A Review Paper on the Surface Optimization of Aluminium Alloy in Milling

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Abstract— The demand for high strength and low weight material in aerospace industries is found to be increasing in fabrication of structures and equipments of aircraft and space satellites. Aluminium alloys possess the characteristics of lightweight and high strength. The identification of the optimum values of input parameters to achieve better surface finish as response parameters. The Aluminium 7075 T651 is worked on the End milling process on the HAAS CNC machine. Different parameters of Cutting Speed, Feed, and Depth of Cut in the Orthogonal Array method using Taguchi method. The results are to be worked on the DOE method on software MINITAB. The material can further be worked upon different input parameters on various machines and for different response parameters. For carrying out the above-mentioned process various papers were referred for guidance and knowledge in the same field of previously carried experiments and results. Various technical concepts and tools like The Taguchi, Orthogonal Array, DOE, ANNOVA, Fuzzy Logic, and Response Parameters etc were learned from the Published papers and it helped extensively in gaining knowledge required for the experiments to be performed on our project.
Key words: Aluminium Alloy, 7075 T651, CNC End Milling, Taguchi, Orthogonal Array, Surface Roughness

I. INTRODUCTION

Surface roughness is an important measure of product quality, since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties like fatigue behavior, corrosion resistance, etc. and functional attributes like friction, wear, light reflection, heat transmission and electrical conductivity, etc. There have been many research developments in modeling surface roughness and optimization of the controlling parameters to obtain a surface finish of desired level, since only the proper selection of cutting parameters can produce a better surface finish. In the manufacturing industries, various machining processes are adopted for removing the material from the work piece for a better product. Out of these, end milling process is one of the most vital and common metal cutting operations used for machining parts because of its ability to remove materials faster with a reasonably good surface quality. In recent times, Computer Numerically Controlled (CNC) machine tools have been implemented to utilize full automation in milling, since they provide greater improvements in productivity increase the quality of the machined parts and require less operator input.

End mill: A rotating cutting tool having a cylindrical shank with the teeth at the end, used for machining sides of metal piece and other object.

II. LITERATURE REVIEW

No	Author	Content	Published
1	Thakur Paramjit Mahesh, R.Rajesh	Optimal selection of process parameters in CNC End Milling of Al7075 T6.	International Conference on Advances in Manufacturing and Material Engineering, AMME 2014
2	J.S. Pang, M.N.M. Ansari, Omar S. Zaroog, Moaz H. Ali, S.M. Sapuan	Design optimizatio n of parameters on the CNC end milling process of halloysite nanotube (HNT/Al/E p) hybrid composite	Housing and Building National Research Center HBRC Journal, 2014
3	A. Arun Premnath, T. Alwarsamy, T. Abhinav, C. Adithya, Krishnakant.	Surface Roughness prediction by response surface methodolog y in Milling of Hybrid Aluminium composites.	International Conference on Modelling Optimisation and Computing, 2012
4	Lohithaksha M Maiyara, Dr.R.Ramanuja mb, K.Venkatesanc, Dr.J.Jeraldd.	Optimizatio n of Machining Parameters for End Milling of 718 Super Alloy Using Taguchi Grey Analysis	International Conference on DESIGN AND MANUFACTURIN G, IConDM 2013
5	Lakshmipathi Tammineni1 and Hari Prasada Reddy Yedula; IJAET,2014	Investigatio n of influence of milling parameters on surface	International Journal of Advances in Engineering & Technology, Jan. 2014.

		roughness and flatness	©IJAET

A. Optimal selection of Process Parameters in CNC END Milling of Al7075 T6

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This paper describes the application of the fuzzy logic integrated with Taguchi method for minimizing the surface roughness and maximizing the material removal rate simultaneously. In CNC End Milling of Al 7075 T6 Aerospace alloy. The Input parameters taken are SPEED, FEED, DOF and NOSE RADIUS. Al 7075 T6 is one of the highest strength alloy in 7000 series family. In Taguchi method, L27 Orthogonal Array with 4 factors and 3 Levels are chosen and S/N ratio is calculated. S/N Ratio of roughness and MRR are fed as inputs to Fuzzy Logic system and output received is Multi response performance index (MRPI) With application of ANOVA, Nose radius and DOC are identified as most signified parameters contributing about 31% of Variance. There was a significant improvement in MRPI of Optimal process parameters as compared to MRPI of initial process parameters

B. Taguchi design optimization of machining parameters on the CNC end milling process of halloysite nanotube with aluminium reinforced epoxy matrix (HNT/Al/Ep) hybrid composite

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This paper introduces the application of Taguchi optimization methodology in optimizing the cutting parameters of end-milling process formachining the halloysite nanotubes (HNTs) with aluminium reinforced epoxy hybrid composite material under dry condition. The machining parameters which are chosen to be evaluated in this study are the depth of cut (d), cutting speed (S) and feed rate (f).While, the response factors to be measured are the surface roughness of themachined composite surface and the cutting force. Anorthogonal array of the Taguchi method was set-upand used to analyse the effect of the milling parameters on the surface roughness and cutting force. The result from this study shows that the application of the Taguchi method can determine the best combination of machining parameters that can provide the optimal machining response conditions which are the lowest surface roughness and lowest cutting force value. For the best surface finish, A1–B3–C3 (d=0.4 mm, S=1500 rpm, f=60 mmpm) is found to be the optimized combination of levels for all the three control factors from the analysis.Meanwhile, the optimized combination of levels for all the three control factors from the analysis which provides the lowest cutting force was found to be A2–B2–C2 (d=0.6 mm, S=1000 rpm, f=40mmpm).

C. Surface roughness prediction by response surface methodology in Milling of Hybrid Aluminuim composites.

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Response Surface Model (RSM) has been developed to predict the surface roughness during face milling of Hybrid composites. Experiments carried out with tungsten carbide insert at various cutting Speed, Feed, and Weight fraction of Alumina. Material used are Al 6061- reinforced with Al2O3 of size 45 micron and Graphitr of 60 microns, which are produced by stir casting route, Central composite face centered secinf order respomnse surface methodology was employed to create a methematical model and the adequacy of model was verified using analysis of variance. Also a comparison has been sone between the result obtained through response surface roughness and experimental values which indicated that the experimental values are very close to the predicted values.

D. Optimization of Machining Parameters for End Milling of 718 Super Alloy Using Taguchi Grey Analysis.

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This study investigated the parameter optimization of end milling operation for Inconel 718 super alloy with multi-response criteria based on the taguchi orthogonal array with the grey relational analysis. Nine experimental runs based on an L9 orthogonal array of Taguchi method were performed. Cutting speed, feed rate and depth of cut are optimized with considerations of multiple performance characteristics namely surface roughness and material removal rate. A grey relational grade obtained from the grey relational analysis is used to solve the end milling process with the multiple performance characteristics. Additionally, the analysis of variance (ANOVA) is also applied to identify the most significant factor. Finally, confirmation tests were performed to make a comparison between the experimental results and developed model. Experimental results have shown that machining performance in the end milling process can be improved effectively through this approach.

E. Investigation of influence of milling parameters on surface roughness and flatness

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This paper deals with the effect of three selective parameters viz. cutting speed, feed and depth of cut on the surface roughness of Aluminium 1050 during milling operation. The main objective of this work is to investigate the influence of the above mentioned parameters on the surface roughness and flatness to obtain the optimum surface texture using Response Surface Methodology and to recommend the best parameters that contribute to obtain the optimum surface roughness value. The values of said three parameters taken for the study are: cutting speed range - 500 to 1500 rpm, feed range - 50 to 70 mm/rev and depth of cut range - 0.5 to 1.5mm, and given as input to the Mini Tab software. As a result 15 number of design of experiments with various combinations of the three parameters under consideration have been generated. Experiments have been conducted in the run order on CNC Milling Machine by using manual coding method, and the surface roughness has been tested using TR-200 surface roughness tester, and the flatness has been tested by using Coordinate Measuring Machine (CMM).The obtained surface roughness and flatness values are analyzed through graphs generated by using Response Surface Methodology (RSM) of Minitab Software. In addition an empirical relation between cutting parameters, surface roughness and Flatness is also derived.

III. METHODOLOGY

A. *Orthogonal array*

In mathematics, in the area of combinatorial designs, an orthogonal array is a "table" (array) whose entries come from a fixed finite set of symbols (typically, {1,2,...,n}), arranged in such a way that there is an integer t so that for every selection of t columns of the table, all ordered t-tuples of the symbols, formed by taking the entries in each row restricted to these columns, appear the same number of times. The number t is called the strength of the orthogonal array. Here is a simple example of an orthogonal array with symbol set {1,2}:

1	1	1
2	2	1
1	2	2
2	1	2

Notice that the four ordered pairs (2-tuples) formed by the rows restricted to the first and third columns, namely (1,1), (2,1), (1,2) and (2,2) are all the possible ordered pairs of the two element set and each appears exactly once. The second and third columns would give, (1,1), (2,1), (2,2) and (1,2); again, all possible ordered pairs each appearing once. The same statement would hold had the first and second columns been used. This is thus an orthogonal array of strength two. [1]

Orthogonal arrays generalize the idea of mutually orthogonal latin squares in a tabular form. These arrays have many connections to other combinatorial designs and have applications in the statistical design of experiments, coding theory, cryptography and various types of software testing. [1]

B. *Signal-To-Noise (S/N):*

The experimental observations are future transformed into signal-to-noise (S/N) ratios. Signal-to-noise (S/N) ratio was used by Taguchi as the quality characteristics of choice and here are several S/N ratios available depending on the type of performance characteristics. The S/N ratio can be characterized into three categories when the characteristics are continuous: Nominal is the best characteristic:[2]

$$S/N = 10\log\frac{\bar{y}}{S_y^2}$$

Smaller the better characteristics:

$$S/N = 10\log\frac{1}{n}\left(\sum y^2\right)$$

Larger the better characteristics:

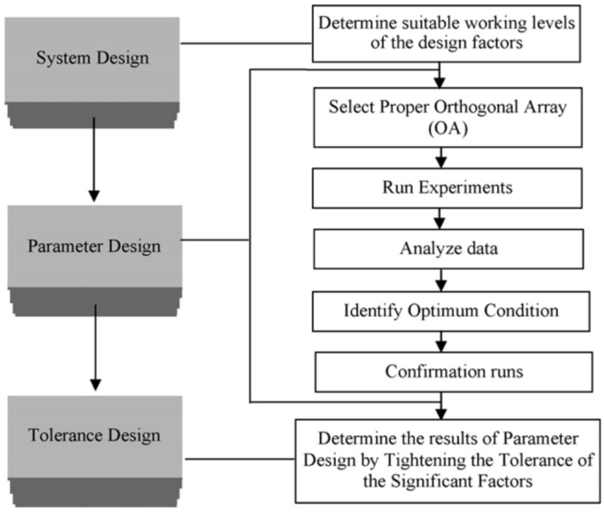
$$S/N = 10\log\frac{1}{n}\left(\sum\frac{1}{y^2}\right)$$

where ‘y’ is the average observed data, ‘S2 y’ the variance of ‘y’, ‘n’ the number of observations, and ‘y’ the observed data. For each type of characteristics, higher or lower value of S/N ratio
indicates the better result value[2]

C. *Taguchi method*

Design of experiments is a powerful analysis tool for modeling and analysing the influence of control factors on performance output. The traditional experimental design is difficult to be used especially when dealing with large number of experiments and when the number of machining parameter is increasing. The most important stage in the design of experiment lies in the selection of the control factors. Therefore, the Taguchi method, which is developed by Dr. Genichi Taguchi, is introduced as an experimental technique which provides the reduction of experimental number by using orthogonal arrays and minimizing the effects out of control factors. Taguchi is a method which includes a plan of experiments with the objective of acquiring data in a controlled way, executing these experiments and analysis data in order to obtain the information about behaviour of the given process. Besides that, it is a set of methodologies that took into account of the inherent variability of materials and manufacturing process during the design stage. It is almost similar to the design of experiment (DOE) but the Taguchi design’s balanced (orthogonal) experimental combination offers more effective technique than the fractional factorial design. This technique has been applied in the manufacturing processes to solve the most confusing problems especially to observe the degree of influence of the control factors and in the determination of optimal set of conditions [2].

In the Taguchi definition, the quality of a product is defined in terms of the loss imparted by the product to the society from the time it is shipped to the customer. The losses due to the functional variation are known as losses due to the deviation of the product’s functional characteristics from its desired target value. Besides that, the noise factors are the uncontrollable factors which cause the functional characteristics of a product that do not achieve its targeted values. The noise factors can be classified as the external factors (temperature and human errors), manufacturing imperfections and product deterioration. The main purpose of quality engineering is to make sure that the product can be robust with the respect of all possible noise factors. So, the Taguchi method could decrease the experimental or product cycle time, reduce the cost while increasing the profit and determines the significant factors in a shorter time period as it can ensure the quality in the design phase [2].



The procedure of Taguchi's design as shown in Fig. 1 can be categorized into three stages viz. system design, parameter design and tolerance design. Parameter design, considered as the most important stage, can determine the factors affecting quality characteristics in the manufacturing process. The first step in Taguchi's parameter design is selecting the proper orthogonal array (OA) according to the controllable factors (parameters). Then, experiments are run according to the OA set earlier and the experimental data are analysed to identify the optimum condition. Once the optimum conditions are identified, then confirmation runs are conducted with the identified optimum levels of all the parameters. The use of parameter design in Taguchi's technique is an engineering method of focusing on determining the parameter settings producing the best levels of a quality characteristic with minimum variation for a product or process. The main Fig. 1 Taguchi design procedure. Taguchi design optimization of machining parameters on the CNC end milling process of hallo site nanotube 139 objective of quality engineering is to make products that are robust in respect of all noise factors. So, Taguchi created standard orthogonal array to accommodate as many factors as possible into control factor selection stage to identify non-significant variables in the earliest opportunity. Taguchi used the signal-to-noise (S/N) ratio as the measurable value of the quality characteristics of the choice. This shows that the engineering systems can behave in a way such that the manipulated production factors can be divided into three categories:

1) Control factors, (factors that affect the process variability as measured by the S/N ratio).
2) Signal factors (factors that do not influence the S/N ratio or process mean).
3) Factors (factors that do not affect the S/N ratio or process mean). [2]

D. Analysis of Variance (ANOVA):

Analysis of variance (ANOVA) tests the hypothesis that the means of two or more populations are equal. ANOVAs assess the importance of one or more factors by comparing the response variable means at the different factor levels. The null hypothesis states that all population means (factor level means) are equal while the alternative hypothesis states that at least one is different. [3]

To perform an ANOVA, you must have a continuous response variable and at least one categorical factor with two or more levels. ANOVAs require data from approximately normally distributed populations with equal variances between factor levels. However, ANOVA procedures work quite well even if the normality assumption has been violated, unless one or more of the distributions are highly skewed or if the variances are quite different. Transformations of the original dataset may correct these violations.

For example, you design an experiment to assess the durability of four experimental carpet products. You put a sample of each carpet type in ten homes and you measure durability after 60 days. Because you are examining one factor (carpet type) you use a one-way ANOVA.[3]

If the p-value is less than your alpha, then you conclude that at least one durability mean is different. For more detailed information about the differences between specific means, use a multiple comparison method such as Tukey's.

The name "analysis of variance" is based on the approach in which the procedure uses variances to determine whether the means are different. The procedure works by comparing the variance between group means versus the variance within groups as a way of determining whether the groups are all part of one larger population or separate populations with different characteristics.[3]

E. Grey Relational Analysis (GRA)

In the GRA, data pre-processing is first performed in order to normalize the raw data for the analysis. In the present study, a linear normalization of the experimental results for surface roughness and material removal rate were performed in the range between zero and one, which is also called grey relational generating. The normalized experimental results xij can be expressed as:[4]

$$x_{ij} = \frac{y_{ij} - \min_j y_{ij}}{\max_j y_{ij} - \min_j y_{ij}}$$

yij for the ith experimental results in the jth experiment. Table 5 shows the normalized results for surface roughness and material removal rate. Basically, the larger the normalized results correspond to the better performance and the best-normalized results should be equal to one. [4]

F. Surface Roughness:

Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface (see surface metrology). However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.[5]

Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces (see tribology). Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion.[5]

Although a high roughness value is often undesirable, it can be difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

Roughness can be measured by manual comparison against a "surface roughness comparator", a sample of known surface rough nesses, but more generally a Surface profile measurement is made with a profilometer that can be contact (typically a diamond stylus) or optical (e.g. a white light interferometer).

However, controlled roughness can often be desirable. For example, a gloss surface can be too shiny to the eye and too slippy to the finger (a touchpad is a good example) so a controlled roughness is required. This is a case where both amplitude and frequency are very important. [5]

G. *Comparison of Surface Roughness and Flatness*

For cutting speed of 1000 rpm at lower depth of cut (0.5 mm) variation in feed rate causes increase in roughness value and flatness, But at higher depth of cut variation in feed rate causes increase in roughness and decrease in flatness. Maximum flatness values are observed, when the roughness value is low and minimum flatness value is observed, when roughness is high as shown in Figures 7 and 10.[5]

For depth of cut 1 mm at lower feed rate 50 mm/rev variation in cutting speed causes increase in roughness value and flatness. But at higher feed rate causes increase in roughness and decrease in flatness, Minimum flatness value is observed, when roughness value is high [5]

IV. Materials and Equipments:

1) Machine - Vertical Milling Centre Makino S33
   Material - Al7075 T6 (590x55x20mm)
   Tool - 16mm End Mill of Iscar
   Measurement - Mitutoyo Surface Roughness Tester
2) Machine - 3-axis OKUMA CNC milling
   MAterial - Halloysite nanotube (HNT) reinforced with aluminium-epoxy hybrid
   Tool - NKO end-milling with four flutes 6 mm
   Measurement - Scanning Electron Microscope Hitachi S-3400N.
3) Machine - ARIX VMC100 CNC Vertical Mill
   Material - Aluminium 6061 with Alumina and Graphite particle
   Tool - 16mm Carbide Insert
   Measurement - Surface Roughness Stylus of 0.8mm
4) Machine - HASS 5 Axis CNC
   Material - Inconel 718 Alloy
   Tool - Uncoated Tungsten Carbide by Sandvik
   Measurement - Mahr Surf Test
5) Machine - LV 45 A40 CNC Vertical Mill
   Material - Al (1050 100x50x19mm)
   Tool - 12mm End Mill
   Measurement – CMM

V. Experimental Procedure

Machining Performance considered are MRR and Surface Roughness. [1]

$$MRR = nxNxfxpxc$$

where,
n - Spindle Speed
N - No. of Tooth
f - Feed Rate (mm/tooth)
p - WIdth of cut
c - Depth of Cut

Levels [1]:

Parameters	Level1	Level2	Level3
Speed (r.p.m)	2000	4000	6000
Feed (mm/tooth)	0.02	0.04	0.06
Depth of cut (mm)	0.2	0.4	0.6
Nose radius (mm)	0.4	0.8	1.2

Orthogonal Array [1]:

No	Speed (r.p.m)	Feed (mm/tooth)	Depth Of Cut(mm)	Nose Radius (mm)	Ra(μm)	MRR (mm^3/min)
1	1	1	1	1	0.11	259.2
2	1	1	2	2	0.18	518.4
3	1	1	3	3	0.12	777.6
4	1	2	1	2	0.28	512.6
5	1	2	2	3	0.46	1025.5
6	1	2	3	1	0.17	1538.2
7	1	3	1	3	0.39	768
8	1	3	2	1	0.28	1536
9	1	3	3	2	0.2	2304
10	2	1	1	1	0.4	512.7
11	2	1	2	2	0.18	1025
12	2	1	3	3	0.13	1538.2
13	2	2	1	2	0.11	1024
14	2	2	2	3	0.5	2048
15	2	2	3	1	0.27	3072
16	2	3	1	3	0.8	1536
17	2	3	2	1	0.13	3072
18	2	3	3	2	0.35	4608
19	3	1	1	1	0.17	768
20	3	1	2	2	0.12	1536
21	3	1	3	3	0.36	2304
22	3	2	1	2	0.18	1536
23	3	2	2	3	0.42	3072
24	3	2	3	1	0.23	4608
25	3	3	1	3	0.61	2384
26	3	3	2	1	0.15	4608
27	3	3	3	2	0.3	6912

ANOVA

Parameter	Degree of Freedom	Sum of square	Mean sum of square	F-Value	%Contribution
Speed	2	0.0588	0.0294	1.511	2.8
Feed	2	0.0722	0.0361	1.856	4.7
Depthof Cut	2	0.1859	0.09295	4.778	20.45
Nose radius	2	0.121	0.0605	3.110	11.47
Error	18	0.3501	0.01945		
Total	26	0.723			

27 different combinations of milled lines with 6 mm width were made by performing an end-milling operation (dry condition) on the hybrid composite sample. The surface roughness measurement was done by using a portable surface roughness tester TR200. Besides that, the cutting forces were also measured online during end-milling operation with a sensitive three component Kistler 5070A type piezoelectric dynamometer with a charge amplifier. [2]

Table 2 Parameters, codes, and level values used for orthogonal array.

Parameter	Code	Level 1	Level 2	Level 3
Control factors				
Depth of cut, *d* (mm)	A	0.4	0.6	0.8
Spindle speed, *S* (rpm)	B	500	1000	1500
Feed rate, *f* (mmpm)	C	20	40	60
Response variable				
Surface roughness, Ra (μm)	–	–	–	–
Cutting force, Fr (N)	–	–	–	–

Table 3 Orthogonal array.

Run	Inner control factor array			R_a	η_{Ra}	F_r	η_{Fr}
	A	B	C				
1	1	1	1	1.15	−1.21	94.31	−39.49
2	1	1	2	1.94	−5.74	41.54	−32.37
3	1	1	3	1.18	−1.47	38.87	−31.79
4	1	2	1	0.96	0.34	16.44	−24.32
5	1	2	2	0.62	4.15	5.45	−14.73
6	1	2	3	0.77	2.25	35.85	−31.09
7	1	3	1	1.06	−0.48	43.78	−32.83
8	1	3	2	0.36	8.95	35.46	−30.99
9	1	3	3	0.29	10.84	83.02	−38.38
10	2	1	1	1.43	−3.12	60.28	−35.60
11	2	1	2	0.89	1.01	1.63	−4.23
12	2	1	3	1.28	−2.14	45.85	-33.23
13	2	2	1	1.10	−0.82	12.76	−22.12
14	2	2	2	0.86	1.36	7.57	−17.58
15	2	2	3	0.77	2.23	23.60	−27.46
16	2	3	1	0.37	8.71	9.46	−19.52
17	2	3	2	0.63	3.97	4.81	−13.64
18	2	3	3	0.84	1.55	47.63	−33.56
19	3	1	1	1.14	−1.12	3.13	−9.92
20	3	1	2	1.80	−5.08	62.40	−35.90
21	3	1	3	1.81	−5.16	93.45	−39.41
22	3	2	1	1.15	−1.22	41.94	−32.45
23	3	2	2	1.43	−3.08	2.27	−7.11
24	3	2	3	2.11	−6.47	42.31	−32.53
25	3	3	1	0.95	0.47	8.41	−18.50
26	3	3	2	1.25	−1.94	23.51	−27.42
27	3	3	3	0.47	6.54	14.23	−23.06
	A	B	C				

A. *Response Surface Methodology [3]*

Response Surface Methodology (RSM) adopts both mathematical and statistical techniques which are useful for modeling and analysis of problem in which a response of interest is influenced by several variables and objectives is to optimize the response. The Objectives of quality improvement including reduction of variability and improved process and product performance, can often be accomplished directly using RSM. In the RSM, the quantitative form of relationship between the desired response and independent input variables is represented as:[3]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	3.436027	9	0.381781	131.2258	< 0.0001	significant
f-feed rate	0.32041	1	0.32041	110.1315	< 0.0001	
v-speed	2.81961	1	2.81961	969.1577	< 0.0001	
w-weight of Alumina	0.13456	1	0.13456	46.25103	< 0.0001	
Fv	0.000612	1	0.000612	0.210529	0.6562	
Fw	0.009113	1	0.009113	3.132153	0.1072	
Vw	0.015313	1	0.015313	5.26322	0.0447	
f^2	0.000778	1	0.000778	0.26736	0.6164	
v^2	0.037528	1	0.037528	12.89909	0.0049	
w^2	0.007384	1	0.007384	2.538063	0.1422	
Residual	0.029093	10	0.002909			
Lack of Fit	0.01376	5	0.002752	0.897396	0.5458	not significant
Pure Error	0.015333	5	0.003067			
Cor Total	3.46512	19				
R^2						0.99
Adj R^2						0.98

The methodology of Taguchi for three factors at three levels is used for the implementation of the plan of experiments. The degrees of freedom required for the study is six and Taguchi's L9 orthogonal array is used to define the 9 trial conditions. Only the main effects are of interest and factor interactions are not studied. The process parameters and levels. Each of the 9 trials or process designs is replicated twice and the average response values are used for the analysis. The experimental layout and corresponding average test results. [4]

Parameter	Unit	Level 1	Level 2	Level 3
Cutting velocity (v)	m/min	25	50	75
Feed rate (f)	mm/tooth	0.06	0.09	0.12
Depth of cut (d)	mm	0.2	0.4	0.6

In the GRA, data pre-processing is first performed in order to normalize the raw data for the analysis. In the present study, a linear normalization of the experimental results for surface roughness and material removal rate were performed in the range between zero and one, which is also called grey relational generating. The normalized experimental results xij can be expressed as:[4]

$$x_{ij} = \frac{y_{ij} - \min_j y_{ij}}{\max_j y_{ij} - \min_j y_{ij}}$$

yij for the ith experimental results in the jth experiment. Table 5 shows the normalized results for surface roughness and material removal rate. Basically, the larger the normalized results correspond to the better performance and the best-normalized results should be equal to one. [4]

Expt. No.	Process parameter			Average Response Values	
	Cutting velocity	Feed rate	Depth of cut	Surface roughness (microns)	Material removal rate (mm^3/sec)
1	1	1	1	0.21	4.308
2	1	2	2	0.25	4.480
3	1	3	3	0.29	4.503
4	2	1	2	0.2	5.643
5	2	2	3	0.27	5.731
6	2	3	1	0.27	5.904
7	3	1	3	0.21	6.906
8	3	2	1	0.23	7.080
9	3	3	2	0.27	7.530

B. *Surface Finish in End milling operations*

The basic geometry of the end milling process. And the factors influencing surface finish in end milling process. [5]

Where,

v = cutting speed (peripheral) of the cutter (m/min)

D = diameter of the cutter (mm)

Ns = rotational speed of the cutter (rev/min)

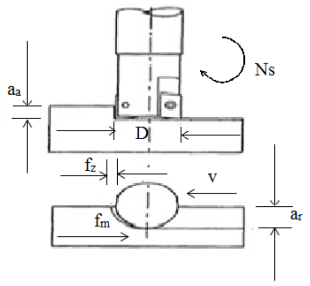
fz = feed per tooth (mm/tooth)

fm = feed per minute (mm/min) or table speed (= fz x z x Ns)

z = number of teeth in the cutter

aa = axial depth of cut (mm)

ar = radial depth (width) of cut (mm).



C. Design of Experiment

The design of experiments technique is an important tool, which permits us to carry out the modelling and analysis of the influence of process variables on the response variable. The response variable is an unknown function of the process variables, which are known as design factors. There are a large number of parameters that can be considered for machining of a particular material in end milling. In the present study most widely used machining parameters such as cutting speed, feed rate and depth of cut are considered as design factors. The range of values of each factor was set at three different levels as shown in Table 1. A full factorial design is used to design factors so that all the interactions between the response variable and process variables can be investigated. For three factors, number of experiments is 15 [5]

S. No	Parameter	Unit	Level-1	Level-2	Level-3
1	Cutting Speed	rpm	500	1000	1500
2	Feed rate	mm/rev	50	60	70
3	Depth of cut	mm	0.5	1.0	1.5

Std Order	Run Order	Cutting speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)
1	1	500	50	1.0
7	2	500	60	1.5
8	3	1500	60	1.5
6	4	1500	60	0.5
15	5	1000	60	1.0
9	6	1000	50	0.5
11	7	1000	50	1.5
10	8	1000	70	0.5
4	9	1500	70	1.0
5	10	500	60	0.5
14	11	1000	60	1.0
12	12	1000	70	1.5
2	13	1500	50	1.0
3	14	500	70	1.0
13	15	1000	60	1.0

Std Order	Run Order	Cutting speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	Surface Roughness (µm)	Flatness (µm)
1	1	500	50	1.0	1.207	0.0610
7	2	500	60	1.5	4.326	0.0624
8	3	1500	60	1.5	4.024	0.0698
6	4	1500	60	0.5	1.022	0.0577
15	5	1000	60	1.0	3.489	0.0573
9	6	1000	50	0.5	1.327	0.0537
11	7	1000	50	1.5	2.236	0.0598
10	8	1000	70	0.5	2.368	0.0596
4	9	1500	70	1.0	4.128	0.0644
5	10	500	60	0.5	1.353	0.0617
14	11	1000	60	1.0	3.257	0.0527
12	12	1000	70	1.5	4.024	0.0546
2	13	1500	50	1.0	0.634	0.0491
3	14	500	70	1.0	4.498	0.0518
13	15	1000	60	1.0	3.368	0.0561

VI. CONCLUSION

The Taguchi-Fuzzy for optimization of process parameter of CNC End Milling of Al7075 T6. A Fuzzy reasoning of multiple factors has been performed by fuzzy logic unit and multi response performance index was developed for each run. [1]

1) Following parameters setting was been identified as to yield the best combination of parameters - A3B1C3D2
2) Significant improvement in surface roughness and MRR
3) Most important factor affecting response have been nose radius and depth of cut
4) Optimization process parameters would solve problems of corrosion and fatigue by material by minimizing roughness. same time it will increase productivity by maximizing MRR[1]

The Taguchi method was performed to select the optimal cutting parameters from varying combinations of cutting parameters for end-milling operations on the HNT-Al/epoxy hybrid composite material. [2]

A basic L27(33) orthogonal array was selected with 27 experimental runs which included the three main factors each at three levels and this proved that the Taguchi parameter design is an efficient way to determine the optimal combination of cutting parameters for lowest surface finish and cutting force. Additionally, the micro-structure surface morphology study was presented on the visual variation of machined surface roughness which seems to be identical to the variation of surface roughness value [2]

Milling of 6061/Al2O3/Gr composite using Tungsten carbide insert under different cutting parameters: [3]

- From RSM model, predicted and measured values are quite close, which indicates that the developed model can be effectively used to predict the surface roughness. Using this model, a noticeable saving in time and cost has been obtained to select the level of milling.
- Speed is major factor, which has more influence on surface roughness, followed by feed rate and weight fraction of Al2O3
- Among the interaction, cutter speed and feed rate has a greater influence compared with other interaction on surface roughness on milling of Al Hybrid MMC composites [3]

It has been established that grey relational analysis is an effective optimization tool for machining of Inconel 718 alloy in end milling. It has been also found that the optimal cutting parameters for the machining process lies at 75m/min for cutting velocity, 0.06 mm/tooth for feed rate and 0.4 mm for depth of cut. [4]

Further it has been observed that there is a 64.8%increase in material removal rate and at the same time a 9.52% decrease in surface roughness. This encourages applying the grey concept for optimizing multi response processing with multiple factors. Analysis of variance shows that the cutting velocity is the most significant machining parameter followed by feed rate affecting the multiple performance characteristics with 56.88% and 34.64% influence respectively. [4]

Surface milling was done on Aluminium 1050 work piece using CNC machine. [5] Three milling parameters namely cutting speed, feed rate and depth of cut were considered for the study. Using Box-Behnken design for combination of parameters was considered and experiments were conducted. Surface roughness and flatness were measured and using response surface methodology empirical relation for roughness and flatness were obtained. Based on the work the following conclusions are arrived at. [5]

1) The predicted surface roughness from the model is compared to the values measured experimentally.
2) The feed rate is a dominant parameter and the surface roughness increases rapidly with the increase in feed rate and decreases with increase in cutting speed, where as the effect of depth of cut is not regular.
3) This technique can produce accurate relationship between machining parameters and surface roughness.
4) In case of flatness significant changes are caused by depth of cut.
5) Maximum flatness values are observed, when the roughness value is low and minimum flatness value is observed, when roughness is high.

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