International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 33 العدد
October 2023 اكتوبر

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

The influence of machining parameters on the surface roughness of aluminium alloy 2024 by using cutting tool made from Medium Carbon Steel C45.

Almabrok. A. Ashor, Wannees. A. Shabeesh, Muftah .O. Elfetory
Higher Institute of Engineering Technologies Zliten, , Libya
almbrok2009@yahoo.com, wanissh@yahoo.com, muftahelfe@gmail.com

ABSTRACT

Cutting tool material, Cutting parameters, cutting tool geometry and workpiece material all play a role in producing the desired product quality at an acceptable cost. The focus of this experimental study is to optimize the cutting parameters using two cutting tools made from medium carbon steel C45. We chose C45 because it is an available and cheap material and we can raise its hardness by heat treatment. In this study, we used heat treatment to get the desirable hardness, and then many operations were conducted on the tools like milling, wire cutting etc. to make cutting tool geometries. The experiments were conducted at the Center for Research and Technical Studies, Mechanical Technology Branch, Tripoli, as well as at the Research and Development Center, Tripoli. In this study, the workpiece was aluminium alloy 2024, and external turning tests were performed. All of the turning tests were performed under cooling conditions on the CNC lathe machine SCHAUBLIN 180-CNC TM A2-6 "TEACH IN"PRECISION LATHE WITH FANUK 18i numerical control. In the study, three parameters have been investigated. These parameters are cutting speed, depth of cut, and feed rate. The Cutting speed for turning operation was (500 rpm, 700 rpm, 900 rpm), feed rate (0.2 mm/rev, 0.25 mm/rev, 0.3 mm/rev) and depth of cut(0.5 mm, 1.0 mm, 1.5 mm). The Taguchi design method was used, which included three levels of cutting speed, three levels of feed, and three levels of depth of cut. The standard orthogonal matrix (L9) has been selected to perform the matrix.

تم استلام الورقة بتاريخ: 5/ 10/2023م وتم نشرها على الموقع بتاريخ: 31/ 10/2023م

Nine experiments were performed each experiment producing a test part which was tested for average surface roughness (R_a μm) and S/N Ratios were calculated.

Keywords: Machining parameters, cutting tool, Medium carbon steel C45, Aluminium alloy 2024, Surface roughness.

تأثير عوامل التشغيل على خشونة السطح لسبيكة الألمنيوم 2024 باستخدام أداة القطع المصنوعة من الفولاذ الكربوني المتوسط C45.

المبروك عبداللطيف عاشور، ونيس ابراهيم شابيش، مفتاح عمر الفيتوري

المعهد العالي للتقنيات الهندسية زليتن – ليبيا

muftahelfe@gmail.com, wanissh@yahoo.com,
almbrok2009@yahoo.com.

الملخص

ان المادة المصنوع منها أداة القطع ومعلمات القطع وزوايا الحد القاطع والمادة المصنوع منها قطعة التشغيل كلها تلعب دورًا في إنتاج المنتج بالجودة المطلوبة وبتكلفة مقبولة. تركز هذه الدراسة التجريبية على تحسين معلمات (parameters) القطع باستخدام أداتي قطع مصنوعتين من الفولاذ الكربوني المتوسط C45. تم اختيار Medium carbon steel C45 لأنه متوفر ورخيص كما يمكننا أن نرفع من درجة صلادته بواسطة المعالجة الحرارية. في هذه الدراسة استخدمنا المعالجة الحرارية للحصول على الصلادة المطلوبة لقد استخدمنا عدة عمليات مثل القطع, التفريز ,التجليخ وكذالك استخدمنا آلة W/C لعمل زوايا الحد القاطع لأدوات القطع. تم اجراء التجارب بمركز البحث والتطوير ومركز البحوث والدراسات التقنية فرع التقنية الميكانيكية طرابلس.

في هذه الدراسة، كانت قطعة التشغيل من سبيكة الألومنيوم 2024، تم إجراء جميع اختبارات الخراطة الخارجية تحت ظروف التبريد على آلة المخرطة " TEACH IN"PRECISION LATHE WITH FANUK 18i ذات التحكم الرقمي. في

تم استلام الورقة بتاريخ: 5/ 10/2023م وتم نشرها على الموقع بتاريخ: 31/ 10/2023م

الدراسة، تم أستخدام ثلاث متغيرات وهي سرعة القطع وعمق القطع ومعدل التغذية، وكانت سرعة القطع لعملية الخراطة (500 دورة في الدقيقة، 700 دورة في الدقيقة، 900 دورة في الدقيقة)، ومعدل التغذية (0.2 ملم/دورة، 0.25 ملم/دورة، 0.3 ملم/دورة) وعمق القطع (0.5 مم، 1.0 مم، 1.5 مم).

تم استخدام طريقة تاقوتشي (Taguchi design), حيث أخذت ثلاث مستويات لسرعة القطع، وثلاثة مستويات للتغذية وثلاثة مستويات لعمق القطع. وقد تم اختيار المصفوفة المتعامدة القياسية (L9) لأداء المصفوفة .

تحصلنا على (9) تجارب .وأخذت من كل تجربة متوسط (3) قراءات مختلفة لنعومة السطح Ra ثم بعد ذلك تم حساب S/N (نسبة الإشارة إلى الضوضاء) رياضيا.

الكلمات الدالة: معلمات التشغيل، أداة القطع، صلب متوسط الكربون C45، سبيكة الومنيوم 2024، خشونة السطح.

1. Introduction

The selection of cutting tool materials is one of the key factors in determining the effectiveness of the machining process (ASM, 1989b). During cutting, the tool is usually exposed to high temperatures, high stresses, rubbing friction, sudden impact, and vibrations.

Therefore, the two important issues in the selection of cutting tool materials are hardness and toughness. Hardness is defined as the endurance to plastic deformation and wear; hardness at elevated temperatures is especially important. Toughness is a measure of resistance to impact and vibrations, which occur frequently in interrupted cutting operations such as milling and boring. Hardness and toughness do not generally increase together, and thus the selection of a cutting tool often involves a trade-off between these two characteristics (Lee, J.; et al, 1999). The first study on surface roughness was performed in Germany in 1931 (Bayrak, 2002). The surface qualities were arranged as the standard DIN 140. Surfaces are expressed as "machined or not machined surfaces". In

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

all machined pieces, the examinations performed by hand and eye are taken into consideration. The surfaces are classified according to tactile feeling and the naked eye. Surface qualities are designated in 4 different forms: coarse, rough, medium and fine.
Kopac & Bahor (1999), studied the interaction of the technological history of a workpiece material and the machining parameters on the desired quality of the surface roughness of a product. The key to producing a better surface finish with any tool is the wear resistance at high cutting speed**.** Hardness is the first requisite of a cutting tool material because it must be able to penetrate other materials. Toughness is also desirable to withstand shock. Cutting tools must work upon many kinds of metals and under a variety of conditions such as speed, feed, wear, rake angle and depth of cutting. No, one cutting material is best for all purposes.
Lin W.S (2008) has studied the effect of cutting speed and feed rate on the surface characteristic by using a cermet tool on austenitic stainless steel 304, and found that the smaller the feed rate, the smaller the surface roughness value.
Also, B.Sidda Reddy, et al., (2008) have studied the effect of cutting speed and feed rate on the surface characteristic by using a carbide tool on aluminium alloy using full factorial design.
The principal cutting tools materials which will be used in this study are Medium carbon steel C.45. The cutting conditions and tool geometry are of primary importance in determining the quality of the surface (Davim, J. P et al., 2008). In this study, the surface roughness produced on workpieces of aluminium alloy AISI2024 was studied using a turning machine and cutting tool made of medium carbon steel C.45.
The aim of this study was to assess the process variability concerning surface roughness, using different cutting conditions with two different tool materials. For this study a nine factorial experiment was performed for each tool, three levels of cutting speed, three levels of feed rate, and three levels of depth of cut.

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

2. Materials and methods

2.1Cutting tool preparation

The selection of a proper material depends on such factors as the cutting operation involved, the machine to be used, the workpiece material, production requirements, cost, and surface finish and accuracy desired. The major qualities required in a cutting tool are hot hardness, resistance to mechanical impact, thermal shock, wear resistance, chemical stability and inertness to the workpiece material (Klocke, F., Klocke, F., & Kuchle, A. 2011).The total number of cutting tools medium carbon steel C45 to be studied is 2 pieces.

The medium carbon steels of the plain carbon type contain 0.30 to 0.52% carbon improves the machinability by heat treatment. The increased carbon content of this group of steels makes them an excellent choice for forged and cold formed products where they can be heat treated to a moderate level and the desired hardness of the finished component is obtained by cold working the part. These steels are commonly used in spring wire, crankshafts, drive keys, cold headed rods and ring gears.

The test pieces were taken from a 40 mm diameter bar and cut by an electric saw machine into sections,155 mm length. Each sides of each specimen were machined flat by using milling machine to get 25 ×20×140 dimensions. One piece is quenched by water and the other piece quenched by oil .

Tables 1 and 2 show the chemical composition and physical properties of AISI C45 Carbon steel respectively (Bringas, J. E. 2004).

Table 1 Chemical composition of AISI C45 Carbon steel

Elements	C	Si	Mn	P	S
Wt.%	0.43-.50	0.2	0.6-0.9	0.04	0.05

Table 2 Physical properties of AISI C45 Carbon steel

Density (kg/dm³)	Hardness (HRC)	Elastic modulus (KN/mm²)	Specific heat (J/kg k°)
7.8	26	200	0.48

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

2.2 Cutting tool Heat Treatment

2.2.1. Austenitize

Two pieces in temperature above upper critical temperature A3 at 860°C for 48 minutes in an electric furnace. The time should be approximately one hour at temperature for each 25 of thickness. One piece is quenched with oil and the other one piece is quenched by water to room temperature (very fast cooling). After quenching, steel is very hard and brittle and practically no use. Structure after quenching is fine martensite which is a complex, hard and brittle structure.

2.2.2Tempering

Set the furnace to the desired tempering temperature (below lower critical temperature) at 200°C. Then load the samples inside the furnace for one hour, then remove samples from the furnace and allow them to cool to room temperature in still air. After tempering, steel becomes tough and loses some hardness. It became use able now.

2.3 Cutting Tool Mechanical Testing

For hardness testing, use a grinding machine to remove oxide layers formed during heat treatment, taking an average of five hardness readings at different positions on the samples.
The average hardness was 45 HRC for water quenching and 40 HRC for Oil quenching.

2.4 Cutting Tool Geometry

In metal cutting operations tool geometry plays a key role in determining the ultimate productivity and tool life of a particular operation (Davim, J. P et al., 2008) & (Klocke, F., Klocke, 2011). Figure 1 shows the tool geometry of C45 carbon steel for turning aluminum alloy 2024.

After heat treatment, the cutting tools angles were cut on the wire cut machine to obtain the correct tool angles

Table 3 shows the tool geometry of C45 carbon steel for turning aluminium 2024.

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 33 العدد
October 2023 اكتوبر

تم استلام الورقة بتاريخ: 5/ 10/2023م وتم نشرها على الموقع بتاريخ: 31/ 10/2023م

Table 3 Tool geometry of C45 carbon steel for turning aluminum alloy 2024

Angles description	Back rake angle	Side rake angle	Side cutting edge	End cutting edge	Side relief angle	End relief angle	Nose radius (R)
Angles degree	20°	16°	15°	8°	14°	10°	0.8mm

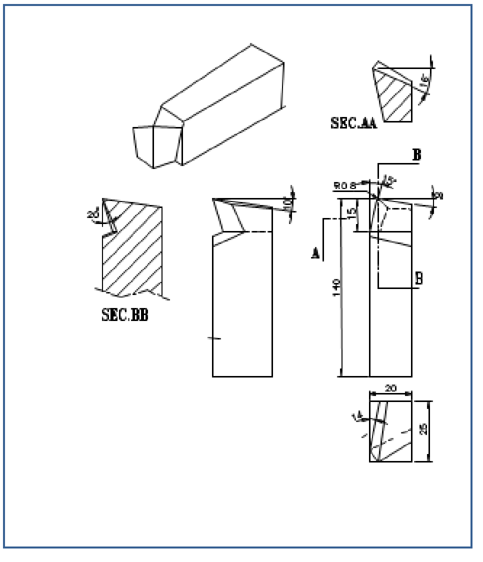

Figure1. Cutting tool geometries of C45 carbon steel for turning aluminum alloy 2024

2.5 Work piece Material

The workpiece material was aluminium alloy 2024; due to its lightweight and high strength and excellent fatigue resistance, it's used for engineering applications like aircraft structures, wings, and fuselages, also used in food processing, oil and gas process industries etc. (Bringas, J. E. 2004).

Tables 4 and 5 show the chemical composition and physical properties of aluminum alloy 2024 respectively (ASM International Handbook Committee 1992).

تم استلام الورقة بتاريخ: 5/ 10/2023م وتم نشرها على الموقع بتاريخ: 31/ 10/2023م

Table 4 Chemical composition of Aluminium alloy 2024 (% wt)

Elements	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Wt.%	0.50	0.5	3.8-4.9	0.3-0.9	1.2-1.8	0.1	0.25	0.15

Table 5 Physical properties of Aluminum alloy 2024

Tensile Strength. MPa	Yield Strength. MPa	Elongation at fracture (L_o=5d) %	Modulus of Elasticity GPa
310-470	170-450	10-20	73

2.6 Measuring of Surface Roughness

The surface roughness was measured in this study by using the ALPA-SM RT-20 + Column Printer device as shown in Figure 2. The surface roughness values were recorded at locations around the circumference at random distances from the edge of the specimens to obtain statistically meaningful data for each factor level combination. Surface roughness (Ra) was chosen as a major parameter in this study.

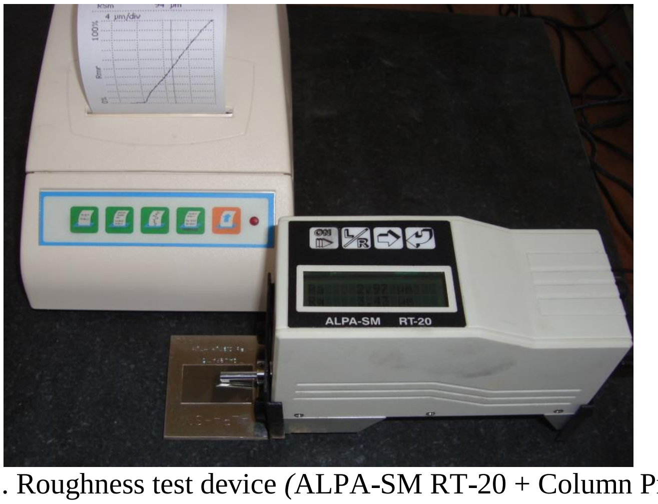

Figure2. Roughness test device (ALPA-SM RT-20 + Column Printer. Ref. Op 1058/S16/025M

تم استلام الورقة بتاريخ: 5/ 10/2023م وتم نشرها على الموقع بتاريخ: 31/ 10/2023م

3. Results and Discussion of the Experiments

3.1Experimental design

Taguchi method is a powerful tool for the design of high quality systems. It provides a simple, efficient and systematic approach to optimize designs for performance, quality and cost (Avner, S. H. 1974). Taguchi method is an efficient method for designing a process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment (DC, M. 1997). Taguchi approach to the design of experiments is easy to adopt and apply for users with limited knowledge of statistics, hence gaining wide popularity in the engineering and scientific community (Nalbant, M., Gökkaya, et al. 2007) and Bayrak, M. 2002).

The desired cutting parameters are determined based on hand book (ASM Handbook Committee 1989). In this method, the main parameters, which are assumed to influence process results, are located at different rows in a designed orthogonal array. With such an arrangement , randomized experiments can be conducted. In general, signal to noise (S/N) ratio (n, dB) represents quality characteristics for the observed data in the Taguchi design of experiments. In the case of surface roughness amplitude, lower values are desirable. These S/N ratios in the Taguchi method are called as the smaller the better characteristics and are defined as follows:

$$\frac{S}{N} = -10\ \log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} {y^2}_i\right)$$

Where y_i is the observed data at the i_{th} trial and *n* is the number of trials. From the S/N ratio, the effective parameters having an influence on process results can be obtained.

3.1.1 Signal to noise ratio

The objective of using the S/N ratio as a performance measurement is to develop products and processes insensitive to noise factors. The S/N ratio indicates the degree of the predictable

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

performance of a product or process in the presence of noise factors. Process parameter settings with the highest S/N ratio always yield the optimum quality with minimum variance (Antony, J., Hughes, M., & Kaye, M. 1999).

3.1.2 Selection of the quality characteristic

There are three types of quality characteristics in the Taguchi methodology, such as smaller-the-better, larger the- better, and nominal the best. The goal of this research was to produce minimum surface roughness (Ra) in an turning operation. Smaller (Ra)values represent better or improved surface roughness. Therefore, a smaller-the-better (Ra) quality, and the higher- the-better (S/N) ratio. Analysis of the influence of each control factor (S, F and D) on the surface roughness Ra has been performed with a so-called signal to noise ratio. Response tables of S/N ratio for surface roughness are show the S/N ratio at each level of control factor and how it is changed when settings of each control factor are changed from one level to other. The influence of each control factor can be more clearly presented with response graphs.
The cutting parameters are shown in Table 6.

Table 6. Machining parameters and their levels for workpiece Aluminum alloy 2024

Symbol	Control factor	Level			Observed values
		1	2	3	
		Minimum	Intermediate	Maximum	
A	Cutting speed (rpm)	500	700	900	Surface roughness
B	Feed Rate (mm/rev)	0.2	0.25	0.3	
C	Depth of cut (mm)	0.5	1	1.5	

Three levels of cutting speed, three levels of feed and three levels of depth of cut were used on Aluminum alloy 2024 workpiece.
The standard orthogonal array (L9) has been selected to perform the matrix experiment in Table 7.

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

Table 8 shows the various cutting parameters for each experiment were used.

Table 7 The Orthogonal Array L_9 for Taguchi DOE (design of experiment)

NO.	Cutting Speed	Feed Rate	Depth of Cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 8. The various cutting parameters for each experiment when the workpiece material was Aluminum 2024.

Exp. No	Cutting Speed		Feed Rate mm/rev	Depth of Cut mm
	m/min	rpm		
1	48	500	0.2	0.5
2	48	500	0.25	1.0
3	48	500	0.3	1.5
4	66	700	0.2	1.0
5	66	700	0.25	1.5
6	66	700	0.3	0.5
7	85	900	0.2	1.5
8	85	900	0.25	0.5
9	85	900	0.3	1.0

3.2 Case number 1

The cutting tool used in this case was medium carbon steel C.45 (water quenching) with a hardness 45 HRC, and the workpiece material was aluminium alloy 2024. The workpiece used was 120 mm in length, 50 mm in diameter. The workpiece was centered on both sides to accommodate in lathe centers, and then skin turned to clean the surface. The diameter of the

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

workpiece was maintained between 48 to 49.5 mm. Figure 3 and 4 show the cutting tool with tool geometries for turning aluminium alloy 2024 and the workpiece respectively

Figure 3 Cutting tool is medium carbon steel C.45 (water quenching)

Figure 4 Aluminum alloy 2024

Table 9 shows the various cutting parameters were performed by using the (L9) orthogonal array. Nine experiments were performed with each experiment producing a test part which was tested for average surface roughness (Ra µm) and calculated the signal to noise ratio S/N.

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

Table 9 Results of L_9 (OA) and data analysis of tool medium carbon steel C.45 (water quenching) and the workpiece material was aluminium alloy2024

Exp. NO.	Cutting Speed rpm	Feed Rate mm/rev	Depth of Cut mm	Experimental values Ra (µm)			Total value Ra (µm)	Average value Ra (µm)	S/N Ratio
				1	2	3			
1	500	0.2	0.5	0.58	0.54	0.55	1.67	0.56	5.03
2	500	0.25	1	0.77	0.68	0.65	2.1	0.7	3.1
3	500	0.3	1.5	0.81	0.9	0.83	2.54	0.85	1.41
4	700	0.2	1	0.49	0.48	0.52	1.49	0.5	6.02
5	700	0.25	1.5	1.12	1.15	1.06	3.33	1.11	-0.91
6	700	0.3	0.5	1.06	1.07	1.08	3.21	1.07	-0.59
7	900	0.2	1.5	0.7	0.77	0.83	2.3	0.77	2.27
8	900	0.25	0.5	0.45	0.46	0.43	1.34	0.45	6.93
9	900	0.3	1	1.25	1.18	1.28	3.71	1.24	-1.87

The results for average surface roughness measurements in Table 9 range from 0.45 to 1.24µm, and experiment number **eight** gives the lowest surface roughness measurements of 0.45 µm, which is corresponding to the largest calculated value of S/N ratio 6.93, and experiment number **nine** gives the largest surface roughness measurements of 1.24µm, which is corresponding to the lowest calculated value of S/N ratio -1.87.

Figure 5 shows the feed rate against the surface roughness at different cutting speeds. It can be seen that the higher cutting speed 900 rpm, at a medium feed rate 0.25 mm/rev, and at the lowest depth of cut 0.5mm gave us the optimal surface roughness.

تم استلام الورقة بتاريخ: 5/ 10/2023م   وتم نشرها على الموقع بتاريخ: 31/ 10/2023م

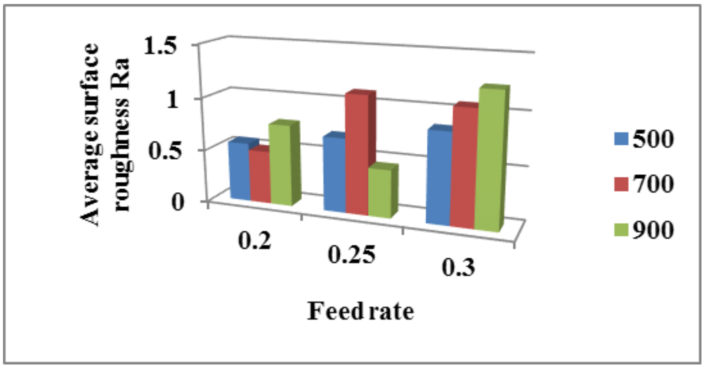

Figure 5. The effect of feed rate on the surface roughness at different cutting speeds

Figure 6 shows the depth of cut against the surface roughness at different cutting speeds. It shows that the lowest value of surface roughness is at the higher cutting speed 900 rpm, at a medium feed rate 0.25 mm/rev, and at the lowest depth of cut 0.5mm**.**

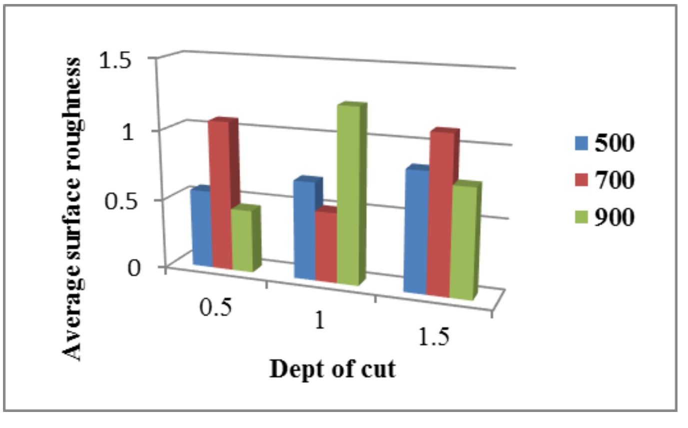

Figure 6.The effect of depth of cut on the surface roughness at different cutting speed.

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

Figure 7 shows the number of experiments against the S/N ratio. It shows the higher value of S/N ratio in experiment number **eight**. Therefore the higher cutting speed 900 rpm, at medium feed rate 0.25 mm/rev, and at the lowest depth of cut 0.5mm gave us the optimal surface roughness.

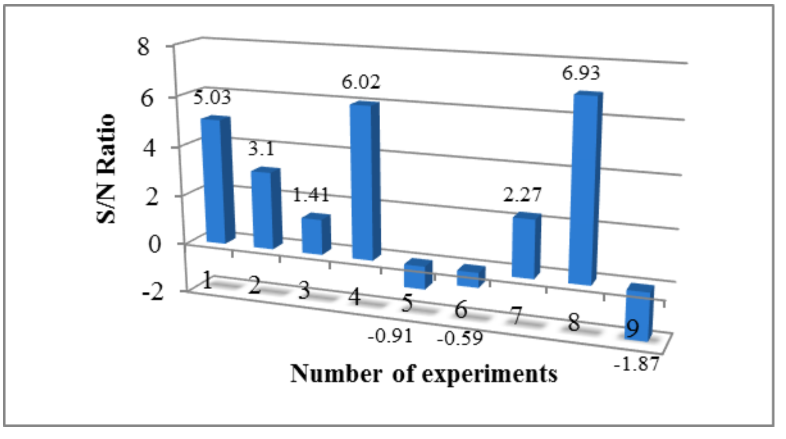

Figure 7 The number of experiments against the S/N ratio.

3.3 Case number 2

The cutting tool used in this case was medium carbon steel C.45 (oil quenching) with hardness 40 HRC, and the workpiece material was aluminium alloy 2024. The workpiece used was 120 mm in length and 50 mm in diameter. The workpiece was centered on both sides to accommodate in lathe centers, and then skin was turned to clean the surface. The diameter of the workpiece was maintained between 48 to 49.5 mm**.** Figures 8 and 9 show the cutting tool with tool geometries for turning aluminium alloy 2024 and the workpiece respectively

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

Figure 8 Cutting tool is medium carbon steel C.45 (oil quenching)

Figure 9 Aluminum alloy 2024

Table 10 shows the various cutting parameters were performed by using the (L9) orthogonal array. Nine experiments were performed with each experiment producing a test part which was tested for average surface roughness (R_a µm) and calculated the signal to noise ratio S/N.

Table. 10 Results of L_9 (OA) and data analysis of tool medium carbon steel C.45 (oil quenching) and the workpiece material was aluminium alloy 2024

Exp. NO.	Cutting Speed rpm	Feed mm/rev	Depth of Cut mm	Experimental values Ra (µm)			Total value Ra (µm)	Average value Ra (µm)	S/N Ratio
				1	2	3			
1	500	0.2	0.5	0.62	0.57	0.61	1.8	0.6	4.43
2	500	0.25	1	0.66	0.67	0.64	1.97	0.66	3.6
3	500	0.3	1.5	0.89	0.92	0.91	2.72	0.9	0.92
4	700	0.2	1	0.65	0.59	0.62	1.86	0.62	4.15
5	700	0.25	1.5	1.2	1.22	1.17	3.59	1.2	-1.58
6	700	0.3	0.5	1.17	1.15	1	3.32	1.1	-0.83
7	900	0.2	1.5	0.8	0.88	0.9	2.58	0.86	1.31
8	900	0.25	0.5	0.57	0.55	0.58	1.7	0.57	4.9
9	900	0.3	1	1.27	1.3	1.33	3.9	1.3	-2.28

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 33 العدد
October 2023 اكتوبر

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

The results for average surface roughness measurements in table 10 are ranged from 0.57 to 1.3µm, and experiment number **eight** gives the lowest surface roughness measurements of 0.57µm, which corresponds to the largest calculated value of S/N ratio 4.9, and experiment number **nine** gives the largest surface roughness measurements of 1.3µm, which is corresponding to the lowest calculated value of S/N ratio -2.28.

Figure 10 shows the feed rate against the surface roughness at different cutting speed. It can be seen that the lowest value of surface roughness at the higher cutting speed 900 rpm, at medium feed rate 0.25 mm/rev, and at the lowest depth of cut 0.5mm.

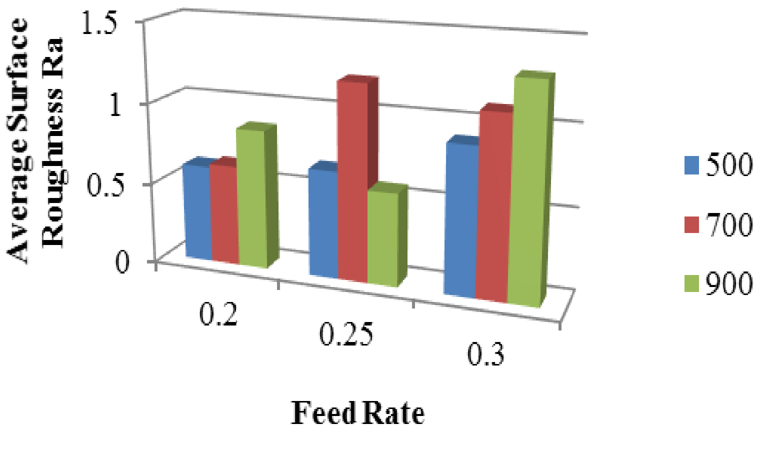

Figure 10 The effect of feed rate on the surface roughness at different cutting speed

Figure 11 shows the depth of cut against the surface roughness at different cutting speeds. It shows that the lowest value of surface roughness is at the higher cutting speed 900 rpm, at medium feed rate 0.25 mm/rev, and at the lowest depth of cut 0.5mm**.**

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

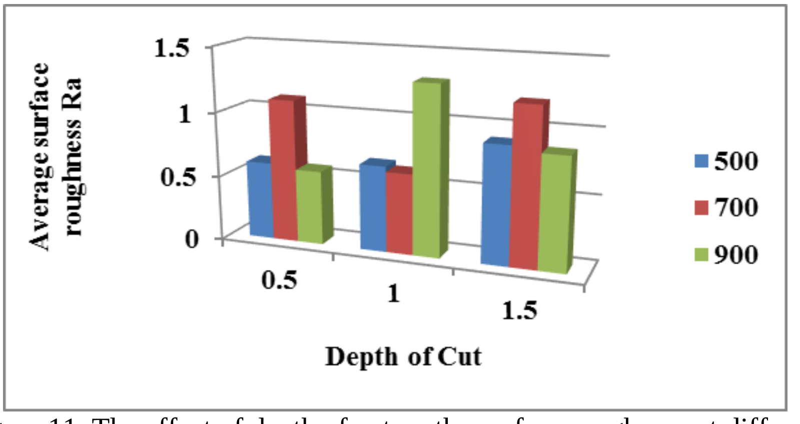

Figure 11. The effect of depth of cut on the surface roughness at different cutting speed.

Figure 12 shows the number of experiments against the S/N ratio. It shows the higher value of S/N ratio in the experiment number **eight**. Therefore the higher cutting speed 900 rpm, at medium feed rate 0.25 mm/rev, and at the lowest depth of cut 0.5mm gave us the optimal surface roughness.

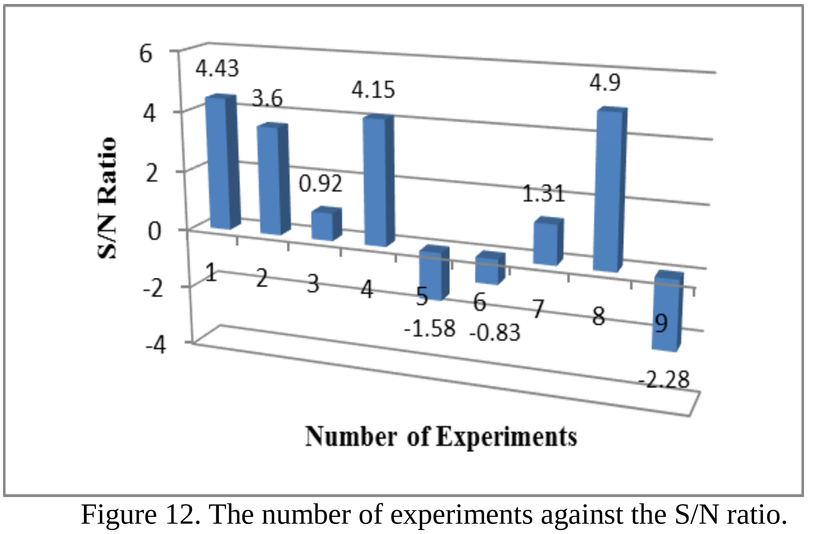

Figure 12. The number of experiments against the S/N ratio.

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

4. Conclusion

Experiments were conducted on the external turning of aluminium alloy 2024 with medium carbon steel C.45 as tool material to find out the effect of cutting speed, feed rate and depth of cut with surface roughness characteristic of the workpiece. In all two different tools were made C45 with water quenching and C45 oil quenching.

In all cases were calculated, each case consisted of 9 experiments suitable combination of cutting speed, feed rate and depth of cut.

C45 tools water quench tools performed better than oil quenching tools because of the high hardness achieved in water quenching.

In general, all the tools gave good results at all speed, feed and depth of cut with less variation in Ra value.

We observe that in both experiments good surface finish was achieved at maximum speed (900 rpm) and lowest depth of cut (0.5 mm) and medium feed rate (0.25 mm/rev).

Table 11 shows the recommendations for cutting tool material, cutting speed, feed rate, and depth of cut for turning aluminium alloy 2024

Table 11 recommendations for turning operations to get optimal surface roughness

Workpiece material	Cutting tool material	Cutting speed rpm	Feed rate mm/rev	Depth of cut mm
Aluminum alloy 2024	Medium carbon steel C45 (water quenching)	900	0.25	0.5
	Medium carbon steel C45 (oil quenching)			

تم استلام الورقة بتاريخ: 5/ 10/2023م وتم نشرها على الموقع بتاريخ: 31/ 10/2023م

References

Antony, J., Hughes, M., & Kaye, M. (1999). Reducing manufacturing process variability using experimental design technique: a case study. Integrated manufacturing systems, 10(3), 162-170.

ASM Handbook Committee. (1989). ASM handbook: volume 16: machining.

ASM International Handbook Committee. (1992). Properties and selection: nonferrous alloys and special-purpose materials. *ASM international*, *2*, 1143-1144.

Avner, S. H. (1974). *Introduction to physical metallurgy* (Vol. 2, pp. 481-497). New York: McGraw-hill.

Bayrak, M. (2002). The Effect of Machining Parameters on Surface Roughness and Their Comparison With Expert System. MSc, Gazi University Institute of Science and Technology, Ankara, Turkey.

Bringas, J. E. (2004). Hand Book of Comparative World Steel Standards.

Davim, J. P., Astakhov, V. P., & Davim, J. P. (2008). Tools (geometry and material) and tool wear. Machining: fundamentals and recent advances, 29-57.

DC, M. (1997). ontgomery, Design and analysis of experiments 4th ed.

Klocke, F., Klocke, F., & Kuchle, A. (2011). Cutting tool materials and tools. Manufacturing Processes 1: Cutting, 95-196

Kopač, J., & Bahor, M. (1999). Interaction of the technological history of a workpiece material and the machining parameters on the desired quality of the surface roughness of a product. *Journal of Materials Processing Technology*, *92*, 381-387.

Lee, J.; et. al. (1999)"Modern Manufacturing" Mechanical Engineering Handbook Ed. Frank Kreith.

تم استلام الورقة بتاريخ: 5/ 2023/10م وتم نشرها على الموقع بتاريخ: 31/ 2023/10م

Lin W.S (2008).* Department of Mechanical and Computer – Aided Engineering National Formosa University, 64 Wunhua Road, Huwei, Yunlin ,Taiwan. " The study of high speed fine turning of austenitic stainless steel". Corresponding author: E-mail address: linwhs@nfu.edu.tw.Received 19.01.2008; published in revised form 01.04.2008.

Nalbant, M., Gökkaya, H., & Sur, G. (2007). Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning. Materials & design, 28(4), 1379-**1385.**

Reddy, B. S., Padmanabhan, G., & Reddy, K. V. K. (2008). "Department of Mechanical Engineering and Technology, Nandyal, Kurnool (Dt), India. The studies effect of cutting speed and feed rate on the surface characteristic by using carbide tool on aluminum alloy using full factorial design. Asian journal of Scientific Research 1 256- 64, 2008 ISSN 1992-1454.