DOI: 10.5604/01.3001.0016.1432

Volume 113 • Issue 2 • August 2022

Journal of Achievements in Materials and Manufacturing Engineering

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Optimisation of variation coolant system techniques in machining aluminium alloy Al319

S. Zainal Ariffin *, A.M. Efendee, A.A.M. Redhwan, M. Alias, A. Arifuddin, M. Kamrol Amri, M. Mohd Ali, K. Khalil, A.R.M. Aminullah, A.R. Hasnain, N.B. Baba

Faculty of Engineering Technology, University College TATI, 24000 Kemaman, Terengganu, Malaysia

* Corresponding e-mail address: zainal@uctati.edu.my

ORCID identifier: https://orcid.org/0000-0002-1350-2152 (S.Z.A.)

ABSTRACT

Purpose: Cutting parameters are often chosen for machining by machine operators in the industry. The experience and efficiency of the machine operator in producing a quality product are frequently used to decide parameter selection—low productivity results from improper parameter selection, inefficient machining, and technological issues. Today's key issues in the machining industry are focusing on increasing machining performance on surface roughness while minimising coolant usage. The study's objective is to enhance the performance of the nozzle lubrication system during the turning operation of an aluminium alloy 319 workpieces (Al319) to generate good surface roughness by applying turning parameters such as cutting speed, feed rate, and the depth of cut.

Design/methodology/approach: Response Surface Method (RSM) was used to create the experimental method for this investigation, carried out using a CNC lathe machine with two axial movements and a wet cooling nozzle with a size of 1.0 mm. Synthetic soluble lubricants, Al_2O_3-coated cemented carbide inserts, and Aluminium alloy 319 were utilised as cutting tools and workpiece materials.

Findings: To study the influence of cutting parameters on surface roughness, the Analysis of Variance (ANOVA) approach was utilised while the response surface method was performed to achieve an optimum machining performance (RSM). When comparing dry and wet cooling systems, the size of 1.0 mm nozzle shows appropriate surface roughness. According to the ANOVA analysis, the key factor impacting the surface roughness as machining performance in lubrication technique experiments was the utilisation of 1.0 mm nozzle size.

Research limitations/implications: The findings of combination machining parameters at a cutting speed of 270 m/min and a cutting depth of 0.60 mm at a feed rate of 0.08 mm/min offered the best results, achieving a surface roughness, Ra of 0.94 µm.

Practical implications: The use of coolant size nozzle 1.0 mm technology combined with the use of correct machining parameters can improve machining cuts.

Originality/value: The novel size of 1.0 mm nozzle in this current research is also valuable for reducing and increasing productivity in the machining business, as well as reducing dependency on machining operators' experience and abilities.

© Copyright by International OCSCO World Press. All rights reserved. 2022

Keywords: Aluminium alloy 319, Coated cemented carbide Al_2O_3, Surface roughness, Respond surface method

Reference to this paper should be given in the following way:

S. Zainal Ariffin, A.M. Efendee, A.A.M. Redhwan, M. Alias, A. Arifuddin, M. Kamrol Amri, M. Mohd Ali, K. Khalil, A.R.M. Aminullah, A.R. Hasnain, N.B. Baba, Optimisation of variation coolant system techniques in machining aluminium alloy Al319, Journal of Achievements in Materials and Manufacturing Engineering 113/2 (2022) 72-77.

DOI: https://doi.org/10.5604/01.3001.0016.1432

MANUFACTURING AND PROCESSING

1. Introduction

Recently, green manufacturing globally emphasises on sustainable manufacturing, that can be demonstrated by sustainability in optimising the turning process cooling systems to ensure efficient technique and economic practice [1]. Implementing sustainable manufacturing uses materials, components, or products but simultaneously reserves natural resources and environmental quality for future generations [2].

The turning process can be operated in either wet or dry conditions with varying coolant nozzle orifices. Standard CNC machines are equipped with a coolant nozzle orifice between 6.0 mm to 12.0 mm, depending on the models of the machine [3]. These varying processing conditions can be used as monitoring of machining conditions or as an extra indicator of surface finish, tool life, tool wear and temperature [4]. Many works on CNC turning in recent studies have been performed on surface roughness, tool life and temperature; however, less work done directly on 1.0 mm coolant nozzle orifice [5]. Few studies have been done on examining surface roughness and the relationship of coolant nozzle orifice size 1.0 mm levels with surface roughness, tool life, tool wear and temperature during the turning process [6].

It is well known that using coolant or lubricating cutting fluid improves the cutting performance during the machining process. Besides, the application of coolant is also required to prevent compromising product quality, such as surface roughness and cutting tool lifetime [7]. Therefore, in this study, wet and dry cooling conditions, as well as a 1.0 mm (inner diameter) cooling nozzle hole, were employed to machine the aluminium alloy Al319.

2. Methodology

2.1. Experimental setup

The experiment is carried out on a Puma 230 Fanuc CNC Lathe with two axes at maximum of 4500 rpm and 6.5 kW power. The cutting material of aluminium alloy Al319 was utilised in the study. The cooling conditions utilised were wet and dry. The rotation of aluminium alloy Al319 was done with a 1.0 mm (inner diameter) cooling nozzle orifice. For each cutting operation, a coated cemented carbide tool was used with a range of minimum and maximum levels of those three machining parameters, namely feed rate, cutting speed, and depth of cut.

2.2. Experimental design

The design of the experiment by response surface method was performed to achieve an optimum machining performance (RSM). Then, the analysis of variance (ANOVA) approach was utilised using Design-Expert 9.0 software. In this experiment, machining parameters are varied, including at the high and low values of depth of cut, cutting speed and feed rate. The turning operation output is indicated by the surface roughness (Ra) [8] using an SJ-210 profilometer surface roughness tester.

3. Results and discussions

3.1. The effect of coolant on surface roughness

Wet and dry cutting processes were performed to analyse the influence of the cutting parameters on the performance of 1.0 mm nozzles. Surface roughness plots are used to evaluate the effect of machining parameter interactions. The 3D surface view and contour plot were built using three distinct components. Empirical models were utilised to determine correlations between responses and variables. Different responses were compared and optimised. The test results were displayed using ANOVA tables. Table 1 shows the results of data analysis using ANOVA with a quadratic model for surface roughness interaction. According to the ANOVA results, The feed rate gives the greatest outcome on surface roughness. In order to analyse future data, case statistics and ANOVA findings were applied.

Table 1.
ANOVA tabulated data for Ra value

Surface roughness response	Total of		Mean	F	P-Value	
Source	Squares	df	Squares	Value	F-value	
Model	4.48	14	4.48	10.82	<0.0001	Significant
A-Cutting Speed	0.41	1	0.41	12.21	0.00003	
B-Feed Rate	3.556E-004	1	3.556E-004	0.011	0.9192	
C-Depth of Cut	0.47	1	0.47	14.08	<0.0001	
D-Coolant Technique: N. Size 1.0 mm (1), Wet (2), Dry (3)	1.34	1	1.34	40.24	<0.0001	
AC	0.90	1	0.90	26.86	0.0001	
AD	0.095	1	0.095	2.83	0.1132	
CD	0.16	1	0.16	4.73	0.0641	
B^2	0.86	1	0.86	25.84	0.0001	
C^2	0.15		0.15	4.38	0.0535	
Residual	0.50	15	0.033			
Lack of Fit	0.28	10	0.028	1.62	0.7558	Not significant
Pure Error	0.22	5	0.045			
Cor Total	4.96	29				

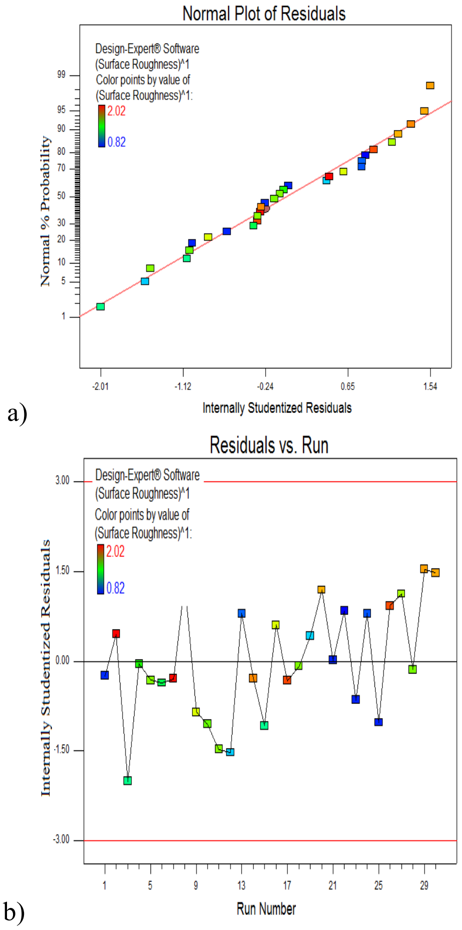


Fig. 1. (a) Normal probability plot (b) residual vs run

According to the results, the model's F seems to be 10.82, indicating that it is significant. Model terms are considered significant if their F-values are less than 0.0500 [2,4]. Models A, C, D, AC, B^2, and C^2 are relevant in this situation. The model is not significant as the amount is more than 0.050. The least important model (B, AB, AD, A^2, BC, BD, CD, D^2) was discarded. The mismatch is tolerable because it is minimal compared to pure inaccuracy.

Table 2.
Statistical value for adjusted R-squared and R-squared

Std Dev.	0.17	R-Squared	0.9099
Mean	1.45	Adj R-Square	0.8259
C.V. %	11.68	Pred R-Squared	0.6726
Press	1.56	Adeq Precision	10.886

As demonstrated in Table 2, Pred R-Squared 0.6726 is in reasonable agreement with Adj R-Squared 0.8259. Adeq Precision is used to determine the signal-to-noise ratio. It is best to have a proportion bigger than four. The signal-to-noise ratio of 10.886 indicates an excellent signal. This show can help you in exploring the world of design. According to the probability maps, the estimated value is statistically equivalent to the measured value. Figure 1 indicate that the balances are mainly straight lines, indicating that the errors are distributed regularly.

According to Design-Expert software, the reaction variable Ra, is the reaction surface equation. The acquired data was used to generate the final equation in terms of coded values. The Designer software created a mathematical model of the surface roughness response equation for the Ra response variable. The acquired data was used to generate the final equation in terms of coded values. The following mathematical model was used to calculate surface roughness:

$$\textbf{Surface roughness}^{1} = 1.58 - 0.14A + 0.017B + 0.15C + 0.29D - 0.039AB - 0.22AC + 0.063AD - 0.021BC - 1.25 \times 10^{-3}BD - 0.085CD + 0.17A^2 - 0.58B^2 + 0.23C^2 - 0.051D^2$$

Figure 2 illustrates the main impact plot for surface roughness, which has the greatest influence on feed rate in dry turning operation. The Ra line vs feed rate revealed when the feed rate rise 0.08 mm/rev to the value of 0.24 mm/rev, the Ra value increased significantly (Fig. 2a). While the speed was increased to 150, 210, or 270 m/min, the surface roughness did not alter considerably (b). Cutting speed influenced the Ra value, following through the depth of cut (Fig. 2c). As a result, the coolant system is an important component that determines the surface roughness value [3], and feed rate is the primary parameter affecting aluminium alloy Al319 turnings.

The most effective interaction items for machining with coolant system conditions for surface roughness are depicted in 3D reaction graphs (Fig. 3b). It is proportional to the feed rate, increasing as the cutting feed rate increases. Surface roughness, on the other hand, has an inverse relationship at the time that the cutting speed rise, it decreases. The combination of the high level of feed rate and cutting speed produces maximum surface roughness. A surface plot of the feed rate versus the cutting speed is provided. Figure 3c shows that surface roughness was lowered when the feed rate and cutting speed were adjusted to their lowest values. Cutting speed and feed rate were determined to have significant reciprocal correlations [7,9].

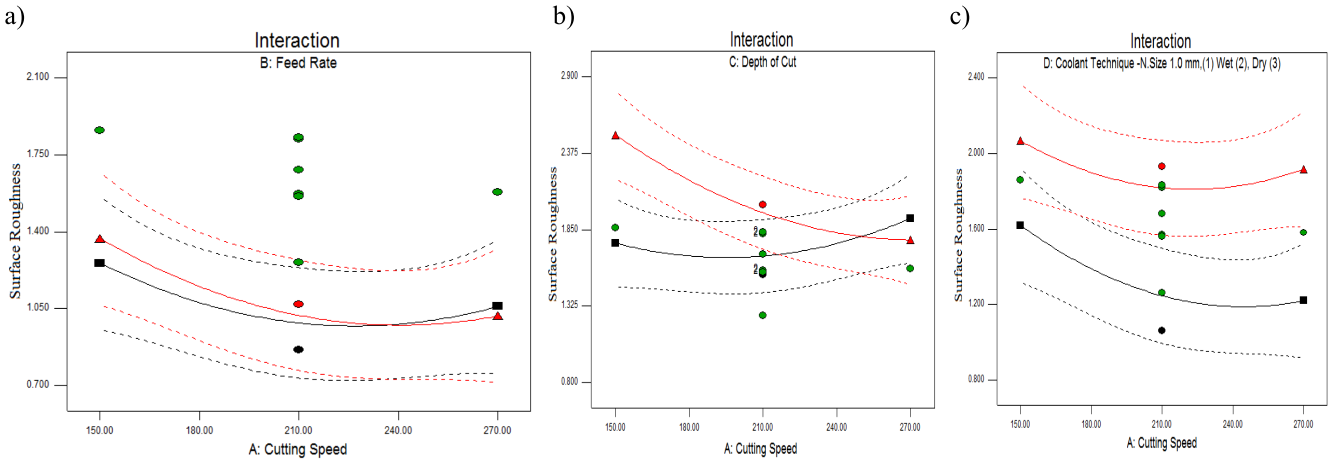


Fig. 2. Interaction effect plots of surface roughness (a) feed rate and cutting speed, (b) depth of cut and cutting speed, and (c) nozzle coolant technique and cutting speed

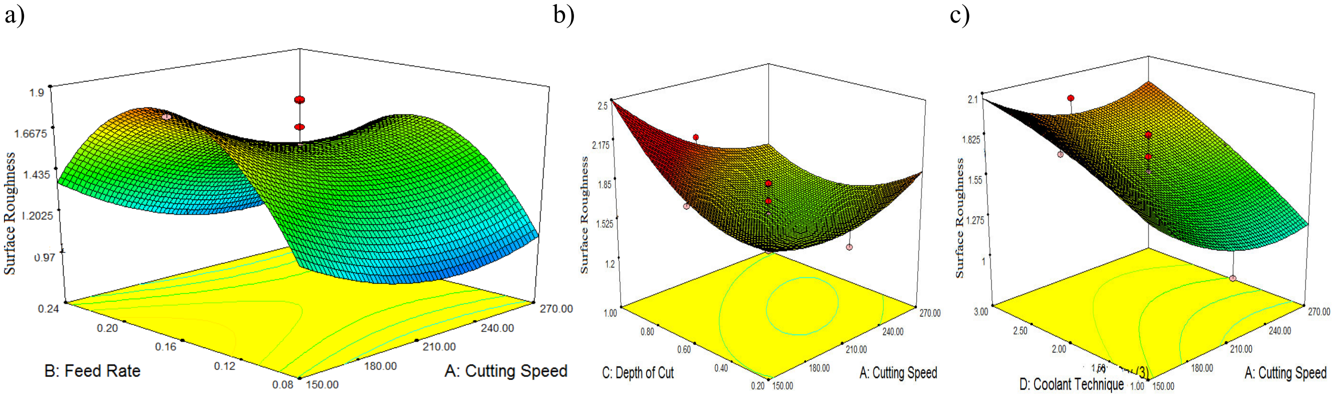


Fig. 3. Surface roughness interaction with turning parameters (a) Cutting speed and feed rate, (b) Cutting speed and depth of cut, (c) Cutting speed and coolant system

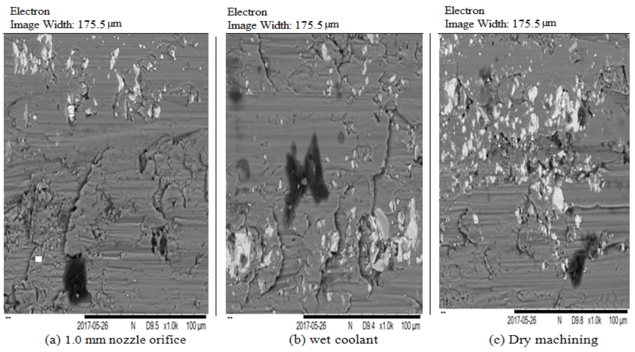
The plot displays a nearly straight correlation between cutting speed and surface roughness as well as cutting depth. Differences in cutting speed result in negligible changes in surface roughness, but variations in cutting depth result in a quicker rate of surface roughness development. The slice depth has a stronger impact on interaction. The large cutting depth and higher cutting speed affect the surface finish.

Surface roughness increased roughly linearly with the coolant system but curvilinearly with cutting speed, as shown in Figure 3c. Modifications to the cooling system substantially impacted surface roughness and these findings are comparable to previous studies [10, 11].

At 0.30 mm flank wear, severe worsening in machined surface roughness was found. When turning with a worn insert, On the surface component, a behaviour similar to the coolant method effect (1.0 mm nozzle size and dry and wet coolant) occurred gradually.

3.2. Morphology of the workpiece

A 25 mm metallographic sample was removed from utilising worn and sharp inserts on the surface and was then examined using SEM micrographs [8,9]. Figure 4 shows a coolant cutting procedure using machining settings as a role in the occurrence of the observed phenomena. The cutting speed rises, the volume of material clinging to the machine surface and the cutting edge increases, resulting in high cutting temperatures [12]. Following the completion of the investigation, all workpieces were evaluated for burr formation.



(a) 1.0 mm nozzle orifice (b) wet coolant (c) Dry machining

Fig. 4. The machined surface observation via SEM for (a) 1.0 mm nozzle orifice, (b) wet coolant, and (c) dry coolant

4. Conclusions

The need for a more cost-effective production process has driven the development of new refrigeration system technologies. The surface roughness was studied in this study using 30 trials on a CNC lathe using a tungsten carbide cutting tool to produce aluminium alloy Al319 alloy. This research evaluated the machining optimisation performance standards for aluminium alloy Al319 alloy CNC turning industrial machines and wet and dry system machining procedures with 1.0 mm cooling nozzles. The process prediction model generated during the research is used as a planning aid for future processes. In multi-objective optimisation, designers use optimisation techniques to generate a collection of acceptable experimental designs for future reference. The cutting settings have been changed to produce the least surface roughness while maintaining the maximum acceptable level of abrasion.

Acknowledgements

The author would like to express his sincere appreciation for the financial support by the Ministry of Higher Education (MOHE) under the Fundamental Research Grant Scheme (FRGS) FRGS/1/2019/TK03/TATI/02/1.

Additional information

The article was presented at the 5th ICET 2021: 5th International Conference on Engineering Technology Virtual Conference KEMAMAN, Malaysia, October 25-26, 2021.

References

[1] J. Kopac, Achievements of sustainable manufacturing by machining, Journal of Achievements in Materials and Manufacturing Engineering 34/2 (2009) 180-187.

[2] A.T. Abbas, F. Benyahia, M.M. El Rayes, C. Pruncu, M.A. Taha, H. Hegab, Towards Optimisation of Machining Performance and Sustainability Aspects when Turning AISI 1045 Steel under Different Cooling and Lubrication Strategies, Materials 12/18 (2019) 3023. DOI: https://doi.org/10.3390/ma12183023

[3] Y. Isik, An experimental investigation on the effect of cutting fluids in turning with coated carbides tool, Strojniški vestnik - Journal of Mechanical Engineering 56/3 (2010) 195-201.

[4] M. Mia, M.A. Khan, N.R. Dhar, High-pressure coolant on flank and rake surfaces of tool in turning of Ti-6Al-4V: investigations on surface roughness and tool wear, The International Journal of Advanced Manufacturing

Technology 90/5-8 (2017) 1825-1834. DOI: https://doi.org/10.1007/s00170-016-9512-5

[5] S. Zainal Ariffin, N.B. Baba, M. Alias, A.R. Yusoff, M.M. Rahman, Effect of Coolant Nozzle Sizes on Turning Aluminum Alloy AL319, Indian Journal of Science and Technology 9/9 (2016) 1-5. DOI: https://dx.doi.org/10.17485/ijst/2016/v9i9/88713

[6] B.Y. Mokritskii, A.V. Morozova, T.I. Usova, Results in Composite Hard-alloy and Mill Design Based on Simulation of Their Operation Conditions, Procedia Engineering 206 (2017) 1093-1098.
DOI: https://doi.org/10.1016/j.proeng.2017.10.600

[7] I. Hanafi, A. Khamlichi, F.M. Cabrera, E. Almansa, A. Jabbouri, Optimisation of cutting conditions for sustainable machining of PEEK-CF30 using TiN tools, Journal of Cleaner Production 33 (2012) 1-9. DOI: https://doi.org/10.1016/j.jclepro.2012.05.005

[8] S. Thamizhmanii, S. Saparudin, S. Hasan, Analyses of surface roughness by turning process using Taguchi method, Journal of Achievements in Materials and Manufacturing Engineering 20/1-2 (2007) 503-506.

[9] C. Shet, X. Deng, Finite element analysis of the orthogonal metal cutting process, Journal of Materials Processing Technology 105/1-2 (2000) 95-109. DOI: https://doi.org/10.1016/S0924-0136(00)00595-1

[10] S. Zainal Ariffn, A.M. Efendee, M. Alias, A.A.M. Redhwan, M.N. Muhamed, A.R. Yusoff, The effect of nozzle coolant supply during machining Automotive material Al319. Advanced Aspects of Engineering Research 4 (2021) 10-18.
DOI: https://doi.org/10.9734/bpi/aaer/v4/7595D

[11] R. Rosnan, A.I. Azmi, M.N. Murad, Effects of Cutting Parameters on Tool Wear and Thrust Force in Drilling Nickel-Titanium (NiTi) Alloys Using Coated and Uncoated Carbide Tools, Key Engineering Materials 791 (2018) 111-115. DOI: https://doi.org/10.4028/www.scientific.net/KEM.791.111

[12] T. Trong Quyet, L. Hong Sam, T. Minh Nhat, T. Anh Son, D. Thanh Liem, T. Quoc Thanh, Effects of Minimum Quantity Lubrication (MQL) on cutting temperature, tool wear and surface roughness in turning AISI-1045 material, VNUHCM Journal of Engineering and Technology 3/SI1 (2020) SI92-SI102. DOI: https://doi.org/https://doi.org/10.32508/stdjet.v3iSI1.726

Creative Commons
Attribution-NonCommercial-NoDerivatives
International 4.0
BY NC ND

© 2022 by the authors. Licensee International OCSCO World Press, Gliwice, Poland. This paper is an open access paper distributed under the terms and conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) license (https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en).