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Impacts Of Age Hardening In Microstructure Of Al2016 Aluminium Alloy At T6 Condition

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Abstract: ***The investigation on aging behavior of Al-Cu has been carried out in a considerable level related to any other combinations, though all aerospace materials comprise other alloying constituents. Twin rolled Al2016 wrought aluminium alloy is one of the experimental components to employ in the aerospace field as a skin material. This work investigates the microstructural formation of Al2016 under T6 condition. As-received material was artificially aged under 170 °C for 24 hours, followed by the stretching process to 3 %. Based on the orientation of grains, this cylindrical bar alloy was sliced in longitudinal direction and transverses direction. These two different specimens were prepared to test in the light optical microscope. The outcome of the micrographs indicated the shape and size of both the specimens. The role of solid solution treatment to receive for such microstructure and the impact of artificial aging on structural properties due to various constituents were discussed.***

Keywords: T6 Al alloy, Al2016, artificial aging, light optical microscope, microstructure.

I. INTRODUCTION

The aerospace industries have long been proponents of advanced engineered materials research and use. The performance needs of a component, which is frequently an important element of a complicated technical practice, are generally what drives demand for those materials. Most aluminium alloys used for wrought products contain less than seven percent of alloying elements. Enhancing the properties of aluminium and improving its working characteristic certain number of elements added. The 2XXX series aluminium alloys are alloyed with copper where the preposition of copper is between 2 wt. % and 9 wt. % along with the additions of manganese, magnesium and zinc [1]. Those are used for applications such as, forgings, extrusions and liquefied gas storage tanks in civil transport and supersonic aircraft [2]. These alloys have lower crack growth rates and thus have better fatigue performance. Therefore, these are used on the lower wings and body skin. The mechanical properties of the heat-treatable types may be improved by quenching from a suitable temperature and then aging [3]. Desirable properties may be obtained through the combination of heat treatment and strain hardening. In order to strengthen and improve the properties of the alloy, there are several heat treatment processes are used and most common is age hardening. Aluminium alloys are strengthened in a number of ways including: solid solution hardening, cold working, dispersion hardening and precipitation hardening. Precipitation hardening is a process whereby a fine precipitate structure is formed in the alloy matrix following a heat treatment process. It is done for redistributing the alloying constituents that segregate from the aluminium during cooling from the molten state; which consists of heating the alloy to a temperature. After solution heat treatment the material is ductile, since no precipitation has occurred. Therefore, it may be worked easily. After a period of time, the solute material precipitates and hardening

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develops [4]. As the composition reaches its saturated normal state, the material reaches its maximum hardness. The precipitate, however, continues to grow. The fine precipitates disappear. They have grown larger, and as a result the tensile strength of the material decreases, known as over-aging. The hardness and tensile strength variation during aging and over-aging is high. More solutionizing can generally be gained from using higher temperatures rather than longer times[5]. Small, coherent precipitates are the most desirable, particularly for Al-Cu-Mg alloys [6]. If, however, over-aged tempers are necessary for good stress corrosion. Age-hardened Al alloys produce the improvement in strength at elevated temperatures, where as a reduction can be found in the elongation.

II. MATERIALS AND METHODS

A. MATERIALS

Cu	Mg	Si	Ag	Mn	Ti	Zr	Fe	Zn	Cr	Ni	Others
4.129	0.616	0.519	0.451	0.185	0.142	0.141	0.092	0.027	0.009	0.005	0.05

Table I: Nominal % Composition of Elements in Al2016

The nominal proportion of as-received Al2016 is given on table I. A cylindrical bar of Al2016 twin rolled aluminium alloy was naturally age-hardened initially. Followed by the same was undergone to T6 condition, where material was kept at solution for 170 °C for 24 hours. After this artificial hardening, it was stretched for 3 %. These heat-treated twin-rolled high strength aluminium alloys are referred as per ASTM standard as Al2016-T6510.

B. SPECIMEN PREPARATION FOR LIGHT MICROSCOPIC TEST

This experimental work concentrates to reveal the surface morphology of the alloys with the aid of light optical microscope. As per the standards ASTM E3-01 and ASTM-E1558–09 the testing specimens were prepared [7], [8]. Shear type cutting machine was used on the round bar material in both longitudinal and transverse direction. The materials were then mounted and polished by various grades of grinding sheets for removing the residues and achieving better surface finish. Followed by the polishing, Ultra-sonic treatment was performed to enhance better cleaning of the materials for conducting a better characterization on light microscope. Eventually, the microstructure of the materials was characterized and grain size was determined from the results of light microscope.

III. RESULT AND DISCUSSION

The light microscope images of Al2016-T6 are given below. All of the rolled grains were coarsely equiaxed and extended along the major plastic flow channel encountered during rolling. Fig. 1 and Fig. 2 shows the longitudinal microstructure conditions of Al2016 alloy at different magnification. These coarse intermetallic particles are often present in this type of alloy. Fig. 1 depicts the Al2016 alloy by coarse equiaxed grains with a size of about 37.5 µm which was calculated by a linear-intercept method as per ASTM standard E112-96, and the large intermetallic particles aligned in the flow direction are Al_2Cu particles [9]. Those particles are looking brightly with sphere shape. And the dark clustered particles of blocky shape contain Mn, Si and Cu. As the Mg: Si ratio is nearly one, Cu-Mg-Si-Al- and Mg_2Si have also formed, and Cu-Mg-Si-Al- is together with $CuAl_2$ [10]. The other elements are distributed inside an aluminium solid solution matrix in this alloy. The predominant secondary-phase particles in Al2016 alloy are CuAl2, Cu-Mg-Al and Cu-Mn-Al [11], [12], which are revealed in Fig. 1. The Al2016 heat-treated alloy was let to undergo the process of age-hardening for 500 hours in 150°C and is known as Al2016-T6. In Fig. 3 and 4, the transverse-oriented grains are depicted. Elongated grains and a few very coarse grains were observed in the transverse specimen. The grains formed are coarse because of excessive heating and soaking.

As indicated in Fig. 3, in the Al2016 transverse specimen, the plastic flow was less evident and also exhibited rather elongated grains about 36 µm in transverse size together with small equiaxed grains in the regions containing large intermetallic particles. The quantity was lower when compared to the previous alloy. Fig. 3 and Fig. 4 showed that the particles with a dark appearance at grain boundaries were of complex chemical composition such as Cu-Mg-Si-Al [11], [13]. At the same time, in these images, spherical shaped Al2Cu grains had a better mark of brightness and these grains were observed in both inter and intragranular stands. Absence of uniformed equiaxed particles were noted. Internal recrystallization phenomenon induced by the intermetallic compounds was denoted by visible particles.

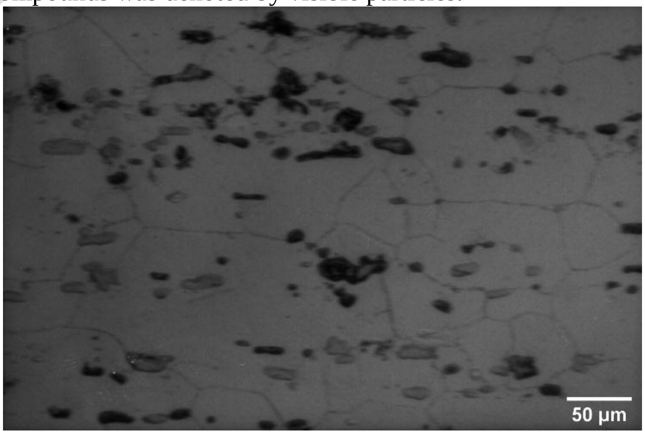

Figure 1: Al2016-T6510- longitudinal oriented - 100X

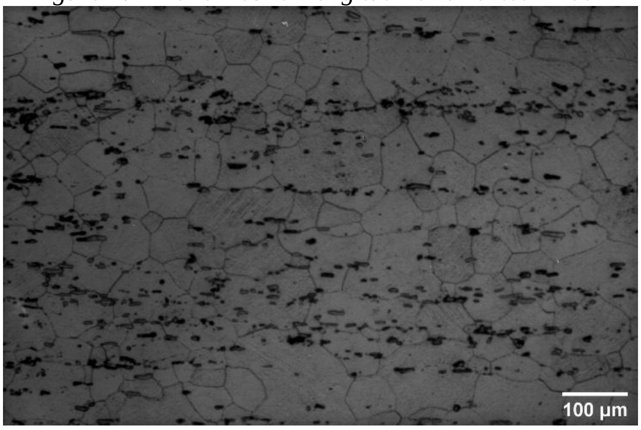

Figure 2: Al2016-T6510- longitudinal oriented - 200X

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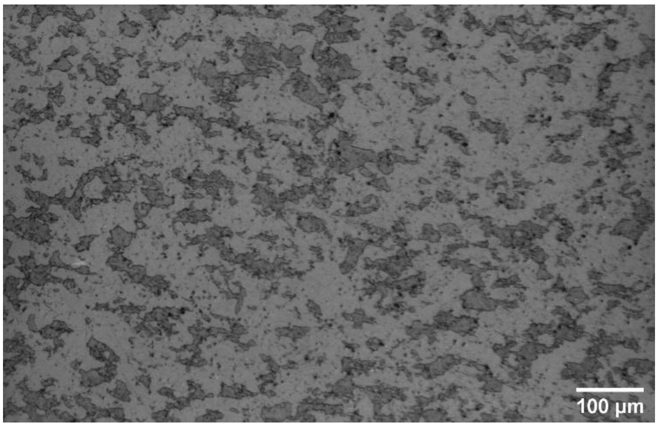

Figure 3: Al2016-T6510- transverse oriented - 100X

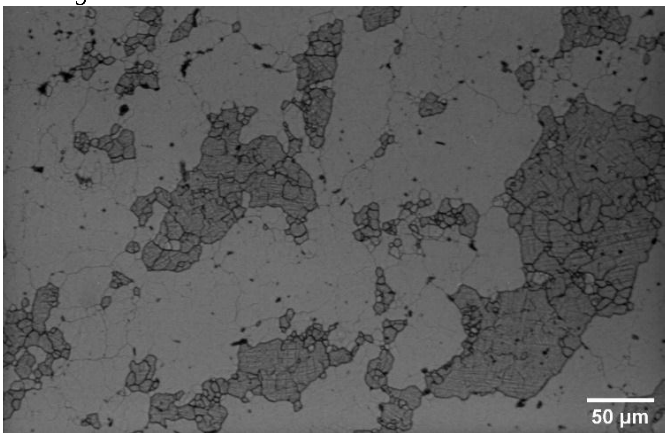

Figure 4: Al2016-T6510- transverse oriented - 200X

Besides copper, Al2016 alloy comprises other significant elements specifically, magnesium, silicon and silver. As a result of solid solution treatment, mixing of magnesium and silicon renders precipitation; this occurs by the Guinier-Preston zone generation and deposition of fine compounds as well [14]. Both confer the additional increase in strength to these alloys. The strength of alloy is improved by manganese as a solid solution or as a finely deposited intermetallic phase. With regards to corrosion resistance, there is no adverse effect encountered [15]. In the existence of usual impurities, manganese has lesser solubility in aluminium [15], [16]. Stretching before ageing significantly lowers T1 and T2 deposition at GBs. The achievable strengths and toughness of goods in a T6 temperament condition are not quite as strong as for items in a T8 condition once stretching is applied.

Al2016 high strength aluminium alloy was alloyed with copper; other significant constituents are magnesium, silicon and silver. Magnesium-silicon combination provides precipitation upon age hardening occurs by formation of Guinier-Preston zones and a very fine precipitate [14]. Both confer the additional increase in strength to these alloys. Manganese increases strength either in solid solution or as a finely precipitated intermetallic phase. It has no adverse effect on corrosion resistance [15]. Manganese has a very limited solid solubility in aluminium in the presence of normal impurities [15], [16]. Zirconium additions of 0.1 to 0.3 % generate a fine intermetallic residue that prevents recovery and recrystallization while also assisting in grain structure management [12]. Copper provides a large improvement in strength while also facilitating precipitation hardening. The addition of copper to aluminium results in a reduction in ductility as well as improved corrosion resistance [11]. Unrecrystallized grains, which increase fracture toughness, are the desired grain arrangement for aged Al-alloys. A few of the highest-strength heat treatable aluminium alloys are included in this group. Aerospace, military vehicles, and rocket fins are perhaps the most common applications for the 2xxx series alloys.

IV. CONCLUSION

Micrographs of metallographic microstructures were gathered and investigated from twin rolled Al2016-T6510 alloy specimens of longitudinal and transverse oriented grains. The average grain size of both specimens indicates the very similar magnitude. Al2016-T6 longitudinally oriented specimens were with virtually sphere-shaped, smaller equiaxed particles, whereas transverse specimens produced irregular globe-shaped, slightly elongated particles; yet, on both specimens, there was room to assume the complicated chemical composition of constituent elements. Longitudinal specimen resembled a kind of the griddle formed microstructures of conventional high-strength aluminium alloy grade materials, whereas that shape has not seen in transverse-oriented specimen.

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