



University of Belgrade, Technical Faculty in Bor



ECOTER

**30th International Conference Ecological Truth
& Environmental Research
2023**

Proceedings

**Editor
Prof. Dr Snežana Šerbula**





University of Belgrade, Technical Faculty in Bor



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& Environmental Research
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PREFACE

The 30th international conference Ecological Truth & Environmental Research – EcoTER'23 kept three areas in focus: ecology, environmental protection and sustainable development. The conference will be held on Mt Stara Planina in hotel Stara Planina, Serbia, 20–23 June 2023. The monograph is published on the occasion of the 30th anniversary of the conference. On behalf of the scientific and organizing committee, it is a great honor and pleasure to wish all the participants a warm welcome to the conference.

The monograph is published on the occasion of the 30th anniversary of the conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 30th international conference Ecological Truth & Environmental Research – EcoTER'23 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These Proceedings 103 papers from the authors coming from the universities, research institutes and industries in 11 countries: Australia, USA, Brazil, Spain, Portugal, Libya, Italy, Bulgaria, Bosnia and Herzegovina, North Macedonia, and Serbia.

As a part of this year's conference, the 5th Student Session – EcoTERS'23 is being held. We appreciate the contribution of the students and their mentors who have also participated in the conference.

The support of the Gold donor and their willingness and ability to cooperate has been of great importance for the success of the EcoTER'23. The organizing committee would like to extend their appreciation and gratitude to the Gold donor of the conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the conference participants for their support to the EcoTER'23. Sincere thanks go to all the people who have contributed to the successful organization of the EcoTER'23.

Prof. Snežana Šerbula,

President of the scientific and organizing committee

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THE INFLUENCE OF AGEING ON THE THERMAL PROPERTIES AND MICROSTRUCTURE OF THE EN AW-6082 GREEN ALUMINIUM ALLOY

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Abstract

The purpose of this work is to investigate the influence of ageing on the thermal properties and microstructure of the EN AW-6082 green aluminium alloy. The heat treatment of the alloy included annealing, solution heat treatment, and ageing at different temperatures and times. Samples were annealed at 550 °C for 6 h and cooled in air in order to remove asfabricated state. After that, solution heat treatment was done at 550 °C for one hour, followed by quenching in ice water in order to obtain a supersaturated solid solution. Samples were aged after quenching at three different temperatures (160 °C, 230 °C, and 330 °C) for 30 and 60 minutes, respectively. After each step in the heat treatment process, samples were separated and investigated. The investigation of the samples included the measurement of the thermal properties and the microstructural investigation of the aged sample. After the ageing treatment, an initial decrease in thermal diffusivity and thermal conductivity was followed by a gradual increase. A microstructural investigation showed the existence of a finely dispersed metastable phase after ageing, causing an increment in thermal diffusivity and thermal conductivity values.

Keywords: EN AW-6082, thermal conductivity, thermal diffusivity, SEM/EDS analysis.

INTRODUCTION

Aluminium alloys from the 6000 series are common industry materials thanks to their good mix of properties such as good ductility, high strength-to-weight ratio, formability, corrosion resistance, recyclability, and non-toxicity [1,2]. Alloys from this series are often used for the production of heat sinks due to their good electrical conductivity, high strength, and good thermal properties [3–8]. For the production of heat sinks the EN AW-6082 aluminium alloy can be a good candidate. Alloys from this series are commonly heat treated in various ways to alter the microstructure and enhance the alloys' characteristics. Precipitation hardening, also known as ageing, is often used to strengthen aluminium alloys from these series. Besides strengthening, ageing process alters the thermal properties as well. Solution heat treatment, quenching to room temperature or below room temperature, and ageing - either natural (at room temperature) or artificial (at higher temperatures) - are all integral parts of this process [9]. As the alloy ages (at different temperatures and times), different types of precipitates appear in the microstructure. Sometimes, those precipitates are very fine and evenly dispersed thus hindering the movement of dislocations, causing the changes in the alloys' microstructure. Many authors had their focus on investigating the influence of different heat treatments on mechanical and electrical properties [3–5,10]. Some authors were investigating the change in thermal properties of the Al-Mg-Si alloy during precipitation

hardening at different temperatures and times [6–8,11,12]. The literature review concludes that ageing is defined primarily by temperature and time during the ageing process. The aim of this study was to better understand the influence of ageing at different temperatures and times, on the thermal diffusivity, thermal conductivity, and microstructure of the EN AW-6082 alloy.

MATERIALS AND METHODS

For this experimental investigation, the EN AW-6082 alloy was chosen. The extruded rectangular bars were delivered in peak aged condition by "AlCu metali d.o.o.". The chemical composition of the alloy (Table 1) was determined using an optical emission spectrometer Belec Compact Port. The samples were annealed in the Heraeus K-1150/2 electric resistance furnace for 6 hours at 550 °C to remove a fabricated state. After that, supersaturated solid solution (α_{SSS}) was obtained by heating the samples to 550 °C for 1 hour and quenching in ice water. Ageing was performed on quenched samples at three different temperatures (160 °C, 230 °C, and 330 °C) for 30 and 60 minutes, respectively. After each step in the heat treatment process, samples were separated and investigated. After quenching (Temper T-W) and after ageing (Temper T6). The investigation of the samples included metallographic phase investigations, as well as the distribution of phases, by using the TESCAN Vega 3 LMU scanning electron microscope equipped with an EDS X-act detector by Oxford Instruments. Preparation of the samples included wet grinding on a series of SiC papers, and polishing with alumina suspension with two different granulations of Al_2O_3 : particle sizes of 0.3 μm and 0.05 μm . Dix-Keller solution was used for the etching of the samples by immersion to reveal the microstructure.

On the TA Instruments DXF 500 thermal conductivity meter, the xenon flash method was applied to determine the thermal diffusivity of the investigated samples after different heat treatments by irradiating the disc-shaped specimens with a diameter of 12.7 mm with the xenon lamp in a nitrogen atmosphere. The thermal conductivity as a function of temperature was calculated according to the equation:

$$\lambda(T) = \rho(T) \times c_p(T) \times \alpha(T) \quad (1)$$

where, λ - thermal conductivity; (W/m·K), ρ – density; (kg/m³), c_p – specific heat capacity; (J/kg·K), α - thermal diffusivity; (mm²/s), T – temperature; (°C).

Table 1 Chemical composition of the investigated alloy, mass. %

<u>Si</u>	<u>Fe</u>	<u>Cu</u>	<u>Mn</u>	<u>Mg</u>	<u>Cr</u>	<u>Ni</u>	<u>Zn</u>
0.807	0.354	0.042	0.453	0.696	<0.012	0.012	0.115
<u>Ti</u>	<u>Pb</u>	<u>V</u>	<u>Co</u>	<u>Sn</u>	<u>Zr</u>	<u>Al</u>	
0.025	0.01	<0.003	0.006	<0.003	<0.003	97.45	



Figure 1 Samples for a) microstructural analysis; b) measurement of thermal properties

RESULTS AND DISCUSSION

The first step in investigating process was the measurement of thermal properties after quenching and after ageing. The presented results demonstrate that ageing influences the thermal properties.

After being aged at 160 °C, 230 °C, and 330 °C for 30 minutes and 60 minutes, thermal diffusivity and thermal conductivity were measured at room temperature. These three ageing temperatures were picked to address three distinct stages in the precipitation sequence. At the lowest temperature, G.P. zones appear; metastable phases were formed at the medium chosen temperature while over-ageing is detected at the highest chosen temperature. Figures 2 and 3 depict the measured values of thermal diffusivity and thermal conductivity as a function of a heat treatment procedure, respectively.

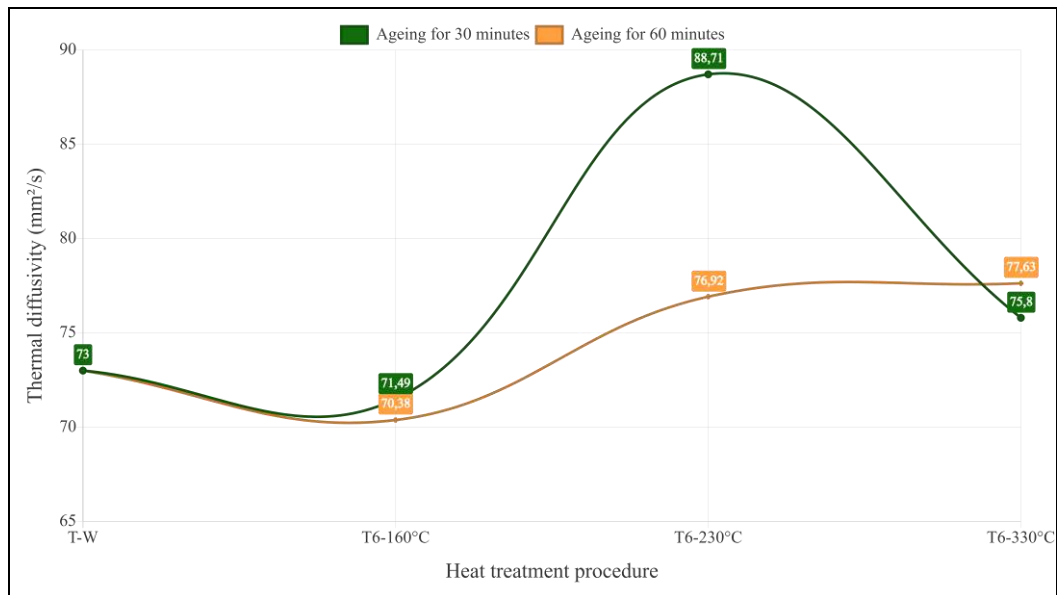


Figure 2 Thermal diffusivity as a function of heat treatment procedure

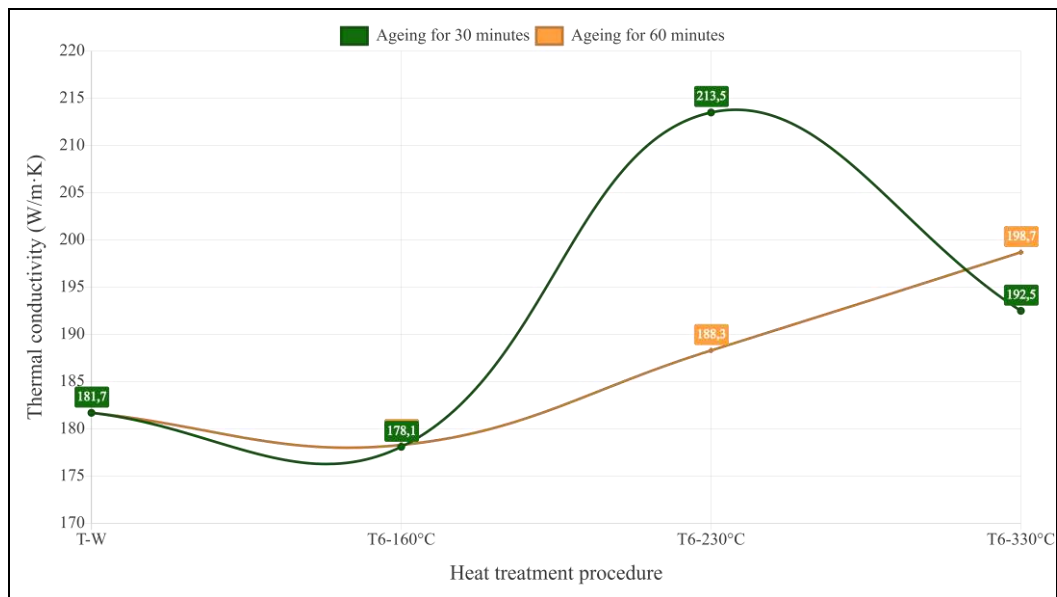
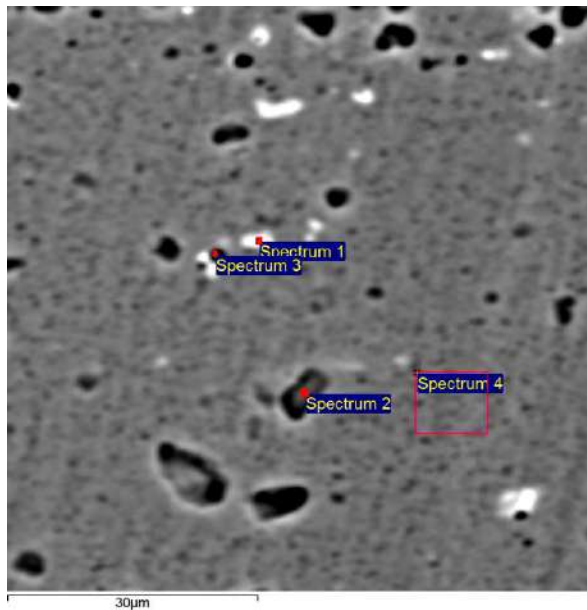


Figure 3 Thermal conductivity as a function of heat treatment procedure (T-W represents the quenched condition and T6 represents the aged condition)

Thermal diffusivity and thermal conductivity values were lower after aging at 160 °C than they were in the quenched condition. This is explained by the high electron scattering effect brought on by the production of fine early-stage precipitates and closely spaced G.P. zones [5,11,13,14]. The values of thermal diffusivity and thermal conductivity of the aged samples are greater in comparison to the quenched sample after ageing at 230 °C for both ageing times. The appearance of a metastable semi-coherent phase is a result of increased ageing temperature, which also causes more intense precipitation, transformation, and breakdown of G.P. zones. These processes are causing the activation and faster mobility of electrons, thus raising the thermal diffusivity values. A continued increase in ageing temperature should lead to a higher release of the alloying elements from the matrix and easier movement of electrons, which leads to an increase in thermal properties, which is evident at an ageing time of 60 minutes, but not after ageing for 30 minutes.

The SEM/EDS investigation was carried out to complete the examination in greater depth and examine the structural change during the ageing. Figure 4 shows a SEM microphotograph with EDS analysis of a sample subjected to artificial aging at 230 °C for 60 min. It can be considered that finely dispersed precipitates of the metastable β'' phase covers the microstructure of the aged samples, which is shown by the rectangular scanned area in spectrum 4 (S4) in Figure 4. Also, some other metastable phases appear in the microstructure, like AlFeMnSi and AlMgSiMnFe, represented by the spectrums S1-S3.



Spectrum	Mg	Al	Si	Mn	Fe	Cu
S1		86.59	5.12	2.83	5.46	
S2	0.57	98.07	1.08	0.13		0.15
S3	0.47	97.85	1.19	0.22	0.27	
S4	0.56	98.38	0.89	0.18		

*All values are in atomic %

Figure 4 SEM/EDS analysis of the EN AW-6082 alloy after ageing at 230°C for 60 minutes

CONCLUSION

The conclusion in this paper can be summarized as follows: after the ageing treatment, an initial decrease in thermal diffusivity and thermal conductivity due to the formation of G.P. zones was followed by a gradual increase. The formation of metastable phases, which resulted in the matrix becoming less saturated, was responsible for the observed rise in values of thermal diffusivity and thermal conductivity. Microstructural investigation showed the existence of a finely dispersed metastable phase after ageing, which can be considered to be β'' causing the increment of thermal diffusivity and thermal conductivity values.

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