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Optimization of Coolant Technique Conditions for Machining A319 Aluminium Alloy Using Response Surface Method (RSM)

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Abstract. Background/Objectives: The paper discusses about the optimum cutting parameters with coolant techniques condition (1.0 mm nozzle orifice, wet and dry) to optimize surface roughness, temperature and tool wear in the machining process based on the selected setting parameters. The selected cutting parameters for this study were the cutting speed, feed rate, depth of cut and coolant techniques condition. Methods/Statistical Analysis Experiments were conducted and investigated based on Design of Experiment (DOE) with Response Surface Method. The research of the aggressive machining process on aluminum alloy (A319) for automotive applications is an effort to understand the machining concept, which widely used in a variety of manufacturing industries especially in the automotive industry. Findings: The results show that the dominant failure mode is the surface roughness, temperature and tool wear when using 1.0 mm nozzle orifice, increases during machining and also can be alternative minimize built up edge of the A319. The exploration for surface roughness, productivity and the optimization of cutting speed in the technical and commercial aspects of the manufacturing processes of A319 are discussed in automotive components industries for further work Applications/Improvements: The research result also beneficial in minimizing the costs incurred and improving productivity of manufacturing firms. According to the mathematical model and equations, generated by CCD based RSM, experiments were performed and cutting coolant condition technique using size nozzle can reduces tool wear, surface roughness and temperature was obtained. Results have been analyzed and optimization has been carried out for selecting cutting parameters, shows that the effectiveness and efficiency of the system can be identified and helps to solve potential problems.

Keywords: **t**urning, infrared thermometer, temperature, coated carbide, Response Surface Method.

1. Introduction

An innovative application method of coolant to the cutting point, which is more effective for coolant using 1.0 mm size nozzle orifice cutting application, is increasingly important in high speed and high efficiency machining of difficult to machine materials including not only metal but aluminum alloy 319 as well. In such cases, the experience of the operator plays a major role, but even for a skilled operator it is very difficult to attain the optimum values each time. The objectives of this project are to evaluate the surface roughness, tool wear and temperature of a three machine condition (design 1.0 mm nozzle orifice, dry and wet) of coated cemented carbide tool when machining aluminium alloy 319. This research applies Response Surface Methods (RSM) approach to studying the impact of turning parameters on the tool wear and temperature and also roughness of turned surfaces. RSM analysis method approach is quality control methodology that combines control charts and process control with product and process design to achieve a robust total design. Workpiece material aluminium alloy 319 is very important in choosing tools, machining parameters and cooling strategy. According to [1] [2], is quantified by various parameters, such as, tool life, chip size, achievable surface finish and/or the amount of specific power consumed. It is influenced by a material's alloy chemistry, additives, microstructure, heat treatment, temper and physical and mechanical properties [3]. In addition, according to[4], lead acts as a lubricant, thus reducing the friction coefficient of friction between the chip and the tool. In this study of temperature measurement, the most widely used infrared thermometer laser was selected for the measuring of cutting tool's average temperature during turning operation. The values within certain range of cutting parameters like cutting speed, depth of cut and feed rate were selected and used for building the mathematical model using CCD based Response Surface Method (RSM). The temperature data of cutting tool was obtained by experimentation and the optimization of selected cutting parameters obtained successfully.

2. Experimentation investigations

Experiment were conducted on PUMA 250 type lathe to study the cooling technique condition used in this research that will bring optimum cutting performance like minimum tool wear and reduction in cutting temperature. The photograph of experimental setup is shown in Figure 1. The material used throughout this researched is a cylindrical aluminum alloy 319 rod with an axial length of 360 mm and the Ø 60 mm.

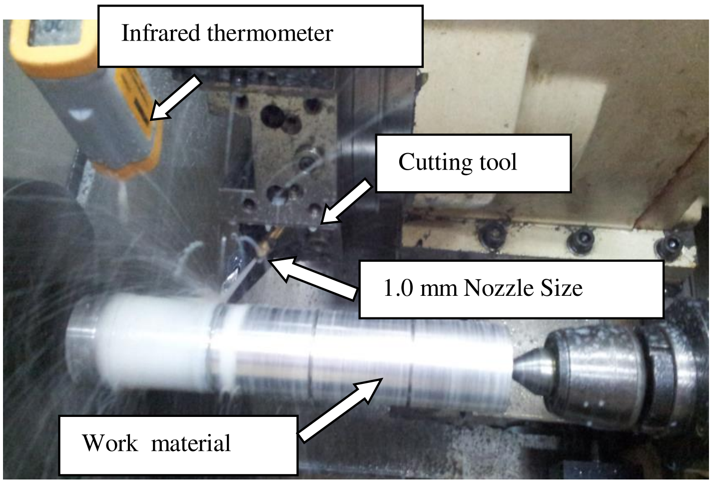


Figure 1. Photographic view of experimental setup.

2.1. Experiment Conditions

The turning process was performed in the following coolant conditions wet cooling, dry cutting and 1.0 mm nozzle orifice. The Central Composite Design (CCD) based RSM was used for the determination of optimum control factors with 3- level factor design with center point six was selected. Values of those factors had been achieved with consideration of the machine tool capacity. There were total 30 combinations of the turning runs were carried out using design expert software to complete experimentation. The experimental conditions with values of level for cutting parameters are shown in table 1 below.

Table 1. Experiment condition with value level for cutting parameter.

	Level 1 (-1)	**Level 2 (0)**	**Level 3 (+1)**
Cutting Speed (rpm)	150	210	270
Depth of Cut (mm)	0.08	0.16	0.24
Feed Rate (mm/rev)	0.2	0.06	1.00
Coolant Condition Technique	dry cutting	wet cooling	1.0 mm nozzle orifice

3. Analysis of Results

3.1. Temperature

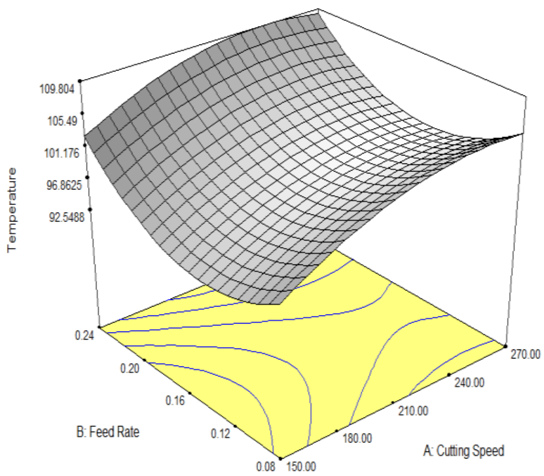
Central Composite Design (CCD) based temperature and tool wear methodology was selected in this work [5] . RSM require more data compare to the Taguchi method to ensure the optimum condition[6]. RSM relates the independent input variables with output (process response). Design Expert software was used to obtain the set of experimental runs of CCD which would help to investigate the influence of three cutting parameters (cutting speed, depth of cut and feed rate) on (temperature) and surface roughness output.

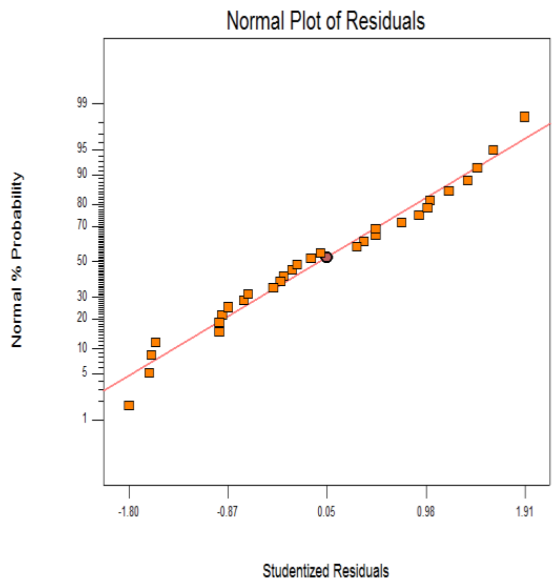
Again this data had been utilized to analyze through Design-Expert Software. The result of Analysis of Variance (ANOVA) has been carried out and as per Table 2 the value of R-squared (0.7667) and predicted R-squared (0.5489) were obtained. From data temperature analysis, a negative "Pred R-Squared" implies that the overall mean is a better predictor of your response than the current model. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 8.515 indicates an adequate signal. This model can be used to navigate the design space.

Table 2. Value of R-Squared and Adjusted R-Squared

Std. Dev	4.33	R-Squared	0.7667
Mean	103.43	Adj R-Squared	0.5489
C.V	4.19	Pred R-Squared	-0.1608
PRESS	1399.2	Adeq Precision	8.515

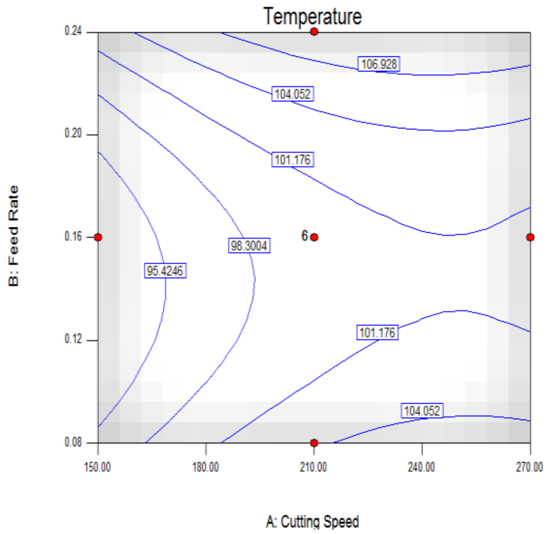
Regression Equation in Un-coded Units:
Temperaturer=+62.94266+0.41185+-196.08684+-4.66598+0.50203-8.56037E004+1002.85416+5.21418+1.68771-0.13021+0.041667+4.16667E-003+11.71875-35.93750-4.29080



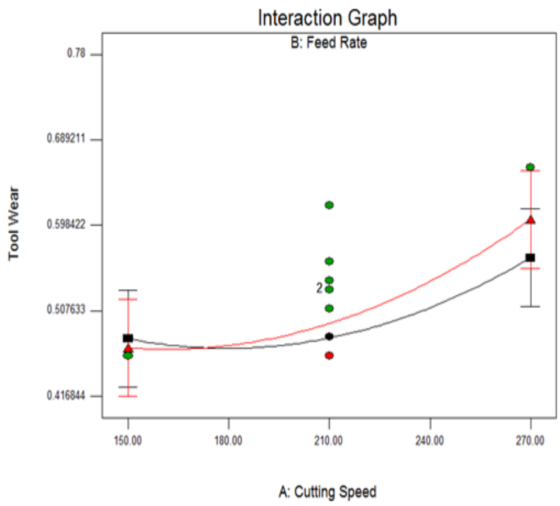


(a) Main and 3D temperature plots of temperture vs Cutting Speed, Feed Rate

(b) Normal plot of residuals of temperature vs Normal % Probability, Studetized Residuals



(c) model graphs of temperature Vs Feed rate, Cutting Speed



(d) perturbation of temperature vs tool wear, Cutting Speed

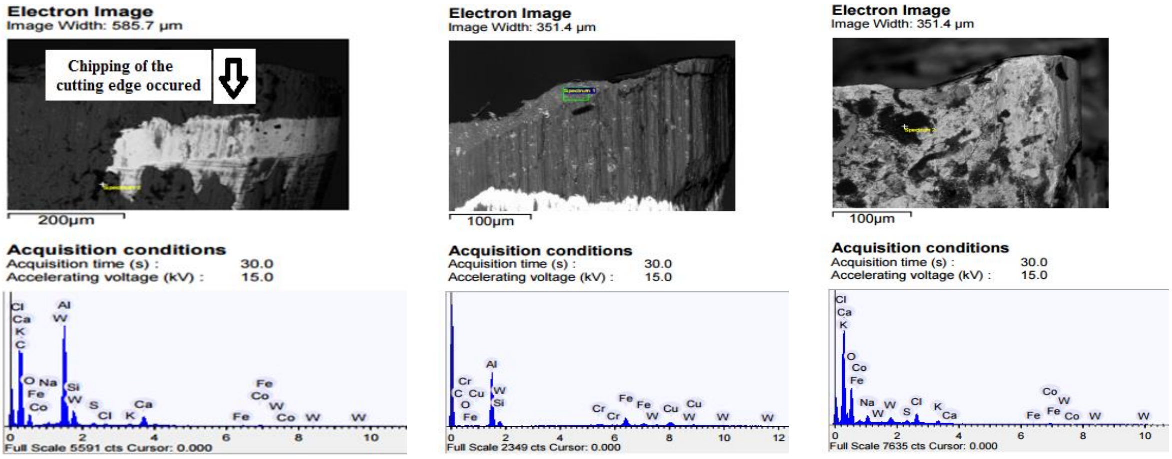
Figure 2. (a) Main and 3D temperature plots of temperture (b)Normal plot of residuals of temperature (c) model graphs of temperature (d) perturbation of temperature.

Figure 2a, 2b, 2c and 2d show the 3D surface plot, normal plot of residuals, model graf and perturbation of temperature is presented temperature was minimized when feed rate and depth of cut were at lowest levels. A significant mutual interaction occurred between cutting speed , feed rate, and depth of cut with cutting condition technique.The optimal dearease in the temperature of tool wear was from 0.56 (μm) to 2.45 (μm), where feed rate was within the range of 0.08 - 0.24 mm/rev, depth of cut in the range of 0.8 - 1.0 mm and cutting speed in the range of 150 -270 m/min. These findings were reported by [7] and [3]

3.2. Effect of tool wear

Figure 3a, 3b, and 3c shows the variation in flank wear with machining time under 1.0 mm nozzle orifice, wet coolant and dry machining under coolant technique condition. 1.0 mm nozzle orifice reduces average auxiliary flank wear on auxiliary cutting edge. The temperature also grew very low considerably. It appears on Figure 3 that temperature and flank wear grows quite fast under dry machining due to more intensive temperature and stress at the too-tips. 1.0 mm nozzle orifice technique appeared to be more effective in reducing tool wear and temperature. However, it is evident that coolant technique condition appeared to be effective in reducing tool wear and temperature as well as controlling the deterioration of the auxiliary cutting edge by thermal effect to adhesive wear and built - up edge formation.

Normal Insert



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

Figure 3. Schematic illustration between 1.0 mm nozzle orifice ,wet coolant, and dry machining

4. Optimization

In this study, RSM has been utilized for single response optimization. The use of response temperature and tool wear optimization helps to calculate the optimal values of input in order to minimize the temperature and tool wear during the turning process of aluminums alloy 319. The constraints for optimization of cutting parameters are shown in Table 3.

Table 3. Constraints for optimization of parameter

Parameter	Lower limit	Higher limit
Cutting speed (rpm)	150	270
Depth of cut (mm)	0.2	1.0
Feed Rate (mm/rev)	0.08	0.24
Environments Cutting	Dry , Wet and 1.0 mm nozzle orifice	

Table 4 shows the values for the input parameters for minimizing temperature and tool wear. It is clearly seen that obtained optimal value is 94.97 for temperature and 0.439 for tool wear for the respective values of cutting speed, depth of cut and feed rate.

Table 4. Optimization Results

Cutting Speed	Depth of Cut	Feed Rate	Temperature	Tool wear	Desirability
150	0.50	0.05	94.97	0.439	0.488

5. Conclusion

This paper focused on temperature and tool wear tester measurement for measuring the average cutting tool temperature during turning operation on lathe machine with work piece material as round bar aluminum alloy 319 and coated cemented carbide as cutting tool. This paper included the effect of cutting temperature on different parameters such as cutting speed, feed rate and depth of cut. Based on the results following conclusions can be made:

- The cutting performance of 1.0 mm nozzle orifice coolant techniques machining is better than the dry and wet machining with wet cutting fluid supply because this technique is capable of reducing the chip-tool interaction and maintains sharpness of the cutting - edges.
- 1.0 mm nozzle orifice coolant techniques flow provided reduced tool wear, improved tool wear, tool life and better surface finish as compare to dry and wet machining of aluminum alloy 319.
- Surface finish and temperature improved mainly due to reduction of wear and damage at the tool tip by the application of 1.0 mm nozzle orifice coolant techniques.
- Optimized values of cutting parameters have been achieved for minimum temperature with desirability of 0.488%, which is highly acceptable.

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