load of 10kg.	WearTest6

Table 1: Symbolic Name for the Different Specimens Used.

Conclusions

The dry sliding wear behavior was studied on aluminium alloys for bearing application in this work. In overall, A390 Hardened to 55 HRc (C1 specimens) performs better than untreated specimen and also A380 alloy but its performance is less compared to A390 Hardened to 60 HRc (C2 specimens) (Table 2). A390 hardened to 55 HRc is found to be equivalent to A380 and cost effective. The SEM examination suggests that the mechanism of material removal is due to plastic deformation. In detail, The reducing agent called Poly Vinyl Alcohol (PVA) (Table 3-5) proved to be a better reducing agent.

- Temperature of size reduction 210°C before aging showed to be the proper temperature.
- Aging time duration of 8 hours seemed to be better over other values.
- Temperature of heat treatment of the order of 800°C was the perfect one.
- Time duration of 5 hours inside the furnace for heat treatment proved to be ideal.

S.No	Specimen name	Specimen symbol
1	Untreated A390 specimen	U
2	$Cr(NO_3)_3$ sol-gel treated A390 having surface hardness of 55 HV	C1
3	$Cr(NO_3)_3$ sol-gel treated A390 having surface hardness of 60 HV	C2
4	Untreated A380 specimen	C3

Table 2: Symbolic Name for the Different Specimens Used.

***Corresponding author:** John Presin Kumar, Mechanical Engineering Department, Singhania University, Pacheri Bari, Distt, Jhunjhunu (Rajasthan), India, E-mail: jpk_1977@yahoo.co.in

Received January 02, 2012; **Published** July 26, 2012

Citation: Kumar JP, Rajavel R (2012) Different Hardness Sol-gel Surface Treatment of A390 Aluminium Alloy and its Tribological Effects. 1: 177. doi:10.4172/scientificreports.177

Copyright: © 2012 Kumar JP, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Citation: Kumar JP, Rajavel R (2012) Different Hardness Sol-gel Surface Treatment of A390 Aluminium Alloy and its Tribological Effects. 1: 177. doi:10.4172/scientificreports.177

Specimen	WearTest1		WearTest2		WearTest3		WearTest4		WearTest5		WearTest6	
	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)
U	0.00093	0.000083	0.00169	0.000088	0.0037	0.000093	0.00097	0.000051	0.00096	0.000055	0.00095	0.000064
C1 (1.5 hrs)	0.00063	0.000043	0.00097	0.000066	0.0015	0.000072	0.00164	0.000033	0.0026	0.000043	0.00096	0.000053
C1 (2 hrs)	0.00057	0.000034	0.00079	0.000057	0.00099	0.000064	0.00068	0.00003	0.00074	0.000042	0.00077	0.000055
C1 (2.5 hrs)	0.00045	0.000032	0.00068	0.000039	0.00088	0.000053	0.00055	0.000025	0.00069	0.000028	0.00064	0.000036
C2 (3 hrs)	0.00047	0.000028	0.00098	0.000074	0.00097	0.000082	0.00076	0.000033	0.00093	0.000036	0.00098	0.000047
C2 (8 hrs)	0.00055	0.000026	0.00065	0.000062	0.00087	0.000073	0.00054	0.000026	0.00086	0.000034	0.00086	0.000046
C2 (9 hrs)	0.00038	0.000024	0.00057	0.00004	0.00065	0.000055	0.00048	0.000018	0.00047	0.000026	0.00056	0.000045
C3 (11 hrs)	0.00025	0.00002	0.00075	0.000055	0.00085	6.12E-05	0.00057	0.000028	0.00059	0.000032	0.00069	0.000057
C3 (15 hrs)	0.000035	0.000018	0.00046	0.00004	0.00068	0.000058	0.0005	0.000023	0.00048	0.000036	0.00049	0.000046
C3 (20 hrs)	0.00039	0.000016	0.00045	0.000037	0.00056	0.000046	0.00038	0.000018	0.00037	0.000034	0.00036	0.00004

Table 3: Reducing agent called Poly Vinyl Alcohol (PVA), Temperature of size reduction 210ºC, Aging time duration of 8 hours, Temperature of heat treatment of the order of 800ºC, Time duration of 5 hours inside the furnace, Particle size of coating material of 180nm, Aging time duration of 10 hours, Temperature inside the furnace of 350ºC for dip coating, Time duration inside the furnace of the order of 7 hours.

Specimen	WearTest1		WearTest2		WearTest3		WearTest4		WearTest5		WearTest6	
	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)
U	0.00094	0.000085	0.00179	0.000091	0.0038	0.000095	0.00098	0.000054	0.00097	0.000058	0.00096	0.000066
C1 (1.5 hrs)	0.00064	0.000045	0.00098	0.000066	0.0017	0.000073	0.00165	0.000034	0.0027	0.000045	0.00097	0.000053
C1 (2 hrs)	0.00058	0.000034	0.00089	0.000058	0.00129	0.000066	0.00069	0.00003	0.00075	0.000042	0.00078	0.000055
C1 (2.5 hrs)	0.00046	0.000035	0.00069	0.000039	0.00089	0.000054	0.00056	0.000025	0.00079	0.000028	0.00074	0.000036
C2 (3 hrs)	0.00048	0.000028	0.00099	0.000075	0.00098	0.000084	0.00076	0.000035	0.00094	0.000037	0.00099	0.000047
C2 (8 hrs)	0.00056	0.000027	0.00066	0.000062	0.00088	0.000075	0.00055	0.000028	0.00087	0.000034	0.00087	0.000047
C2 (9 hrs)	0.00039	0.000025	0.00058	0.00004	0.00066	0.000057	0.00049	0.000018	0.00048	0.000027	0.00057	0.000047
C3 (11 hrs)	0.00025	0.00003	0.00076	0.000055	0.00086	0.000065	0.00059	0.000029	0.00062	0.000034	0.00069	0.000057
C3 (15 hrs)	0.000036	0.00002	0.00047	0.00005	0.00069	0.000058	0.00047	0.000025	0.00051	0.000037	0.00052	0.000048
C3 (20 hrs)	0.00041	0.00002	0.00046	0.00004	0.00058	0.00005	0.00038	0.000019	0.00038	0.000036	0.00039	0.00004

Table 4: Reducing agent called Poly Vinyl Alcohol (PVA), Temperature of size reduction 210ºC, Aging time duration of 8 hours, Temperature of heat treatment of the order of 800ºC, Time duration of 5 hours inside the furnace, Particle size of coating material of 180nm, Aging time duration of 10 hours, Temperature inside the furnace of 350ºC for dip coating, Time duration inside the furnace of the order of 7 hours.

Specimen	WearTest1		WearTest2		WearTest3		WearTest4		WearTest5		WearTest6	
	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)	Specific wear rate (mm^3/Nm)	Volumetric wear loss (cm^3)
U	0.00096	0.000087	0.0018	0.000091	0.0038	0.000097	0.00098	0.000054	0.00098	0.00006	0.00097	0.000066
C1 (1.5 hrs)	0.00065	0.000047	0.00098	0.000066	0.0018	0.000073	0.0017	0.000034	0.0028	0.000045	0.00097	0.000057
C1 (2 hrs)	0.00058	0.000034	0.0009	0.000059	0.0013	0.000066	0.0007	0.00003	0.0008	0.000046	0.0009	0.000055
C1 (2.5 hrs)	0.00047	0.000035	0.00069	0.000039	0.0009	0.000058	0.0006	0.000028	0.0008	0.000028	0.00074	0.000036
C2 (3 hrs)	0.0005	0.000029	0.00099	0.000078	0.00099	0.000087	0.00077	0.000037	0.00094	0.000037	0.00099	0.000047
C2 (8 hrs)	0.00056	0.000027	0.00067	0.000064	0.00089	0.000075	0.00056	0.000028	0.00088	0.000036	0.00088	0.000047
C2 (9 hrs)	0.00039	0.000027	0.0006	0.00004	0.00066	0.000058	0.00049	0.000019	0.00049	0.000027	0.00058	0.000049
C3 (11 hrs)	0.00027	0.00005	0.00078	0.000055	0.00087	0.00007	0.0006	0.00003	0.00064	0.000034	0.00069	0.00007
C3 (15 hrs)	0.000037	0.00002	0.00047	0.00006	0.00069	0.000058	0.00048	0.000025	0.00053	0.00004	0.00052	0.000048
C3 (20 hrs)	0.00043	0.00002	0.00047	0.00005	0.00059	0.00006	0.00039	0.00002	0.0004	0.000036	0.00039	0.00005

Table 5: Reducing agent called Poly Vinyl Alcohol (PVA), Temperature of size reduction 210ºC, Aging time duration of 8 hours, Temperature of heat treatment of the order of 800ºC, Time duration of 5 hours inside the furnace, Particle size of coating material of 180nm, Aging time duration of 10 hours, Temperature inside the furnace of 350ºC for dip coating, Time duration inside the furnace of the order of 7 hours.

- Particle size of coating material of 180 nm promised to be best.
- Aging time duration of 10 hours was the correct value over other possible durations.
- Temperature inside the furnace of 350ºC for dip coating seemed to be giving better results.

Time duration inside the furnace of the order of 7 hours proved to be best out of all other values.

References

1. Zhang Ying, Yi Dan-qing, Li Wang-xing, Ren Zhi-sen, Zhao Qun, et al. (2007) Transformation of microstructure after modification of A390 alloy. Trans Nonferrous Met Soc China 17: 413-417.
2. Prasad SV, Asthana R (2004) Aluminium metal-matrix composites for automotive applications: tribological considerations. Tribology Letters 17: 445-453.
3. Shi B, Ajayi OO, Fenske G, Erdemir A, Liang H (2003) Tribological performance of some alternative bearing materials for artificial joints. Wear 255: 1015-1021.

4. K Zhang (2005) Effects of test conditions on the tribological behavior of a journal bearing in molten Zinc. Wear 259: 1248-1253.

5. Fei Zhou, Koshi Adachi, Koji Kato (2006) Friction and wear behavior of BCN coatings sliding against ceramic and steel balls in various environments. Wear 261: 301-310.

6. Wang L, Nie X, Lukitsch MJ, Jiang JC, Chang YT (2006) Effect of tribological media on tribological properties of multilayer Cr(N)/C(DLC) coatings. Surface and coatings technology 201: 4341-4347.

7. David A. Mower (2007) An investigation of wear resistant coatings on an A390 die-cast aluminium substrate, M. S Thesis, BrighamYoung University.

8. Podgoric S, Jones BJ, Bulpett R, Troissi G, Franks J (2009) Diamond like carbon/epoxy low friction coatings to replace electroplated chromium. Wear 267: 996-1001.

9. Musameh SM, Jodeh SW (2007) Tribological behavior of chromium nitride coating by unbalanced magnetron sputtering. J of active and passive electronic devices 2: 93-103.

10. Krzysztof C Kwiatkowski, Charles M Lukehart (2000) Nanocomposites prepared by sol-gel methods, Dept of chemistry, Vanderbilt University, USA.