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THE INVESTIGATION OF MICROHARDNESS VALUES IN TERMS OF TEMPERATURE AND DURATION OF AGED ALUMINIUM 2XXX AND 6XXX ALLOYS ACCORDING TO STATISTICS

ABSTRACT

In this study, statistical values of microhardness were investigated in terms of temperature and duration of aged aluminium 2XXX and 6XXX alloys. AA 2024 and AA 6063 aluminum alloys were solution treated at two different temperatres of 490°C and 520°C. Then all samples were cooled to room temperature. After this process, the samples were aged at three different temperatures (140°C, 180°C, 220°C) for ten different periods of time (2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 h.). The microstructure of the aged samples was examined by optical SEM-EDS and X-Ray analysis. The hardness values of the aged samples were tested by microhardness tests. The samples were examined by Multivariate Analysis of Variance (MANOVA) with a confidence level of %95 to find out whether a statistically significant difference occurs. As a result of this analysis, temperature and duration on the wear behaviours of aged aluminium 2XXX and 6XXX alloys were statistically significant in microhardness values.

Keywords: AA2024, AA6063, Microhardness, MANOVA, Statistic

YAŞLANDIRILMIŞ 2XXX VE 6XXX ALÜMİNYUM ALAŞIMLARINDA SICAKLIK VE SÜRENİN MİKROSERTLİK DEĞERLERİNE ETKİSİNİN İSTATİSTİĞE GÖRE İNCELENMESİ

ÖZET

Bu çalışmada, mikrosertliklerin istatistiksel değerleri yaşlandırılmış 2xxx ve 6xxx serisi alaşımların sıcaklık ve şartlarına gore incelenmiştir. AA2024 ve AA6063 alüminyum alaşımları farklı iki sıcaklıkta 490 ve 520 C de çözeltiye alınmışlardır. Tüm örnekler oda sıcaklığında soğutulmuştur. Bu işlemden sonra üç farklı sıcaklıkta (140°C, 180°C, 220°C)ve on farklı sürede (2, 4, 6, 8, 10, 12, 14, 16, 18, 20 saat) yaşlandırılmıştır. Yaşlandırılmış örneklerin mikroyapı incelemeleri için SEM-EDS ve X-Ray analizleri yapılmıştır. Yaşlandırılmış numunelerin sertlik dağılımları mikrosertlik testi ile belirlenmiştir. İstatistiksel olarak farklılıklar olup olmadığını bulmak için %95 güvenirlikle MANOVA yardımıyla örnekler incelenmiştir. Sonuç olarak yaşlandırılmış 2XXX ve 6XXX alüminyum alaşımlarının mikrosertlik değerlerinin sıcaklık ve süreye bağlı olarak güvenilir olduğu saptanmıştır.

Anahtar Kelimeler: AA2024, AA6063, Mikrosertlik, MANOVA, İstatistik

1. INTRODUCTION (GİRİŞ)

Precipitation strengthening is one of the most important hardening methods used for strengthening aluminium alloys. In this process, the second phase is precipitated within matrix phase. The hardness and strength values increase as a result of precipitation of a new precipitate due to period and heat from supersaturated solid solution [1 and 2].

With convenient alloying and heat treatment, hardness increased 40 times compared to high purity aluminium. The AA 2024 aluminium alloy with a wide range of properties such as strength and having the highest hardness values among aluminium alloys, is used in engineering applications such as aeroplane constructions, orthopaedic soles, rivet and pulling wheels. AA 6063 aluminium alloy is used in architecture sector for windows, doors, curtain walls, interior fittings, frame systems, lighting, ladders, railings etc. and is used in electronics and machinery industries for heat sink sections, electronic modules, electro motor housings, flexible assembly systems, special machinery elements, truck and trailer flooring, pneumatic installation, railway, and inside applications [3 and 4].

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

In this study, statistical values of microhardness were investigated in terms of temperature and duration of aged aluminium 2XXX and 6XXX alloys. AA 2024 and AA 6063 aluminum alloys were solution treated at two different temperatres of 490°C and 520°C. Than, the samples were examined by Multivariate Analysis of Variance (MANOVA) with a confidence level of %95 to find out whether a statistically significant difference occurs. As a result of this analysis, temperature and duration on the wear behaviours of aged aluminium 2XXX and 6XXX alloys were statistically significant in microhardness values.

3. MATERIAL AND METHOD (MALZEME VE YÖNTEM)

3.1. Materials, Aging Treatments and Hardness Measurement

In this study AA 2024 ($AlCuMg_2$) and AA 6063 ($AlMg_2Si$) wrought alloys were used as the test materials. Both of the alloys were supplied from SEYDISEHIRALUMINUM and ACAMETAL (Turkey). The chemical composition of the used material is given in Table 1. Specimens of 10 mm diameter and 6 mm in height from AA 2024 and AA 6063 aluminium alloys were manufactured by extrusion for adhesive wear and hardness test.

Table 1. Chemical compounds of the materials used in the experiments
Tablo 1. Deneylerde kullanılan malzemelerin kimyasal analizleri

Element	Si	Fe	Cy	Mn	Mg	Zn	Cr	Ti	Al
AA 2024	0,37	0,38	4,28	0,43	1,46	0,18	0,016	0,019	Balance
AA 6063	0,52	0,3	0,08	0,1	0,82	0,1	0,03	0,06	Balance

AA 2024 and AA 6063 aluminium alloys were solution treated at two different temperatures of 490 and 520±5°C for 2 h in a furnace. Then both specimens were cooled to room temperature. After this process, the specimens were aged at three different temperatures (140, 180, 220°C) for ten different periods of time (2, 4, 6, 8, 10, 12, 14, 16, 18, 20 h.) for artificial aging (T6). The microhardness of AA 6063 aluminium alloys were tested under 10 gr load by using of a AFFRI SYSTEM hardness measurement apparatus were made (Figure 1). The results of hardness values were given in Table 2 and Table 5.

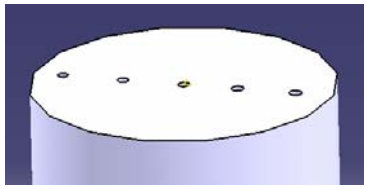

Figure 1. Microhardness measurement points of AA 2024 and AA 6063 aluminium alloys
(Şekil 1. AA2024 ve AA6063 alüminyum alaşımlarının mikrosertlik ölçüm noktaları)

Table 2. Microhardness values of AA 2024 have been aged samples
(Tablo 2. Yaşlandırılmış AA2024 numunelerinin mikrosertlik değerleri)

140°C									
2 HOURS	4 HOURS	6 HOURS	8 HOURS	10 HOURS	12 HOURS	14 HOURS	16 HOURS	18 HOURS	20 HOURS
125,3	142,3	135,5	130,1	129	147,5	160,9	137	153,3	163,4
139	134,2	137,6	140,5	130,7	151,9	158,4	139	162,1	149,6
138	139,5	143,4	146,1	147,4	143,4	156,5	149,8	165	158,1
132,9	148,3	146,3	150,6	137,5	153,9	147,7	156,9	159,6	163,7
132,4	143,5	138,3	152,5	151,5	156,7	155,5	153,3	160	160,7
180°C									
2 HOURS	4 HOURS	6 HOURS	8 HOURS	10 HOURS	12 HOURS	14 HOURS	16 HOURS	18 HOURS	20 HOURS
138,3	132,6	133,5	146,1	152,7	168,3	194,9	152,5	163	152,3
135,2	134	161,7	143,9	156,3	178,8	175,3	158,1	193,8	141,6
129,3	138,7	144,8	145,3	150,6	180,3	195,5	157,7	172,5	143,9
132	138,3	143,9	138,5	161,1	182,3	158,4	144,1	187,8	120,8
141,6	144,8	131	149,8	159,6	191	168,3	140,9	152,7	
220°C									
2 HOURS	4 HOURS	6 HOURS	8 HOURS	10 HOURS	12 HOURS	14 HOURS	16 HOURS	18 HOURS	20 HOURS
128,9	115,5	125	120,3	110,7	132,9	124,3	133,1	118	129
117,6	113,5	122,1	122,3	126,8	120,3	122	126,5	122,4	142,1
124,7	116,5	119	119,5	130,5	121,3	122,4	129,6	122,4	117,4
126,9	112,5	129,8	130,9	119,7	118	129,8	124,9	127,2	132,1
126,6	114,4	142,5	119,7	112,9	126,6	111,8	120,5	134,4	128,4

3.2. Microstructural Analysis (Mikroyapı Analizi)

Microstructures of AA 2024 and AA 6063 alloys with as-cast and artificial aging were characterized by using a Jeol Jsm-6060 Scanning Electron Microscope (SEM) and an Energy Dispersive x-ray Spectroscopy (EDS). Figure 2 (a) and (b) shows the secondary phases in matrix, obtained from SEM photographs of the AA 2024 and AA 6063 aluminium alloys.

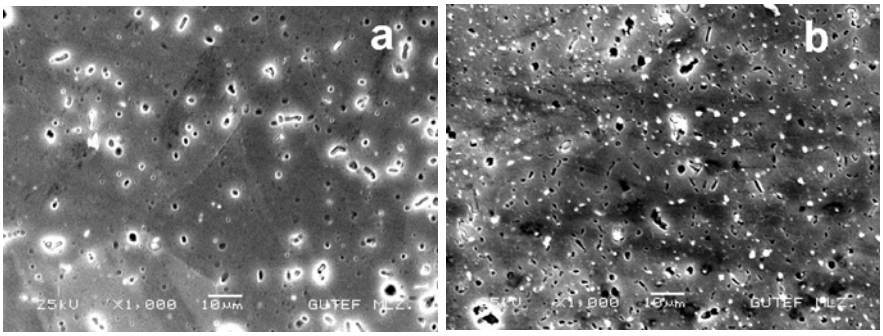

Figure 2. SEM photographs of the (a) AA 6063 and (b) AA 2024 aluminium alloys.
(Şekil 2. (a) AA 6063 ve (b) AA 2024 aluminyum alaşımlarının SEM fotoğrafları)

3.3. Multivariate Double-Side Analysis of Variance (MANOVA) (Çok Değişkenli Varyans Analizi-MANOVA)

In this study, Multivariate Analysis Of Variance – MANOVA method was applied to find out whether there were differences among the microhardness values. This analysis is an important part of the multivariate statistical analysis. If we accept presumption concept as a must for all statistical studies, the presumptions of the MANOVA application here are as follows; the presumptions in which each group shows multivariate normal distribution, the presumptions in which the variance-covariance matrixes of the groups show a homogeny pattern and presumptions like in a group the number of observations should not be less than the number of variants. In this study, the constant term is preferred for the model. Also, it is observed that one piece of data is missing in the data set so this piece of data was excluded in the analysis. Multivariate analysis has two presumptions basically and these are multivariate normal distribution of the observation evaluations for the groups and also homogeneity of the variance and covariance matrixes. In this study, it is presumed that both presumptions are satisfied and the hardness values are coded from 1 to 10 in accordance with the duration and the levels of the neat is coded from 1 to 3 (Table 3). Larger F value indicates that the variation of the process parameter makes a big change on the performance characteristics [5, 6 and 7]. A loss function is used to calculate the deviation between the experimental value and the desired value [8]. Regression analysis method is usually used to obtain this type of relation. In this study, non-linear regression analysis was used to establish a model between the experimentally obtained values and temperature. In the MANOVA, a loss function is used to calculate the deviation between the experimental value and the desired value [9].

Table 3. The observation values between the coded units and the related unit (AA 2024) (Tests of Between-Subjects Effects)
(Tablo 3. Kodlanmış birimler ile ilgili birimler arasındaki gözlem sayıları (AA2024) (Konu faktörleri arasında)

		Label Nauns	N
Duration unit	1,00	2 hours	15
	2,00	4 hours	15
	3,00	6 hours	15
	4,00	8 hours	15
	5,00	10 hours	15
	6,00	12 hours	15
	7,00	14 hours	15
	8,00	16 hours	15
	9,00	18 hours	15
	10,00	20 hours	14
Temperature Degree	1,00	140°C	50
	2,00	180°C	49
	3,00	220°C	50

Many test methods were used in multivariate analysis to test whether there is significant difference between average vectors. In general these are:

- Wilks' lamda tests statistic,
- Pillai's trace statistic,
- Hotelling's trace statistic,
- Roy's lamda tests statistic [10 and 11].

It is said that Wilks Lamda approach is the most effective and most use among the other ones in MANOVA [12 and 13].
In this frame, when the related data set was analyzed in the frame of MANOVA and the results of this analysis were evaluated with index test statistics; moreover, the results of the "Wilks' Lambda" test statistics were taken into account. When we analyzed the data set with SPSS 15.0 we reached the values on Table 3. According to the the significance column of the results of the analysis made with SPSS 15.0 packaged software (Table 4), it was clear that the groups of "duration" and "heat level" were meaningful. Namely, these hardness values showed meaningful variance at 0.95 dependability level in terms of both heat values and duration values. Duration and heat level showed a relation with a total of 67.7 percent of the changes in the hardness level. (R^2= 0.677) (Table 4).

Table 4. The values related to the groups and and their significancy (AA 2024)
(Tablo 4. Gruplarla ilgili değerler ve grupların anlamlılıkları (AA 2024))

Source	Totals of squares (Type3)	Freedom Degree	Avarage Squares	F	Significance
Corrected Model	34495,373(a)	11	3135,943	26,146	,000
Intercept	2990857,862	1	2990857,862	24936,443	,000
Time	9146,115	9	1016,235	8,473	,000
Temperature	25396,222	2	12698,111	105,871	,000
Error	16431,675	137	119,939		
Total	3039168,530	149			
Corrected Total	50927,048	148			

a R Squared = 0,677 (% Contribution= Time: 0,177 ; Temperature: 0,500)

Table 5. Microhardness values of AA 6063 aged samples
(Tablo 5. Yaşlandırılmış AA 6063 numunelerinin mikrosertlik değerleri)

140°C									
2 HOURS	4 HOURS	6 HOURS	8 HOURS	10 HOURS	12 HOURS	14 HOURS	16 HOURS	18 HOURS	20 HOURS
48,6	48,2	63	79,8	70,1	81,4	90,3	94,1	95,3	98,6
56,2	56,3	67,8	76	69	82,5	85,7	94	91	96,6
56,4	52,1	62,1	77,2	71,1	82,1	84,6	87,8	89,1	88,4
51	55,8	60,7	71,6	69,8	89,5	73,5	83,8	87,6	97,4
51,9		62,6	67,3	69,4	78,8	79,4	83,7	91,3	102,2
180°C									
2 HOURS	4 HOURS	6 HOURS	8 HOURS	10 HOURS	12 HOURS	14 HOURS	16 HOURS	18 HOURS	20 HOURS
65,6	82,6	104,2	91,5	93,6	97,7	97,5	97,2	86,6	86,1
74,6	77,7	92,1	92	92,2	97,1	94,2	80,5	92,6	94,6
73	82,5	94,6	86,6	100	98	82,6	90,4	92,2	91,8
72,9	92,1	106,6	90,7	92	99,3	90,2	92,8	90,9	89
72,8	84,2	94,5	89,7	97,2	94,2	100,4	96	88,6	96,5
220°C									
2 HOURS	4 HOURS	6 HOURS	8 HOURS	10 HOURS	12 HOURS	14 HOURS	16 HOURS	18 HOURS	20 HOURS
73,4	87,2	73,8	75,7	74	59,9	69,1	71,3	68	58,9
84,4	89,2	75,3	73,8	75,8	86,7	74,6	75,4	73,1	53,5
77,8	74,4	77,3	74,5	73,2	76,7	67,9	64,8	75,2	61
73,7	83,6	87,4	72	70,6	65,2	74	73,2	69,6	62,6
		74,4			76,6	88,7	68,8	67,6	59,3

Generally the value of the determination coefficient (R^2= 0.677) showed a great significances and also it was possible to state that "duration" and "heat level" were efficient in the hardness level difference. The duration and heat level of AA 6063 alloy showed 48.6 percent of the total difference in the hardness values. (R^2= 0.486) (Table 4). Here, the value of the determination coefficient (R^2= 0.486) did not have significances, and it was possible to maintain that "duration" and "heat level" could affect the difference %50 in the hardness (Table 6 and 7).

Table 6. The observation values between the coded units and the related unit (AA 6063) (Tests of Between-Subjects Effects)
(Tablo 6. Kodlanmış birimler ile ilgili birimler arasındaki gözlem sayıları (AA 6063) (Konu faktörleri arasında)

		label nauns	N
Duration unit	1,00	2 hours	14
	2,00	4 hours	13
	3,00	6 hours	15
	4,00	8 hours	14
	5,00	10 hours	14
	6,00	12 hours	15
	7,00	14 hours	15
	8,00	16 hours	15
	9,00	18 hours	15
	10,00	20 hours	15
Temperature Degree	1,00	140°C	49
	2,00	180°C	50
	3,00	220°C	46

Table 7.The values related to the groups and their significancy (AA 6063)
(Tablo 7. Gruplarla ilgili değerler ve grupların anlamlılıkları (AA 6063))

Source	Totals of squares (Type3)	Freedom Degree	Avarage Squares	F	Significance
Corrected Model	12471,128(1)	11	1133,739	11,432	,000
Intercept	915220,533	1	915220,533	9228,689	,000
Time	4241,798	9	471,311	4,752	,000
Temperature	8546,512	2	4273,256	43,090	,000
Error	13189,774	133	99,171		
Total	953404,920	145			
Corrected Total	25660,902	144			

a R Squared = 0,486 (% Contribution= Time: 0,153 ; Temperature: 0,333)

4. CONCLUSIONS (SONUÇLAR)

The examples were aged with 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 hours heat treatment periods, and under 140, 180 and 220°C working temperatures. The microhardness results of the examples after this process were evaluated statistically and the correlation between the hardness differences in terms of the heat and duration changes were examined and the following results were obtained.

- The microhardness values of AA 2024 and AA 6063 aluminium alloys changed at the level of %95 dependability in accordance with the heat and duration changes.
- The microhardness values of AA 2024 and AA 6063 aluminium alloys measured under 140, 180 and 220°C with 4, 6, 8, 10, 12, 14, 16, 18 and 20 hours periods did not show %95 dependability according to the kind of metal alloys (AA 2024, AA 6063).

- When the microhardness results were compared in the frame of the hardness level with the aim to reach on the aged metal surface, it is concluded that the heat and duration should be applied separately in aging process of AA 2024 and AA 6063 aluminium alloys.

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REFERENCES (KAYNAKLAR)

1. Durmuş, H.K., Özkaya E., Meriç, C., (2006). The use of neural networks for the prediction of wear loss and surface roughness of AA 6351 aluminium alloy. Materials & Design: 27, 2, 156-159.
2. Ertürk, T., Kazazoglu, E., Newby, J.R., and Niemeier, B.A., (1982). Effect of Aging on Bulk Formability of Aluminum Alloys Formability of Metallic Materials—2000 A.D., ASTM STP 753, American Society for Testing and Materials, 19–34.
3. Scheuring, J.N., Grandt A.F., (1995). Evaluation of Aging Aircraft Material Properties, Structural Integrity in Aging Aircraft, 47, American Society of Mechanical Engineers, Aerospace Division, ASME, New York, NY, USA, 99–103.
4. Meyveci, A., (2007). Investigation of wear behaviors of aged aluminium 2XXX and 6XXX alloys. Karabuk University Graduate School of Natural and Applied Sciences Department of Machine, Master Thesis, Karabuk.
5. Lıao Y.S, Chu Y.Y. and Yan, M.T., (1997). Study of wire breaking process and monitoring of WEDM. Int. J. Mach. Tools Manuf., 37(4), 555-567.
6. Ross, P.J., (1996). Taquchi Tecniques for Quality Engineering, 2nded., McGraw-Hill, New york.
7. Lın, J.L, Wang K.S, Yan B.H., and Tarng, Y.S., (2000). An investigation into improving worn electrode reliability in the electrical discharge machining process. Int. J. Adv. Manuf. Technol.,16(6), 113-119.
8. Tosun, N., (2003). The effect of the cutting parameters on performance of WEDM. KSME International Journal, 17(6), 816-824.
9. Tanyildizi, H. and Coskun, A., (2008). The effect of high temperature on compressive strength and splitting tensile strength of structural lightweight concrete containing fly ash, Construction and Building Materials, 22, 2269–2275.
10. Alpar, R., (2003). Uygulamalı çok değişkenli istatistiksel yöntemlere giriş 1, ss:141, Nobel Kitapevi, Ankara.
11. Gregory, C., (1998). Multivariate Analysis of Variance (MANOVA) I. Theory.
12. Taskin, M., Kejanli, H., Firat, E.H., and Caligulu, U., (2008). The investigation of microhardness values in terms of between the Ni and Cu foil on the TLP diffusion bonding of Ni-Ti-Cu alloys manufactured by P/M method according to statistics. Firat University, Science and Engineering Rewiev, 20(2), 379-388.
13. Özdamar, K., (2004). Paket İstatistikler ile Veri Analizi I-II, Kaan Yayınevi, Eskişehir.