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Effect of aging time and temperature on properties of AA7075 alloy

Yaşlandırma süresinin ve sıcaklığının AA7075 alaşımının özelliklerine etkisi

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Abstract

In this study, the effect of aging at different temperatures and times on the properties of AA7075-T6 alloy was investigated. The samples prepared for the experimental studies were subjected to the solution, quenching, and then aging heat treatment at 100 °C and 200 °C for different periods (42-66-90 hours). The properties of the experimental samples were investigated by hardness, compression test, and scanning electron microscope (SEM). As a result of the studies, it was determined that the aging heat treatment had a positive effect on the microstructure and mechanical properties of the AA7075 alloy compared to the reference sample. Especially as a result of the heat treatments at 100 °C, higher results were obtained in hardness and compression strength compared to the initial values.

Keywords: Aging, Compressive strength, Hardness

Öz

Bu çalışmada, farklı sıcaklı ve sürelerde uygulanan yaşlandırma işleminin, AA7075-T6 alaşımının özelliklerine etkisi incelenmiştir. Deneysel çalışmalar için hazırlanan numuneler, çözeltiye alma, su verme, daha sonra 100 °C ve 200 °C sıcaklıkta farklı sürelerde (42-66-90 saat) yaşlandırma ısıl işlemine tabi tutulmuşlardır. Deneysel numunelerin, sertlik, basma deneyi ve taramalı elektron mikroskobu (SEM) özellikleri incelenmiştir. Yapılan çalışmalar sonucunda, yapılan yaşlandırma ısıl işleminin AA7075 alaşımının özelliklerini referans numuneye göre olumlu yönde etkilediği tespit edilmiştir. Özellikle 100 °C de yapılan ısıl işlemler sonucu sertlik ve basma mukavemetinde başlangıç değerlerine göre daha yüksek sonuçlar elde edilmiştir.

***Anahtar kelimeler**: Yaşlandırma, Basma mukavemeti, Sertlik*

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1. Introduction

Aluminum is one of the most important non-ferrous metals. The most important features of aluminum materials are lightness, durability, easy processing, ability to conduct heat and electricity, resistance to oxidation, magnetic and non-toxic, light-reflecting and pleasing to the eye. Especially low weight/strength ratio, oxidation resistance, light reflection and anodic coating feature have made aluminum materials a widely used metal in the machinery industry (Budak, 2016; Gültekin & Korkmaz, 2021; Şenel, 2020; Şenel & Gürbüz, 2020).

Aluminum alloys can be divided into two main groups as wrought and cast. Some alloying elements such as copper in aluminum alloys, whose strength and hardness can be increased by heat treatment, and sometimes the elements that are added as alloying elements create situations that cannot be heat treated. Thus, according to their sensitivity to heat treatment, aluminum alloys are divided into two subgroups as heat-treatable and non-heat-treatable alloys. It is the general name given to alloys whose mechanical properties can be improved after controlled heating and cooling processes. Those in the group of those that can be subjected to heat treatment; 2011, 2014, 2017, 2018, 2024, 2025, 4032, 6151, 6061 and 7075 (Kibar, 2010; Al-Saadi & Tunay, 2017).

7075 aluminum alloy, a typical heat treatment alloy, is widely used in aerospace, nuclear industry, transportation, and other fields (Li et al., 2018). The use of aluminum and its alloys in many industrial applications such as the automotive industry, aerospace industry and various marine structures is increasing day by day. However, the need to obtain quality and reliable products imposes important responsibilities on aluminum alloys in terms of strength rather than lightness. Aluminum alloys can meet the expectations in terms of mechanical properties only by heat treatment. Since 7XXX series aluminum alloys are highly susceptible to corrosion in the T6 temper state, which provides high hardness and strength, an over-aging process known as T73 has been developed in recent years to improve the corrosion resistance of these alloys. However, the T73 temper reduces the strength of the alloy by 10-15% while increasing the corrosion resistance of the alloy. At the end of the studies aimed at combining the strength and corrosion properties at the optimum value, the regression and re-aging (RRA, retrogression and re-aging) process was found. The RRA process is defined as a two-stage heat treatment process, retrogression, and aging, and is applied to alloys in the T6 temper state (Cina, 1974).

Aluminum alloys; contain one or more of the main alloying elements such as silicon, copper, magnesium, zinc, and manganese. Elements such as iron, chromium, and titanium can be found in low amounts. In addition, some special alloys may contain nickel, cobalt, tin, lead, or vanadium. Elements such as Cu, Zn, Mg, Mn, Fe, Pb, and Bi, which are alloying elements added to aluminum alloys, positively affect the mechanical properties of aluminum. In addition, heat treatments applied to aluminum alloys increase the wear resistance by directly affecting the mechanical properties of the materials (Aydın, 2002). The increase in hardness by heat treatment applied to aluminum alloys for hardening is provided by the thin and homogeneous precipitation of the second phase precipitates in the matrix, especially light aluminum alloys used in the aircraft industry are hardened by precipitation hardening and this process does not affect the hardening. Not only the mechanical properties but also the magnetic and conductivity properties of the material. For this reason, aging heat treatment is also applied to improve the properties of electronic materials (Ak, 2012). They stated that alloying elements such as Cu, Zn, Mg, Mn, Fe, Pb, and Bi added to aluminum alloys affect the mechanical properties of aluminum, while heat treatments applied to aluminum alloys directly affect the mechanical properties of the materials (Naeem & Mohammed, 2013).

In the artificial aging processes, to investigate the effect of the aging process on 7075 aluminum alloy, processes were generally carried out at a single temperature and at a single time (El-Amoush, 2011; Xiao et al., 2011; Rokni et al., 2017). However, it is seen that processes are not carried out at different temperatures and at different times. In this study, AA7075-T6 alloys with circular cross-sections were subjected to solution aging and artificial aging using different temperatures and different times. The effects of artificial aging processes on the properties of 7075 aluminum alloy were investigated.

2. Material and method

Resolution and artificial aging of the AA7075 alloy in the T6 state, which is the subject of the study, was carried out using different temperatures and different times. Taking into account the tests to be made at the end of the artificial aging process and the different parameters to be applied during the artificial aging, samples with a diameter of 10 mm and a length of 20 mm were prepared on the CNC lathe using machining methods. In the study, 7075 aluminum alloy in T6 state, which was taken into the solution at 485 °C for 2 hours, was rapidly cooled in water at room temperature, and then artificial aging was applied to the samples at different temperatures and different waiting times specified in Table 1 and Figure 1. In the previous studies, the changes in the mechanical properties of the aluminum alloy (7075) in the aging processes were examined and aging heat treatment was applied at these temperatures and times to reach the optimum values. A heat treatment furnace was used for the applied artificial aging processes.

Table 1. Aging parameters

Sample Number	Solution temperature (°C) – 2 hour	Aging temperature (°C)	Aging time (hour)
T6	-	-	-
2			42
3		100	66
4			90
10	485		42
11		200	66
12			90

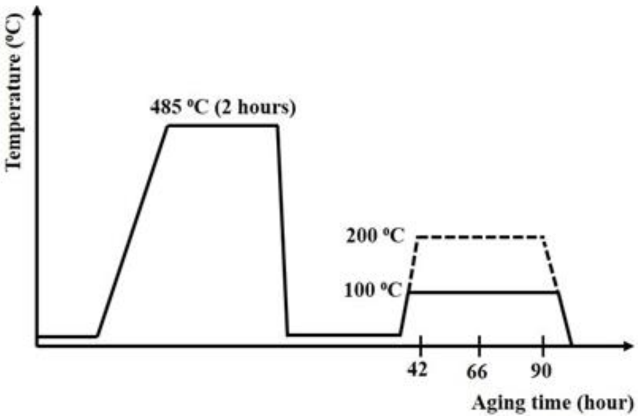

Figure 1. Aging parameters graph

The samples prepared according to the specified standards for metallographic examination were sanded under water with SiC abrasives with grit numbers 180, 320, 400, 600, 800, 1000, and 1200, respectively. After sanding, the samples were polished with 0.3-micron diamond paste. The samples were prepared by cleaning and spraying ethyl alcohol on their surfaces. Samples prepared for microstructural studies were etched in Keller's reagent (2 ml HF, 3 ml HCl, 5 ml HNO_3, 190 ml pure water) for 8-15 seconds. Etched samples were examined with a JEOL brand JSM 7001F model scanning electron microscope.

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Vickers hardness method was used to measure the hardness values. In preparation for the hardness measurement process, the samples were polished and smoothed with Metkon, Forcipol metal sanding, and a polishing device. Microhardness measurements; A Buehler Micromet 2001 micro hardness device was used. The hardness measurement was carried out by pressing the sample surface for 15 s at a load of 10 gf using a

136º Vickers diamond square pyramid tip, creating traces of deformation on the surface. Compression tests were performed with the Besmak brand BMT-100E model test device at 2 mm/min. with the printing speed. A Compression test was used considering that embrittlement may occur with excessive aging in materials as a result of heat treatments carried out at high temperatures and times, and it would be more appropriate to evaluate all experimental results in terms of the same parameter. In addition, since the compression test specimens are smaller in size and size than the tensile test specimens, it was thought that the aging processes performed on small specimens would create a more homogeneous effect on the whole material, and it was thought that this would make the results of the tests more stable.

3. Results and discussion

7075-T6 aluminum alloys were immediately applied to the quenching process after being in solution for 2 hours at 485 °C, and then artificial aging was applied at different temperatures such as 100 °C and 200 °C and for 42, 66, and 90 hours. The effects of aging on mechanical properties were investigated. The result of the spectral analysis performed to determine the percent composition of alloying elements is given in Table 2.

Table 2. Chemical composition of aluminum 7075 alloy used in experimental studies

Element	Al	Si	Fe	Mn	Cu	Mg	Zn	Cr	Zr
Weight %	89.8	0.213	0.541	0.019	1.581	2.589	5.670	0.0151	0.0278

The hardness values obtained from the hardness measurements of the samples at different aging parameters are given in Figure 2. It is seen that the hardness values of the samples that were artificially aged after being taken into the solution were higher than the hardness value of the reference (AA7075-T6 and 20 °C) sample. When the samples were artificially aged at different times and temperatures were examined, the highest hardness value was found in the samples aged at 100 °C and 42 hours. It is observed that there is a decrease in hardness values in other samples whose artificial aging process continues at the same temperature and whose duration is prolonged. It is understood from the literature that the reason for the decrease in hardness values with the increase in the aging time in this period may be caused by excessive aging and coarsening of the microstructure precipitates depending on time. When the increase in aging temperature is examined, it is observed that there is a decrease in hardness as the aging temperature increases (Geçkinli, 2002; Hansen et al., 2004; Chen et al., 2009; Baydoğan et al., 2010; Durmuş et al., 2011; Özyürek et al., 2012; Yilmaz et al., 2012; Demirel & Karaağaç, 2020).

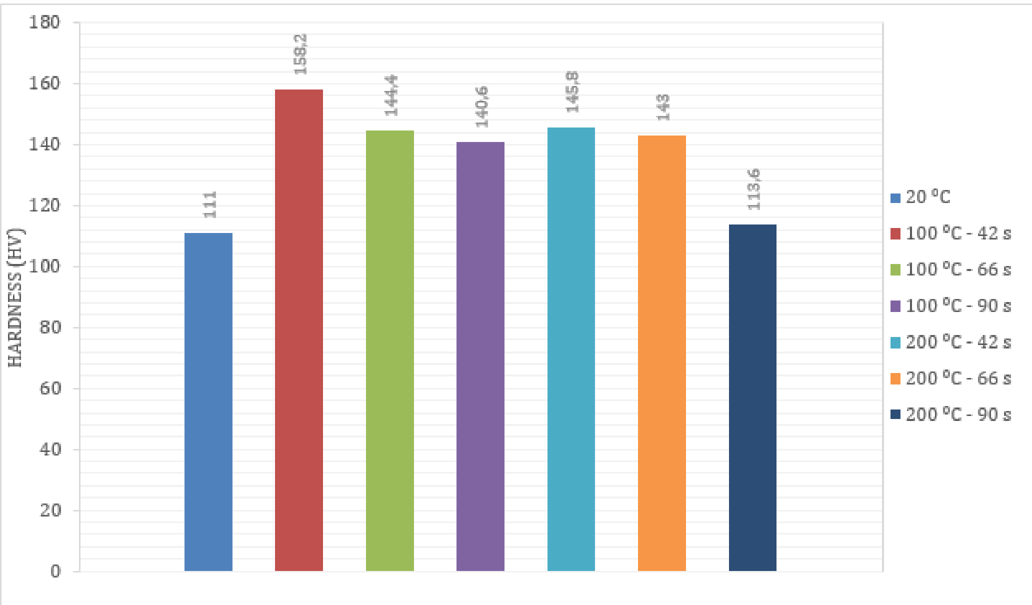

Figure 2. Hardness variation graph

When the compressive strength values are examined, it is seen in Figure 3 that the compressive strength values increase in the artificially aged samples. The main hardening components in 7075 aluminum alloys are the GP zones and the η' phase. The hardness of the material increases when the precipitated particles hinder the dislocation movement since the 2nd phase grains formed after the precipitation process are mostly harder than the matrix. The precipitate particles are generally harder than the matrix and prevent dislocation movement during deformation. In this case, the dislocation part remaining between the precipitates moves depending on the applied tension to overcome the precipitate particles and surround the particles. Since the dislocations move in all directions, the number of rings around the precipitate increases and causes an increase in the dislocation density in the material. The strength increases resulting from the aging heat treatment are due to the precipitates formed in the aluminum matrix. These precipitates caused an increase in compressive strength values at low temperatures by preventing dislocation movements caused by deformation during the experiments. It was determined that the strength values decreased with the increase in temperature. However, increases in elongation values were also observed (Geçkinli, 2002; Hansen et al., 2004; Chen et al., 2009; Baydoğan et al., 2010; Durmuş et al., 2011; Özyürek et al., 2012; Yilmaz et al., 2012).

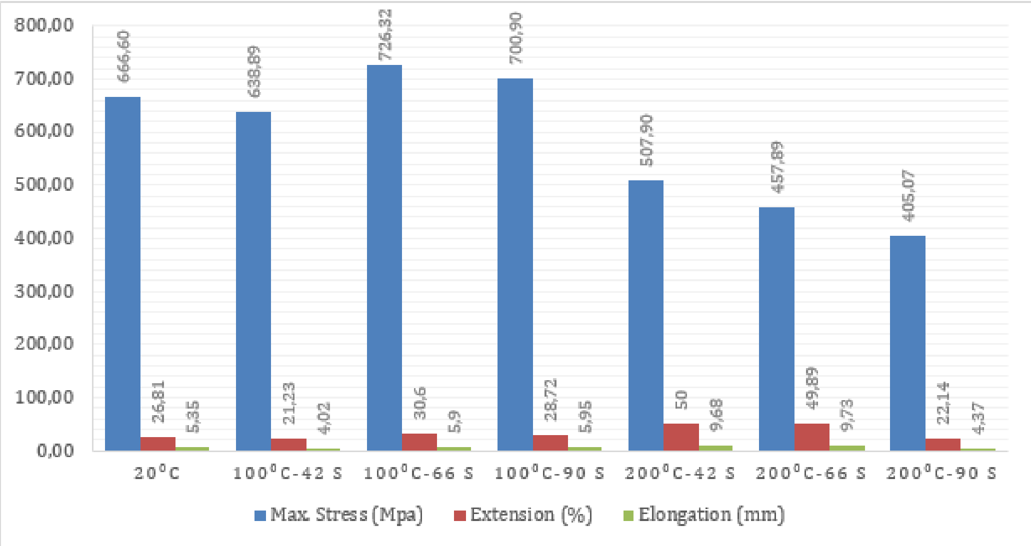

Figure 3. Compressive strength graph

Microstructure SEM pictures and EDS analyses taken from experimental samples are given in Figures 4-5. In EDS analysis, it is thought that the zinc and copper ratios are higher than the other points and a second phase is formed in the microstructure. During aging in the microstructure, GP-I and GP-II zones are formed and the metastable η' phase occurs as aging progresses. With the re-dissolution of the η' phase, both new ones are formed and the η' phase continues to grow and turns into the stable η phase (Hansen et al., 2004; Güleryüz & Kaçar, 2011; Özer & Karaaslan, 2017).

Despite the microstructural properties of the AA7075 alloy, the ή-phase ($MgZn_2$) precipitates, which are expected to form in the structure by aging heat treatment, are not visible due to their nano-size. It is thought that microstructural examinations should be made with a transmission electron microscope (TEM) to visualize the second phase precipitates formed in the structure by the aging process. In a previous study (Kalyon & Özyürek, 2017), it was reported that $MgZn_2$ phase was formed in the structure as a result of aging heat treatment (Şimşek et al., 2018; Altuntaş, 2020; Karaaslan et al., 2007).

The strength increases resulting from aging heat treatment are caused by sediments in the matrix of aluminum. These sediments have caused an increase in the pressure and set values to prevent dislocation movements caused by deformation during experiments. It is also understood from previous studies that when the temperature value is increased at a point, the particles that occur in the precipitous are increased more rapidly, growing and reducing the ability to prevent dislocation movements as a result of growth (Geçkinli, 2002; Hansen et al., 2004; Chen et al., 2009; Baydoğan et al., 2010; Durmuş et al., 2011; Özyürek et al., 2012; Yilmaz et al., 2012).

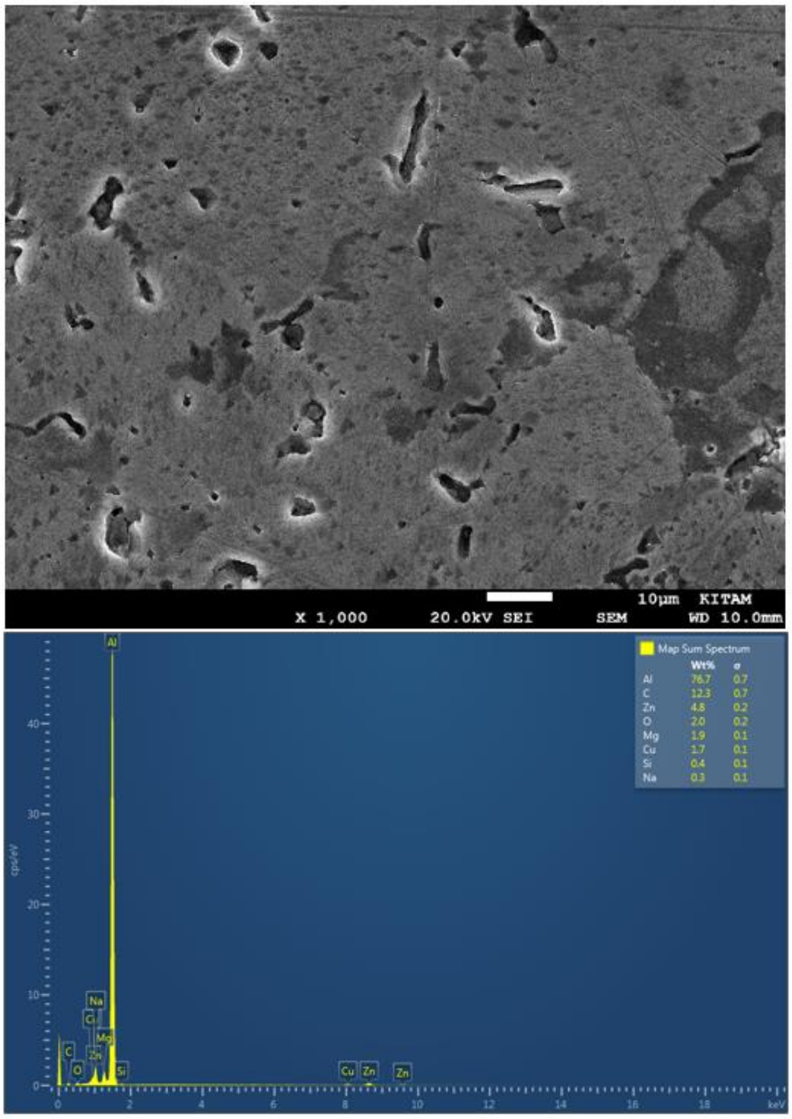

Figure 4. SEM - EDS results of the artificially aged sample at 100 °C for 42 hours

4. Conclusions

In this study, solution treatment, quenching, and then artificial aging heat treatments at different temperatures and times were applied to 7075 aluminum alloys in the T6 state. In the study, the effects of selected heat treatment parameters on the microstructure and mechanical properties of AA7075 alloy were investigated.

Results from experimental studies:

- Solution aging and artificial aging apply to 7075 aluminum alloys, as a precipitation-controlled phenomenon, and can also be applied to other alloys of the 7000 series. It was determined that the compressive strength values of the samples, which were taken into the solution at 485 °C for 2 hours, cooled rapidly in room temperature water and, heat-treated at 100 °C, were higher than the reference sample.

- When the compressive strength values are examined, it is seen that the solution treatment and artificial aging process affect the compressive strength values. In the case of excessive aging, it is observed that the compressive strength of the samples begins to decrease, and this situation increases with the increase in temperature and time.

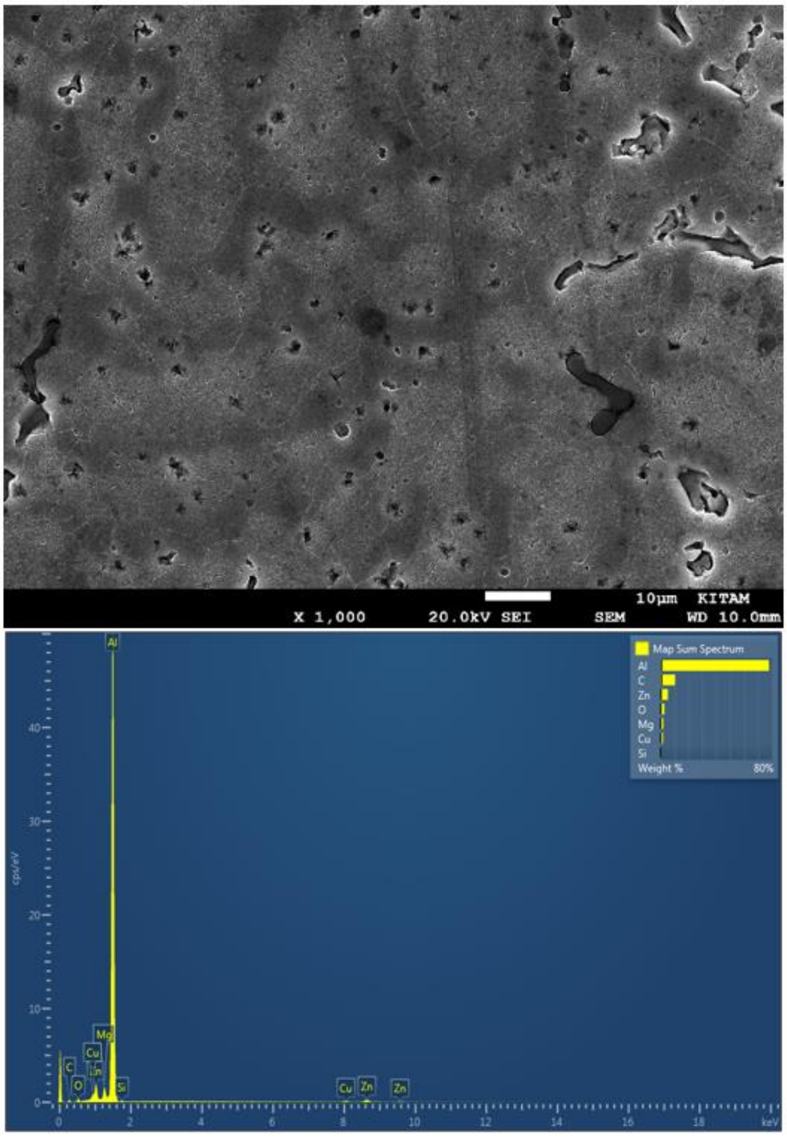

Figure 5. SEM - EDS results of the artificially aged sample at 200 °C for 90 hours

- When the hardness values of the aged samples are taken into account and evaluated with different aging times, the highest hardness values are found in the samples artificially aged for 42 hours.
- When the hardness values of the aged samples are taken into consideration and evaluated at different temperatures, the highest hardness values are found in the samples artificially aged at 100 °C.

- When the hardness values of the artificially aged samples are taken into consideration and evaluated, it has been observed that the aging time has increased along with the excessive aging and a decrease in the hardness values due to this.

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Author contribution

The authors contributed equally to the research.

Declaration of ethical code

The authors of this article, declares that the material and the methods used in this study do not require ethical committee approval and/or special legal permission.

Conflicts of interest

The authors declare that there is no conflict of interest.

References

Ak, M. (2012). *AA206 alüminyum döküm alaşımında empürite demirin mekanik özelliklere etkilerinin incelenmesi* [Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü].

Altuntaş, G. (2020). *Al 7075 alaşımına RRA ısıl işlem ve ön deformasyon etkilerinin incelenmesi* [Yüksek Lisans Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü].

Al-Saadi, H. I. A. & Tunay, R. F. (2017). Suni yaşlandırma işleminin alüminyum alaşımının sertliği üzerine etkisi. *Mühendislik Bilimleri ve Tasarım Dergisi*, *5*(3), 525-532.

Aydın, B. (2002). *AA2014 Alaşımında yaşlandırma ısıl işleminin işlenebilirlik üzerindeki etkilerinin incelenmesi* [Yüksek Lisans Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü].

Baydoğan, M., Çimenoğlu, H., & Kayali, E. S. (2004). RRA işleminin 7075 alaşımının mekanik özelliklerine etkisi. *İtüdergisi/d, 3*(6), 108-116.

Budak, S. (2016). *Alüminyum silisyum alaşımı bir yatak malzemesinin aşınma performansına kolemanit ilavesinin etkisinin incelenmesi/Investigation of effect of colemanite addition on the wear performance of an aluminum silicon alloy journal bearing material* [Doktora Tezi, Fırat Üniversitesi Fen Bilimleri Enstitüsü].

Chen, J., Zhen, L., Yang, S., Shao, W., & Dai, S. (2009). Investigation of precipitation behavior and related hardening in AA 7055 aluminum alloy. *Materials Science and Engineering: A, 500*(1-2), 34-42. https://doi.org/10.1016/j.msea.2008.09.065

Cina, B.M., (1974). *Reducing the susceptibility of alloys, particularly aluminum alloys to stress corrosion cracking*, U.S. Patent, No: 3,856,584. Washington, DC: U.S. Patent and Trademark Office.

Demirel, M. Y., & Karaağaç, İ. (2020). 7075-T6 alaşımının mikroyapı ve mekanik özelliklerine tavlama işleminin etkisinin deneysel olarak araştırılması. *Politeknik Dergisi, 23*(2), 283-289. https://doi.org/10.2339/politeknik.534322

Durmuş, H., Uzun, R. O., & Şahin, S. (2011). Retrogresyon işleminin 7075 alüminyum alaşımının aşınma davranışına etkisi*. 6 th International Advanced Technologies Symposium (IATS'11)* (pp. 16-18), Elazığ.

El-Amoush, A. S. (2011). Intergranular corrosion behavior of the 7075-T6 aluminum alloy under different annealing conditions. *Materials Chemistry and Physics, 126*(3), 607-613. https://doi.org/10.1016/j.matchemphys.2011.01.010

Geçkinli, E. (2002). Alüminyum alaşımlarının ısıl işlemi, *2. Isıl İşlem Sempozyumu*, 07-08 Şubat, İstanbul.

Güleryüz, K., & Kaçar, R. (2011). Deformasyon yaşlanmasının AA7075 alüminyum alaşımının mekanik özelliklerine etkisinin incelenmesi. 6th International Advanced Technologies Symposium (IATS'11) (Vol. 147, p. 152), Elazığ.

Gültekin, K., & Korkmaz, Y. (2021). AA2024-T3 alüminyum alaşımlarına uygulanan farklı yüzey hazırlama ve pürüzlülük işlemlerinin yapıştırma bağlantılarına etkisi. *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 11*(4), 1269-1281. https://doi.org/10.17714/gumusfenbil.895318

Hansen, V., Karlsen, O. B., Langsrud, Y., & Gjønnes, J. (2004). Precipitates, zones and transitions during aging of Al-Zn-Mg-Zr 7000 series alloy. *Materials science and technology, 20*(2), 185-193. https://doi.org/10.1179/026708304225010424

Kalyon, A., & Özyürek, D. (2017). Investigation of the effect of different heat treatments on wear behavior of AA7075 alloy. *Acta Physica Polonica A*, *131*(1), 150-152.

Karaaslan, A., Kaya, I., & Atapek, H. (2007). Effect of aging temperature and of retrogression treatment time on the microstructure and mechanical properties of alloy AA 7075. *Metal Science and Heat Treatment*, *49*(9), 443-447.

Kibar, E. (2010). *7075 alüminyum alaşımlarına uygulanan RRA ısıl işlemlerinin mikroyapı ve mekanik özelliklere etkisi* [Yüksek Lisans Tezi, Sakarya Üniversitesi Fen Bilimleri Enstitüsü].

Li, R., Liu, T., Su, R., & Qu, Y. (2018). Microstructure and mechanical properties of spray-formed 7075 alloy during retrogression. *Journal of Materials Engineering and Performance, 27*(9), 4437-4443. https://doi.org/10.1007/s11665-018-3606-1

Naeem, H. T., & Mohammed, K. S. (2013). Retrogression and re-aging of aluminum alloys (AA 7075) containing nickel. *Digest Journal of Nanomaterials & Biostructures (DJNB), 8*(4).

Özer, G., & Karaaslan, A. (2017). Properties of AA7075 aluminum alloy in aging and retrogression and reaging process. *Transactions of Nonferrous Metals Society of China*, *27*(11), 2357-2362. https://doi.org/10.1016/S1003-6326(17)60261-9

Özyürek, D., Yilmaz, R., & Kibar, E. (2012). RRA işleminde yeniden çözeltiye alma parametrelerin 7075 alüminyum alaşimlarinin çekme dayanimina etkisi. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 27*(1), 193-203.

Rokni, M. R., Widener, C. A., Champagne, V. K., Crawford, G. A., & Nutt, S. R. (2017). The effects of heat treatment on 7075 Al cold spray deposits. *Surface and Coatings Technology*, *310*, 278-285. https://doi.org/10.1016/j.surfcoat.2016.10.064

Şenel, M. C. (2020). Toz metalürjisi yöntemiyle üretilen saf Al ve Al-B4C, Al-Al2O3 kompozitlerin mekanik ve mikroyapı özelliklerinin karşılaştırılması. *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 10*(3), 783-795. https://doi.org/10.17714/gumusfenbil.689359

Şenel, M. C., & Gürbüz, M. (2020). Mikron altı boyutlu alümina katkısının ve soğuk deformasyon işleminin üretilen alüminyum kompozit yapının mekanik özellikleri ve mikroyapısına etkisi. *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 10*(1), 76-85. https://doi.org/10.17714/gumusfenbil.528780

Şimşek, İ., Yıldırım, M., Özyürek, D., & Tunçay, T. (2018). AA7075 alaşımının T6 ısıl işleminde yaşlandırma süresinin aşınma davranışı üzerine etkisi. *İleri Teknoloji Bilimleri Dergisi*, 7(1), 42-49.

Xiao, Y. P., Pan, Q. L., Li, W. B., Liu, X. Y., & He, Y. B. (2011). Influence of retrogression and re-aging treatment on corrosion behaviour of an Al–Zn–Mg–Cu alloy. *Materials & Design, 32*(4), 2149-2156. https://doi.org/10.1016/j.matdes.2010.11.036

Yilmaz, R., Özyürek, D., & Kibar, E. (2012). Yeniden çözeltiye alma parametrelerinin 7075 alüminyum alaşımlarının sertlik ve aşınma davranışlarına etkisi. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 27*(2), 429-438.