

A Review on Optimisation of CNC End Milling Machining Parameters

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ABSTRACT: During the machining operation, it is essential to have a proper selection of machining parameters. Nowadays machining parameters are mainly selected on the basis of previous work experience of the process planner or thumb rule or machining data handbook. All these techniques are very tedious and time-consuming. Therefore, there is a need to develop a model that could able to find the optimal machining parameters for the required surface Quality characteristics machining. In this work, an attempt is made to review the literature on the effect of machining parameters such as Cutting speed, feed rate, Depth of cut, nose radius, coolant flow, tool wear, environmental conditions, etc. to obtain the optimum machining parameters and the extents of the significant influence of the process parameters for CNC End Milling operations. Many researchers have used the various techniques such as Taguchi method, Design of Experiments (DOE), Response surface methodology (RSM), Grey Relational Analysis (GRA), Artificial Neural Network (ANN), Fuzzy Logic, Central Composite Design (CCD), Genetic Algorithm (GA), gravitational search algorithm (GSA) and so on have become very popular due to its versatile usage in various field of engineering applications especially in machining problems.

KEYWORDS: End milling; Taguchi method; Optimisation; Surface Roughness; MRR; SN ratio; ANOVA;

I. INTRODUCTION

As a basic machining process, milling is one of the most widely used metal removal processes in industry and milled surfaces are largely used to mate with other parts in the die, aerospace, automotive, and machinery design as well as in manufacturing industries. Surface roughness is an important measure of the technological quality of a product and a factor that greatly influences manufacturing cost. The mechanism behind the formation of surface roughness is very dynamic, complicated, and process dependent; it is very difficult to calculate its value through theoretical analysis [2]. Therefore, machine operators usually use “trial and error” approaches to set-up milling machine cutting conditions in order to achieve the desired surface roughness. Obviously, the “trial and error” method is not effective and efficient and the achievement of a desirable value is a repetitive and empirical process that can be very time consuming. The dynamic nature and widespread usage of milling operations in practice have raised a need for seeking a systematic approach that can help to set-up milling operations in a timely manner and also to help achieve the desired surface roughness quality.

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II. LITERATURE REVIEW

J.S. Pang et al. [1] were introduced the application of Taguchi methodology for optimisation of CNC end-milling cutting parameters for machining on the hybrid composite material halloysite nanotube with aluminium reinforced epoxy matrix (HNT/AL/Ep) under dry condition. The machining parameters depth of cut, cutting speed, and feed rate are selected as input parameters. While, surface roughness and the cutting force are taken as response factors. An orthogonal array $L_{27}(3^3)$ Taguchi based design of experiment was selected. The result shows that at Depth of Cut (0.4mm), cutting speed (1500rpm) and feed rate (60mmpm) gives the optimum set of control factor for best surface finish. Meanwhile the lowest cutting force was found at Depth of Cut (0.6mm), cutting speed (1000rpm) and feed rate (40mmpm). 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.

Julie Z. Zhang et al.[2]was presented a study of surface roughness optimisation of CNC face milling operation using Taguchi Design methodology for machining on aluminum blocks. The study included feed rate, spindle speed and depth of cut as a control factors, and the operating chamber temperature and the tool wear were selected as a noise factors. An orthogonal array of $L_9(3^4)$, a total of 36 Experimental runs, covering three main factors each at three levels and two noise factor each at two levels were selected. Also ANOVA analysis were carried out to identify the significant factors affecting the surface roughness. . The result shows that the control factor of spindle speed (3500rpm), feed rate (30ipm) and depth of cut (0.06in) were provides the best result. ANOVA analysis shows that feed rate was not significant factor affecting surface finish and spindle speed was significant factor affecting surface finish. Also the confirmation run indicated that the selection of the optimal levels for all the parameters produced the best surface roughness. In addition, one of the noise factor, tool wear, was found to be statistically significantly improve the surface roughness whereas the temperature have not significantly affects the surface roughness.

Vijay S et al.[3] Were carried out an experiment on Titanium alloy Ti-6Al-4V for optimisation of End milling machining parameters using Taguchi methodology and ANOVA analysis for designing the experiments and for validation of experiments results. Machining parameters like cutting speed (m/min), feed per tooth (mm) and axial depth of cut (mm) are considered as input parameters and surface roughness and cutting force as a response factors. An orthogonal array of L_{16} was selected based on three factors and four levels design. From Taguchi analysis it was also observed that the axial depth of cut was most significant factor on cutting force, which was followed by feed per tooth and cutting speed. Likewise for surface roughness the feed per tooth was most influencing factor, which was followed by axial depth of cut and cutting speed. For conformation of experiment ANOVA is performed with a confidence level of 95%. The result of analysis showed that axial depth of cut contributes the most for the cutting force and feed per tooth contributes the most for surface roughness. The result of Taguchi design of experiment and ANOVA validate each other.

Lohithaksha M Maiyar et al. [4] were carried out an investigation on Inconel 718 superalloy for the parameter optimisation of end milling operation by using multi-response criteria based on the Taguchi orthogonal array with the grey relational analysis. Cutting speed, feed rate and depth of cut are considered as input parameters and surface roughness and material removal rate as a response. An orthogonal array of L_9 was selected and nine experimental runs are performed. A grey relational analysis was performed for multiple performance characteristics. Additionally, to identify the most significant factor the analysis of variance (ANOVA) is also applied. Experimental results have shown 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. 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.

J.A. Ghani et al. [5] was presented a study on hardened steel AISI H13 to optimize cutting parameters in end milling machine with TiN coated P10 carbide insert tool under semi-finishing and finishing conditions of high cutting speed by using Taguchi optimization methodology. Cutting speed, feed rate and depth of cut are evaluated as a milling parameters. To analyse the effect of these milling parameters, L_{27} orthogonal array, signal-to-noise (S/N) ratio and Pareto analysis of variance (ANOVA) are employed. The analysis of the result shows that the optimal combination for

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low resultant cutting force and good surface finish are at high cutting speed, low feed rate and low depth of cut. Additionally, other significant effects such as interaction among milling parameters are also investigated by Using Taguchi method for design of experiment (DOE) also analysis shows that interaction of feed rate and depth of cut are more significant.

Thakur Paramjit Mahesh et al. [6] was 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 aluminium alloy. The input parameters taken into consideration are speed, feed, depth of cut and nose radius. Al 7075 T6 is one of the highest strength aluminium alloys in 7000 series family. In Taguchi method, L_{27} orthogonal array with 4 factors and 3 levels are chosen and S/N ratios are calculated. The S/N ratios of roughness and material removal rate are fed as inputs to fuzzy logic system and output received is Multi response performance index (MRPI). With application of ANOVA, the nose radius and depth of cut are identified as the most significant parameters contributing about 31% of the variance. Further a confirmation test showed that, there was a significant improvement in MRPI of optimal process parameters as compared to MRPI of initial process parameters.

Avinash A. Thakre [7] Present work on 1040 MS material on CNC vertical milling machine using carbide inserts to optimized the milling machining parameter to minimize surface roughness by using Taguchi method. Spindle speed, feed rate, depth of cut and coolant flow are selected as milling parameters to optimize the surface roughness. An orthogonal array L_9 with four factors and three levels for each variable are selected. To identify most significance parameters ANOVA is employed. The results analysis shows that coolant flow is the most significant parameter in controlling the surface roughness, followed by spindle speed. The optimal parameters for surface roughness are obtained as spindle speed of 2500 rpm, feed rate of 800 mm/min, 0.8 mm depth of cut, 30 lit/min coolant flow.

Harish Holkar et al. [8] were carried out work on AISI 321 grade of stainless steel to optimize the end milling parameters by using Taguchi approach. The end milling tests were carried out with PVD multilayer coated cemented carbide (TiN/TiAlN/TiN) end mill tools. Cutting speeds, feed rates and a constant depth of cut are selected as input parameters. While surface roughness, flank wear and Material Removal Rate (MRR) are analysed. An orthogonal array L_9 , S/N ratio, and ANOVA are employed to optimize the cutting parameters. The result of the analysis showed that feed rate as the more significant parameter for surface roughness, whereas the cutting speed was identified as the more significant parameter influencing flank wear and MRR.

M. Fakkir Mohamed et al. [9] were discussed an investigation on EN 19 & EN24 alloy steel to optimized the CNC milling machining parameters by using Taguchi methodology. Spindle speed, Feed rate & Depth of cut are selected as control parameters. While the Surface Roughness, Material Removal Rate and Machining time as a response variable. An orthogonal array of L_{16} selected and total of 16 experimental runs was conducted. Analysis of result showed that for EN 19 material spindle speed is the most influencing parameter on material removal rate and depth of cut on machining time.

M.Subramanian et al. [10] were carried out an experiment on Aluminum (Al 7075-T6) to optimize the cutting parameters on shoulder milling machine by using Response surface methodology to conducting experiments. Cutting speed, cutting feed rate and axial depth of cut are selected as machining parameters were as cutting forces as response factor. For predicting cutting force the second order mathematical model in terms of machining parameters was developed. The optimization of milling parameters to obtain minimum cutting force genetic algorithms (GA) was employed. Additionally, ANOVA is used to find adequacy of the predictive models and to identify most significance parameters. The analysis result showed that the deviation between the predicted results and the experimental results is well within the limit of 95% confidence level. Also, it was found that cutting speed has a most significant influence on cutting force followed by cutting feed rate and the axial depth of cut.

Reddy Sreenivasulu [11] was presented a study on Glass Fiber Reinforced Polymeric composite material (GFRP) to optimize the CNC milling machining parameters by using Taguchi design method and artificial neural network (ANN). Cutting speed, feed rate and depth of cut are selected as control parameters were as the delamination damage and surface roughness as a response factor. From the result of ANOVA, it showed that cutting speed and depth of cut are the most significant factors on the responses. Additionally, to compare the predicted values with the experimental values, artificial neural network (ANN) has been applied and the results of ANN concluded that the

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Vol. 6, Issue 6, June 2017

deviations between the predictive model results and the experimental measurements are found in the range of 3.7%, it shows good agreement.

Deepak Kumar et al. [12] were carried out a work on Aluminium alloy Al 6063-T6 to optimize the CNC end milling machining parameters by using Response Surface Methodology (RSM) and Central Composite Design (CCD). Spindle speed, feed rate, axial depth of cut and radial depth of cut are selected as input parameters while surface roughness and flatness as response factors. Second-order mathematical models have been developed using Response Surface Methodology (RSM). Design-Expert software, based on 4-factor, 5-level Central Composite Design (CCD) is used to carried out the milling experiments. The developed models have been validated using verification experiments. The result showed that feed rate is most significant parameter followed by the depth of cut, i.e. radial depth of cut and also the axial depth of cut. And the predicted values of surface roughness and flatness from the proposed model compares well with the obtained experimental values.

Table1. Summary of review Papers

Sr. No.	Year	Author's Name	Material	Technique/ Methodology used	Input Parameters	Output Parameters	Most Significant
01	2013	J.S. Pang et al.[1]	Halloysite nanotube with aluminium reinforced epoxy matrix (HNT/AL/Ep)	Taguchi L27 OA, Morphology study	Speed, feed rate, DOC	Surface roughness, cutting force	-
02	2007	Julie Z. Zhang et al.[2]	Aluminium	Taguchi L9 OA, ANOVA	Speed, feed rate, DOC, operating chamber temperature and the tool wear	Surface roughness	Speed, Tool wear
03	2013	Vijay S et al. [3]	Titanium alloy Ti-6Al-4V	Taguchi L16 OA, ANOVA	Speed, feed rate, DOC	Surface roughness and Cutting force	Feed rate, DOC
04	2013	Lohithaksha M Maiyar et al.[4]	Inconel 718 Superalloy	Taguchi L9 OA, ANOVA, GRA	Speed, feed rate, DOC	Surface roughness, MRR	Speed, Feed rate
05	2004	J.A. Ghani et al.[5]	Hardened steel AISI H13	Taguchi L27 OA, Pareto ANOVA	Speed, feed rate, DOC	Surface roughness, cutting force	Feed rate, depth of cut (interaction)
06	2014	Thakur Paramjit Mahesh et al.[6]	Aluminium	fuzzy logic integrated with Taguchi method L27 OA, ANOVA	Speed, feed rate, DOC, Nose radius	Surface roughness, MRR	Nose radius, DOC
07	2013	Avinash A. Thakre [7]	1040 MS	Taguchi L9 OA, ANOVA	Speed, feed rate, DOC, Coolant flow	Surface roughness	Coolant flow, Speed
08	2016	Harish Holkar	stainless steel	Taguchi L9 OA,	Speed, feed	Surface	Feed rate,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

		et al.[8]	Of grade AISI 321	ANOVA	rate, DOC	roughness, MRR, Flank wear,	Speed
09	2016	M. Fakkir Mohamed, et al.[9]	EN 19 & EN24 alloy steel.	Taguchi L16 OA,	Speed, feed rate, DOC	Surface roughness, MRR, machining Time	Speed, Feed rate
10	2013	M.Subramanian et al.[10]	Aluminum (Al 7075-T6)	RSM,GA, and ANOVA	Speed, feed rate, DOC	Cutting Force	Speed, Feed rate
11	2013	Reddy Sreenivasulu[11]	Glass Fiber Reinforced Polymeric composite material (GFRP)	Taguchi L16 OA, ANOVA, artificial neural network	Speed, feed rate, DOC	Roughness and Delamination damage Factor (Fd)	DOC, Speed
12	2015	Deepak Kumar et al.[12]	Aluminium alloy Al 6063-T6	Response Surface Methodology (RSM) and Central Composite Design (CCD)	Speed, feed rate, axial DOC, radial DOC	Surface roughness, Flatness	Feed rate, DOC

III. CONCLUSION

From the above Literature review we observed that many investigators have suggested various methodologies such as Taguchi technique, Design of Experiments (DOE), Response surface methodology (RSM), Grey Relational Analysis (GRA), artificial neural network (ANN), fuzzy logic, Central Composite Design (CCD), Scatter search technique, genetic algorithm, gravitational search algorithm (GSA), Morphology study etc. To explain the effect of machining parameter on various output parameters (response factors) such as Surface roughness, MRR, cutting force, Machining Time, Flatness etc.

There are many parameters that can be considered in optimize milling machining processes. The few input parameters (controlled factors) were reported include Cutting speed, feed rate, Depth of cut, nose radius, coolant flow, tool wear, environmental conditions etc. The most three parameter that uses by literature is the depth of cut, feed rate and cutting speed.

We also found the feeding rate is the most influencing parameter on Surface roughness followed by cutting speed and Depth of cut. And cutting speed is a most influencing parameter on MRR followed by Depth of cut and feed rate and the least influencing parameter is nose radius.

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