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Experimental Studies on Tensile and Wear Behaviour of Precipitation Hardened AA2024 (Al-4.5Cu) Alloy

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Abstract
In the present study, tensile and wear behaviour of AA2024 alloy were studied. Squeeze casting process was used to produce AA2024 alloy. Squeeze cast AA2024 alloy reveals distribution of both soluble and insoluble intermetallic compounds in the α-aluminium matrix. In order to improve the mechanical properties and condition the microstructural features, precipitation hardening (solutionizing and ageing) treatment was carried out by keeping temperature and time as variables. Ageing treatment was carried out at 120°C with varying time interval. Tensile and hardness studies were carried out on the aged alloys. There is a greater increment in strength and hardness at precipitation conditions. Wear behavior of the alloy was studied using the pin-on-disc technique with varying load and keeping sliding speed and time as constant. Precipitation hardened alloy shows better wear resistance than that of cast and solutionized alloy

Keywords: AA2024 alloys, Precipitation hardening, tensile behaviour, Wear.

1. Introduction

Of late, the automotive and aerospace industries are looking for light weight structural alloys for better fuel consumption and cost saving. In current industrial practice, the use of AA2xxx series alloys plays a vital role. It is due to their superior mechanical properties, corrosion resistance, weldability and good wear resistance etc. In the present investigation, the alloying elements such as Cu had been increased and suitable thermal treatments, precipitation hardening treatment (T6), was carried out to improve the mechanical properties. It was observed formation of complex intermetallic compounds in aluminum alloy by increasing alloying content [1-5]. A specific morphology and size of intermetallic compound obtained by heat treatment contributed in strengthening of alloy. Copper containing AA 2xxx series, Al-4.5Cu alloy was widely used for airplane wing structures. It was well documented that copper addition increased the volume fraction of precipitates in Al-Zn-Mg alloy and enhanced stress corrosion cracking (SCC) resistance [6-9]. Precipitation hardening treatment is intensely used in industry for a variety of heat treatable Al alloys to increase their strength by fine tuning coherent / semi-coherent precipitates such as $MgZn_2$, Al_2Cu, etc.

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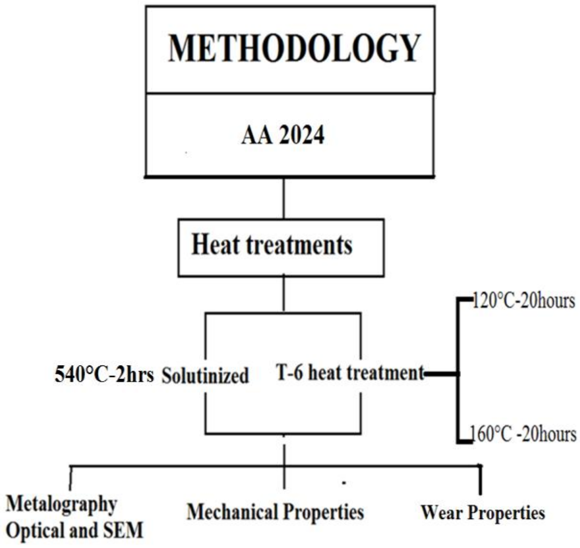
Squeeze casting is a unique technique which minimizes porosity with controlled structural refinement. The squeeze casting process, combing the advantage of casting and forging processes, has been widely used to produce quality casting and producing complex parts with high dimensional accuracy and repeatability. This process helps in producing near-net components [10-12]. Cast Al-12Zn-3Mg-2.5Cu alloy revealed complex microstructure with lamellar eutectic [13]. Addition of 2 wt.% Al–5Ti–1B master alloy to Al–12Zn–3Mg–2.5Cu alloy showed the reduction its grain size and subsequently increased in strength and hardness by T6 heat treatment [14]. C912 alloy in aged condition showed strength more than 700 MPa with good stress corrosion resistant [15]. Wear and tear of engineering components is the big issue in industries such as automotive, etc. Wear studies of aluminum alloys and composites were widely studied many researchers. It was reported that composites and alloy with hard dispersoids exhibited better wear resistance than that of base alloys. Ammar J. Khaleel et al reported that the effect of zinc addition in aluminum to resist dry sliding wear. The results showed that the wear rate decreases with increasing the Zinc proportion for the test samples [16]. AA7075 alloy reinforced with SiC via powder metallurgy method had resulted increasing wear resistance. Formation of mechanically mixed layer (MML) during wear test increased the wear resistance [17]. M. Alipour reported dry sliding wear performance of the Al–12Zn–3Mg–2.5Cu in normal atmospheric conditions. The T6 treated aluminium alloy showed considerably improved wear resistance to the dry sliding wear [18]. Cast A7075 and AA7075 SAF 2205 composite were processed by liquid metallurgy route. It was concluded that composite material had lower friction coefficient, less weight loss and slower wear rate than that of cast material [19].

1.2 Methodology



2. Experimental procedure

Al-4.5Cu (wt.%) alloy was prepared by squeeze casting method with controlled process parameters. The raw materials were melted in a crucible type furnace at 750°C and poured in to the preheated die. Before pouring, the liquid metal was treated with flux and 5Ti-1B as grain refiner. The liquid metal was pressed at 30MPa in a hydraulic press. Before pressing, the die was preheated at 300°C with the help of heating rod. In order to understand the precipitation hardening (T6) behaviour, the alloy was solution treated at 540°C for 24hrs followed by water quenching. Ageing treatment was carried out at 120°C, 20hrs with varying time interval. Mechanical properties such as hardness and tensile studies were conducted on cast and precipitation hardened

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AA 2024 alloy. Tensile and hardness tests were conducted using Tinius Olsen, UK (Model: H50 KS) tensile machine and Wilson hardness, respectively. Dry sliding wear tests were conducted using a conventional pin-on-disc testing machine to appraise room temperature wear behaviour of the AA 2024 aluminum alloy. Wear test samples were prepared as per ASTM G99 standards. The specimen (cylindrical pin) size is 6 mm diameter and 12 mm length as shown in fig.1. The rotating disc was made up of EN-32 steel with hardness of 65HRC. Weight loss was determined from the final and initial weight with the help of precision electronic balance accuracy of 0.001g. The tests were conducted with varying load (10N to 40N) and constant speed 2000m. The following equations were used to determine wear rate.

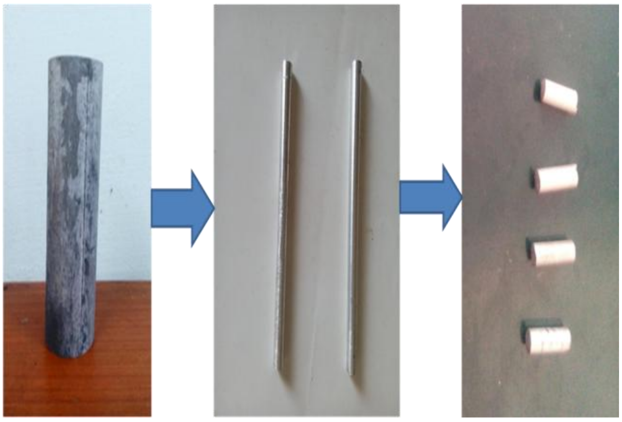

Fig. 1 Wear samples of AA 2024

Parameters taken constant during sliding wear test

Distance between centre of disc and centre of sample (r) = 21.8mm

Diameter (d) = 43.6mm

Velocity (V) = πdN/60

1.2 = π x (43.6 x 10-3) x N/60

N = 526rpm

Time (t) = Displacement / Velocity = 2000/1.2 = 1666.67s

Wear calculation

Wear rate = Volume loss / Sliding distance

Volume loss = mass loss/ density

Wear resistance = 1/ Wear rate

Specific wear rate = Wear rate/load

Wight loss = 0.1g for as cast material on 40n load

Volume = (mass/density) = 0.1/2.8

= 35.71X 10-3 cm3 = 35.71 mm3

Wear rate = 35.71/2000 = 1.785X10-5 (mm3/m)

3. Result and Discussion

3.1 Wear behaviour of precipitation hardened (T6) AA 2024 alloy

Wear data obtained for AA 2024 alloy at different conditions are tabulated (Table-1). Figure 2 relates the wear rate with increasing load. Wear rate of cast ($4.11x10^{-5}mm^3/m$) condition is more than aged ($3.21x10^{-5}mm^3/m$). Wear rate of cast is 20% more than that of aged conditions. Wear rate increases with increase in applied load from $1.8x10^{-5}mm^3/m$ for 10N to $4.11x10^{-5}mm^3/m$ for 40N load with an increase of 55%. Coefficient of friction almost remains constant for all the time of wear. Coefficient of friction increases from 0.43 for 10N load to 0.54 for 40N load causing overall increase of 55%.

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Table-1 Wear data obtained for AA 2024 alloy at different conditions

Conditions	Mass loss (g)	Volume (mm^3)	Wear rate (mm/m^3)	COF
Cast				
10N	0.100	35.71	1.78×10^{-5}	0.43
20N	0.145	51.78	2.60×10^{-5}	0.48
30N	0.190	67.85	3.40×10^{-5}	0.52
40N	0.230	82.14	4.11×10^{-5}	0.54
Solutionized (450°C-24hrs)				
10N	0.135	48.21	2.41×10^{-5}	0.32
20N	0.180	64.28	3.21×10^{-5}	0.36
30N	0.230	82.14	4.10×10^{-5}	0.39
40N	0.280	100	5.00×10^{-5}	0.41
Aged (120°C-20hrs)				
10N	0.080	28.57	1.428×10^{-5}	0.52
20N	0.120	42.85	2.142×10^{-5}	0.54
30N	0.160	57.14	2.857×10^{-5}	0.59
40N	0.200	71.42	3.214×10^{-5}	0.68

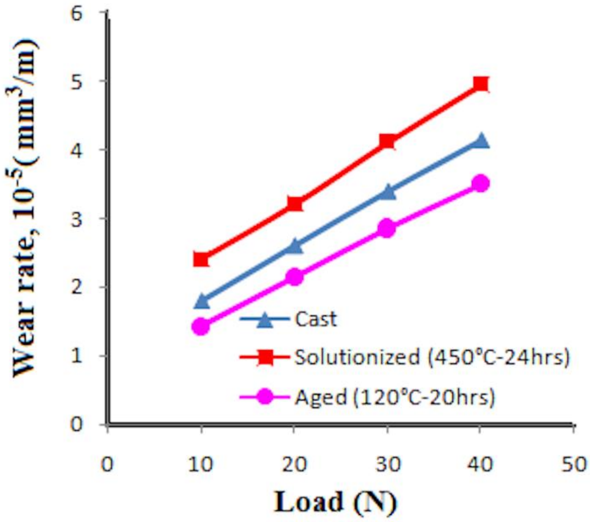

Fig. 2 Wear rate of different loads on AA 2024 alloy a) Cast b) Solutionized and c) Aged (120˚C-20hrs) conditions

3.2 SEM micrograph wear track surface of AA 2024 alloy after T6 treated at 120˚C for 20hrs

Figure 3 shows the worn surface of AA 2024 Cu alloy at different conditions cast, solutionized and aged. Figure 3a shows the worn surfaces of the cast alloy and it can be observed that the alloys at low velocity mild oxidation wear marks are visible. Figure 3b and 3c show the worn surface of solutionized alloy and Aged (120˚C-20hrs). The worn surface has mainly oxidation marks and debris particle due to delamination.

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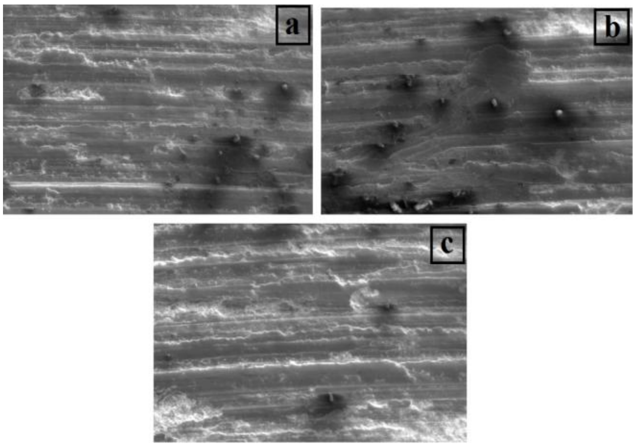

Fig 3 SEM micrograph wear track surface of AA 2024 alloy after T6 treated at 120˚C for 20hrs in different conditions a) Cast b) Solutionized and c) Aged (120˚C-20hrs) conditions

The relation between sliding distance and coefficient of friction of alloy is expressed in fig. 4. Before attaining the stable region, A running-in period is observed before attaining the stable region. It is noticed the stable value of coefficient of friction followed by strong fluctuation in the friction coefficient in cast, solutionized and aged conditions. Figure 5 shows the friction coefficient of the AA 2024 aluminum alloy under the load of 10N to 40N, respectively. The friction coefficient is increased at the starting of sliding with increasing load. Solutionized condition shows lower friction coefficient than that of cast condition because of plastic nature of solutionized alloy. Aged alloy shows higher friction coefficient than that of conventional AA 2024 alloy because of effect of precipitation hardening.

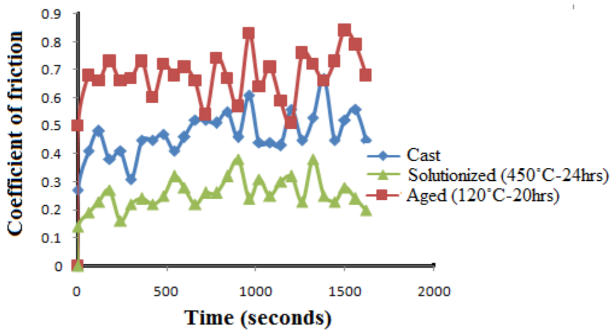

Fig 4 Coefficient of friction comparing time of wear on load at 40N, AA 2024 alloy
a) Cast b) Solutionized and c) Aged (120˚C-20hrs) conditions

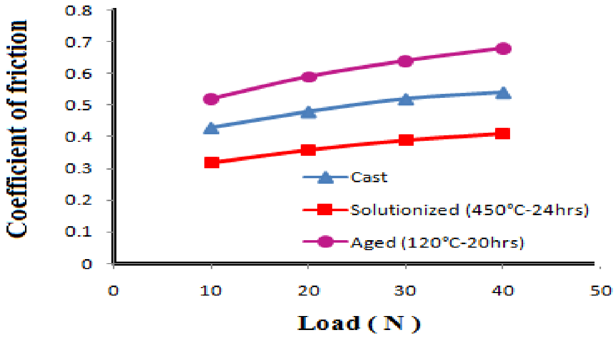

Fig 5 Coefficient of friction comparing different loads on AA 2024 alloy
a) Cast b) Solutionized and c) Aged (120˚C-20hrs)

SEM micrographs of worn surfaces of AA 2024 aluminum alloy after T6 treated at 120˚C for 20hrs in different loads at10N, 20N, 30N and 40N are shown in Fig. 6. The worn surface of alloy tested in 10N load is shown in Fig. 6 a. Micrograph shows the shallow grooves, scratches and fractured oxide layers. The worn surfaces of alloy with 20N and 30N show little rough surface and insoluble particles are observed. Similar trend is observed with 40N. The coalescence of wear tracks and sub-surface delamination are produced wear cracks. Due to the delamination of the sub-surface layers, the materials removal is being taking place. At higher load, 40N, the insoluble hard particles remove the materials by abrasion. The grooves indicate the removal of thick oxide layers. The deposited oxide debris in the grooves acts as wear resistant layer.

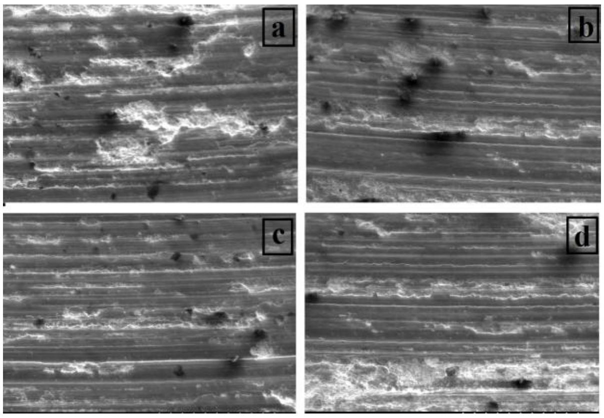

Fig 6 SEM micrograph wear track surface of AA 2024 alloy after T6 treated at 120˚C for 20hrs in different conditions a) 10N, b) 20N, c) 30N and- d) 40N

4. Conclusions

1. AA 2024 alloy shows coarse intermetallic compound, both soluble and insoluble, homogeneously distributed throughout the matrix and grain boundaries.
2. Precipitation behaviour of AA 2024 alloy is a bit sluggish due to the presence of insoluble intermetallic compounds which delay the solutionizing of soluble compounds and evolution of fine precipitates during ageing.
3. Precipitation hardening results increment in UTS than that of cast alloy with 6% ductility.
4. This is attributed by nano-scale size of precipitates distributed homogeneously throughout the matrix.
5. Precipitation hardened alloy shows increased wear resistance than that of cast and solutionized alloy. However, the co-efficient of friction is low.

5. Reference

[1] M. Alipour, B.G. Aghdam, H. Ebrahimi Rahnoma, M Emamya**.** Investigation of the effect of Al–5Ti–1B grain refiner on dry sliding wear behaviour of an Al–Zn–Mg–Cu alloy formed by strain-induced melt activation process. Materials and Design, 2013, 46: 766–775.

[2] G. Chen, J. Jiang, DU. Zhiming, QI Cao, XIN Zhang**.** Formation of Fine Spheroidal Microstructure of Semi-Solid AleZneMgeCu Alloy by Hyperthermally and Subsequent Isothermally Reheating. Materials Science and Technology, 2013, 29(10): 979-982.

[3] M. Dixit, R.S. Mishra, K.K Sankaran**.** Structure–property correlations in Al 7050 and Al 7055high-strength aluminum alloys. Materials Science and Engineering A, 2008, 478: 163–172.

[4] M.F. Ibrahim, A.M. Samuel, F.H. Samuel**.** A preliminary study on optimizing the heat treatment of high strength Al–Cu–Mg–Zn alloys. Materials and Design, 2014, 57: 342–350.

[5] R. Ranganatha, V. Anilkumar, S. Vaishaki Nandi, R.R. Bhat, B.K. Muralidhar**.** Multi-stage heat treatment of aluminium alloy AA7049. Transactions of Nonferrous Metals Society of China, 2013, 23: 1570-1575.

[6] Y.G. Liao, X.Q. Han, M.X. Zeng, M.

Jin. Influence of Cu on microstructure and tensile properties of 7XXX series aluminum alloy. Materials and Design, 2014,

[7] T. Dursun, C. Soutis. Recent developments in advanced aircraft aluminium Alloys. Materials and Design, 2014, 56: 862–871.

[8] B. Sarkar, M. Marek, E.A. Sratke. The effect of copper content and heat treat ment on the stress corrosion characteristics of Al–6Zn–2Mg–xCu alloys. Metall Trans A, 1981, 12A: 1939–43.

[9] N.Q. Chinh, J Lendvai, D.H. Ping, K. Hona. The effect of Cu on mechanical and precipitation properties of Al–Zn–Mg alloys. Alloys Compound 2004, 378: 52–60.

[10] L.J.Yang. The effect of casting temperature on the properties of squeeze cast aluminium and zinc alloys. Journal of Materials Processing Technology, 2003, 140: 391–396.

[11] L.J.Yang. The effect of solidification time in squeeze casting of aluminium and zinc alloys. Journal of Materials Processing Technology, 2007, 192–193:114–120.

[12] C. Fatih, S. Can Kurnaz. Hot tensile and fatigue behaviour of zinc–aluminium alloys produced by gravity and squeeze casting. Materials and Design, 2005, 26: 479–485.

[13] N. Pourkia, M. Emamy, H. Farhangi, S.H. Seyed Erahimi. The effect of Ti and Zr elements and cooling rate on the microstructure and tensile properties of a new developed super high strength aluminum alloy. Materials Science and Engineering A, 2010, 527: 5318–5325.

[14] M. Alipour, M. Emamy. Effects of Al-5Ti-1B on the structure and hardness of a super high strength aluminum alloy produced by a strain-induced melt activation process. Materials and Design, 2011, 32: 4485–4492.

[15] Y.L. Wua, U.F.H. Froesa, A.Alaverza, C.G. Lib, J.Liuc. Microstructure of properties of a new super-high strength Al-Zn-Mg-Cu alloy-C912. Materials & Design, 1997, 18(46): 211-215.

[16] Ammar J. Khaleel, Adel M. Bash. Study the effect of Zinc addition on dry sliding wear rate of pure aluminum. Academic Research International. Vol 4 no-5, 2013. 234-243.

[17] B Venkataraman, G Sundararajan. Correlation between the characteristics of the mechanically mixed layer and wear behaviour of aluminium, Al-7075 alloy and Al-MMCs. Wear, 245(1-2) (2000), 22-38.

[18] M. Alipour, M. Azarbarmas, F. Heydari, M. Hoghoughi, M. Alidoost, M. Emamy. The effect of Al–8B grain refiner and heat treatment conditions on the microstructure, mechanical properties and dry sliding wear behavior of an Al–12Zn–3Mg–2.5Cu aluminum alloy. Materials and Design 38 (2012) 64–73.

[19] Ahmet Karaaslan, Alptekin Kısasöz, Ş. Hakan Atapek, Kerem Altuğ Güler. Dry Sliding Wear Behavior of Cast A7075 and A7075/SAF 2205 Composite Material. High Temp. Mater. Proc. 2016; 35(5): 487–492.