A Survey on Optimization of Process Parameters in Milling

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Abstract - *In modern manufacturing CNC Machining has growing importance. CNC Milling is one of the most commonly used machining process in manufacturing different components. There are different milling processes viz, face milling, end milling, profile milling, pocket milling, peripheral milling etc., These processes are used in different applications. Hence optimization of machining parameters is most important to reduce the machining time as well as to get good surface finish. Surface Roughness plays an important role in determining how a real object will interact with its environment. There are different parameters that influence the surface roughness while machining a component. In this paper an attempt is made to review the research carried so far in CNC milling and scope for future work.*

Key Words: Milling, Optimization, Process Parameters, Review, Surface roughness

1. INTRODUCTION

Surface finish is the most important quality to accept the machined components. Rough surfaces generally undergo more wear and have higher friction coefficients than smooth surfaces. Surface finish is sometimes act as a good tool to judge the function of mechanical elements, since irregularities on the surface may form centers for cracks or corrosion. There are different controllable and non-controllable parameters which affect the surface finish of a component. Machining parameters, Work piece material properties, Tool material properties and tool geometry are various factors that influence the quality of the surface. Milling is one of the most commonly used machining process in manufacturing industry. Now a days CNC Milling is mostly preferred to improve the quality of machining and to reduce the machining time. As CNC milling is an expensive process it is necessary to select proper machining parameters to reduce the machining cost. Many researchers did extensive research to optimize the machining parameters to reduce the machining time, machining cost and to improve the surface quality.

2. LITERATURE REVIEW

2.1 End Milling

A mathematical model for the prediction of surface roughness in end milling was described by M. Alauddin etal., [1] using response surface methodology. Speed, feed and depth of cut were considered as the influencing parameters. Response surface contours were constructed and used to determine the optimum conditions for a required surface roughness. J A Ghani et al., [5] applied Taguchy optimization technique to find the influence of speed, feed, depth of cut surface finish. It was found that high speed with low feed gives good surface finish but generate high cutting force. M. T Hayajneh et al., [7] designed a set of experiments to characterize the surface quality in end milling using multi regression model. The study was to find the effect using Liquid Nitrogen Coolant and TiAlN coated solid carbide tools to find the surface roughness. B. C. Routara et al., [11] investigated the effect of spindle speed, feed and depth of cut on surface finish produced in CNC end milling. In this study the effect of work material variations on five surface roughness parameters was conducted. Using response surface methodology optimal cutting conditions also obtained for different surface roughness parameters. S.Moshat et al.,[12] experimented on aluminium to find the optimal parameters to optimize material removal rate and surface roughness. Multi objective optimization with component analysis was used to model the quality parameters with process parameters. Vijay Kumar Jha etal.[13] developed a data mining model using decision tree and ANN to study the influence of process parameters on surface roughness by using some controllable parameters like speed, feed and depth of cut and uncontrollable parameters like tool geometry, material properties of tool and work piece. Neural network model was adopted, if accuracy was required & if time restriction was there, decision tree had been adopted. A.Shokarni et.al.,[14] explained the use of cryogenic cooling through experimentation in machining Inconel 718 with TiAlN Coated solid Carbide tool. It was concluded that cryogenic cooling was useful to improve surface roughness and power consumption, but it had increased the tool wear rate significantly. Nitin Agarwal [17] discussed multi regression model using speed, feed & depth of cut as controllable parameters and surface roughness as quality characteristic. The developed model was analyzed using t-test and conformation experiments. But it was observed that the surface roughness increases with depth of cut or if depth of cut is low feed rate effects the surface roughness. A model was developed using Artificial Neural Networks to study the influence of cutting speed, feed rate and depth of cut on the delamination damage and surface roughness on Glass Fiber Reinforced Polymeric composite material (GFRP) during end milling by Reddy Srinivasulu [20]. Lohithaksha M Maiyara et al.,[21] investigated the effect of cutting parameters in end milling on Inconel 718 super alloy with multi response criteria. ANOVA was applied to identify the most significant factor. Taguchi OA & Grey relational analysis was used to model the quality parameters & compared with the experimental results. Vegetable oil based coolants was used by E.Kuram et.al., [22] in milling AISI 304 material. Effects of cutting fluid types were investigated as function of three cutting parameters on process responses. D-Optimal method was used to optimize the process parameters. A.I Azmi etal [23] discussed the tool wear prediction in machining composite materials like fiber reinforced polymer using multiple regression analysis and neuro fuzzy modeling for tool reconditioning or tool replacement periodically. Ali R.Yildiz [24], [25] applied cuckoo search algorithm and a new hybrid approach for optimizing the process parameters in end milling and compared with other evolutionary algorithms. T P Mahesh etal [30] applied Fuzzy logic with Taguchi method to optimize process parameters, speed feed, depth of cut & nose radius on Al 7075 alloy. SR & MRR were taken for fuzzy logic system & output was MRPI Multi Response Performance Index and concluded that nose radius & depth of cut are most significant. W. Li, et.al.,[31] experimented the end milling of Inconel 718 alloy using PVD coated tool. Tool wear effect on surface integrity & its impact on fatigue performance of the material was investigated at each level of tool flank wear. Fatigue endurance limits of the machined samples at different, reliability levels were calculated & correlated with the experimental values. J.S Pang et.al.,[32] used Taguchi optimization of end milling parameters in machining halloysite Nano tubes with Al reinforced epoxy hybrid composite material under dry condition. The machining parameters that were evaluated in the study are the depth of cut (d), cutting speed (S) and feed rate (f) and the response factors considered were the surface roughness and the cutting force. To characterize MRR, Surface texture and parallelism of OHNS steel after end milling operation, N.V.Malvade et.al.,[33] used Taguchi method. The analysis using Taguchi method revealed that, in general the depth of cut significantly affects the MRR and speed significantly affects the surface roughness. To improve the tribological characteristics of Al6061-T6 B.Rahmati et.al.,[34] discussed the use of MoS2 Nano lubricant in milling. To reduce cutting force, temperature & surface roughness, nano-lubricant concentration, nozzle orientation and air carrier pressure were used to build the relation. Ravi Kumar D Patel,et. al., [35] applied ANN to model the process parameters for predicting surface roughness using speed, feed rate & depth of cut. From this study they discussed that surface finish was most effected by feed, speed & then depth of cut. The Gaussian process regression (GPR) was proposed for modeling and predicting the surface roughness in end face milling on C45E4 steel by G.Zhang et.al., [36] with speed, feed & depth of cut. In this, they also discussed the effect of tool vibration on machined surface quality using 3D maps. Vikas Pare, et.al., [38] made experimentation to find the optimum machining conditions for the end-milling of composite materials using GSA. The input variables were cutting speed, feed, the depth of cut and the step-over ratio and surface roughness was the output variable. Experiments were conducted on Al2O3 + SiC metal matrix composite. Sukdev S.Bhogal et.al., [39] studied the effect of process parameters on tool vibration & surface roughness during end milling of En-31 tool steel. RSM was used for modeling the surface finish & tool wear with different combinations of process parameters. The end milling of AISI 1045 steel, using carbide inserts coated with titanium nitride (TIN) was investigated by T. G. Brito et.al., [41] to get good surface finish. In this study process parameters as well as the noise parameters related to cutting fluid were considered. Uros Zuperl et al., [42] applied adaptive neuro-fuzzy inference system (ANFIS) and Teaching Learning Based Optimization (TLBO) algorithm to optimize the cutting parameters in ball-end milling. The dynamic cutting force components had been modeled using an adaptive neuro-fuzzy inference system (ANFIS) based on design of experiments and then TLBO algorithm was used to determine the objective function maximum (cutting force surface) by consideration of cutting constraints. Shunyao Du et. al., [43] applied Taguchy grey relational analysis technique to find the optimal machining parameters for milling Titanium alloy TB17. He considered the machining parameters as well as tool geometry as influencing factors to obtain optimum surface finish. The influence of process parameters in end milling of AISI P20 steel was studied through a linear equation formed with the experimental results by Wasim Khan et.al.,[44]. From the study it was found that cutting speed was the most influencing factor for surface finish. A normal boundary intersection with multivariate mean square error approach was applied by Danielle Martins Duarte Costa et al.,[46] to optimize the independent parameters for dry end milling of the AISI 1045 steel. In this study four input parameters and six response variables were considered. João Ribeiro et al., [47] investigated to optimize the process parameters using Taguchy design of experiments on hardened steel block (steel 1.2738) with tungsten carbide coated tools. The independent parameters considered was the feed/tooth, cutting speed and radial depth of cut and it was found that radial depth of cut showed more influence on surface integrity. Md A Rahman, et.al.,[48] studied influence of machining parameters on vibration and surface integrity while milling Inconel 718 with Minimum Quantity Lubrication. The study concluded that depth of cut and feed rate were the influencing factors for vibration and cutting speed is for surface roughness.

2.2 Face Milling

A feed forward neural network model was designed by P. Benerodes, et al., [2],[3] to find the most influencing process parameter in face milling by considering speed, feed and depth of cut. Different methodologies and practices employed to optimize the machining parameters in general machining process were also compared to identify the better method for optimal surface integrity. Machining characteristics based on orthogonal arrays on cobalt based alloy were studied by E Bagci et.al, [6]. The effect of speed feed and depth of cut were considered for the study as the machining parameters to build the model. D. Bajic et. al.,[9] described the modelling of surface roughness with machining parameters using regression analysis and neural networks. Based on obtained results it was observed that neural networks model gives better explanation of optimal parameters are calculated using simplex algorithm. The use of Taguchi technique for face milling of mild steel with zinc coated inserts was discussed by Milon D. Selvam et al., [15]. Genetic Algorithm was applied to optimize quality parameter surface roughness as with number of passes, depth of cut, spindle speed and Feed rate as working parameters. The results are confirmed with the experimental results with a little variation. S.Bharathi Raja et al.,[16] developed a mathematical model using particle swarm optimization (PSO) to predict surface roughness based on experimental results. Considered parameters are speed, feed , depth of cut and through confirmation experiments they showed a negligible difference between predicted roughness and actual roughness values while machining Aluminium. Surasit Rawangwong et. al, [18],[19],[29] studied the effect of spindle speed, feed and depth of cut on surface roughness in face milling of aluminum semi-solid 2024 and Semi-Solid AA 7075 using full factorial design and experimentation was done with a twin cutting edge tool. With the obtained result a linear equation was formed and Mean absolute percentage error was calculated and compared with the test results. M.S.Sukumar et.al., [37] applied Taguchi & ANN approach to optimize the process parameters in face milling of Al 6061 material. C16 orthogonal array was used to design the experiments and ANN to model the surface roughness with speed, feed & depth of cut. With confirmation tests they have found that both give same result for surface finish. Sener karabulut et.al., [40] studied the effect of process parameters on surface roughness using ANN & Taguchi method. A7039/ Al2O3 metal matrix composites were used to study the optimization in face milling. The material texture was also considered as one of the effecting parameter.

2.3 Other Milling Processes

F. Dweiri et al., [4] studied the effect of process parameters on surface roughness in CNC down milling using fuzzy model. With adaptive neuro fuzzy inference system, the machining parameters were analyzed. Og˘uz Colak et al., [8] predicted the surface texture in sculptured surfaces using evolutionary algorithms. Gene expression programming method was used for characterizing the surface roughness in milling. As the selection of parameters as well as the path strategy was more influencing in pocket milling, C. Gologlu et al., [10] studied the modelling of surface roughness using Taguchy parameter design. Modeling of the milling parameters to measure the surface roughness was done using Taguchy method on different path strategies and found different optimal parameters for different path strategies. Mandeep chahal et.al.,[26] studied the effect of process parameters on surface roughness & MRR using one variable at a time approach [OFAT]. It was estimated the range of Process Parameters for specific material and for a particular tool. The influence of pocket geometry and tool path strategy on quality parameters like surface roughness and cutting forces was described by on P.E Romero et.al., [27] in pocket milling of UNS A96063 alloy. From the studies it was proposed that these parameters also effect machining time. The effect of tool path strategies on different characteristics were also explained in this study. H. Pereza, et.al., [28] analysed and validated different strategies for peripheral milling average-chip-thickness based cutting force model was used for analysis. C Burlacu, et.al., [45] experimented on micro milling of the C45W steel to minimize the surface roughness using a mathematical model. The chemical characteristics were also studied with the help of spectral analysis and chemical composition was measured at one point and two points, graphical and tabular.

End Milling:

Work piece material	Input parameters	Output parameters	Method
190 BHN steel	speed, feed rate and depth of cut	surface roughness	Response Surface Methodology
hardened steel AISI H13	speed, feed rate and depth of cut	Surface roughness and cutting force	gene expression programming method.
Aluminium, Brass, Mild steel	speed, feed rate and depth of cut	surface roughness	Response Surface Methodology
Aluminium	speed, feed rate and depth of cut	surface roughness	PCA based multi objective optimization technique
Inconel 718 Nickel-Based Alloy	speed, feed rate and depth of cut	surface roughness, power consumption and tool wear	
GFRP Composite Material	Speed, feed rate and depth of cut	Surface Roughness and Delamination Damage	Taguchy Method
AISI 304	Speed, feed rate and depth of cut	specific energy, tool life and surface roughness	Taguchy Method
halloysite nanotube with aluminium reinforced epoxy matrix (HNT/Al/Ep) hybrid composite	speed, feed rate and depth of cut	Cutting Force and Surface Roughness	Taguchy Method
OHNS steel	speed, feed rate and depth of cut	material removal rate (MRR), surface roughness, parallelism	Genetic Algorithm
EN-31 tool steel	speed, feed rate and depth of cut	Surface Roughness and Tool Vibration	Gaussian process regression and cause analysis

TB17 alloy	the cutting fluid condition, milling speed, feed per tooth, axial depth of cut , radial depth of cut , rake angle , clearance angle and helix angle	surface roughness, surface microhardness, and surface residual stress	Taguchi-Grey relational analysis method
EN 31 steel	spindle speed, feed rate and depth of cut	surface roughness	Central composite rotatable design (CCRD) a model in RSM

Face Milling:

Work piece material	Input parameters	Output parameters	Method
mild steel	speed, feed rate and depth of cut, Number of passes	surface roughness	GA modelling
Aluminium	speed, feed rate and depth of cut	surface roughness	PSO technique for mathematical modelling
aluminum 7075-t6	speed, feed rate and depth of cut	surface roughness	Taguchy Method
Semi-Solid AA 7075	speed, feed rate and depth of cut	Surface quality and Tool Wear	Taguchy Method
Aluminum 6061-T6	speed, feed rate and depth of cut	surface roughness	RSA &GA
AA7039/Al2O3 metal matrix composites	speed, feed rate and depth of cut	Cutting Force and Surface Roughness	Particle Swarm Optimization technique, Artificial neural networks (ANN) and regression analysis
carbon steel St 52-3	speed, feed rate and depth of cut	Surface Roughness	regression analysis and neural networks

3. SCOPE FOR FUTURE WORK

The discussion presented here is an overview of recent developments in the field of milling.

In this study it was understood that there were some contradictions regarding influence of speed, feed and depth of cut on surface roughness. That might be because of different cutting conditions, various materials, and different parametric levels in consideration.

From above studies the scope for future research may be as discussed below:

Most of the research work was done on end milling and then on face milling. The other types of milling processes were considered by very less number of researchers. In most of the research work, spindle speed, Feed rate and depth of cut was considered as the major influencing parameters either in end milling or face milling. Very little work had been reported on effect of tool geometry and tool material properties. Most of the research on optimization had been carried out on process parameters for improvement of a single quality characteristic such as surface roughness or cutting force. Much less research was presented on multi objective optimization of the output parameters and tool wear. Research may be carried on the optimization for other milling processes also.

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