Study on mechanical and wear properties of hypereutectic Al-18Si-3.6Cu-0.34Ce alloy

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Abstract. In the present study an effort was made to find the mechanical and wear properties of a heat treatable hyper eutectic aluminium-silicon alloy. The alloy was prepared by conventional casting method in the form of ingots, and then chemical compositions of the alloy analysis are made by spectro spark emission spectrometer. The as cast alloy test samples are T6 heat treated by solutionizing at 500°C for 1h followed by water quenching and isothermal ageing treatment at 210°C for different aging time was achieved. The tensile test was carried out for as cast and cast aged conditions of different aging time of 1h, 3h, 5h and 7h. It was observed from tensile test the ultimate tensile strength of 1h (193.83Mpa) and 3h (168.68Mpa) aged (T6 treated) samples improved the UTS by 22% and 7% respectively as compared to as cast sample (158Mpa). Dry sliding Wear test was conducted at constant sliding speed of 1m/s, 2m/s, 3m/s and 4m/s with varying load 10-40N. From the dry sliding wear study confirmed that wear rate and coefficient of friction are load dominant, In spite at higher sliding speed and load lower friction was noticed.

Keywords: Alloy, Hypereutectic, T6 treatment, Wear Rate.

1. Introduction
Aluminum and its alloys are the second most structural material used after the steel due to its versatile engineering properties and have low density of 2.7gm/cm³ Its almost one third of steel (7.83 gm/cm³) weight. Commercially the Al-Si base alloys are most widely used because of their special traits such as high strength to light weight ratios, good castability, better wear resistance, corrosion resistant and machinability [1]. Hyper eutectic Aluminum-Silicon alloys are the most prominent metal composites to manufacture the wear resistant spares used in automobile industry such as engine piston cylinder body, engine head and aerospace industry [1–5] along with this; hyper eutectic aluminum silicon alloys are potentially being used at high temperature environments [6].
The presence of Rare earth metals such as Ce in the hypereutectic Aluminum-Silicon base alloy, the primary silicon crystal were significantly refined, eutectic Silicon phase of large $\alpha$-Al to smaller $\alpha$-Al grain size phase were modified to fine fibrous structure [7].

The rare earth metal Ce can remarkably improve the primary Silicon crystals size and morphology of coarse star like and polygonal shape to finer Si blocky shape with Ce concentration. Ce was an effective modifier for eutectic silicon [7,8]. Hence improves the mechanical and wear properties of the alloy.

Hypereutectic Aluminium-Silicon Alloy with high percentage of silicon (18 wt %) leads the alloy to excellent casting characteristics. Inclusions of Silicon in a pure aluminum greatly enhance fluidity, with hot tear resistance and better feeding characteristics. To the large extent Aluminium-Silicon compositions are used in most of the casting exercise [8]. And copper (3.6 wt%) was used to produce the heat treatable superior metal of light weight to high strength for automotive applications, Copper is one of the effective precipitation strengthening factor in Aluminium-silicon alloy. Addition of Copper about 5% assists the alloy with attractive strength and toughness after forced or natural aging. By forced aging (T6 treatment) will improve the inert metallic compound dissolution and nucleation rate, hardness improved with copper addition, because of precipitation hardening [9, 10]. Earlier studies confirmed that varying the copper proportion up to 5% will improve the hardness and also investigated the T6 heat treatment effects on Al-Si-Cu alloy and concluded that T6 treatment play the key role on its mechanical and macrostructure properties [11].

2. Experimentation

2.1. Chemical composition. In the present study, the hypereutectic ranged alloy, with light weight heat treatable 3xx.x grade Al-18Si-3.6Cu-0.34Ce was prepared by conventional casting method. The castings are in the ingot form of 30mm diameter and 190mm length. The chemical constituent of the prepared alloy was examined with the help of spark emission spectrometer (Make - PAN Alytical XRD and XRF Instrumentation, Model QSN 750-II single or multi matrix system.) at Karnataka material testing and research, summary of chemical composition are listed in Table 1.

| Table 1. Summary of chemical composition (wt %) of Al-18Si-3.6Cu-0.34Ce alloy. |
|-------------------|---|---|---|---|
| Alloy             | Si | Cu | Ce | Al |
| Al-18Si-3.6Cu-0.34Ce | 18 | 3.6| 0.34| Balance |

2.2. Tensile test. The tensile test specimens are prepared from the as cast ingots as well as from cast aged ingot bars according to ASTM 8E standards. These specimens are tested for as cast and T6 heat treated conditions; precipitation hardening was achieved by the guidelines of ASM hand book. Heat treatment was attained by using muffle furnace having temperature accuracy of $\pm 3^\circ$C. This process involves solutionizing followed by homogenization. Solutionizing was done at 510 $^\circ$C for a soaking time of 1hr Followed by sub zero temperature water quenching and homogenizing at 210 $^\circ$C for different aging time of 1, 3, 5 and 7 hours followed by air cooling. For all conditions of the alloy samples tensile test was carried out on UTM machine (model TUF-C-20000). The effect of aged condition results will be compared with the as cast condition result and the same is plotted as shown in Figure 2. For a 1hour T6 heat treated sample the tensile stress verses strain is shown in Figure 1.
2.3. Wear test. The dry sliding wear test experiments was conducted using pin on disk wear experiment setup [Make - DUCOM instruments] as per the ASTM G99-05 measures. The wear testing pin samples dimension of 30mm length \( \times \) 10mm diameter rounded bars with flat surface are prepared by machining the ingot bars on lathe machine. The wear test was conducted at constant speed of 1m/s, 2m/s, 3m/s and 4m/s with varying normal load from 10 to 40N for a predetermined sliding distance of 2000m. During the wear test, temperature and the frictional force developed on the test specimens are noted continually from the display on controlling unit of pin on disk wear testing machine setup. These sample pins weight are noted before and after the wear test using an electron balance instrument with accuracy of \( 10^{-7} \)kg. Weight loss due wear was recorded and Samples are washed with the acetone to avid oxidation of worn surfaces. Weight loss method was applied to find the volumetric loss and then volumetric wear rate was determined. Using these data volumetric wear rate verses load and speed. Coefficient of friction verses load and speeds were drawn.

3. Results and Discussions

3.1. Mechanical Test. Tensile test was conducted for as cast and cast aged hyper eutectic Al-18Si-3.6Cu-0.34Ce alloy. Figure 2. Show the comparative ultimate tensile strength of an alloy at different test condition.
From the UTS test results it was observed that an improvement in the Ultimate tensile Strength of 1hr (193.8Mpa) and 3 hr (168.7Mpa) aged sample by 22% and 7% as compared to that of as cast condition(158.5Mpa) respectively due the re-precipitation with redistribution of CuAl2 phase improve the hardness and tensile strength by T6 treatment of alloy [12].

3.2. Wear study of as cast alloy. Dry sliding wear study was conducted on a polished disk of hard counter surface of EN-32 with HRC 62-65, room temperature of 30°C and humidity around 60%. At constant speed with varying load test was carried out for as cast condition; from the wear test at different level of speeds of 1m/s, 2m/s,3m/s and 4m/s. with varying load 10-40N.

The trend shows in Figure 2(a, b) that with the normal load the volumetric wear rate was also increased for every speed level, and other side of observation at higher sliding speeds of 2-3m/s lower volumetric wear rate was recorded.
From the Figure 3(a, b). The Coefficient of friction during wear was increased with load at lower constant sliding speed, and moderate change was notice at higher sliding speeds of 3m/s and 4m/s. hence wear decreases with speed during constant load due to reduced contact time.

4. Conclusions:
1. Refinement and re-precipitation of primary and eutectic Si crystals of alloy by T6 heat treatment; The UTS of 1hr and 3hr aged are notably enhanced by 22% and 7% respectively as that of As cast condition.
2. Volumetric wear rate of as cast alloy is a load dominant, at constant sliding speed of 2-3m/s, moderate change in wear rate was noticed for varying load of 10-40N.
3. Coefficient of friction at constant sliding speed despite increase with load. At higher sliding speed alloy shows low friction.
5. References

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