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The Effect of Different Cooling Methods to Hole Quality and Tool Life in the Drilling of AA7075 and AA2024 Aluminum Alloys

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ABSTRACT

Controlling the amount of the cutting fluid used in machining processes is important in terms of its effects on the environment, human health, and also on the total cost of production. In this study, the AA7075 and AA2024 aluminum alloys were subjected to drilling process using four different cooling conditions (internal MQL, external MQL, conventional cooling and compressed air cooling), four different cutting speeds (100, 125, 150, 175 m/min) and four different feed rates (0.10, 0.15, 0.20, 0.25 mm/rev). At the end of experiments which have been performed with respect to Taguchi experimental design method, in addition to the hole quality such as surface roughness of hole, diametrical deviation, ovality and axial deviation, wear/build-up edge on cutting tools were investigated. The obtained data were evaluated by performing ANOVA and Signal/Noise (S/N) tests. At the end of experiments, it was determined that cooling method has the most effect on output parameters. It was observed that while the lowest values were found at conventional cooling application, the results from the application of internal MQL were very similar to conventional cooling method. While increased feed rate generally caused increase in all the output parameters, the cutting speed has unclear effect on the test results. The results of the hole quality obtained from the AA7075 alloy were found to be better than the results obtained from the AA2024 alloy, especially in poor cooling conditions such as compressed air cooling and external MQL application.

AA7075 ve AA2024 Alüminyum Malzemelerine Delik Delinmesinde Farklı Soğutma Yöntemlerinin Delik Kalitesine ve Takım Ömrüne Etkisi

MAKALE BİLGİSİ

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ÖZET

Talaşlı imalat işlemlerinde kullanılan kesme sıvısı miktarının kontrolü, hem doğaya ve insan sağlığına olan etkisi açısından hem de toplam üretim maliyeti açısından çok önemlidir. Bu çalışmada, AA7075 ve AA2024 alüminyum alaşımları dört farklı soğutma yöntemi (içten MMY, dıştan MMY, geleneksel soğutma ve basınçlı havayla soğutma), dört farklı kesme hızı (100, 125, 150, 175 m/dk) ve dört farklı ilerleme (0.10, 0.15, 0.20, 0.25 mm/dev) kullanılarak delik delme işlemine tabi tutulmuştur. Taguchi deney tasarımına göre yapılan deneyler sonunda deliklerin yüzey pürüzlüğü, çaptan sapma, dairesellikten sapma ve silindiriklikten sapma olmak üzere delik kalitesi ve takımlarda meydana gelen aşınma/sıvanmalar incelenmiştir. Elde edilen veriler ANOVA ve Sinyal/Gürültü (S/N) testleri yapılarak değerlendirilmiştir. Deneyler sonunda çıktı parametrelerini en çok soğutma yönteminin etkilediği tespit edilmiştir. En düşük değerler geleneksel soğutma uygulamasında gözlenirken, içten MMY uygulamasında elde edilen sonuçların geleneksel soğutma yöntemine çok yakın olduğu görülmüştür. İlerlemedeki artış tüm çıktı parametrelerinde genelde artışa neden olurken, kesme hızının çıktı parametreleri üzerindeki etkisi daha belirsiz olmuştur. Özellikle basınçlı havayla soğutma ve dıştan MMY uygulaması gibi yetersiz soğutma şartlarında AA7075 alaşımından elde edilen delik kalitesi sonuçlarının AA2024 alaşımından elde edilen sonuçlara göre daha iyi olduğu görülmüştür.

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1. INTRODUCTION (GİRİŞ)

In recent years, the rapidly increasing use of aluminum in industrial areas, has become one of the most versatile engineering materials with a unique combination of properties and structures. With various combinations of features on the behavior of these materials in the processing duration it is done a lot of work to this day and still continuing research on this subject [1]. When these studies examined, it is seen that processing conditions and the metallurgical structure of the material modify the workability of aluminum [2-5]. The main problem of workability of Aluminum is in the control of chips. Also due to the ductility of the material adheres to the cutting tool, it causes the other processing problems [6-7].

In machining, especially the removal of chips from the cutting zone is the most common problems in the processing type of drilling operation. In drilling process, the chip formation occurs in a closed area and cannot be seen. The chip evacuation and injection of cutting fluid is more difficult. Friction between the chip and the helix channels and between the drill and worked surfaces is much greater. Rake angle varies over the cutting edge and therefore exists in different cutting conditions over the cutting edge. Therefore, removal of chips in drilling process occur in a much more complex and severe conditions according to the machining process with a single-edge cutting tool [8-9]. There have been many studies for solving such problems encountered in the drilling process to this day. Researchers have investigated chip formation (geometry and movement), hole quality, the force acting on the cutting tool and cutting tool life in order to monitor performance of machining during drilling process. They have examined the optimum cutting parameters and have tried to estimate the best machining performance by experimental methods and mathematical analysis [10-13].

As with all machining process, cutting fluid application is important in the drilling process in the solution on the problems. Because in this process, cutting fluid lowers the heat generated in the cutting zone and reduces friction of the cutting tool-chip interface with lubricating effect. It also helps to move away chips from the cutting zone. Thus, the cutting fluid helps to increase tool life and improved product quality [14]. In drilling operation, the positive effect of the cutting fluid application to machining performance has been demonstrated in many studies [16-19]. However, a successful manufacturing process, cannot be expressed only by production economics including product quality, product amount and time. It is also directly related to the impact of the environment and human health [20]. Thus, reducing the amount of cutting fluid used in machining process, arises a requirement as a result of aforementioned issues. Another important points here is that, while reducing the amount of cutting fluids used in machining process is to adversely affect the product quality and cutting tool life [21]. In recent years Minimum Quantity Lubrication (MQL) method has been used to eliminate the adverse effect of cutting fluids, to reduce production cost and improve product quality [14-15]. Some researchers have investigated the effect of this method, which can be applied to the cutting zone as an oil mist inside or outside the tool, on the machining performance by comparing it with the conventional cooling method. [22-25]. In some of these studies, MQL method yielded results close to conventional cooling, while in some others insufficient performance was observed.

In order to investigate the reasons of the different results obtained in the current studies on MQL, it is aimed to determine the effect of oil mist and compressed air separately as well as the application of MQL method internally and externally. Therefore, some experiments were carried out with four different cooling methods: compressed air cooling, external MQL method, internal MQL method and conventional cooling method. In addition, two different aluminum materials were used in the experiments and the effect of the material factor changed by the cooling method was investigated.

2. MATERIAL AND METHOD (MATERYAL VE YÖNTEM)

In this study, the effects of different cutting parameters and different cooling conditions on hole quality (Surface roughness-Ra, circular deviation D_{XY}, cylindrical deflection-D_Z, diametral deviation-D) and cutting tool life in drilling of AA7075 and AA2024 aluminum alloys were investigated.

Using the Taguchi experimental design method, four different cutting speeds, four different feeds and four different cooling conditions were selected as the test input. Hole quality and cutting tool wear is defined as output parameters. Four-level 4x4x4 L16 experimental design was formed using the Taguchi experimental design method. In this way, the number of 64 experiments was reduced to 16. The same design was repeated for both materials (AA7075 and AA2024), thus reducing the total number of experiments from 128 to 32. Control factors and levels of the experimental design are given in Table 1.

Table 1. Control factors and levels for the experiments (Deneyler için kontrol faktörleri ve seviyeleri)

	Factors	**Unit**	**1. Level**	**2. Level**	**3. Level**	**4. Level**
1	Cooling method (A)		Internal MQL	External MQL	Conventional Cooling	Compressed Air cooling
2	Cutting speed (B)	*m/min*	100	125	150	175
3	Feed rate (C)	*mm/rev*	0.10	0.15	0.20	0.25

Considering the factors in Table 2.1, the most suitable design for the experimental study Taguchi L16 orthogonal sequence was selected. Table 2 shows the experimental design determined with the help of Minitab statistical software.

Table 2. Taguchi L16 orthogonal experimental design for AA7075 (AA7075 için Taguchi L16 dikey dizinli deney tasarımı)

		A	**B**	**C**
Test No	**Variables**	**Cooling Method**	**Cutting Speed *(m/min)***	**Feed Rate *(mm/rev)***
T1	A1B1C1	Internal MQL	100	0.10
T2	A1B2C2	Internal MQL	125	0.15
T3	A1B3C3	Internal MQL	150	0.20
T4	A1B4C4	Internal MQL	175	0.25
T5	A2B1C2	External MQL	100	0.15
T6	A2B2C1	External MQL	125	0.10
T7	A2B3C4	External MQL	150	0.25
T8	A2B4C3	External MQL	175	0.20
T9	A3B1C3	Conventional Cooling	100	0.20
T10	A3B2C4	Conventional Cooling	125	0.25
T11	A3B3C1	Conventional Cooling	150	0.10
T12	A3B4C2	Conventional Cooling	175	0.15
T13	A4B1C4	Compressed Air Cooling	100	0.25
T14	A4B2C3	Compressed Air Cooling	125	0.20
T15	A4B3C2	Compressed Air Cooling	150	0.15
T16	A4B4C1	Compressed Air Cooling	175	0.10

The same operations were carried out in the drilling of AA2024 alloy and 16 different cutting conditions were numbered in the range T26-T41. A new cutting tool is used for each cutting conditions. The cutting tools used are two-edged, helical, 8 mm diameter, internal cooling groove, uncoated carbide drills.

In order to examine the wear occurring in the tools, 30 different holes are repeated for each different cutting conditions. Using the arithmetic mean of the results obtained from repetition experiments, an average value was obtained for each different cut and the results were examined according to these values. The experimental setup is shown schematically in Figure 1.

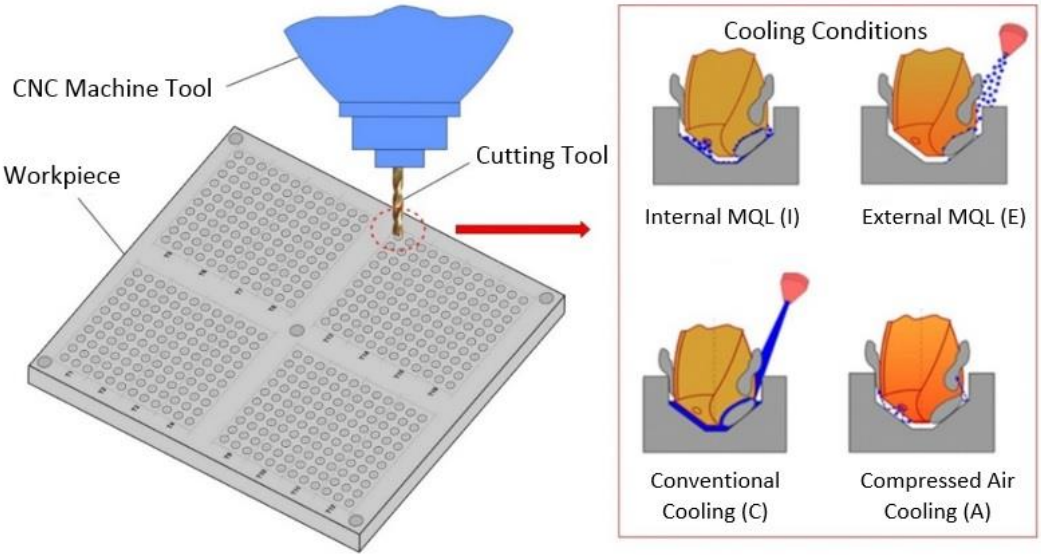

Figure 1. Schematic representation of the experimental setup (Deney düzeneğinin şematik görünümü)

Two different aluminum alloys were used as the workpiece material in the experiments. These are AA 7075 and AA 2024 aluminum alloys. These 25 mm-thick aluminum workpieces are drilled through the length. The chemical and mechanical properties of the AA2024 and AA7075 alloys are given in Table 3.

Table 3. Chemical and mechanical properties of AA7075 and AA2024 aluminum alloys (AA7075 ve AA2024 alüminyum alaşımlarının kimyasal ve mekanik özellikleri)

	Si	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Heat treatment**	**Yield stress *(MPa)***	**Tensile stress *(MPa)***	**Elongation *(%)***	**Hardness *(Brinell)***	**Elasticity *(GPa)***
AA 2024	0.5	4.5	0.6	1.5	0.1	0.2	T4	315-330	440-465	20.0	120	73.1
AA 7075	0.4	1.6	0.3	2.5	0.3	5.6	T6	460-505	530-570	10.0	150	72

The experiments were performed at the ECOSPEED 2600 (HSM) high speed machining center. Technical information about the machine tool is given in Table 4.

Table 4. Technical properties of ECOSPEED 2600 CNC machine (ECOSPEED 2600 CNC tezgahının teknik özellikleri)

Name of Machine	**ECOSPEED 2600 (HSM) high-speed machining center**	
Control Unit	SIEMENS 840D	
Maximum spindle speed	30 000	*rev/min*
Machining table	2500x7000	*mm*
Feeds in Axis	X:65 000, Y ve Z:50.000	*mm/min*
Movements in Axis	X: 6800, Y: 2600, Z: 670 A:±40º, B: ±40º	*mm*

Cooling system of the ECOSPEED machine is the Digital-Super VOGEL MQL system. This system is capable of both internal and external cooling. Constant flow rate and pressure were used in the experiments. Haughton CDT-ML MAX 200 brand cutting fluid was used in MQL system. For internal MQL and external MQL applications, this coolant is applied at a constant pressure of 5 bar."Opet Fuchs Ecocool S PT 45", which is used in the traditional cooling method, was applied to the cutting zone at a pressure of 10 bar from the outside of the tool. In the compressed air cooling method, the air sent to the cutting zone was again applied through the tool at a pressure of 10 bar.

Circularity, cylindricality and dimensional accuracy of the holes were measured with DUE Glabal Performance brand coordinate measuring machine (CMM). The accuracy of the bench was 0.002 mm and measurements were carried out in a room with constant ambient temperature (21-24 °C). In order to obtain a reliable result, four measurements were made for each hole measured and the arithmetic mean of these measurements were taken.

Mahr brand Perthometer M1 type of tabletop surface roughness measuring device was used for surface roughness measurements of the holes. For the reliability of the measurements, four measurements were made for each hole measured from separate points. The mean surface roughness (Ra) values were determined for each hole by taking the arithmetic mean of the values obtained as a result of the measurements.

3. EXPERIMENT AND OPTIMIZATION RESULTS (DENEY VE OPTİMİZASYON SONUÇLARI)

In the drilling process for AA7075 and AA2024 alloys, the change according to cooling conditions and the feed parameters of the average values calculated by taking the arithmetic average of the hole quality values (Surface roughness-Ra, Deviation from diameter-D, Deviation from Circularity-D_{XY} and Deviation from Axial / Cylindrical- D_Z,) measured in the 30 drilling tests repeated for each cutting condition are shown in the graphs in Figure 2.

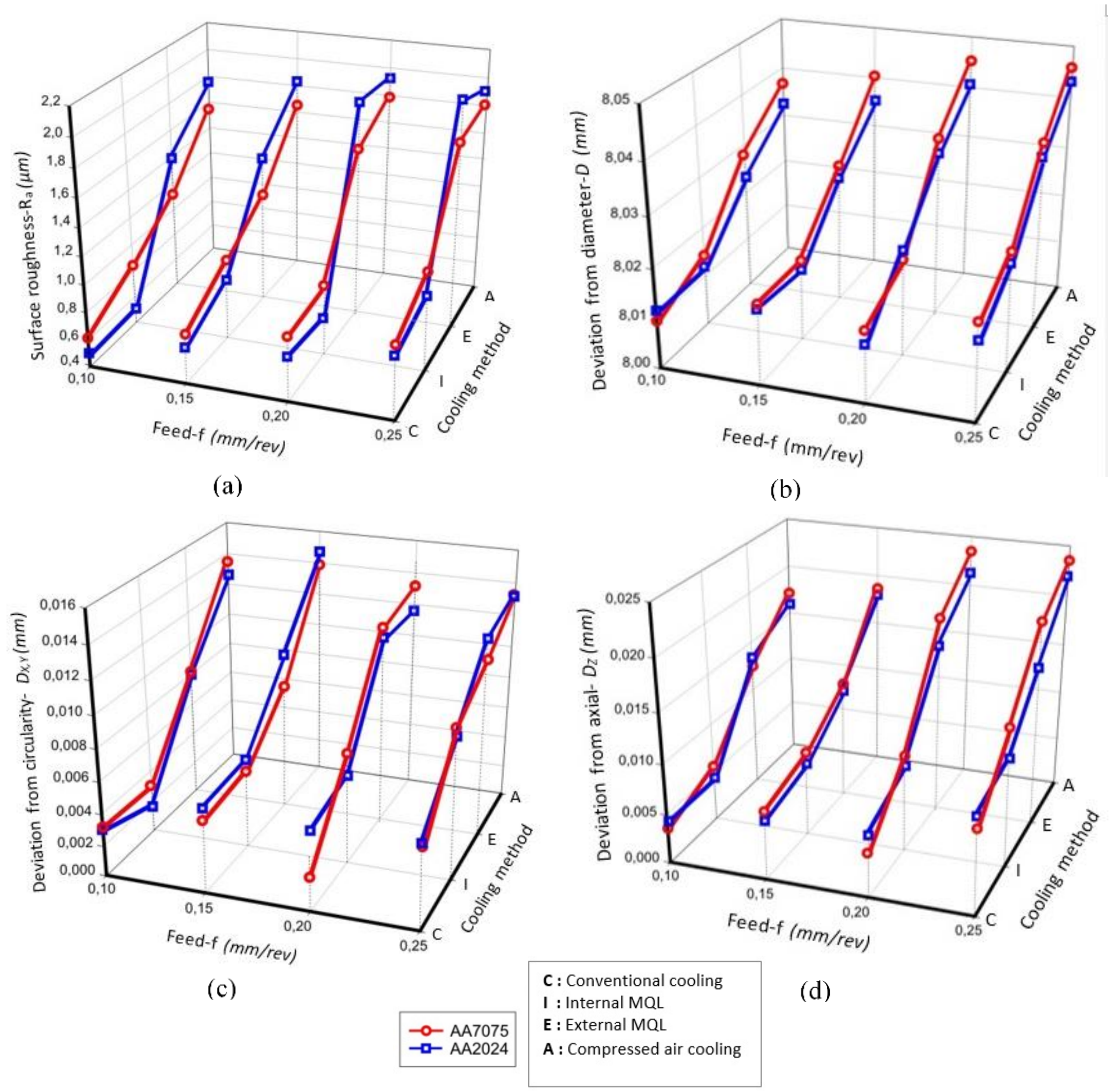

Figure 2. Variation of hole quality according to feed and cooling conditions (a): Surface roughness -*Ra*, (b): Deviation from diameter -*D*, (c): Deviation from Circularity -$D_{X,Y}$, (d): Axial deviation -D_Z

(Delik kalitesinin ilerleme ve soğutma şartlarına göre değişimi (a):Yüzey pürüzlüğü-*Ra*, (b):Çaptan sapma-*D*, (c):Dairesellikten sapma-$D_{X,Y}$, (d):Eksenel sapma-D_Z)

In the graphs shown in Figure 3, the variation of arithmetic average of the hole quality values measured in 30 drilling tests repeated for each cutting condition in AA7075 and AA2024 alloys is shown according to the cutting speed (Vc) and cooling conditions.

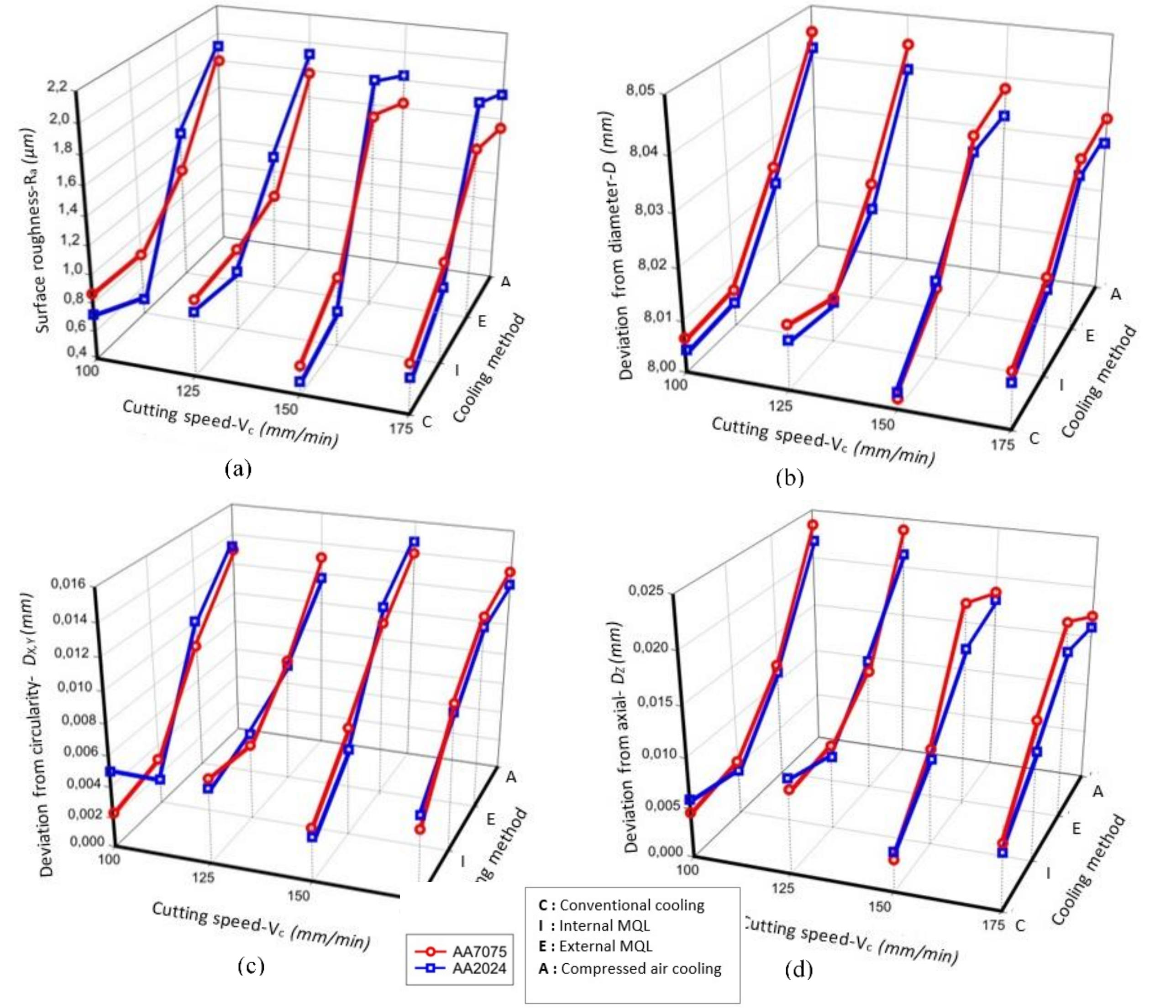

Figure 3. Variation of hole quality according to cutting speed parameters and cooling conditions (a): Surface roughness -*Ra*, (b): Deviation from diameter -*D*, (c): Deviation from Circularity -$D_{X,Y}$, (d): Axial deviation -D_Z (Delik kalitesinin kesme hızı parametresi ve soğutma şartlarına göre değişimi (a):Yüzey pürüzlüğü-*Ra*, (b):Çaptan sapma-*D*, (c):Dairesellikten sapma-$D_{X,Y}$, (d):Eksenel sapma-D_Z)

When the graphs in Figure 2 and Figure 3 are examined, it is clear that the most effective factor on hole quality is the cooling method. When the results of surface roughness (Ra), deviation from diameter (D), deviation from circularity ($D_{X,Y}$) and axial deviation (D_Z) are examined under the same cutting conditions in both figures, the worst hole quality was obtained with compressed air cooling method (A), and the best hole quality was obtained with conventional cooling method (C). The conventional cooling method is followed by internal MQL (I) and external MQL (E) methods, respectively.

When the results are examined, it is seen that the material factor changes the effect of cooling methods on hole quality. This was clearly observed especially in surface roughness results. In Figure 2 (a) and Figure 3 (a) graphs, the conventional cooling and internal MQL method showed lower surface roughness in AA2024 alloy under all conditions, while compressed air cooling and external MQL method showed lower surface roughness in AA7075 alloy under all conditions. One of the most important factors that negatively affect the hole quality factors such as surface quality, deviation from circularity and deviation from diameter is the accumulation of chips. The large and unstable accumulation of chips on the cutting edge deteriorates the quality and precision of the surface being machined [26]. Build-up edge (BUE) of ductile aluminum alloys in the cutting edge triggers chip formation. It is known that the film layer formed at the tool-chip interface by a good cooling method prevents the BEU formed on the cutting edge of the tool and ensures the preservation of the tool geometry and thus the intact tool geometry affects the hole quality positively [6, 27]. In the researches, it has been observed that the internal MQL application is as effective as the conventional cooling application in lubrication of tool-workpiece interface [28, 2]. When the graphs of Figures 2 and 3 are examined in the light of this information, it is thought that the BUE formed on the tool with the AA2024 alloy which is more ductile than AA7075 alloy is less to the conventional cooling and internal MQL application where lubrication is good. Where, it is thought to be much higher in compressed air cooling and external MQL application where lubrication is poor. Therefore, it can be said that the cooling methods change the effect of the workpiece material on the hole quality. It is considered that the inner MQL method for ductile materials such as AA2024 may be an alternative to conventional cooling method in terms of hole quality when the results of measured surface roughness (Ra), deviation from diameter (D), deviation from circularity ($D_{X,Y}$) and axial deviation (D_Z) are examined.

When the changes in cutting parameters were examined, it was observed that especially the effect of external MQL application on the hole quality was changed. While the difference between the hole quality results measured in external MQL application and the hole quality results measured in compressed air cooling application is higher in low cutting parameters, it is seen that this difference decreases considerably in high cutting parameters. From these results, it can be said that the external MQL application is relatively effective at low cutting parameters while preventing friction with lubrication, whereas it is said that the lubrication feature is inadequate because the increasing loads affecting the tool and increasing chip volume make the cutting conditions difficult at high cutting parameters. In addition, it is observed that the results obtained with the conventional cooling method and the internal MQL method are very close to each other at low cutting speeds and feed rates.

Looking at the graphs, it is seen that the increase in the feed rates parameter generally affects the hole quality negatively. The increase in cutting speed has a more unstable effect on hole quality. The increase in cutting speed reduced surface roughness, but caused an increase in geometric results, including deviation from diameter, deviation from circularity and deviation from cylindricality. It is known that the increased cutting speed facilitates cutting by increasing the temperature in the cutting zone. It is considered that the reduction of friction due to the reduced contact area at the tool-workpiece interface with increasing temperature improves the surface quality [29]. However, it should not be underestimated that cutting parameters that cause excessive temperature increase will accelerate the deformation of the cutting tool and reduce its life. Furthermore, unlike other types of machining, chip evacuation is a major problem in drilling. With the increase in cutting speed, the increase in chip volume per unit time makes the discharge of the chip difficult. It is thought that chip jamming increases the vibration by increasing the loads coming to the tool and adversely affects the cutting edges and hole quality of the tool (Figure 4).

3.1. Analysis of Variance (Varyans Analizi)

The data were subjected to ANOVA test in order to determine the degree of effect of the process parameters which are material type, cooling method and cutting parameters on hole quality(surface roughness (Ra), deviation from diameter (D), deviation from circularity ($D_{XY)}$ and axial deviation (D_Z), which is the quality characteristic. ANOVA tests also showed that the most effective factor on the process parameters was the cooling method. The most effective parameter after cooling was feed rate. It has been observed that the material factor is not an effective parameter especially for geometric tolerance results. It has been seen that the cooling methods applied reduced the effect of the material factor on the results. In the ANOVA tests, the results of surface roughness, deviation from diameter, deviation from circularity and deviation from cylindricality are given in Tables 5, 6, 7 and 8, respectively.

Table 5. ANOVA results for surface roughness of AA7075 and AA2024 (AA7075 ve AA2024 ile ilgili yüzey pürüzlülüğü için ANOVA sonuçları)

Source	DF	SS'	SS	MS	F	P	PD (%)
Material type	1	0.00839	0.00839	0.00839	0.31	0.584	0.4
Cooling method	3	6.36370	6.36370	2.12123	78.12	0.000	88.0
Cutting speed (V_c)	3	0.06532	0.06532	0.02177	0.80	0.508	0.9
Feed (f)	3	0.69579	0.69579	0.23193	8.54	0.001	9.6
Error	21	0.57020	0.57020	0.02715	-	-	1.1
Total	31	7.70341	-	-	-	-	100.0

DF: Degree of freedom, SS': Pure sum of squares, SS: Sum of squares, MS: Mean square, PD : Percentage distribution, F: F-Test statistics, P: Significance values

Table 6. ANOVA results for deviation from diameter of AA7075 and AA2024 (AA7075 ve AA2024 ile ilgili çaptan sapma için ANOVA sonuçları)

Source	DF	SS'	SS	MS	F	P	PD (%)
Material type	1	0.0000543	0.0000543	0.0000543	13.95	0.001	1.0
Cooling method	3	0.0049058	0.0049058	0.0016353	420.55	0.000	86.2
Cutting speed (V_c)	3	0.0000487	0.0000487	0.0000162	4.18	0.018	0.9
Feed (f)	3	0.0005969	0.0005969	0.0001990	51.17	0.000	10.5
Error	21	0.0000817	0.0000817	0.0000039	-	-	1.4
Total	31	0.0056873	-	-	-	-	100.0

DF: Degree of freedom, SS': Pure sum of squares, SS: Sum of squares, MS: Mean square, PD : Percentage distribution, F: F-Test statistics, P: Significance values

Table 7. ANOVA results for deviation from circularity of AA7075 and AA2024 (AA7075 ve AA2024 ile ilgili dairesellikten sapma için ANOVA sonuçları)

Source	DF	SS'	SS	MS	F	P	PD (%)
Material type	1	0.0000002	0.0000002	0.0000002	0.26	0.615	0.1
Cooling method	3	0.0004068	0.0004068	0.0001356	208.12	0.000	81.3
Cutting speed (V_c)	3	0.0000381	0.0000381	0.0000127	19.50	0.000	7.6
Feed (f)	3	0.0000413	0.0000413	0.0000138	21.12	0.000	8.3
Error	21	0.0000137	0.0000137	0.0000007	-	-	2.7
Total	31	0.0005001	-	-	-	-	100.00

DF: Degree of freedom, SS': Pure sum of squares, SS: Sum of squares, MS: Mean square, PD : Percentage distribution, F: F-Test statistics, P: Significance values

Table 8. ANOVA results for deviation from cylindricality of AA7075 and AA2024 (AA7075 ve AA2024 ile ilgili eksenel sapma için ANOVA sonuçları)

Source	DF	SS'	SS	MS	F	P	PD (%)
Material type	1	0.0000058	0.0000058	0.0000058	3.83	0.064	0.5
Cooling method	3	0.0009549	0.0009549	0.0003183	209.13	0.000	80.3
Cutting speed (V_c)	3	0.0000236	0.0000236	0.0000079	5.17	0.008	2.0
Feed (f)	3	0.0001724	0.0001724	0.0000575	37.75	0.000	14.5
Error	21	0.0000320	0.0000320	0.0000015	-	-	2.7
Total	31	0.0011887	-	-	-	-	100.0

DF: Degree of freedom, SS': Pure sum of squares, SS: Sum of squares, MS: Mean square, PD : Percentage distribution, F: F-Test statistics, P: Significance values

3.2. Investigation of Wear on Cutting Tools (Kesici Takımlardaki Aşınmanın İncelenmesi)

At the end of 30 drilling, the drills used in MQL application (a), external MQL application (b), conventional cooling (c) and compressed air cooling (d) conditions are given with SEM photographs in Figure 4.

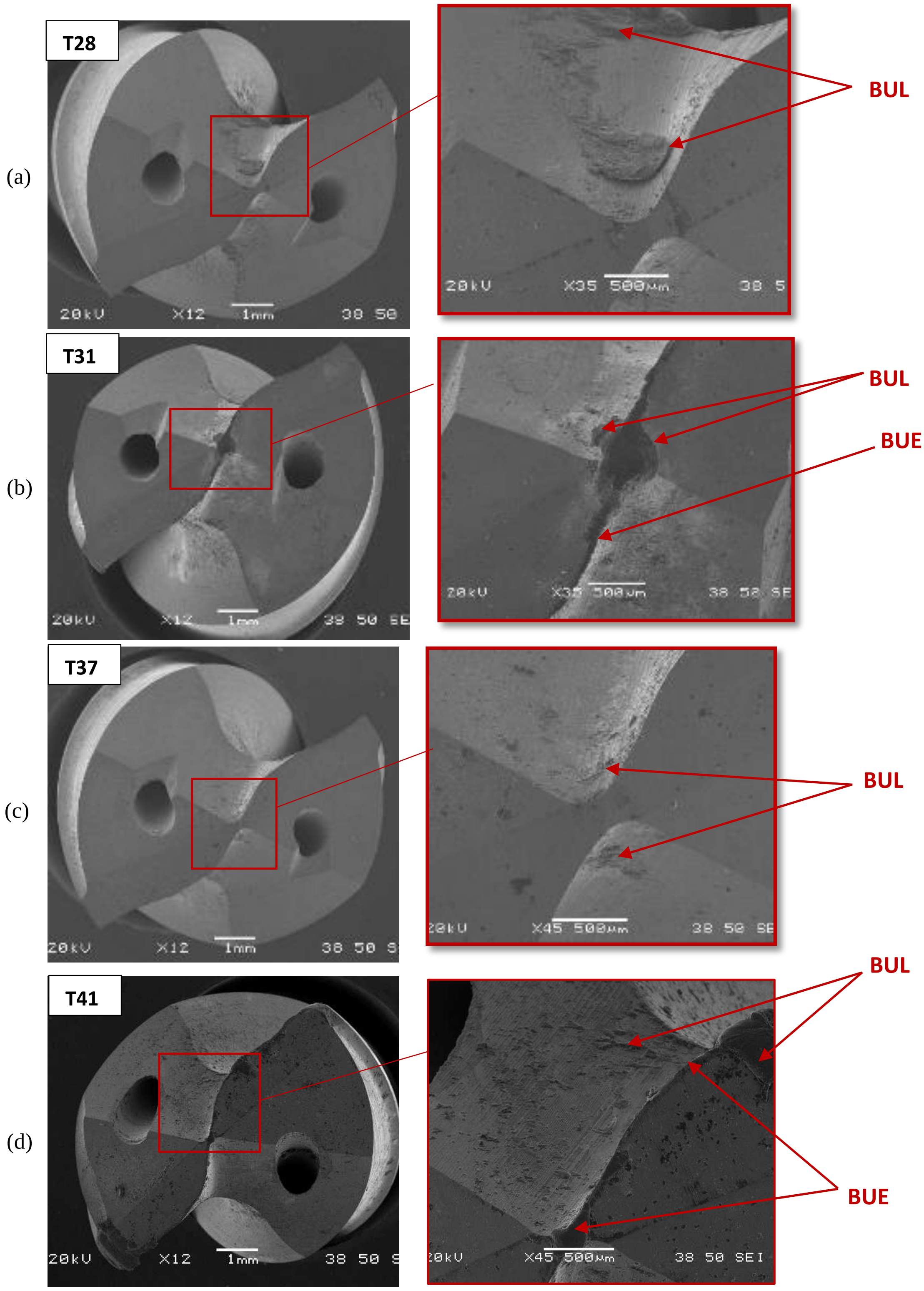

Figure 4. SEM photos of drills used in 30 hole drill repeat on AA 2024 alloy. Result obtained in: (a) Internal MQL condition, (b) External MQL condition, (c) Conventional cooling condition, (d) Compressed air cooling condition (AA2024 alaşımına 30 delik delme tekrarında kullanılan matkapların SEM fotoğrafları: (a) İçten MMY şartı, (b) Dıştan MMY şartı, (c) Geleneksel soğutma şartı ve (d) Basınçlı havayla soğutma şartı)

It is clearly seen in Figure 4 that the built-up edge (BUE) formation on the cutting edges and the built-up layer (BUL) formation on the chip flow surfaces along with the plastering is higher in compressed air cooling (d) and external MQL application (b). These two cooling conditions are much more inadequate than the internal MQL (a) and conventional cooling (c) conditions for reducing the heat generated in the cutting zone and reducing the friction by the lubricating effect. Therefore, it can be said that it is insufficient to prevent the plastering (BUE-BUL) due to temperature and pressure on cutting edges and flow surfaces. This is thought to cause increases in average surface roughness (Ra) results.

In terms of average surface roughness, the highest roughness values were obtained in compressed air cooling application. Especially in conditions where high cutting parameters are used, the increase in Ra values measured from the first hole to the last hole at the end of 30 drilling repetitions in external MQL application is seen to be higher than the increase amount measured in the application of cooling with compressed air, unlike the average Ra values.

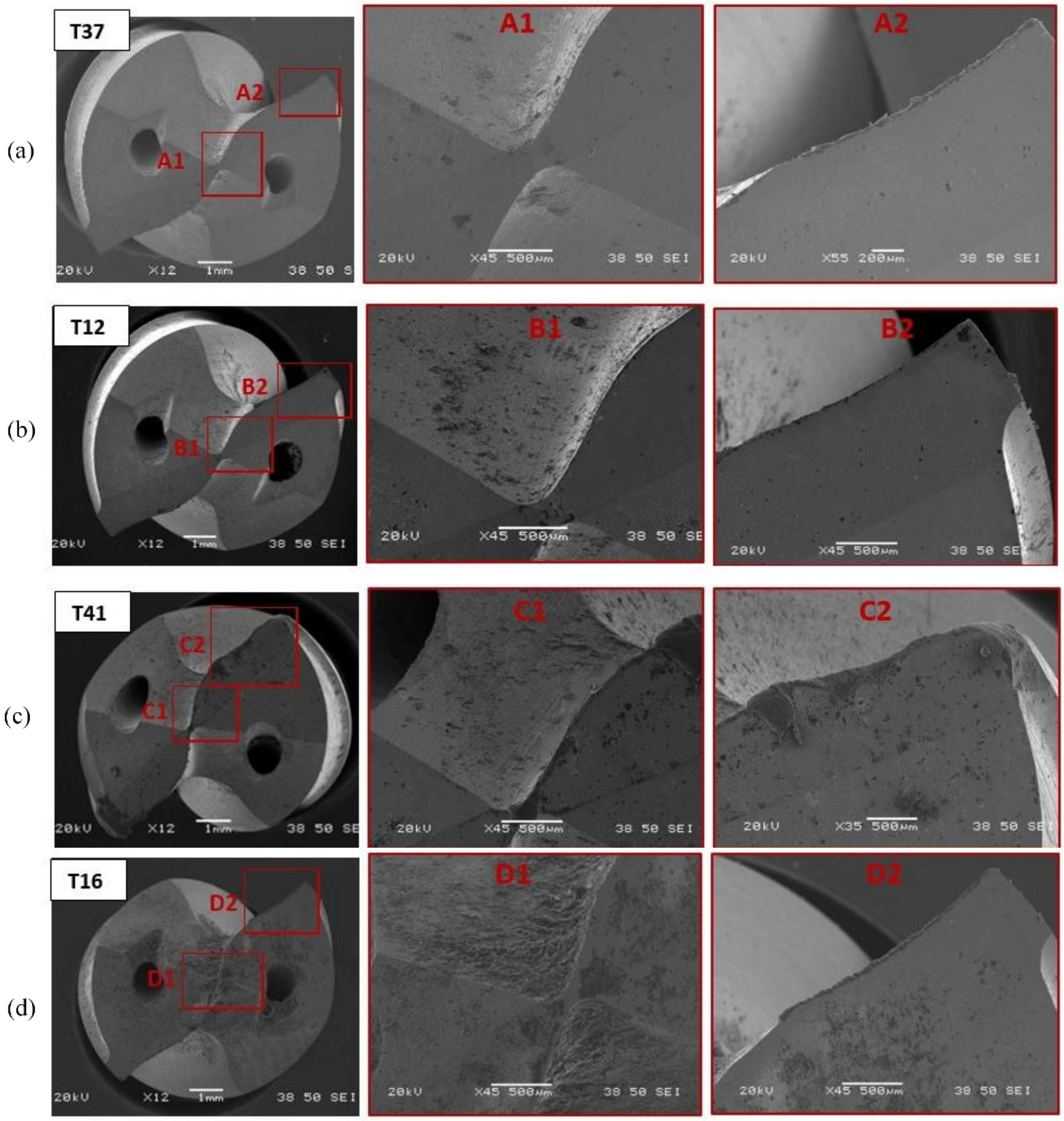

Figure 5. SEM photos of drills used in 30 hole drilling repeats on AA2024 and AA7075 alloys. Results obtained in: (a) Conventional cooling condition for AA2024 alloy, (b) Conventional cooling condition for AA7075 alloy, (c) Compressed air cooling condition for AA2024 alloy, (d) Compressed air cooling conditions for AA7075 alloy. (AA2024 ve AA7075 alaşımlarına 30 delik delme tekrarı sonunda matkapların SEM fotoğrafları: (a) AA2024 alaşımı için geleneksel soğutma, (b) AA7075 alaşımı için geleneksel soğutma, (c) AA2024 alaşımı için basınçlı havayla soğutma ve (d) AA7075 alaşımı için basınçlı havayla soğutma şartlarında elde edilen sonuçlar)

In compressed air method, air is applied through the cutting tool, while in external MQL method, application of air and coolant by nozzles externally is thought to cause in this result. It can be said that in the external MQL application a small amount of externally injected coolant cannot penetrate into the hole and reach the end of the cutting tool. On the other hand, in the application of compressed air cooling, it is assumed that the air is supplied through the tool at a pressure of 10 bar, resulting in faster discharge of the chips.

In order to examine the effect of the workpiece material factor on the results, SEM photographs are shown in Figure 5 where the cutting tool wear can be observed in the drilling of holes in AA7075 and AA2024 alloys under the same conditions. Figure 5 shows the tools used to drill AA2024 (a) and AA7075 (b) alloys using conventional cooling application, where the best hole quality results are obtained at the end of 30 holes drilling. In addition, cutting wear and plastering of the tools (BUE/BUL) used for drilling AA2024 (c) and AA7075 (d) alloys are clearly seen in Figure 5, using the compressed air cooling application where the worst hole quality results are obtained.

In Figure 5-c and Figure 5-d show that the tools have more deformations in the conditions of cooling with compressed air, where the quality of the poor holes is obtained in both materials drilling. Under the conditions where conventional cooling is applied, the tools are seen to have less deformation (Figure 5-a and Figure 5-b). Compared to the AA7075 alloy and the AA2024 alloy in terms of the measured amount of Ra from the first hole to the last hole, and even in terms of the average Ra value, it is generally seen that the value of Ra obtained from the AA2024 alloy is higher under the inadequate cooling and lubrication conditions. This is in line with the deformation images of the tools used in the conditions mentioned in Figure 5-c and Figure 5-d. It is thought that the tool will be exposed to BUE rather than cutting wear when drilling the aluminum alloy. Since the AA2024 alloy is more ductile than the AA7075 alloy, this is considered to be the case because the AA2024 alloy is more plastered to the cutting tool [14, 30].

4. CONCLUSIONS (SONUÇLAR)

In this study, drilling experiments were performed with uncoated carbide tools on AA7075 and AA2024 aluminum alloys by using Taguchi experiment design and applying different cooling conditions with different cutting parameters. At the end of the experiments, the hole quality (average surface roughness, deviation from diameter, deviation from circularity, deviation from cylindricality) and tool wear were examined and the results obtained are summarized below:

At the end of the experiments, it was seen that cooling parameters had the most effect on output parameters. This is clearly seen in the graphs and SEM images of the cutting tools.

- ✓ While the lowest tool deformation and lowest drill quality deviation values were observed in conventional cooling application, the results obtained in internal MQL application were found to be very close to the conventional cooling method. The highest tool deformation and the highest deviation values in hole quality were observed in compressed air cooling.
- ✓ It has been observed that the difference between the results obtained in external MQL and compressed air cooling applications from outside is reduced under conditions where high cutting parameters are used. It has been observed that the difference between the results obtained in internal MQL and conventional cooling applications is reduced under conditions where low cutting parameters are used. While the increase in feed rates led to an increase in all test results, the effect of the cutting speed on the test results was more uncertain.
- ✓ Hole quality results obtained from AA7075 alloy were found to be better than AA2024 alloy, especially under inadequate cooling conditions such as compressed air cooling and external MQL application. This situation was observed more clearly especially in surface roughness.

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