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# Effect of microstructure on wear behaviour of aluminium 2014 (Al2014)

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**Abstract.** The paper investigates the effect of ageing on the hardness and wearing of Al2014. Precipitation hardening and ageing were carried out on the samples. The samples were solution treated at 550°C and were naturally aged. Quenching was carried out using ice-brine solution. Vickers Hardness were taken at regular intervals till 900 hours. The peak hardness value of the natural aged sample was found to be 86HV (93 hours) as compared to the untreated sample (32.4HV) The wear tests were conducted at 10N, 500rpm for 30 minutes. After the tribo test it was observed that the coefficient of friction increased by 7.06% in the naturally aged sample, but the wear rate in case of as-received samples was 46% higher than that of the naturally aged sample. The change in the microstructure of Al2014 is the primary reason for the difference in wear rate of the samples. The present work will help to understand the influence of heat treatment of aluminium alloy on wear properties.

## 1. Introduction

Aluminium alloys are strengthened by heat treatment method subject to alloy should have such alloy element which can form coherent precipitate. Aluminium 2014 responds heat treatment. It contains copper, magnesium and silicon as principle alloying element. The strength of the alloy is improved by grain refinement and precipitation hardening techniques significantly [1,2].

According to International Alloy Designation System (IADS) aluminium alloys of 2XXX, 6XXX and 7XXX respectively are heat- treatable. Tempering is an effective form of heat treatment for strengthening of the above aluminium alloys. According to IADS tempering designation T4 indicates alloy has been solution treated, quenched and naturally aged [3].

A similar trend in hardness can also be observed when the heat- treatable aluminium alloys are made into composites. Pavithouran et al studied the hardness properties of Al6061 reinforced with silicon carbide (SiC) and graphite particles.

Hardness increased with increase in SiC but decreased when graphite content increased to a certain level, which is due to the fact that binding energy and also hardness of graphite is less [4]. Chacko et al [5] studied the ageing behaviour of Al2014- 15 vol% SiC composite and found same variation of hardness in T4 and T6 conditions. Jha et al [6] showed that by adding strontium to Al2014- SiC composite hardness can be increased by artificial ageing.

## 2. Experimental details

### *2.1. Material*
The aluminium alloy Al2014 was bought as extruded cylindrical rods of diameter 30 mm from a local vendor at Chennai. Its chemical composition, as shown in Table 1, was obtained by using ASTM E1251- 2011 standard.

**Table 1.** Chemical composition of Al2014 as- received sample.

| Elements | Al | Cu | Si | Mn | Mg | Fe |
|---|---|---|---|---|---|---|
| Weight % | Remainder | 4.639 | 0.799 | 0.638 | 0.594 | 0.187 |

### *2.2. Heat Treatment Process*
Samples of 10 mm diameter and 30mm length were cut from the as- received sample. They were then kept in an alumina crucible and solution treated to 550°C for 1 hour in a furnace. They were then quenched in ice- brine solution. Six of them were put in an alumina crucible and kept in the furnace at 550°C for 1 hour in the furnace.

### *2.3. Measurement of Hardness*
The sample heated to 550 °C (T4 samples) was polished in emery papers of grades 220, 400 and 600 and its hardness was measured using a Vickers Hardness Testing Machine (Make: FIE). A load of 50N was applied. Time of contact of the sample and the indenter was kept as 4 seconds. This process was carried out at intervals for a period of 845 hours.

### *2.4. Measurement of Roughness*
The surface roughness of the samples was measured using a SurfCom contact type of profilometer. The roughness values were kept between 0.2- 0.3 µm.

### *2.5. Investigation of Microstructures of the Samples*
The T4 and as- received samples were again polished on the circular cross- section using emery papers of with grit size 220, 400, 600, 800 and 1000. The samples were then polished on a disc polishing machine, where diamond lubricant spray (Hiffin fluid) was used to moist the velvet cloth and diamond paste was applied on the metal surface which acted as an abrasive material. The polished samples were then washed with running water and then dried. It was then etched with Keller's Reagent with an etching time of 10 seconds. It was again washed with running water and then dried. The microstructures of the samples were studied using an Olympus optical microscope.

### *2.6. Investigation of Wear Characteristics*
The wear characteristics of the samples were tested on a pin-on-disc tribometer manufactured by Magnum in dry condition. The disc was of EN 31 with hardness 58-50 Rc. A load of 10 N was applied on the pin (Al 2014) during the 30 minutes test. The disc was rotated at 500 rpm.

### *2.7. Surface characterization*
In order to understand the severity of the wear, the wear tracks on Al 2014 pin were analysed using a using a FEI Quanta 200 Field Emission Scanning Electron Microscopy.

## 3. Results and Discussions

### *3.1. Hardness*
Figure 1 shows the effect of natural ageing on the sample, which was solution treated to a temperature of 550°C. The hardness first increased till 42 hours and then maintained a constant value. This was

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due to the gain of activation energy at room temperature of the super- saturated metal which led to the formation of Guinier-Preston (GP) zones. GP zones are fine-scaled near the order of 3–10 nm in size of solute enriched regions of the material, which offer physical obstructions to the motion of dislocations. Hardness of the extruded sample was measured as 35.6 HV. Hence the value of hardness increased on T4 treatment. Table 2 shows the values of the hardness measured.

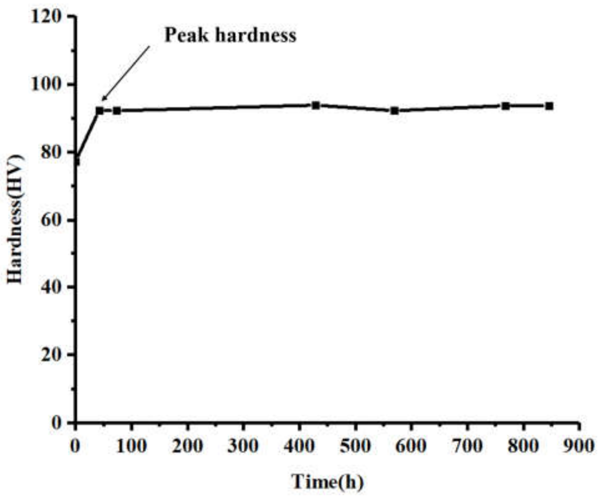


**Figure 1.** T4 hardness curve of the sample.

**Table 2**. Measurement of Vickers Hardness of T4 Sample.

| Time (hour) | Hardness (HV) |
|---|---|
| 0 | 77.3 |
| 42 | 92.27 |
| 73 | 92.23 |
| 429 | 93.87 |
| 569 | 92.23 |
| 767 | 93.67 |
| 845 | 93.60 |

The extruded sample hardness was measured as 32.6 HV. The peak hardness of T4 samples show that it is 93.87 HV, which occurred due to GP Zone formation.

### *3.2. Microstructure*
Figure 2 shows the microstructures of the samples. Figure 2(a) shows the microstructure of the alloy in as received condition (extruded), where the grains are heavily elongated and the θ phase is seen to be elongated at the grain boundary. In Figure 2(b), the second phase is seen to be in lesser amount due to solution treatment. Though, the grain boundaries are not revealed properly, but the shape of the grains seems to be equiaxed. T4 heat treatment have resulted in formation of GP zones, which is not visible in the optical microstructure.

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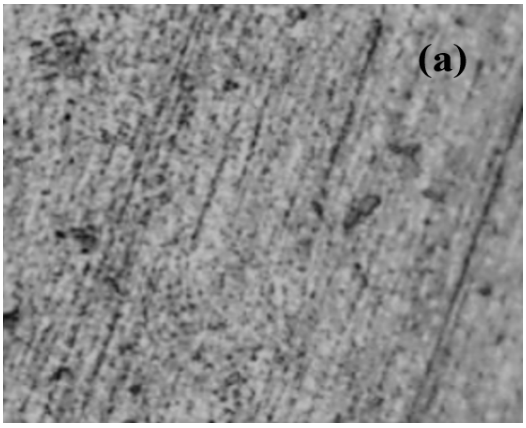


**Figure 2 (a).** Microstructure of extruded sample at 100X.

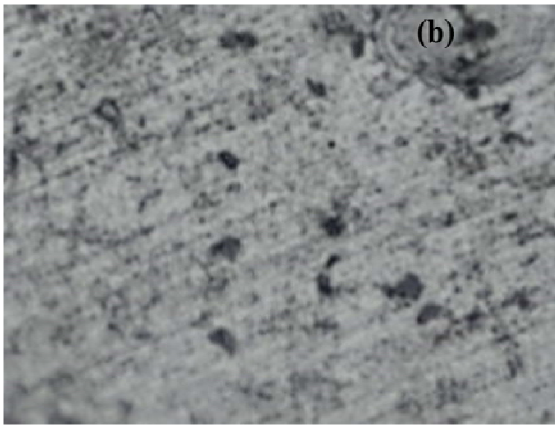


**Figure 2 (b).** Microstructure of T4 sample at 100X.

*3.3. Wear test*

Figure 3 shows that due to ageing treatment (T4) the coefficient of friction is increased, though not significantly. But the wear rate has decreased appreciably. During T4 treatment fine GP zones are formed, which act as harder dispersions in the aluminium matrix. This hard phase reduces the wear rate, but could not influence the coefficient of friction. Due to the heat treatment and formation of GP zones, the hardness of Al2014 has also increased. This increase in hardness could reduce the wear rate to a significant extent.

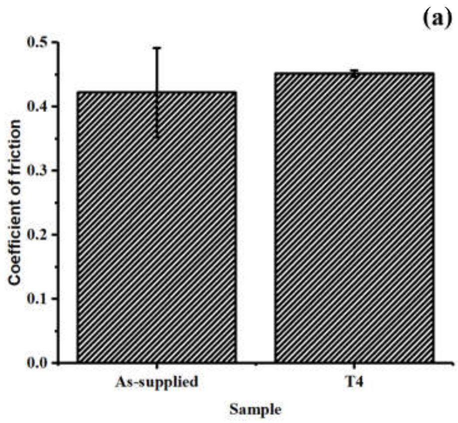


**Figure 3 (a).** Variation of coefficient of friction with the heat treatment.

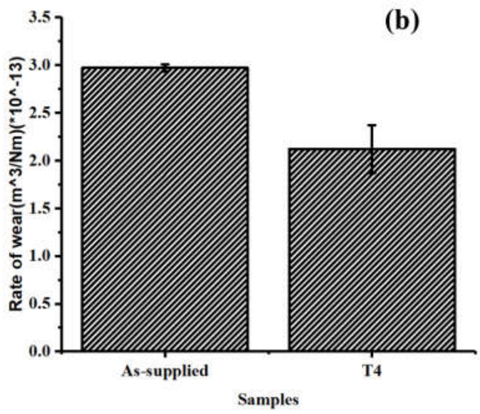


**Figure 3 (b).** Variation of wear with heat treatment.

*3.4. Surface characterization*

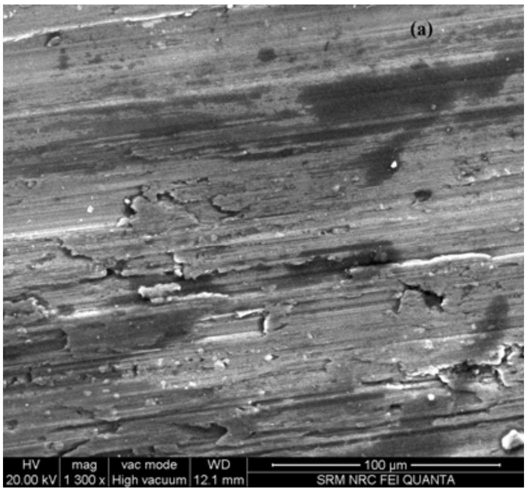


**Figure 4 (a).** FESEM image of extruded sample.

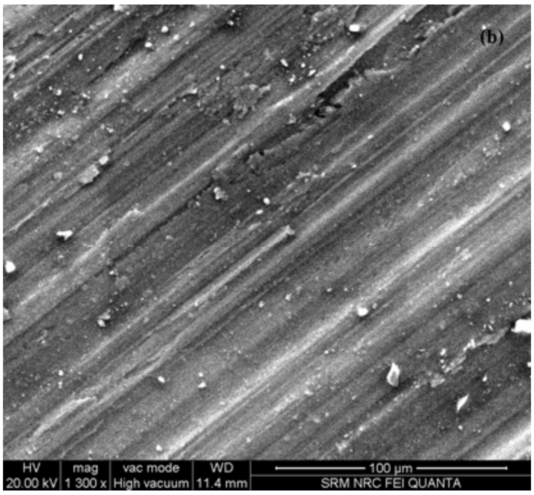


**Figure 4 (b).** FESEM image of T4 sample.

Figure 4 (a) and figure 4(b) show the surface degradation in the two samples. Figure 4(a) shows higher amount of crack as there is more surface-to-surface contact, as compared to T4 sample (figure 4b). This is due to the low hardness of the extruded sample.

## 4. Conclusions

The hardness of T4 sample increased due to the solution treatment of the extruded sample. The results of tribo-tests indicated that the coefficient of friction increased by 7.06% for the hardened sample, but the wear rate in case of as received samples was 46% more than natural aged sample. T4 treatment can be used to increase hardness of an Al2XXX sample and also improve wear properties. The present work will help to understand the influence of heat treatment of aluminium alloy on wear properties. Future test must focus on the wear rate of Al2XXX in long-lasting tests, both for dry and lubricated conditions.

## 5. References

[1] Gadpale V, Pragya B, and Manoj M 2018 *IOP Conf. Series: Mater. Sci. & Eng*. **338**.
[2] Chand S, Madhusudhan D, and Uma A 2016 *Int. J. Adv. in Mech. and Civil Eng.* ISSN: 2394-2827 **3** (3).
[3] Polmear I J 2006 *Light Alloys-4$^{th}$ Ed.* Butterworth-Heinemann eBook ISBN: 9780080496108.
[4] Pavithouran B. and Swathanandan J 2015 *Int. J. Technol. Enhance. & Emerg. Eng. Research* **3** (04).
[5] Chacko M and Nayak P 2014, *Int. J. of Mater. and Metal. Eng.* **8** (3).
[6] Jae - Ho J and Dae - Geun H 2013 *Trans. Nonferrous Met. Soc. China* **23** 631−635.