IJMTST is UGC Approved Journal with Journal Id: 43137

International Journal for Modern Trends in Science and Technology, 8(S06): 197-203, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST08S0729
Available online at: https://www.ijmtst.com/vol8si07.html

Fabrication of Aluminium Metal Matrix Composite and Optimization of Various Process Parameters of Machining

M. Sreenivasa Rao, R. Saiteja, V. Phanikumar, T.Sreenivas, T.Ramesh

Department of Mechanical Engineering, Godavari Institute of Engineering and Technology(A), JNTUK, Kakinada.

To Cite this Article
M. Sreenivasa Rao, R. Saiteja, V. Phanikumar, T.Sreenivas and T.Ramesh.. Fabrication of Aluminium Metal Matrix Composite and Optimization of Various Process Parameters of Machining.. International Journal for Modern Trends in Science and Technology 2022, 8(S06), pp. 197-203. https://doi.org/10.46501/IJMTST08S0729

Article Info
Received: 26 April 2022; Accepted: 24 May 2022; Published: 30 May 2022.

ABSTRACT

Now a days, metal matrix composites are playing a pre-dominant role in manufacturing of various components due to its superior mechanical properties and good corrosive resistance. Machining of these composites is a challenging task due to addition of hard reinforcement particles in the matrix material. Aluminum alloys are widely used for commercial applications of transportation, aerospace, construction, naval vessels manufacturing and similar engineering industries. In the present work, Al T_i B_2 is fabricated by using stir casting process and machining is carried out to investigate the influence of various process parameters on machining. A Face Centered Central Composite design of RSM is employed to carry out the experimentation and to develop predictive equations for Metal removal rate and Surface finish. Further RSM is applied for optimization of process parameters.

KEYWORDS:Fabrication,Optimization,Turning,RSM,ANOVA.

1. INTRODUCTION

Constant research is carried out to reduce weight and wear rate and to improve specific strength of metallic components used in numerous industrial appliances and machinery. The lighter aluminum alloys reinforced with a range of ceramic particulates, classified as aluminum matrix composites (AMCs), offers a solution to increase the working range of materials[1]. A metal matrix composite system is generally designated simply by the metal alloy designation of the matrix and the material type, volume fraction, and form of the ceramic reinforcement. Metal Matrix composites (MMCs) are the combination of two or more distinct phases that has improved properties than the monolithic alloy. The application of MMC's greatly increasing due to their high strength and toughness at elevated temperatures coupled with low-density.Metals are extremely versatile engineering materials. A metallic material can exhibit a wide range of readily controllable properties through appropriate of alloy composition and thermomechanical processing method[2]. The extensive use of metallic alloys in engineering reflects not only their strength and toughness but also the relative ease and low cost of fabrication of engineering components by a wide range of manufacturing processes[3]. The development of MMCs has reflected the need to achieve property combinations beyond those attainable in monolithic metals alone. Thus, tailored composites resulting from the addition of reinforcements to a metal may provide enhanced specific stiffness coupled with improved

fatigue and wear resistance, or perhaps increased specific strength combined with desired thermal characteristics in the resulting MMC. However, the cost of achieving property improvements remains a challenge in many potential MMC applications[4].

Machining of these composites is a challenging task due to addition of hard reinforcement particles in the matrix material. Aluminum alloys are widely used for commercial applications of transportation, aerospace, construction, naval vessels manufacturing and similar engineering industries In the present work, Al T_iB_2 is fabricated by using stir casting process and machining is carried out to investigate the influence of various process parameter[4]. In stir casting we use stirrer to agitate the molten metal matrix. The stirrer is generally made up of a material which can withstand at a higher melting temperature than the matrix temperature. Generally graphite stirrer is used in stir casting. The stirrer is consisting of mainly two components cylindrical rod and impeller. The one end of rod is connected to impeller and other end is connected to the shaft of the motor. Stirrer isgenerally held in vertical position and is rotated by a motor at various speeds. The resultant molten metal is then poured in die for casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement. A major concern in associated with the stir casting is segregation of reinforcement particles due to various process parameters and material properties result in the non-homogeneous metal distribution[4]. The various process parameters are like wetting condition of metal particles, relative density, settling velocity etc.The distribution of particle in the molten metal matrix is also affected by the velocity of stirrer, angle of stirrer, vortices cone etc. In this method first the matrix metal is heated above its liquid temperature so that it is completely in molten state. After it is cooled down to temperature between liquid and solidus state means it is in a semi-solid state. Then preheated reinforcement particles are added to molten matrix and again heated to fully liquid state so that they mixed thoroughly each other.

Machining is carried out on a CNC lathe machine that provides the power to turn the work piece at a given rotational speed and to feed the cutting tool at a specified rate and depth of cut therefore, three cutting parameters, i.e. cutting speed, feed rate, and depth of cut, need to be determined in a turning operation[4].MRR and SR are important parameters to evaluate cutting performance. The influence of cutting speed, feed rate depth of cut and percentage reinforcement is examined. The main objective of this paper is to carry out the experiments by selecting different variables and their levels, applying RSM and ANOVA, and then analyzing the results obtained. The results obtained that RSM and ANOVA conclude is reliable methods and it can be readily applied to different metal cutting processes with greater confidence[5]. The mechanical properties in terms of hardness and impact test were carried out. It was observed that the hardness and impact strength of Al-8001-9% TiB2 in-situ composite was improved by the Al-8001 alloy respectively[3].

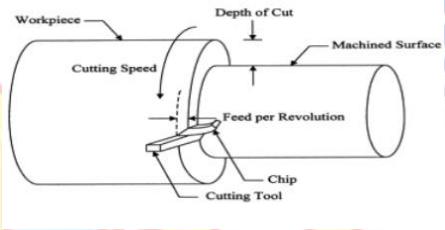

Fig.1. turning operation in lathe machine

Further RSM is applied for optimization of process parameters. On many occasions, a system (an industrial process, a method of analysis, a synthesis, etc.) is in operation and the researcher wonders about the possibility of improving the results by only changing the values of the parameters that controlthe operation of the system[5]. This demands exploration of an admissible region of the space where the parameters vary. This involves two stages: (i) to experiment in some points of this region and to obtain the results, and (ii) to make a prediction of the results that would be obtained in the rest of the points by evaluating the reliability of this prediction. After that, the researcher will know if the results from his/her system can be improved, and to what extent and the values of the parameters that will have to be used for it.

The response surface methodology (RSM) is, above all, a collection of criteria to decide in what points of the feasible region the experimentation should be made, in such a way that the prediction is most precise

(whenever possible). Once the researcher has defined the problem, the domain of experimentation and the response, the RSM provides, on the one hand, alternative experimental strategies and, on the other hand, the criteria to evaluate them. The great advantage is that this task of adapting the experimentation to the problem under study is accomplished before carrying out the experiments. A Face Centered Central Composite design of RSM is employed to carry out the experimentation and to develop predictive equations for Metal removal rate and Surface finish[3].

2.EXPERIMENTAL DESIGN & PROCEDURE

Collecting materials as per requirement and carrying different steps for fabrication of Al Ti B_2,rod with dia 30 and 10cm length has been fabricated for experimental setup. $AlTiB_2$is fabricated by using stir casting process. Stirrer is generally held in vertical position and is rotated by a motor at various speeds[6].The resultant molten metal is then poured in die for casting. Stir casting is suitable for manufacturing composites with up to 33% volume fractions of reinforcement[6].

Fig:2 Stir casting *Fig:3 AlTiB2 rods*

Turning operation is carried out in a Lathe Machine manually under an operator's supervision. There are two types of motion in a turning operation. One is the cutting motion which is the circular motion of the work and the other is the feed motion which is the linear motion given to the tool. The three machining parameters i.e., Spindle speed, Feed rate and Depth of cut are used for material removal rate[5].

Fig :4 CNC turning machine

2.1 RSM (Response surface method)

RSM is a statistical and a mathematical technique which aims at reducing the cost of expensive analysis methods and their associated numerical noise. The problem can be approximated as described in with smooth functions that improve the convergence of the optimization process because they reduce the effects of noise and they allow for the use of derivative-based algorithms. It is used in analyzing the problems in which an output or response influenced by several variables and the goal is to find the correlation between the response and the variables[5].

Initially, a set of experiments are designed to measure the mean response of interest. Then a mathematical model is developed followed by the determination of experimental factors that produces the maximum and minimum value of response. The two-dimensional and three-dimensional model graphs are drawn depicting the interactive effects of process variables[5].

2.2 Analysis of variance Analysis of Variance (ANOVA)

ANOVA is a statistical decision making tool, used to analyze the experimental data, for detecting anydifferences in the response means of the factors being tested. ANOVA is also needed for estimating the error variance for the factor effects and variance of theprediction error. In general, the purpose of analysis of variance is to determine the relative magnitude of theeffect of each factor and to identify the factors significantly affecting the response under consideration[2].

Table 1:Factor settings, surface roughness data and MRR

Std	Run	Block	A:Speed N	B:Feed mm/rev	C:Depth of Cut mm	MRR	SF
17	1	Block 1	1500	1.25	1	3.67	6.8
14	2	Block 1	1500	1.25	1.5	4.9	7.2
2	3	Block 1	2000	1	0.5	4	5.7
12	4	Block 1	1500	1.5	1	4.2	7.8
1	5	Block 1	1000	1	0.5	0.93	4.2
5	6	Block 1	1000	1	1.5	2.9	5.8
11	7	Block 1	1500	1	1	3	7.2
13	8	Block 1	1500	1.25	0.5	3.2	5.8
16	9	Block 1	1500	1.25	1	3.8	7.5
6	10	Block 1	2000	1	1.5	3.7	8.2
8	11	Block 1	2000	1.5	1.5	5.9	9.5
7	12	Block 1	1000	1.5	1.5	3.2	6.7
4	13	Block 1	2000	1.5	0.5	3.5	5.2
19	14	Block 1	1500	1.25	1	3.9	7.1
10	15	Block 1	2000	1.25	1	3.47	6.5
15	16	Block 1	1500	1.25	1	3.6	6.67
18	17	Block 1	1500	1.25	1	3.9	7.2
20	18	Block 1	1500	1.25	1	3.2	6.2
9	19	Block 1	1000	1.25	1	1.43	6.34
3	20	Block 1	1000	1.5	0.5	0.74	4.2

3. RESULTS AND DISCUSSION

1.Material Removal Rate

MRR is one of the most critical constraints which decide the quality of a product. The cutting parameters which influence the most are cutting speed, feed rate, depth of cut for the given composition of weight percentage reinforcement. The quadratic model developed using the RSM software is statistically significant for the analysis of MRR[7]. The result of the model is given in the form of ANOVA table in Table 2. The value of R2 and adjusted R2 for MRR is 95.67 and 91.32 per cent, respectively. Hence it provides an excellent relationship between the regression model of the factors and response.

The associated p-value for the model is lower than 0.05 (i.e. α ¼ 0.05 or 95 per cent confidence) which shows that the model is considered to be statistically significant. Further, A, B, C, AB, AC,BC, A^2, $B^2$and C^2 only have significant effects on MRR. The results show that the feed rate is the most significant factor which influences the MRR since it has the higher F-value[8]. The other model terms are insignificant. The experimental values are analyzed using response surface analysis and the following relation has been established for MRR of Al-TiB2 MMC.

Table 2: ANOVA OF MMR

Response	1 MRR					
ANOVA for Response Surface Quadratic Model						
Analysis of variance table [Partial sum of squares - Type III]						
	Sum of		Mean	F	p-value	
Source	Squares	df	Square	Value	Prob > F	
Model	26.65181	9	2.961312	23.20031	< 0.0001	significant
A-Speed	12.92769	1	12.92769	101.2816	< 0.0001	
B-Feed	0.90601	1	0.90601	7.098107	0.0237	
C-Depth o	6.77329	1	6.77329	53.06513	< 0.0001	
AB	0.316013	1	0.316013	2.47579	0.1467	
AC	0.678613	1	0.678613	5.316569	0.0438	
BC	1.272013	1	1.272013	9.965543	0.0102	
A^2	3.300057	1	3.300057	25.85419	0.0005	
B^2	0.008182	1	0.008182	0.0641	0.8053	
C^2	0.700057	1	0.700057	5.484573	0.0412	
Residual	1.276411	10	0.127641			
Lack of Fit	0.928327	5	0.185665	2.666969	0.1527	not signifi
Pure Error	0.348083	5	0.069617			
Cor Total	27.92822	19				

The response values for MRR in ANOVA gives percentage contribution of each parameter shown in Table:2.The Model F-value of 23.20 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate modelterms are significant.In this case A, B, C, AC, BC, A^2, $C^2$are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

The "Lack of Fit F-value" of 2.67 implies the Lack of Fit is not significant relative to the pure error. There is a 15.27% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good -- we want the model to fit.

The experimental values are analyzed using response surface analysis and the following relation has been established for MRR of Al-TiB2 MMC.

Final Equation in Terms of Coded Factors:

$$MRR = 3.63 + 1.14 \times A + 0.30 \times B + 0.82 \times C + 0.20 \times A \times B - 0.29 \times A \times B + 0.40 \times B \times C - 1.10 \times A^2 + 0.005 \times B^2 - 0.50 \times C^2$$

The ANOVA table concludes that the maximum F-value signifies higher contribution by the input process parameters and hence it can be observed that the cutting

speed andfeed rate has maximum contribution towards MRR.

Table 3: Optimization values of MMR

Number	Speed	Feed*	DOC*	Desirability
1	2000	1.46	0.59	1
2	2000	1.46	0.87	1
3	2000	1.45	1.04	1
4	2000	1.19	1.41	1
5	2000	1.39	0.55	1
6	2000	1.25	1.24	1
7	2000	1.11	1.06	1
8	2000	1.29	1.31	1
9	2000	1.35	1.33	1
10	2000	1.22	1.23	1

Illustration of factor effects on metal removal rate

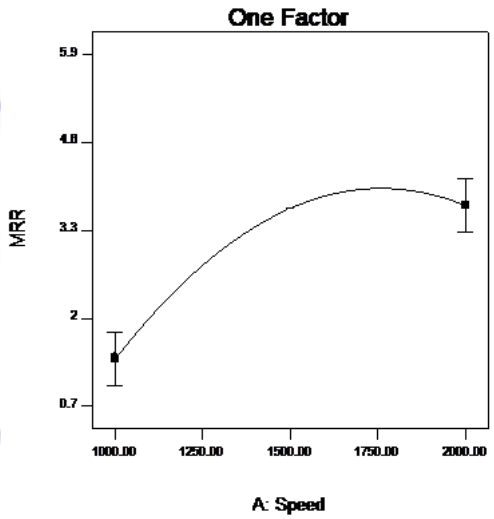

Fig 5: Model graph between Speed andMRR

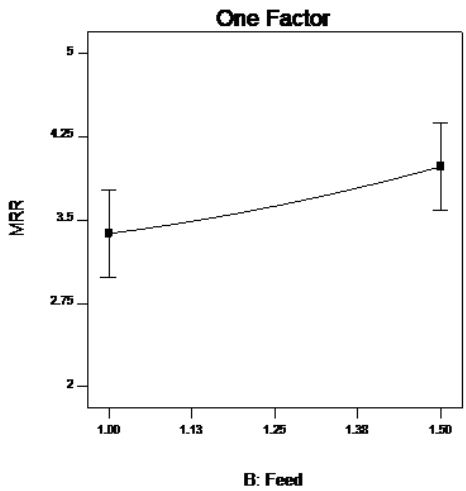

Fig 6: Model graph between Feed and MRR

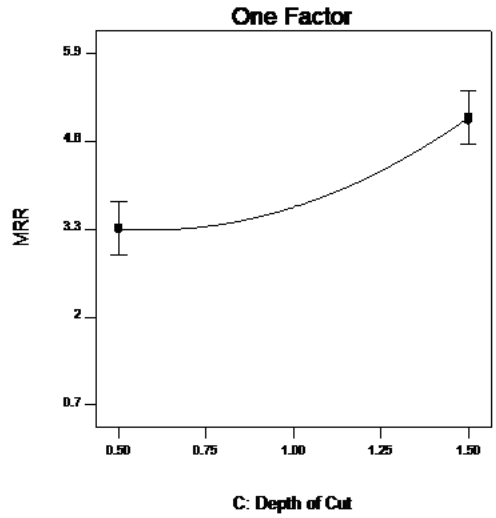

Fig 6: Model graph between Depth of cut and MRR

Response surface graph showing the effect of cutting speed and feed rate on MRR

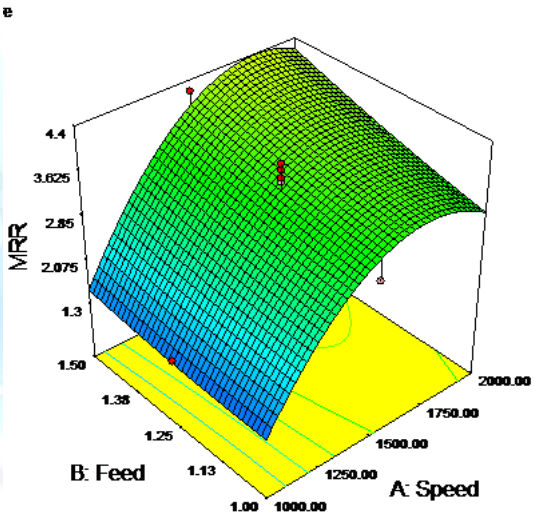

Fig 8: Response surface graph showing the effect of cutting speed and feed rate on MRR

Figure 8 shows the response surface graph between the individual parameters of the cutting speed and feed rate influencing the MRR. It clearly shows that when feed rate increases, MRR increases in an enormous amount when compared to cutting speed. Since the fact that if the feed rate increases, there will be an increase in the feed force applied which enforces more removal of metal and hence the MRR increases[9].

2 Surface finish

The response data recorded in table 1, for surface roughnessare subjected to ANOVA for finding the significant factors, at

above 95% confidence levels and the result of ANOVA for these response parameters are presented in the Tables 5.

Table 5: ANOVA OF SF

Response 2	SF					
ANOVA for Response Surface Quadratic Model						
Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	27.23372	9	3.025969	9.524675	0.0008	significant
A-Speed	6.17796	1	6.17796	19.44603	0.0013	
B-Feed	0.529	1	0.529	1.665104	0.2260	
C-Depth o	15.129	1	15.129	47.62072	< 0.0001	
AB	0.00125	1	0.00125	0.003935	0.9512	
AC	0.91125	1	0.91125	2.868292	0.1212	
BC	0.91125	1	0.91125	2.868292	0.1212	
A^2	1.128001	1	1.128001	3.550546	0.0889	
B^2	0.531301	1	0.531301	1.672346	0.2250	
C^2	0.863801	1	0.863801	2.718938	0.1302	
Residual	3.176978	10	0.317698			
Lack of Fit	2.134895	5	0.426979	2.04868	0.2250	not significa
Pure Error	1.042083	5	0.208417			
Cor Total	30.4107	19				

The Model F-value of 9.52 implies the model is significant. There is only a 0.08% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, C are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Final Equation in Terms of Coded Factors:

$$SF = 6.97 + 0.79 \times A + 0.23 \times B + 1.23 \times C - 0.012 \times A \times B + 0.34 \times B \times C - 0.64 \times A^2 + 0.44 \times B^2 - 0.56 \times C^2$$

Table 6: Optimization values of SF

Number	Speed	Feed*	DOC*	Desirability
1	1000	1.24	1	1
2	1000	1.48	1.22	1
3	1000	1.44	1.47	1
4	1000	1.45	1.33	1
5	1000	1.39	0.93	1
6	1000	1.04	0.7	1
7	1000	1.28	1.18	1
8	1000	1.38	0.61	1
9	1000	1.24	1.07	1
10	1000	1.4	0.85	1

Illustration of factor effects on surface finish

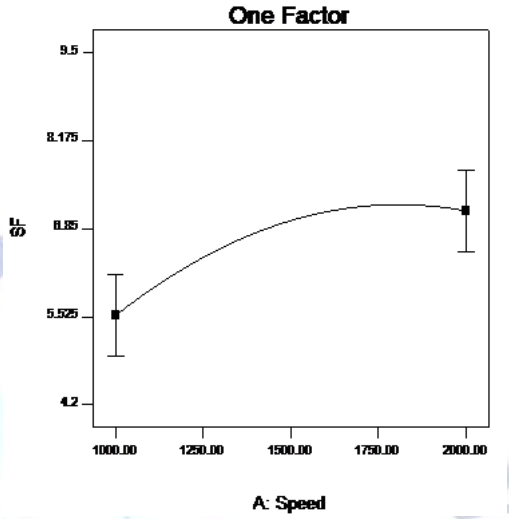

Fig 9:Model graph between speed and surface finish

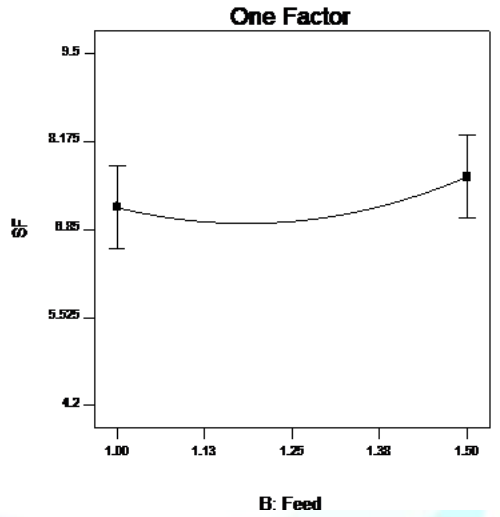

Fig 10: Modelgraph between feed and surface finish

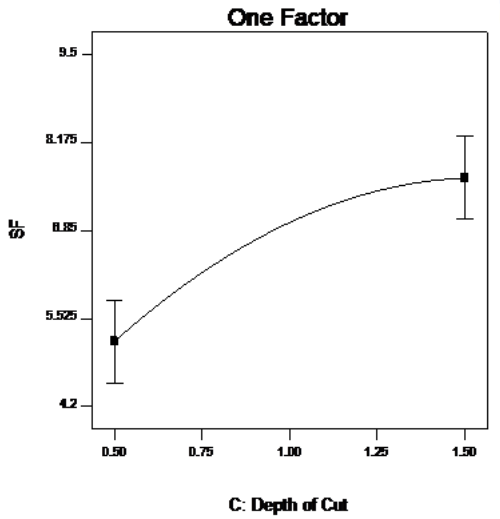

Fig11:Model graph between Doc anf surface finish

Response surface graph showing the effect of cutting speed and feed rate on Surface finish

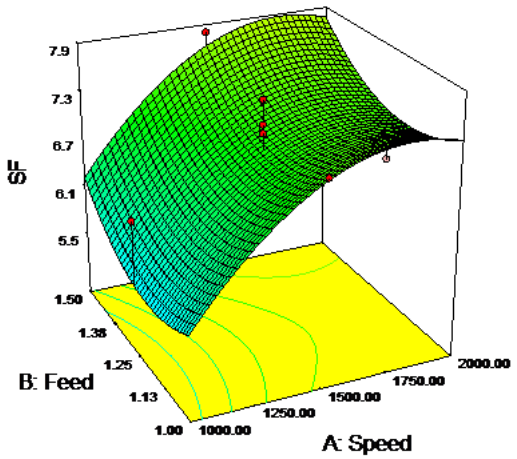

Fig 12:Response surface graph showing the effect of cutting speed and feed rate on Surface finish

Figure 12 shows the response surface graph between the individual parameters of the cutting speed and feed rate influencing the surface finish.

4. CONCLUSION

Using RSM model, the parameters which are having the influence on MRR on machining Al-TiB2 composite has been assessed.

The value of MRR increases as much when the cutting speed increases and also an equal amount of increase in MRR is observed when the feed rate is increased. The cutting speed has greater influence on the MRR followed by the feed rate. The mathematical model is successfully formulated in order to predict the value of MRR for random input values.

The optimal condition of cutting parameters for higher material removal rate for the Al8001//TiB2 composite material

Number	Speed*	Feed*	DOC*	Desirability
1	1171.3	1.03	1.42	1
2	1424.6	1.11	1.09	1
3	1598.8	1.3	1.33	1
4	1798.2	1.15	0.61	1

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] J. David Raja Selvam, "Predicting the efect of machining parameters on turning characteristics of AA7075/TiB2 in situ aluminum matrix composites using empirical relationships," vol. 40, no. 555, pp. 5–18.

[2] L. Emmanual, "Investigation of Surface Roughness and Material Removal Rate on Machining of TIB2 Reinforced Aluminum 6063 Composites: A Taguchi's Approach," vol. 24.

[3] S. Suresh, "Aluminium-Titanium Diboride(AlTiB2) Metal Matrix Composities: Chalangees and Opportunites," vol. 38, 89-97.

[4] K. Ramadevi, "OPTIMIZATION OF PROCESS PARAMETERS IN TURNING OF ALUMINIUM METAL MATRIX COMPOSITES," vol. 03, no. 07, pp. 753–758.

[5] A. Ramesh Prakash, "Modeling and analysis of process parameters on metal removal rate (MRR) in machining of aluminium titanium diboride (Al-TiB2) compositera," vol. 11, pp. 1–14.

[6] M. Muthukumaran Ramasamy, "Aluminium (Al7050) Metal Matrix Composites: A Review of Reinforcement and Mechanical Characteristics," vol. 02003, pp. 2–5.

[7] N. Shenbaga Vinayaga; Vettivel, S. C.; Selvakumar, N., "Mechanical behavior and wear prediction of stir cast Al-TiB2 composites using response surface methodology," pp. 3–20

[8] D. Arulkirubakaran, "Performance of surface textured tool during machining ofAl-Cu/TiB2 composite," pp. 638–646.

[9] B. HARDIK, "A Review Paper for Optimization of Surface Roughness and MRR in CNC Milling," vol. 01, no. 0504, pp. 1–7.