Műszaki Tudományos Közlemények vol. 17. (2022) 50–54.
DOI: Hungarian: https://doi.org/10.33895/mtk-2022.17.11
English: https://doi.org/10.33894/mtk-2022.17.11

EXAMINATION OF AGING OF ALSI1MGMN TYPE ALUMINIUM ALLOY

Mohammed MUDABBIRUDDIN,[1] Tünde Anna KOVÁCS[2]

[1] *Óbuda University, Doctoral School on Materials Sciences and Technologies, Budapest, Hungary, mohammed.mudabbir@uni-obuda.hu*

[2] *Óbuda University, Bánki Donát Faculty of Mechanical and Safety Engineering, Budapest, Hungary, kovacs.tunde@bgk.uni-obuda.hu*

Abstract

In the world of manufacturing, aluminium alloy is mostly used because of its suitable properties, such as mechanical behaviour and machinability. The formation of the cluster, the erosion and corrosion, the precipitation process, artificial ageing and other factors are also discussed in this study. From the practical point of view, the main objective of this experimental study is the investigation of the ageing process of AlSi1MgMn (EN AW 6082 T6) aluminium alloy. To investigate the compound precipitation in the aluminium alloy, a heat treatment process is conducted after which a hardness test is performed and hardness values evaluated to obtained the optimal hardness value according to ageing time and temperature. Significant results have been obtained in the hardness test, however, the metallography shows no clear significant result. For better results, more tests are suggested.

Keywords*: AlSi1MgMn, ageing, heat treatment, hardness.*

1. Introduction

The ageing of materials generally depends on the material properties, while the ageing of technical systems depends on their application. Ageing can be classified into three groups: thermal, mechanical and electrical. The main causes of ageing can be erosion and corrosion, wear and tear, and lack of maintenance which can cause a sudden failure and can lead to damage whole system **[1]**. Time-dependent failure rates can also depend on the weather. To overcome this problem and to increase the efficiency of any technical system, the prediction of failure on bus cable ageing is very important. Fatigue property plays a very important role in predicting ageing of the used material and mechanical properties, authors presented their work for this problem. To understand material behaviour, mathematical modelling can be used.

In today's "Industry 4.0" environment, aluminium alloys are mostly used in various fields of application due to their excellent properties: low density, adequate strength and hardness, excellent castability and corrosion resistance. These properties make Al–Si–Mg alloys a sought-after material for various applications in the construction, automotive, and aerospace industries. The main areas of application are high-stress applications, lattice structures, bridges, cranes, transport applications, copper barrels, beer barrels and milk barrels. It should be borne in mind that the mechanical properties of AlMgSi alloys primarily depend on processing technology.

Over the years, many authors have studied aluminium alloys and the dependence of their mechanical properties on different heat treatment conditions. Extensive research on the properties of aluminium alloys has been presented. Forging and plastic forming is presented in **[2],** and these methods were also used to analyze the strength of the 6082 Al alloy. In order to estimate the fatigue life, a short-cycle fatigue test is performed for AlMgSi alloys with different chemical compositions and microstructures [3] literature. Previous work shows that cracking in this type of alloy is due to the presence of magnesium and chromium. In an alloy with a high magnesium content, the phenomenon of the formation of precipitates occurs more often than in an alloy with a low magnesium content during the natural ageing process. The AlMgSi alloys family are aged to improve properties, the goal is not hardness, but increased ultimate tensile strength and yield strength [4, 5]. During the artificial ageing of AlMgSi alloys, the precipitation process was studied with experimentally. Alloys of this type are widely used as structural materials, so it is worthwhile to improve the production process and the properties of the material. The crack growth behaviour of aluminium alloy 6082-T6 is studied in the literature [6]. Applying the "Paris" law, fatigue crack growth can be observed in the samples. In this study, the effect of two types of incisions, curved U-incision and V-incision, are considered. Using Paris law in test specimens, fatigue crack growth rate is obtained. Two types of notches are taken into consideration for this study i.e. Curved U-notch and V-notch. Results show that the curved U-notch shows a higher value of stress as compared to V-notch. An ageing model is executed to predict the ageing life under different stress values. The fatigue test was performed and compared with 2017A-T4 and 6082-T6 aluminium alloys. Based on mean torsion stress, after statistical analysis, this model uses measured data to estimate ageing. Based on the heat treatment time and temperature, precipitation behaviour is examined by differential scanning calorimetry, Scanning Electron Microscopes (SEM), Transmission Electron Microscopes (TEM) metallographic analyses, and hardness testing [8]. Aluminium alloys such as 6082-T6, 6060, 6005A, and 6063 were used for the test with varying cooling rates. The behaviour of the precipitates in a certain cooling speed range showed the same result. The literature [9] examines the ageing behaviour of aluminium alloy 6082 with the help of Vicker microhardness measurements, mild micro ageing, and tensile strength test analysis [9]. During material testing, the microscopic image after etching does not provide a clear answer concerning the hardening of the material. The effect of welding techniques and the effects of alloys are examined in the literature [10].

2. Material and heat treatment

2.1. AlMgSi (6082-T6)

Precipitation of alloys that can be refined, such as aluminium, is expected to contain scattered fine precipitates, which can range from spherical to lamellar. Therefore, an aluminium-based alloy - AlMgSi (6082-T6) - is used for further analysis. Aluminium alloy 6082-T6 is an alloy for cold working means it is a member of the aluminium-magnesium-silicon alloy family. It is typically formed by extrusion and rolling. They are usually heat-treated to create a material with greater strength but less breathability. It is difficult to produce thin-walled, complex shapes from the 6082 alloys using extrusion. Aluminium alloy 6082-T6 is a medium-strength alloy with excellent erosion and corrosion resistance properties. Among the 6000 series alloys, it has the highest strength.

The chemical composition and material properties of T6-6082 aluminium alloy are listed in Tables 1 and 2.

Table 1. *Chemical Composition*

Element	Percentage %
Al	95.2 - 98.3%
Cr	0.25% max.
Cu	0.1% max.
Fe	0.5% max.
Mg	0.6 - 1.2% max.
Mn	0.4 - 1% max.
Si	0.7 - 1.3% max.
Ti	0.15% max.
Zn	0.2% max.
Other	0.15% max.

Table 2. *Material Properties*

Properties	Value
Density	2.71 g/cm^3
Young's Modulus	71 GPa
Ultimate tensile strength	140–330 MPa
Yield strength	280 MPa
Hardness Vickers	35-100 HV
Brinell Hardness	84 HB
Melting Point	555 °C

2.2. Heat Treating

The most important heat treatment used to increase the strength of aluminium alloys is ageing, which includes solvent annealing, rapid cooling, and ageing. The research aims to study the ageing process of the used aluminium alloy. First, the 6082-T6 sample was cut into 5 different parts, each 4x3.5 cm in size. These samples were labelled according to their heat treatment. The samples were then heated in an oven at 550 °C for one and a half hours (solvent annealing). All the samples were taken out after heating and then cooled in cold water. Solvent annealing was performed at 550 °C for 1 hour for each piece. After this process, it was heat treated using different ageing times. The duration is respectively 1 hour, 5 hours, 10 hours and 24 hours at a constant temperature of 200 °C. After ageing, these samples were individually cooled to room temperature in still air, and then a hardness test was performed on each sample, using Vickers hardness measurement. **Figure 1** shows the temperature-time diagram of the performed heat treatment process.

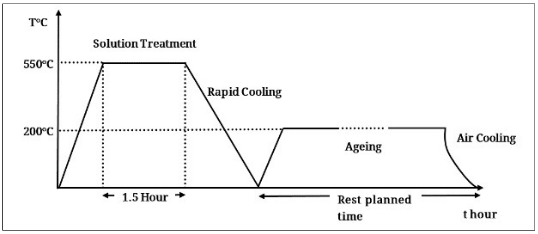

Figure 1. *Ageing heat treatment process diagram*

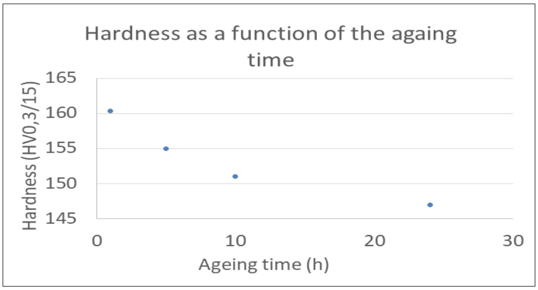

Figure 2. *Graphical representations of obtained hardness values*

3. Results and Discussion

3.1.Hardness test

FFatigue failure depends on many factors, such as the type and condition of the material, the geometry of the structural elements, the type of loading or the state of stress. During the experiments, four aged samples, one hardened sample and one control sample without heat treatment were examined (**Table 3**). The load used for hardness measurement is 300 g, and the test time is 15 seconds (HV0.3/15). Five measurements were taken on each sample, and the hardness value was determined by calculating the average. The obtained values were designed on a graph, as a function of ageing time and hardness (**Figure 2**).

Table 3. *Hardness Vickers value of each sample*

No. of Samples	Description	Reading in HV03/15
1	Original Control Sample	101.63
2	Solution treated at 550°C and Quenched	144.33
3	Ageing at 200°C for 1 hours	160.33
4	Ageing at 200°C for 5 hours	155
5	Ageing at 200°C for 10 hours	151
6	Ageing at 200°C for 24 hours	147.66

The hardness measurement results are shown in a diagram. We wanted to show the effect of the ageing time on the hardness as a function of the ageing time. The diagram clearly shows that the highest hardness was obtained after 1 hour of ageing. Longer ageing heat treatment caused a decrease in hardness.

3.2.Metallography

– Preparation of the microscopic examination: 1. Making a cross-section 2. Casting the piece 3. Grinding 4. Polishing and 5. Etching.

After the hardness test, all the samples were embedded so that grinding and polishing could be performed afterwards, and then the microscopic examination was performed. The casting of the piece is done with a resin material to give it the final shape for further preparation. The cast samples were prepared by sanding them with coarse sandpaper. For the sanding process, we progressed from 80-grit sandpaper to fine 2500-grit sandpaper. Keller's reagent, which is a mixture of nitric acid, hydrochloric acid and hydrofluoric acid, was used for about 10-15 seconds for etching. After etching, we perform a microstructural examination using an optical microscope.

Figures 3–8. shows images of all age-hardened aluminium alloys. These images are taken by optical microscope with 1000x zoom (50 μm).

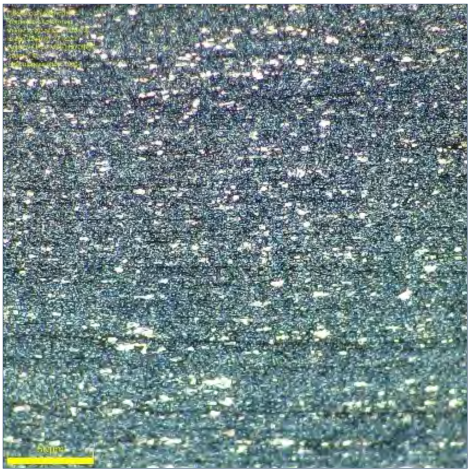

Figure 3. *Control Sample*

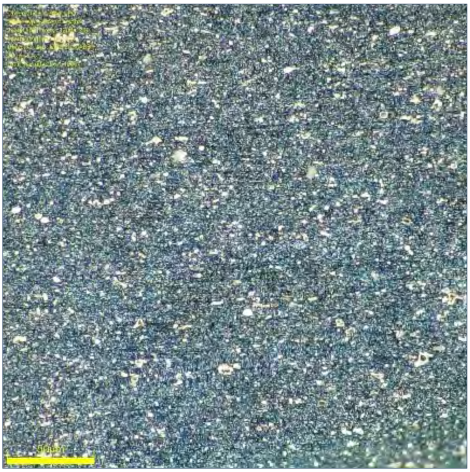

Figure 4. *Quenched Sample 2 at 550°C for 1 hour*

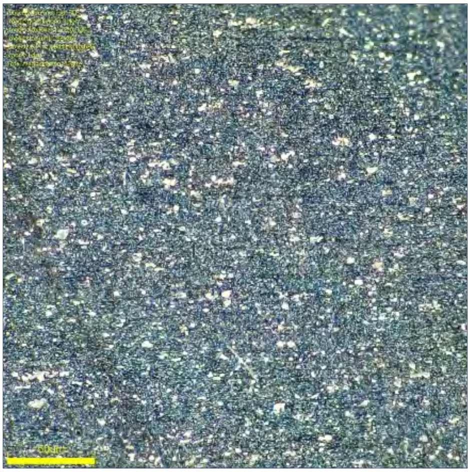

Figure 5. *Sample 3 At 200°C for 1 hour*

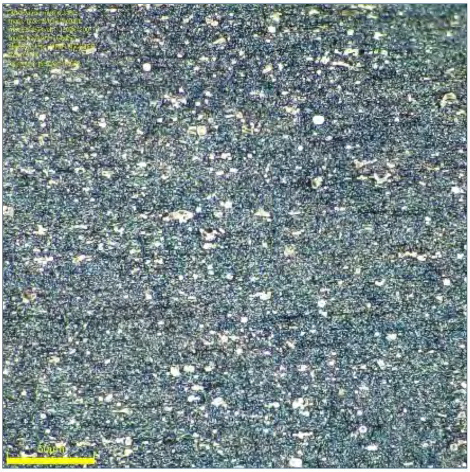

Figure 6. *Sample 4 At 200°C for 5 hour*

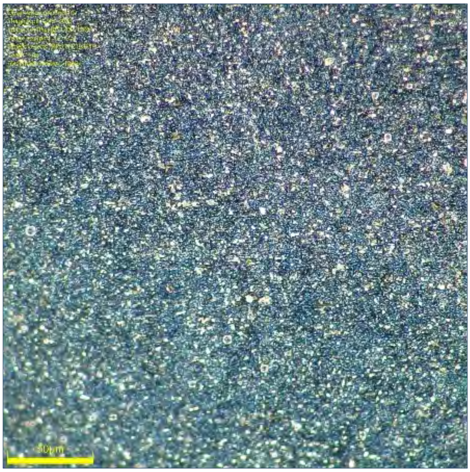

Figure 7. *Sample 5 At 200°C for 10 hour*

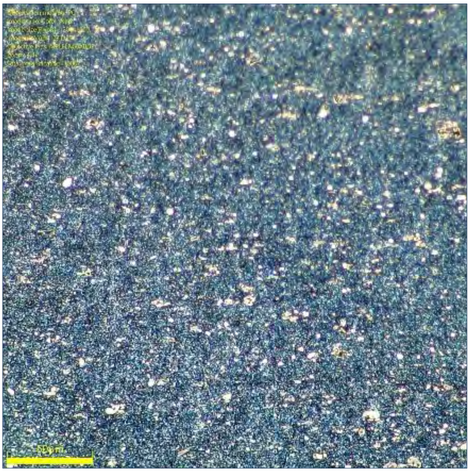

Figure 8. *Sample 6 At 200°C for 24 hour*

4. Conclusion

In this study, AlMgSi (6082) aluminium alloy was aged by heat treatment and evaluated by hardness measurement. We have explained the process step by step. Overall, it can be said that during the test, it can be noticed in the hardness measurements that the hardness of sample 3 is the highest, therefore ageing at 200 °C for 1 hour can be considered as the optimal ageing heat treatment.

After the hardness measurements, we tried to observe the precipitates with the metallographic tests. No significant results were visible in metallography. This metallographic examination was performed with an optical microscope, for better results it would be recommended to use other techniques, such as a scanning electron microscope or a transmission electron microscope.

References

[1] M. Mudabbiruddin., L. Pokoradi: *Aging of Technical Systems – Literature Review.* Journal of Production Engineering, 24/1. (2021) 69–74. https://doi.org/10.24867/JPE-2021-01-069

[2] N. Kumar, G. M. Owolabi, R. Jayaganthan: *Al 6082 Alloy Strengthening through Low Strain Multi-axial Forging*. Materials Characterization, 155. (2019) 109-761. https://doi.org/10.1016/j.matchar.2019.06.003

[3] L. P. Borrego, L. M. Abreu, J. M. Costa, J. M. Ferreira: *Analysis of Low Cycle Fatigue in AlMgSi Aluminium Alloys*. Engineering Failure Analysis, 11/5. (2004) 715–725. https://doi.org/10.1016/j.engfailanal.2003.09.003

[4] J. Kim, J. Im, M. Song,I. Kim.: *Effects of Mg Addition and Pre-aging on the Age-Hardening Behavior in Al-Mg-Si.* Metals, 8/12. (2018) 10-46. https://doi.org/10.3390/met8121046

[5] M. Stipcich, A. Cuniberti, V. Noseda Grau.: *Electrical Resistometry Study of an AlMgSi Alloy under Artificial Aging*. Journal of Alloys and Compounds, 542. (2012) 248–252. https://doi.org/10.1016/j.jallcom.2012.07.031

[6] J. A. F. O. Correia, A. M. P. De Jesus, A. S. F. Alves, G. Lesiuk, P. J. S. Tavares, P. M. G. P. Moreira.: *Fatigue Crack Growth Behaviour of the 6082-T6 Aluminum Using CT Specimens with Distinct Notches*. In: Procedia Structural Integrity. Vol. 2. Catania, Italy, 2016. 3272-3279. https://doi.org/10.1016/j.prostr.2016.06.408

[7] K. Kluger.: *Fatigue Life Estimation for 2017A-T4 and 6082-T6 Aluminium Alloys Subjected to Bending-Torsion with Mean Stress*. International Journal of Fatigue, 80. (2015) 22–29. https://doi.org/10.1016/j.ijfatigue.2015.05.005

[8] B. Milkereit, N. Wanderka, C. Schick, O. Kessler.: *Continuous Cooling Precipitation Diagrams of Al-Mg-Si Alloys*. Materials Science and Engineering A, 550. (2017) 87–96. https://doi.org/10.1016/j.msea.2012.04.033

[9] M. Fujda, M. Matvija, M. Glogovský, I. Orišenko.: *Natural Aging Behaviour of the EN AW 6082 and Lead Free EN AW 6023 Aluminium Alloys*. Manufacturing Technology, 17/5. (2017) 19–20. https://doi.org/10.21062/ujep/x.2017/a/1213-2489/MT/17/5/701

[10] G. Cornacchia, S. Cecchel.: *Study and Characterization of EN AW 6181/6082-T6 and EN AC 42100-T6 Aluminum Alloy Welding of Structural Applications: Metal Inert Gas (MIG), Cold Metal Transfer (CMT), and Fiber Laser-MIG Hybrid Comparison.* Metals, 10/4. (2020) 1–21. https://doi.org/10.3390/met10040441