Advances and Applications in Mathematical Sciences
Volume 21, Issue 9, July 2022, Pages 5317-5324

RESPONSE SURFACE SUPPORTED TURNING FOR ALUMINIUM AL7075 ALLOY

RAM KRISHNA RATHORE[1], KAMAL DAS[2], ADARSH VERMA[2], MOHNISH VERMA[2], K. LAVANYA[2] and DEEPANKAR[2]

[1,2]Department of Mechanical Engineering
Rungta College of Engineering and Technology
Bhilai, CG, India-490024

Abstract

Because of their low density and great toughness, aluminium-based alloys have become increasingly popular in modern industry. One of the most common cutting tool failure modes when machining aluminium is when the material being machined clings to the tool cutting edge. As a result, the surface quality of the product suffers. The manufacturing industry's goal with the arrival of the fourth industrial revolution is to manufacture a big number of products in a short amount of time. This study uses MTab FlexTurn Computer Numerical Control (CNC) equipment to optimize machining constraints in the Aluminum Alloy 7075 turning. The effects of speed (500, 1000 and 1500 rpm), feed (0.10, 0.15 and 0.20 mm/rev), and cutting depth (0.3, 0.5 and 0.8 mm) on the turning of Aluminum 7075 alloy in a CNC machine are investigated in this experiment. This paper studies the effect of Machining parameters combinations for the material removal rate (MRR) and machining time (MT) for turning procedure on Aluminium Al 7075 alloy. In this study, the Taguchi L27 orthogonal array methodology is coupled with response surface design (RSM) to generate the correlation between the input and the responses and give the optimum cutting conditions.

1. Introduction

Industrial technology is advancing in the modern scenario. For which there is a need for engineers to be ready for targeting economical production, better surface finish products, a small amount of tool wear through optimum resources utilization. Turning is a very significant production procedure for industries [12]. In the current scenario, a high priority is placed on exactness,

2020 Mathematics Subject Classification: 05B15.

Keywords: Turning, Aluminum 7075 Alloy, Taguchi, Response surface methodology, optimization.

*Corresponding author; E-mail: krish.rathore@gmail.com

Received January 18, 2022; Accepted May 18, 2022

also known as accuracy, and the work piece's surface roughness is minimised.

Out of all the popularly adopted non-ferrous materials in engineering applications, Aluminium Alloy 7075 are a highly preferred material due to their desired characteristics, which are high strength to weight ratio, good ductility, resistance towards corrosion, high availability in nature and cheaper cost [13]. A large material removal rate is attained by raising the values of cutting factors like Cutting Speed, Feed and Depth of cut [14]. The machining process becomes critical because it is always completed in order to turn composites into technical components [1]. Due to the hardness and abrasive character of the reinforcing particles, Metal Matrix Composites (MMCs) are difficult to process. As a result, machinability investigations have become more important in the field of composites [2]. The researchers took into account a variety of factors, including metallurgical properties, cutting tool geometry, workpiece characteristics, and process parameters like cutting speed, feed rate, and depth of cut. Significant output reactions impacted by elements such as chemical, physical, and thermo mechanical parameters that interact throughout the machining operation include cutting zone temperature, surface roughness, and tool wear [3]. During the machining of AISI H11 steel, the influence of cutting speed, feed, depth of cut, and workpiece with varying hardness values of cutting forces is considered. They used RSM to create a mathematical model, which they then evaluated using ANOVA software [4]. The Taguchi method [5] was used to determine the best output responses in the turning process and to choose parameters and their values. The Taguchi technique was employed as a methodical paradigm for the design and analysis of trials. The authors established a successful strategy for developing high-quality items at a reasonable cost [6].

Various traditional optimization techniques, such as Lagrange's method, geometric programming, goal programming, dynamic programming, and so on, have previously been successful in optimising various turning process variables. Fuzzy logic [11], genetic algorithms [7], scatter searches, Taguchi techniques [9-10], and response surface methodology are some of the most recent optimization approaches that are presently being employed in industrial applications for optimum process variable selection [12]. A detailed examination of optimization strategies has revealed that design of experiment-based approaches for optimal process variable settings can be successfully applied in the industrial context. [8] Researcher also utilized the RSM to search for the connections between several illustrative outputs and one or more than one outputs. The main aspect of RSM is utilizing a collection of designed experiments to search for optimal output through ANN. The researcher used the Taguchi method for Optimizing parameters of turning for aluminium alloy 7075 [9]. It is clear from the response table for the S/N ratio of surface roughness that cutting speed is the most important factor for MRR preceded by Feed rate and the least significant factor is the depth of cut. A clear indication of Analysis of Variances (ANOVA) for S/N ratio for machining time shows that the cutting speed is majorly contributing than feed rate for surface roughness [11].

In machining industries, the conservative cutting conditions of using handbook-based estimation for finding the suitable combination of parameters are still prevalent at the level of process planning [10]. Despite the fact that many researchers have looked into the experimental investigation and modelling of Al7075 alloy, no work has been identified on the modelling of CNC turning of Al7075 alloy utilising a response surface approach (RSM). As a result, RSM was employed in the proposed work to model CNC turning of Al7075 alloy utilising the L27 Taguchi technique.

2. Materials and Methods

Aluminium alloy AA7075 rods with a diameter of 24 mm were obtained, and the materials were visually inspected for any cracks or damage on the surface. Each specimen had a length of 150 mm and a diameter of 24 mm when it was made. The diameter of the raw materials does not change, and just the length needs to be reduced. As a result, the long raw material was cut into 150 mm rods. For this inquiry, the turning operation was explored. This turning can be done on a variety of machines, such as standard lathes, but only CNC machines can achieve higher accuracy [24]. As a result, turning operations are flawlessly completed in this inquiry with the help of a Siemens 802D operated MTab FlexTurn CNC machine.

The turning process parameters (N, F, and D), as well as two responses (MRR, and MT) for exploratory trials, are also listed in Table 1. The twenty-seven numbers of specimens were machined using an L27 orthogonal array and 27 runs with parameter correlations in CNC turning. TNMG115100 tungsten carbide insert is the cutting tool used for research with the specified specification. Coated carbide tools have demonstrated superior performance when compared to uncoated carbide tools [1]. The workpiece material for this work is Aluminum Alloy 7075[Anita]. Workpieces with a diameter of 25mm and a length of 65mm are taken for 27 trails. The turning programme has been organised and is ready to be input into the CNC machine. The work piece's initial and final weights are measured and recorded using appropriate measurement tools. The machining time is recorded using a stopwatch, and the material removal rate is determined using a mathematical relationship.

3. Results and Discussion

After DOE generation through Taguchi L27 Array and the experimental response measurement, the prediction model is generated through response surface methodology (RSM) full factorial design. The Speed, Feed and DOC (Depth of cut) are taken as input variable and Material Removal Rate (MRR) and Machining Time (MT) are taken as continuous responses. Table 2 shows the predicted computational regression fit (R-square) model for MRR and MT as 95.49% and 98.38%, which depicts a very good curve fit for the responses.

Table 1. L27 orthogonal array with experimental response finding.

S. No.	Speed rpm	Feed mm/rev	DOC mm	MRR mm3/s	MT sec	S. No.	Speed rpm	Feed mm/rev	DOC mm	MRR mm3/s	MT sec
1	500	0.10	0.3	76.082	145	15	1000	0.20	0.5	145.58	66
2	500	0.15	0.3	88.180	113	16	1000	0.10	0.8	88.207	117
3	500	0.20	0.3	96.085	100	17	1000	0.15	0.8	123.01	81
4	500	0.10	0.5	60.630	135	18	1000	0.20	0.8	150.13	64
5	500	0.15	0.5	79.082	108	19	1500	0.10	0.3	144.98	81
6	500	0.20	0.5	104.88	95	20	1500	0.15	0.3	156.82	59
7	500	0.10	0.8	84.213	131	21	1500	0.20	0.3	193.40	46
8	500	0.15	0.8	78.291	100	22	1500	0.10	0.5	108.49	82
9	500	0.20	0.8	76.258	98	23	1500	0.15	0.5	159.52	58
10	1000	0.10	0.3	88.967	116	24	1500	0.20	0.5	239.03	46
11	1000	0.15	0.3	124.55	80	25	1500	0.10	0.8	141.43	78
12	1000	0.20	0.3	146.53	68	26	1500	0.15	0.8	184.07	58
13	1000	0.10	0.5	87.460	118	27	1500	0.20	0.8	248.28	43
14	1000	0.15	0.5	112.83	82						

Table 2. Model Summary.

S	R-sq	R-sq(adj)	R-sq(pred)	
12.9007	95.49%	93.10%	85.30%	MRR
S	R-sq	R-sq(adj)	R-sq(pred)	
4.50939	98.38%	97.52%	95.37%	MT

The regression equations for MRR and MT are shown by equation 1 and 2 respectively in un-coded units. This regression equations shows the correlation among the input and the output variables.

MRR = 188.1 - 0.1408 Speed - 721 Feed - 162 DOC + 0.000041 Speed*Speed + 1509 Feed*Feed + 76.7 DOC*DOC + 0.765 Speed*Feed + 0.0679 Speed*DOC + 151 Feed*DOC (1)

MT = 294.7 - 0.0624 Speed - 1492 Feed - 35.2 DOC - 0.000002 Speed*Speed + 3356 Feed*Feed + 5.2 DOC*DOC + 0.0400 Speed*Feed +

0.0137Speed*DOC+49 Feed*DOC (2)

The goal of Response Surface Methods (RSM) in this case is optimization, or determining the best set of factor levels to achieve a specific goal. The two responses MRR and MT are shown in the table 3 which is optimized with central composite design of RSM. Table 3 also depicts the solution achieved after optimization and the input parameter combinations are found as 1500 rpm, 0.2 mm/rev, and 0.8 mm for speed, feed and depth of cut respectively, which gives us the optimum value as 44.41 seconds and 240.42 mm3/s for machining time and material removal rate respectively for the responses.

Table 3. Parameters.

Response	Goal	Lower	Target	Upper	Weight	Importance
MT	Minimum		43.00	145	1	1
MRR	Maximum	60.63	248.28		1	1

Solution	Speed	Feed	DOC	MT (Fit)	MRR (Fit)	Composite Desirability
1	1500	0.2	0.8	44.405 5	240.416	0.972056

The variable settings and the level of response fits are represented in the table 4. This shows a good prediction of output responses for the non-linear regression model developed through response surface methodology through central composite design.

Table 4. Multiple Response Prediction

Variable	Setting
Speed	1500
Feed	0.2
DOC	0.8

Response	Fit	SE Fit	95% CI	95% PI
MT	44.41	3.28	(37.48, 51.33)	(32.64, 56.17)
MRR	240.42	9.39	(220.61, 260.23)	(206.75, 274.08)

The current factor level settings are shown by the numbers at the top of each column. The minimized value of responses (MRR = 24.42 mm3/s and MT = 44.41 sec.) are shown with the composite desirability of 0.9721 for the shown input values.

4. Conclusion

The proposed research examines the effects of cutting speed, feed, and cutting depth on the turning of Aluminum 7075 alloy using an MTab FlexTurn CNC machine. The Taguchi approach produced significant design of experiments for running the trials in the CNC machine while examining their effects on metal removal rate and machining time with the help of L27 orthogonal array. Through RSM central composite design, the best fits for MRR and MT were obtained to ensure the correct prediction. The maximum material removal rate was obtained at a speed of 1600 rpm, and a 0.25 mm/min feed with 2 mm cutting depth through the multi-objective response surface optimizer. This research works deals with the reduction of uncertainty in the manufacturing process and enhance the productivity of the turning process for the Aluminum 7075 alloy.

References

[1] T. Rajmohan, K. Palanikumar and S. Prakash, Grey-fuzzy algorithm to optimise machining parameters in drilling of hybrid metal matrix composites, Compos, Part B Eng. 50 (2013), 297-308. doi:10.1016/j.compositesb.2013.02.030 [CrossRef] [Google Scholar]

[2] E. Kılıçkap, O. Çakır, M. Aksoy and A. Inan, Study of tool wear and surface roughness in machining of homogenised SiC-p reinforced aluminium metal matrix composite, J. Mater. Process. Technol. 164 (2005), 862-867. doi:10.1016/j.jmatprotec.2005.02.109. [CrossRef] [Google Scholar]

[3] W. Grzesik, Influence of tool wear on surface roughness in hard turning using differently shaped ceramic tools wear, 265 (2008), 327-335 doi:10.1016/j.wear.2007.11.001. [CrossRef] [Google Scholar]

[4] H. Aouici, M. A. Yallese, K. Chaoui, T. Mabrouki and J.-F. Rigal, Analysis of surface roughness and cutting force components in hard turning with CBN tool: Prediction model and cutting conditions optimization, Measurement 45 (2012) 344-353. doi:10.1016/j.measurement.2011.11.011 [CrossRef] [Google Scholar]

[5] A. Kulandaivel and S. Kumar, Effect of magneto rheological minimum quantity lubrication on machinability, wettability and tribological behavior in turning of Monel K500 alloy. Mach. Sci. Technol. 24 (2020), 810-836. doi:10.1080/10910344.2020.1765179 [CrossRef] [Google Scholar]

[6] T. Sathish, P. Sevvel, P. Sudharsan and V. Vijayan, Investigation and optimization of laser welding process parameters for AA7068 aluminium alloy butt joint. Mater. Today Proc. 37 (2021), 1672-1677. doi:10.1016/j.matpr.2020.07.196 [CrossRef] [Google Scholar]

[7] Ram Krishna Rathore, Amit Sarda, Rituraj Chandrakar, An Approach to optimize ANN Meta model with Multi Objective Genetic Algorithm for multi-disciplinary shape optimization, International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, 2(1) (2012), 1-8.

[8] Aman aggarwal and Hari singh, An optimization method of the machining parameters in high-speed machining of stainless steel using coated carbide tool for best surface finish Sadhana 30(6) (2005), 699-707.

[9] P. Jayaraman, Multi-response optimization of machining parameters of turning AA6063 T6 aluminium alloy using grey relational analysis in Taguchi method, Procedia Engineering 1(97) (2014), 197-204.

[10] V. V. Sahithi, T. Malayadrib and N. Srilatha, Optimization of turning parameters on surface roughness based on Taguchi technique, Materials Today: Proceedings 1(18) (2019), 3657-66.

[11] S. Dewangan and R. K. Rathore, Analysis of cutting process parameter during turning of EN 31 for minimum surface roughness using Taguchi method, International Research Journal of Engineering and Technology (IRJET) 6 (2019), 832-834.

[12] S. Dewangan, R. K. Rathore, Review on cutting process parameter for surface roughness during turning operation, parameters 6(03) 2019.