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Institute Bor

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Editors:
Ljubiša Balanović
Dejan Tanikić

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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,
Prof. dr Ljubiša Balanović

Љубиша Балановић

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MICROSTRUCTURE ANALYSIS OF EN AW 6061 ALLOY USING A SEM MICROSCOPE AFTER ARTIFICIAL AGING

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Abstract
Aluminium alloys from the Al-Mg-Si system are crucial because they can be used both as cast and plastic-processed states. In this work, the aluminium alloy EN AW 6061 was used for testing. Microstructural changes during the ageing of the alloy were observed. During the ageing process, the samples were heated at different temperatures of 160 °C, 180 °C, 200 °C and 220 °C in different time intervals of 4 h, 5 h, 6 h and 7 h. The alloy has previously been exposed to a specific plastic deformation and heat treatment. The microstructure was studied using a scanning electron microscope, SEM.

***Keywords**: microstructure, ageing, plastic deformation, scanning electron microscope*

1. INTRODUCTION

The most essential properties that characterize this alloy from other aluminium alloys are its superior strength, outstanding workability through plastic deformation, good surface characteristics after processing, and excellent corrosion resistance in atmospheric and seawater environments [1, 2]. This alloy belongs to the group of aluminium alloys that can be strengthened by cold plastic deformation and heat treatment – ageing (thermal deposition). Plastic deformation is used to increase the number of dislocations, while ageing is a process in which the alloy is reinforced by the production of a very tiny quantity of uniformly distributed secondary phase in the metal base [3]. Particles of the secondary phase are known as precipitates, so this process is also called precipitation strengthening [4]. The process of solution annealing, tempering, and eventually thermal deposition raises the material's mechanical characteristics to the highest possible level.

Magnesium and silicon are the two major alloying components of alloy EN AW 6061. Copper, manganese, chromium, iron, titanium, and zinc can also be found in addition to these main elements. The main alloying elements form the Mg_2Si phase, which is also the basis for precipitation strengthening. The optimal ratio for the appearance of the Mg_2Si phase is Mg/Si=1.73, but it is very difficult to obtain this ratio under practical conditions. As a result, most of the alloys include too much silicon or magnesium, which is the basic condition for the occurrence of thermal deposition [5, 6]. The purpose of strengthening by thermal deposition is to create uniformly distributed precipitated particles in the plastic base. The precipitated particles act as barriers to the movement of dislocations, which strengthens the heat-treated alloy through the strengthening process. The mechanism's limitation is that aged alloys can only be used at specific temperatures. At higher temperatures, the formed precipitates begin to grow and, after a period of time, if the temperature is high enough, they dissolve [3].

Controlled thermomechanical treatment can lead to significant improvements in yield stress and hardness in aged aluminium alloys. Micro mechanisms that regulate the fracture characteristics of such alloys depend on the coherence and distribution of precipitates, the size and shape of grains, as well as the presence of other phases that occur due to a certain concentration of impurities [7].

2. EXPERIMENTAL

The alloy of the Al-Mg-Si system with the required chemical composition was obtained by melting the technically pure metals of aluminium, silicon and magnesium in an electrical resistance furnace with a reducing atmosphere. The alloy was cast in a steel mould, and the obtained ingot has these measurements: 21×21×85 mm. After that, the casting was homogeneously annealed for 6 hours at 560 °C in a chamber furnace and then cooled in air at room temperature. Then, the casting was cut under a water jet and four samples with dimensions of 10×10×85 mm were obtained for further tests. The next step was cold rolling on a rolling machine that had been calibrated for each sample. After rolling, alloy samples were obtained in the form of a wire with a diameter of 5 mm. The total degree of deformation of the initial samples, achieved by applied cold plastic deformation, was 80.4%. Such a high degree of deformation caused a significant strengthening of the alloy and the impossibility of its further plastic processing. For this reason, recrystallization annealing was performed at a temperature of 520 °C for 15 minutes. Then the process of cold plastic deformation continued on the calibrated rolling mill. The total degree of deformation achieved in this second segment of rolling was 37.6%. A sample was obtained in the form of a wire, square cross-section, dimensions 3.5 × 3.5 mm. Wires with a cross-section of Ø 3.50 mm were obtained by drawing. After that, the samples were solution annealed at 520 °C for 30 minutes before being quenched in cold water. Shortly after that, the samples were artificially aged for 4 h, 5 h, 6 h, and 7 h at temperatures of 160 °C, 180 °C, 200 °C, and 220 °C.

3. RESULTS AND DISCUSSION

The chemical composition of the alloy was determined using X-ray fluorescence analysis (XRF) and the NITON XL 3t-950 device. Figure 1 displays the spectrum for the aluminium alloy EN AW 6061, and Table 1 shows the chemical composition of the alloy.

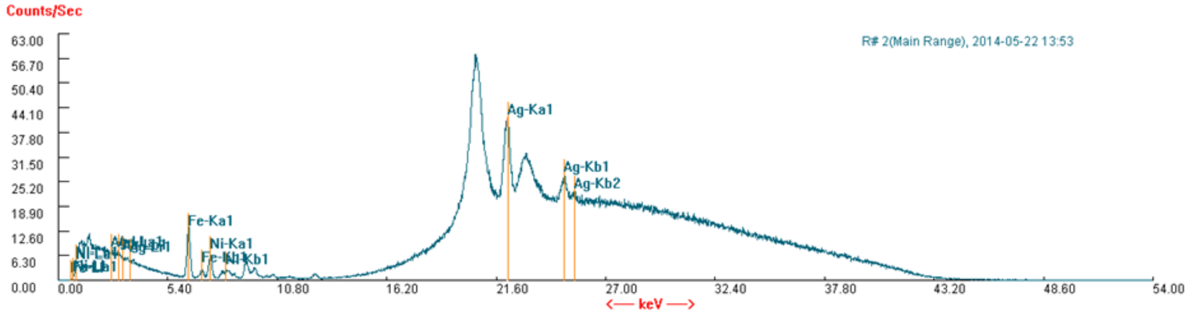
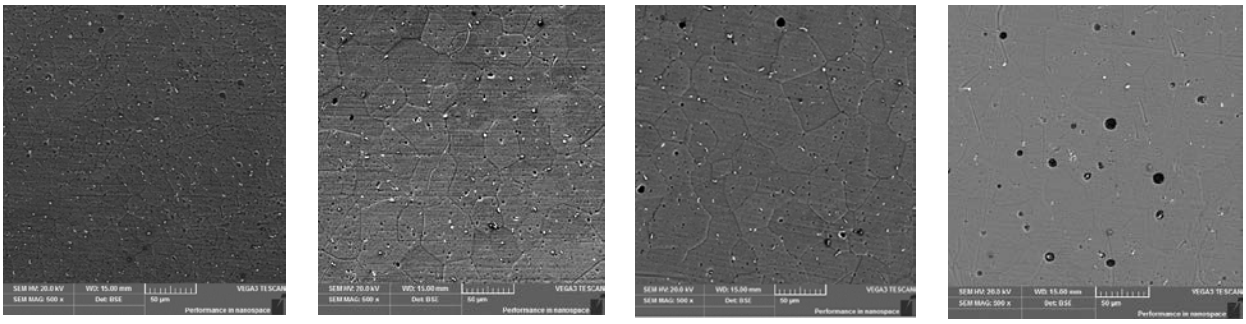


Figure 1 - Spectrograms of EN AW 6061 alloy

Table 1 - Chemical composition of EN AW 6061 alloy

Element	Al	Mg	Si	Cr	Fe
(mas %)	97,54	1,26	0,819	0,231	0,222

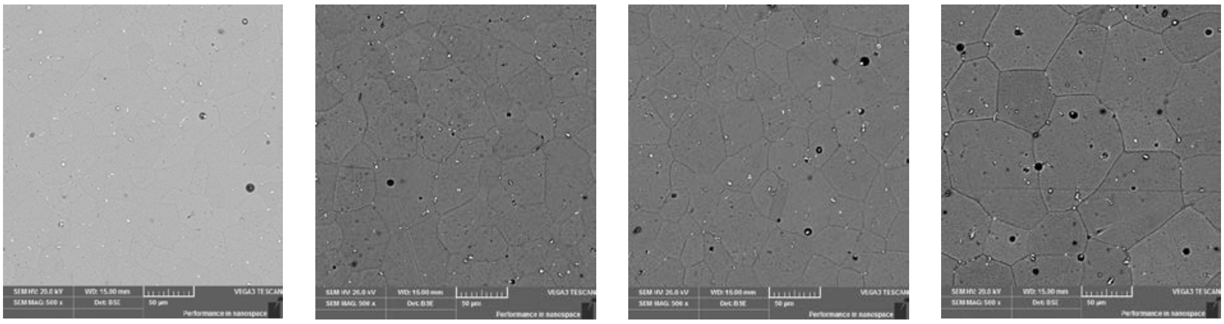
Figures from 2 to 5 show the microstructure of the studied samples exposed to various heat treatment cycles. The samples were observed on an SEM with a magnification of 500x.



a) b) c) d)

Figure 2 - Microstructure of EN AW 6061 alloy annealed at 160 °C for a duration of
a) 4 h, b) 5 h, c) 6 h, d) 7 h

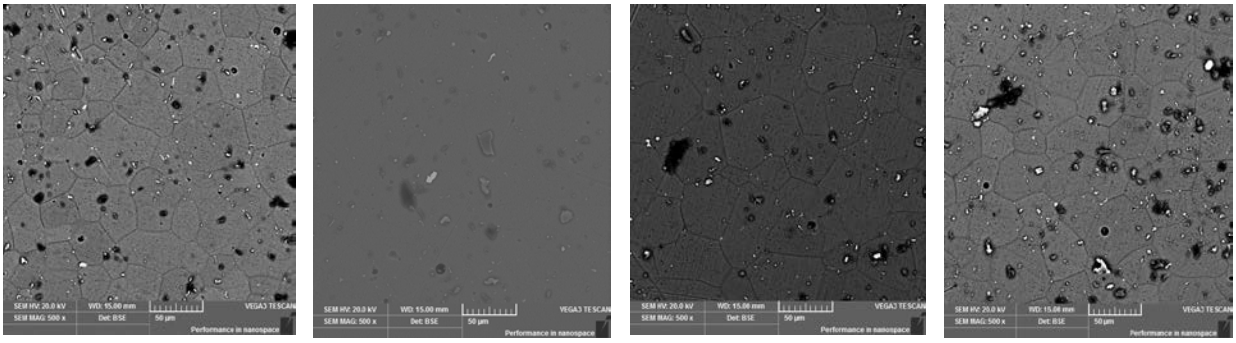
Studying the microstructures in Figure 2, it is clear that the structure is the finest in the sample that was treated for 4 hours. The boundaries cannot be seen in the case of the 7 hour treated sample.



a) b) c) d)

Figure 3 - Microstructure of EN AW 6061 alloy annealed at 180 °C for a duration of
a) 4 h, b) 5 h, c) 6 h, d) 7 h

In Figure 3, grain boundaries are clearly visible on all microstructures. The sample that was thermally treated for 4 hours has the finest microstructure, but the grain boundaries are also little visible. The biggest grains can be seen in the sample that was treated for 7 h, and the boundaries are most clearly defined.



a) b) c) d)

Figure 4 - Microstructure of EN AW 6061 alloy annealed at 200 °C for a duration of
a) 4 h, b) 5 h, c) 6 h, d) 7 h

Figure 4 shows samples annealed at 200 °C with clearly defined boundaries and a uniform grain size. Only in the case of the sample that was thermally treated for 5 h, it is not possible to observe the grain boundaries. With these samples, it is difficult to determine which sample has the tiniest grains and which has the coarsest grains.

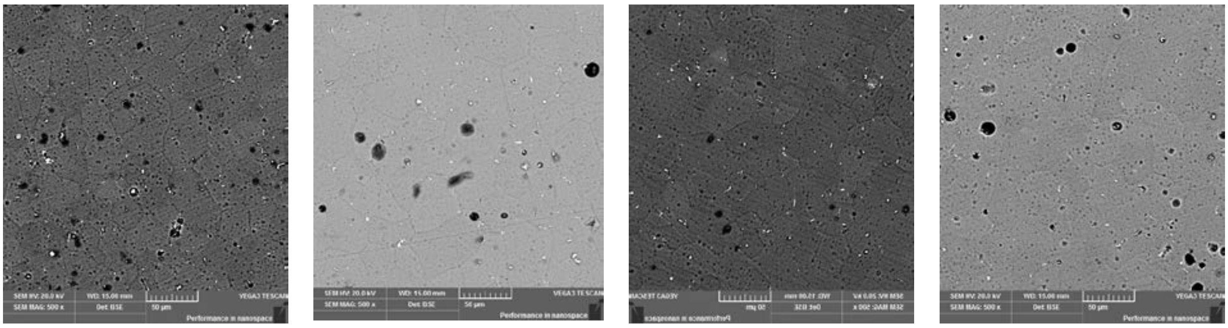

a) b) c) d)

Figure 5 - Microstructure of alloy EN AW 6061 annealed at 220 °C for a duration of
a) 4 h, b) 5 h, c) 6 h, d) 7 h

The microstructures of the samples shown in Figure 5 represent the samples annealed at 220 C. It is possible to observe the growth of the grains and that their boundaries are not clearly visible. Similar conclusions can be found in Hossain and Kurny's study on the impact of aging temperature on the structural and mechanical characteristics of the Al-6Si-0.5Mg alloy [7].For all examined samples, the general conclusion is that during heating, atoms of the precipitate phase are separated from the supersaturated α solid solution. atoms of the precipitating phase represent nucleation centers, which lead to the formation and growth of precipitates. After a certain time of keeping the alloy at a defined temperature, an equilibrium structure consisting of α + β phase is formed, that is, β phase is obtained which is in the form of uniformly distributed precipitate particles, which is in accordance with the literature [3].

4. CONCLUSION

The basic aspect of the study of the properties of metals and alloys is microstructural characterisation. The microstructure is determined by the methods of obtaining the alloy, metallurgical processing, heat treatment, etc. The term microstructure defines the size and shape of crystal grains, their orientation and distribution of the basic structural phase, as well as other phases present. Metallographic tests of the EN AW 6061 alloy in this paper were performed with the help of SEM microscopy and it was concluded that the β phase is uniformly distributed in the metal base consisting of the α phase. A comparison of the grain size as a function of annealing time and temperature was also made.

ACKNOWLEDGEMENTS

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REFERENCES

[1] S. Shabestari, F. Shahri, J. Mater. Sci., 39 (6) (2004) 2023-2032.
[2] K. Kumar, The aluminium alloy selection and applications, The Aluminum Association Inc, Washington, 1998.
[3] S. Ivanov, B. Stojanović, Termička obrada metala, Tehnički fakultet, Bor, 2018.
[4] S. Pogatscher, H. Antrekowitsch, H. Leitner, T. Ebner, P.J. Uggowitzer, Acta Mater., 59 (2011) 3352-3363.
[5] L. Zhen, W. D. Fei, S. B. Kang, H. W. Kim, J. Mater. Sci., 32 (1997) 1895-1902.
[6] M. Yildirim, D. Ozyurek, Mater. Des., 51 (2013) 767-774.
[7] A. Hossain, A. S. W. Kurny, Universal J. Mater. Sci., 1 (1) (2013) 1-5.

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