Optimization of Milling Parameters of Al7068 with Rock Dust Reinforcement using Taguchi Technique

Prashanth B[1], Dr. N B Doddapattar[2], S Puneeth[3]
[1, 2] *Cambridge Institute of Technology, North campus, Bengaluru*
[3]*Research Scholar, JSS Science and Technology University, Mysuru*

Abstract - **The industries involved in manufacturing of components try to fabricate components at a lower price than the competition to be profitable. The components are made using several processes to achieve the final form. Milling is one of the machining processes highly used during the machining of the components. To achieve lowest cost of production can be achieved only through experimentation and parameter optimization. The main objective of this paper is to optimize the parameters for the milling of AMMC Al7068/Rock Dust. An array of experiments was conducted using the Taguchi technique for different percentages of rock dust in the composite. Statistical analysis was used to understand the effect of the parameters on the surface finish and strength of the components. The spindle speeds are 900rpm, 1100rpm and 1200rpm. The feed charges are 120mm/min, 210mm/min and 250 mm/min. Depth of cut is zero 0.5mm and 1.0mm and 1.5mm. Taguchi analysis is utilized to identify the optimum parameter values and correlate feed, spindle speed, depth of cut and rock dust composition. Validations of the modelled equations are proved to be well within the settlement with the experimental statistics.**

Index Terms - **Machining, Taguchi approach, Al7068, Rock dust, spindle speed.**

I.INTRODUCTION

Milling is a primary machining operation in which the work is fed to a cylindrical rotating tool to remove material. Normally, the type of milling operation is determined by the orientation of the spindle axis with the work piece i.e., Horizontal and Vertical. The cutting tool used in this operation is known as a milling cutter which contains teeth or flutes for cutting. For general purposes, the milling operation creates a plane surface after cutting. Different geometries can be created using milling cutters of different profiles. Milling operation is considered as an interrupted cutting operation where the tooth of milling cutter enters and exits the work piece through every revolution. This interrupted cutting movement induces the tooth to a cycle of impact force and thermal shock on each rotation.

The vast majority of the enterprises utilize distinctive machining strategies, in particular boring, turning, and processing, among others, just as, the mix of these methods. Nonetheless, the productivity isn't something very similar for all machining methods, for example to get a similar part there is a more reasonable machining strategy that permits a superior quality for the machining time and lower power utilization. The best strategy relies upon the objective to be accomplished. Today, the most generally utilized machining process in the business is processing because of its high adaptability, particularly in case it is related with the mathematical control. A few examinations center have around the processing system to improve the nature of the completing surface and time creation time Shivade (2014), Ghani (2004) and Zhang (2007). Notwithstanding, one issue that emerges frequently is the way these new advances developed in the business. In this unique circumstance, sufficient preparation of encounters is introduced as one of the ways of accomplishing the intensity qualities or basic variables. The utilization of the logical strategy in the execution of exploratory undertakings is related with the establishments of present day measurable, hypothetical and test, which started in the twentieth century and is generally because of Ronald Fisher (1925) and (1935). The principal down to earth use of Design of Experiments (DOE) was in British Textile in 1930, Box (1978). From the applicable commitments of Fisher, numerous exploratory plans were produced for the most shifted circumstances, remembering for machining processes, Yih-Fong (2006) and Chang and Kuo (2007).

As indicated by the machining objective and the decision of a cutting device, there are various mixes of boundaries, fundamentally cutting velocity, feed rate, hub or spiral cut profundity, when consolidated can prompt an extremely unmistakable outcomes as far as machined surface quality and apparatus wear. In any case, it is truly challenging to characterize the best mix that gives a lower unpleasantness esteem and, at same time, boosting the apparatus life. Likewise, it is fundamental to diminish costs without lessening the nature of results. The nature of the machined surface is typically assessed by estimating surface harshness, which is a major trait of the surface quality. Regularly, the surface unpleasantness is gotten tentatively, being additionally conceivable, as per a few analysts, be anticipated through numerical calculations, Suresh et al. (2003), Sing and Rao (2007), albeit, these examinations are extremely devouring cycle and costly. To get the best blend of boundaries it is important to test an enormous number of mixes, which is unfeasible for the business. Advancement strategies are an intriguing answer for limit the quantity of mixes of trial tests.

Somewhat recently, numerous streamlining procedures have been created for machining, Aggarwal and Singh (2005), being the most utilized fluffy rationale, Palanikumar et al. (2006), hereditary calculations, Wang and Jawahi (2004), Taguchi strategy, Yang and Tarng (1998), dark social examination, Tzenga et al. (2009), and the surface reaction strategy Myers and Montgomery (1995). In this work was carried out the Taguchi technique for the minimization of surface unpleasantness in processing activity.

The Taguchi technique, Ross (1996), depends on the factual plan of exploratory tests that can financially fulfill the cycle for improving the production of a section. One of the benefits of this strategy is that few elements are considered immediately, including the clamor factors. This strategy is an integral asset, however, should be joined with other measurable instruments, like examination of difference (ANOVA), head part investigation (PCA), Moshat et al. (2010) or social examination, Lin (2004) to broaden the aftereffects of the Taguchi.

A few creators have concentrated on the machining system by partner the Taguchi strategy, Nalbant et al. (2007), Hasçahk and Çaydas (2008), Ribeiro et al. (2017), to improve the most well-known controllable boundaries like cutting rate, feed rate and profundity of cutting. The objective on this large number of works is to diminish surface unpleasantness by applying the Taguchi-based strategy and decide the machining boundaries which have the main commitment for the surface wrapping up. In any case, there are a few boundaries that weren't accounted, like temperature, vibrations and instrument wear.

II. EXPERIMENTAL PROCEDURE

Table 1 shows the design of experiments used for finding the optimum parameter values used during milling of Al7068/Rock Dust composite. Table 2 gives the orthogonal array of 16 experiments which try to cover the range of the levels decided in the orthogonal array. The parameters used are Feed rate, Spindle Speed, depth of cut and rock dust composition. Taguchi technique was used to identify the factors and levels and an array of the experiments.

Table 1. Design of Experiments for Optimization of milling for Al7068/rock dust composition

Parameters	Unit	Notation	Limits			
			Level 1	Level 2	Level 3	Level 4
Feed rate (A)	mm/min	f	30	50	70	90
Spindle Speed (B)	RPM	N	1000	1500	2000	2500
Depth of cut (C)	mm	d	1	1.5	2	2.5
Rock Dust Composition (D)	%	%RD	2.5	5	7.5	10

Table 2: Orthogonal array for Optimization of milling for Al7068/rock dust composition

Expt No	A	B	C	D
1	30	1000	1	2.5
2	30	1500	1.5	5
3	30	2000	2	7.5
4	30	2500	2.5	10
5	50	1000	1.5	7.5
6	50	1500	1	10
7	50	2000	2.5	2.5
8	50	2500	2	5
9	70	1000	2	10
10	70	1500	2.5	7.5
11	70	2000	1	5
12	70	2500	1.5	2.5
13	90	1000	2.5	5
14	90	1500	2	2.5
15	90	2000	1.5	10
16	90	2500	1	7.5

III. RESULTS AND DISCUSSIONS

The experimentation performed to find the optimum parameters has 16 experiments and the results are given in table 3. The results under observation were surface roughness, material removal rate, machining time, machining force and machining power. The results were used in finding the Signal-to-Noise ratio for each of the responses and these results are given in table 4. Although all the results are analysed separately to get individual S/N ratio, the average response of all the results combined show that the feed rate has the highest contribution and hence has a Rank 1 followed by Depth of cut, Rock Dust composition and spindle speed. The optimum value of the factors is Feed rate at 90mm/min, Spindle Speed at 1000RPM, Depth of cut at 2.5mm and Rock Dust composition at 7.5%.

Table 3: Response data for milling of Al7068/Rock dust composition using L16 Taguchi orthogonal array

Ex pt No	Surface Roughness	Material Removal Rate	Machining Time	Machining Force	Machining Power
1	1.348	287.730	3.197	0.836	43.750
2	1.253	445.770	3.302	0.836	65.625
3	1.393	572.700	3.182	0.836	87.500
4	1.455	716.550	3.185	0.836	109.375
5	7.522	747.975	1.995	2.089	109.375
6	6.439	491.650	1.967	0.928	72.917
7	8.423	1195.375	1.913	1.741	182.292
8	3.096	959.400	1.919	1.114	145.833
9	1.229	1390.340	1.419	3.899	204.167
10	0.747	1749.300	1.428	3.249	255.208
11	0.997	672.140	1.372	0.975	102.083
12	0.905	1014.930	1.381	1.170	153.125
13	5.840	2240.100	1.106	6.267	328.125
14	5.242	1719.900	1.062	3.342	262.500
15	4.770	1335.015	1.099	1.880	196.875
16	3.492	890.730	1.100	1.003	131.250

Table 4: Average S/N Ratio for all the responses for milling of Al7068/Rock Dust composition

Level	Feed Rate	Spindle Speed	Depth of Cut	Rock Dust Composition
1	-46.72	-52.24	-47.75	-52.00
2	-51.23	-52.20	-51.38	-52.15
3	-54.20	-52.05	-53.70	-52.23
4	-56.41	-52.08	-55.74	-52.18
Delta	9.70	0.19	7.99	0.22
Rank	1	4	2	3

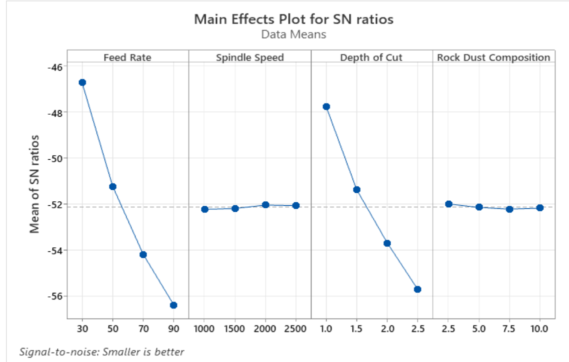

Figure 1. Average S/N Ratio for all the responses for milling of Al7068/Rock Dust composition

Table 4 and Figure 1 gives the data for the overall Signal-to-Noise ratios for the surface roughness, material removal rate, machining time, machining force and machining power. The results in the table indicates a ranking for the parameters with the feed rate having a rank of 1 followed by depth of cut, spindle speed and rock dust composition respectively. The optimum values for having a better milling operation is achieved by having the least signal-to-noise ratio which in this case is Feed rate of 30mm/min, spindle speed of 2000RPM, depth of cut of 1mm and rock dust percentage of 2.5%.

The following equations give the empirical expressions for mathematically calculating the response values as studied in this paper.

$$\textit{Surface Roughness} = 3.384 - 2.022\text{Feed Rate}_{30} + 2.986\text{Feed Rate}_{50} - 2.415\text{Feed Rate}_{70} + 1.451\text{Feed Rate}_{90} + 0.600\text{Spindle Speed}_{1000} + 0.036\text{Spindle Speed}_{1500} + 0.511\text{Spindle Speed}_{2000} - 1.147\textit{Spindle Speed}_{2500} - 0.316\textit{Depth of Cut}_{1.0} + 0.228\textit{Depth of Cut}_{1.5} - 0.645\textit{Depth of Cut}_{2.0} + 0.732\textit{Depth of Cut}_{2.5} + 0.595\textit{Rock Dust Composition}_{2.5} - 0.588\textit{Rock Dust Composition}_{5.0} - 0.096\textit{Rock Dust Composition}_{7.5} + 0.089\textit{Rock Dust Composition}_{10.0} \quad (1)$$

$$\textit{Material Removal Rate} = 1026.9 - 521.2\textit{Feed Rate}_{30} - 178.3\textit{Feed Rate}_{50} + 179.8\textit{Feed Rate}_{70} + 519.6\textit{Feed Rate}_{90} + 139.7\textit{Spindle Speed}_{1000} + 74.8\textit{Spindle Speed}_{1500} - 83.0\textit{Spindle Speed}_{2000} - 131.4\textit{Spindle Speed}_{2500} - 441.3\textit{Depth of Cut}_{1.0} - 140.9\textit{Depth of Cut}_{1.5} + 133.7\textit{Depth of Cut}_{2.0} + 448.5\textit{Depth of Cut}_{2.5} + 27.6\textit{Rock Dust Composition}_{2.5} + 52.5\textit{Rock Dust Composition}_{5.0} - 36.7\textit{Rock Dust Composition}_{7.5} - 43.5\textit{Rock Dust Composition}_{10.0} \quad (2)$$

$$\textit{Machining Time} = 1.91397 + 1.3024\textit{Feed Rate}_{30} + 0.0342\textit{Feed Rate}_{50} - 0.5142\textit{Feed Rate}_{70} -$$

$0.8224 Feed\ Rate_{90} + 0.0152 Spindle\ Speed_{1000} + 0.0256 Spindle\ Speed_{1500} - 0.0228 Spindle\ Speed_{2000} - 0.0180 Spindle\ Speed_{2500} - 0.0052 Depth\ of\ Cut_{1.0} + 0.0301 Depth\ of\ Cut_{1.5} - 0.0188 Depth\ of\ Cut_{2.0} - 0.0061 Depth\ of\ Cut_{2.5} - 0.0259 Rock\ Dust\ Composition_{2.5} + 0.0107 Rock\ Dust\ Composition_{5.0} + 0.0120 Rock\ Dust\ Composition_{7.5} + 0.0032 Rock\ Dust\ Composition_{10.0}$ (3)

$$Machining\ Force = 1.937 - 1.102 Feed\ Rate_{30} - 0.469 Feed\ Rate_{50} + 0.386 Feed\ Rate_{70} + 1.185 Feed\ Rate_{90} + 1.335 Spindle\ Speed_{1000} + 0.151 Spindle\ Speed_{1500} - 0.580 Spindle\ Speed_{2000} - 0.907 Spindle\ Speed_{2500} - 1.002 Depth\ of\ Cut_{1.0} - 0.444 Depth\ of\ Cut_{1.5} + 0.360 Depth\ of\ Cut_{2.0} + 1.086 Depth\ of\ Cut_{2.5} - 0.165 Rock\ Dust\ Composition_{2.5} + 0.360 Rock\ Dust\ Composition_{5.0} - 0.143 Rock\ Dust\ Composition_{7.5} - 0.052 Rock\ Dust\ Composition_{10.0} \quad (4)$$

$$Machining\ Power = 153.12 - 76.56 Feed\ Rate_{30} - 25.52 Feed\ Rate_{50} + 25.52 Feed\ Rate_{70} + 76.56 Feed\ Rate_{90} + 18.23 Spindle\ Speed_{1000} + 10.94 Spindle\ Speed_{1500} - 10.94 Spindle\ Speed_{2000} - 18.23 Spindle\ Speed_{2500} - 65.62 Depth\ of\ Cut_{1.0} - 21.87 Depth\ of\ Cut_{1.5} + 21.87 Depth\ of\ Cut_{2.0} + 65.62 Depth\ of\ Cut_{2.5} + 7.29 Rock\ Dust\ Composition_{2.5} + 7.29 Rock\ Dust\ Composition_{5.0} - 7.29 Rock\ Dust\ Composition_{7.5} - 7.29 Rock\ Dust\ Composition_{10.0} \quad (5)$$

IV. CONCLUSIONS

The results obtained can be used to conclude that, the hardness of the composite increases with increase in rock dust reinforcement percentage. The optimum value of rock dust reinforcement is seen at 2.5%. The S/N ratio shows that the feed rate has the highest impact with a very low S/N ratio than other parameters. Under the experimental conditions given in this paper, the parameters for optimum milling operation are found to be Feed rate of 30mm/min, spindle speed of 2000RPM, depth of cut of 1mm and rock dust percentage of 2.5%.

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