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A Review on Optimization of CNC End Milling Process Parameters

Hemantsinh Pratapsinh Rao
Department of Mechanical Engineering,
S V B I T,Gandhinagar-382650

Mr. Rajat Dave
Department of Mechanical Engineering,
S V B I T, Gandhinagar-382650

Mr. Riddhish Thakore
Department of Mechanical Engineering,
S V B I T, Gandhinagar-382650

Abstract: "Quality and productivity play paramount role in today's manufacturing market. Now a day's due to very stiff and cut throat competitive market condition in manufacturing industries. The main objective of industries reveal with engendering better quality product at minimum cost and increment productivity. CNC end milling is most vital and mundane operation use for engender machine part with desire surface quality and higher productivity with less time and cost constrain. To obtain main objective of company regards quality and productivity. In the present research project an endeavor is made to understand the effect of machining parameters such as cutting speed (m/min), aliment rate (mm/min),depth of cut (mm) that are influences on responsive output parameters such as Surface Roughness(Ra) and Material Abstraction Rate(MRR) by utilizing optimization philosophy. The effort to investigate optimal machining parameters and their contribution on engendering better Surface quality and higher Productivity. Thus by Analysing experimental and theoretically data optimization of process parameters are to be carried out."

Keywords: CNC end milling, Optimization, Surface roughness(Ra), Material removal rate(MRR), Carbide tool material, Alluminium alloy.

I. Introduction

"As a fundamental machining process, milling is most commonly utilized in industries and machine shops today for machining components to precise size and shapes, which are acclimated to mate with other components in die, aerospace, automotive and machinery design. Among variants of milling processes, end milling is most paramount milling operation due to its capability of engendering intricate geometric surfaces with plausible precision and surface finish. Additionally, it is capable of engendering a variety of configurations utilizing milling cutter. Minute and medium size industries are manufacturing different components of main assembly for ecumenical industries and consumers. Aluminium alloys are extensively utilized as a main engineering material in sundry industries such as automotive industries, the mould and die components manufacture and the industry in which weight is the most paramount factor. Surface roughness is a consequential quantification of product quality since it greatly influences the performance of mechanical components as well as engenderment cost. These materials avail machining and possess superior machinability Index. Milling is one of the most commonly used machining processes in aluminium alloys shaping. It has considerable economical consequentiality because it is customarily among the culminating steps in the fabrication of industrial mechanical components. Their effects on products are paramount because they may cause some critical quandaries such as the deterioration of surface quality, thus reducing the product durability and precision. As mentioned above, surface roughness is a consequential quantification of product quality. Surface roughness has an impact on the mechanical properties like fatigue deportment, corrosion resistance etc. Sometimes, sundry catastrophic failures causing high costs have been attributed to the surface finish of the components in question. As a result, there have been many great research developments in modelling surface roughness and optimization of the variable parameters to obtain a surface finish of desired level since the only opportune cull of cutting parameters can engender a better surface finish. Nevertheless, such studies are far from completion since it is very arduous to consider all the parameters that control the surface roughness of a particular manufacturing process. The parameters have an effect on the surface roughness including machining parameters and cutting implement properties etc. In the manufacturing industries, sundry machining processes are adopted to abstract the material from a workpiece for the better product. Similarly, end milling process is one of the most vital and mundane metal cutting operations utilized for machining components because of its competency to abstract materials more expeditious with a plausibly good surface quality. In recent times, numerical controlled machine implements have been implemented to realize full automation in milling since they provide more preponderant ameliorations in productivity, increment the quality of the machined components, and require less operator input. A brief review of literature on surface roughness and MRR in milling is presented here."

II. Literature Review

Many investigators have suggested sundry methods to explicate the effect of process parameter on surface roughness and MRR in CNC end milling process.

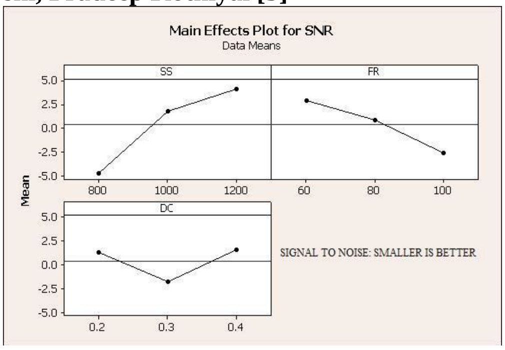
B. Ramesh, et al [1] "this paper has described the utilization of Replication Surface Methodology (RSM) to investigate the relative influence of milling process parameters (spindle celerity, victual and depth of cut) on quality characteristics (surface roughness and material abstraction rate), adequacy analysis of replication surface models and to procure optimal process parameter levels in the culled range which leads to procure high machining quality and productivity in conventional milling of beryllium copper alloy plate utilizing 6 mm carbide end mill. Predicated on the experimental results and methodology utilized, the conclusions can be drawn for straight grooving operation are that Surface roughness and material abstraction rate increases as speed and victual increases. Lower Ra is achieved at medium haste, lower aliment and medium depth of cut. Higher MRR is achieved at higher speed and aliment and lower depth of cut.Feed is more paramount followed by speed in influencing Ra and haste is more consequential followed by victual in influencing MRR.The replication surface models developed for MRR and Ra with milling process parameters deems to be fit.The optimal parameter levels in conventional milling of beryllium copper alloy utilizing 6 mm carbide end mill can be concluded as 4416 rpm spindle celerity, 0.49 mm/rev victual and 2 mm depth of cut by which 507.3378 mm3/min MRR and 0.7950μm Ra is obtained.Lower MRR will lead to higher surface finish."

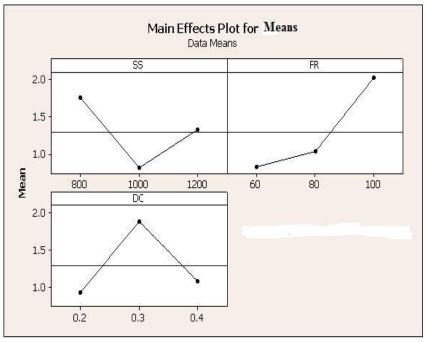
K.D Theja, et al [2] "In this paper, experiments were conducted on a potent and precise 3-axis CNC vertical machining center, mode employing a perpetually variable spindle expedite to a maximum of 6000 rpm and with a maximum spindle power of 5.5kW. The victual rates can be set up to a maximum of 10m/min. Experiments were conducted as per the deign matrix. Cutting haste, Victual and Depth of cut were taken as the process parameters and the output replications i.e. Material abstraction rate and Implement wear resistance were taken as the output replications. Full factorial design was acclimated to carry out the experimental design. Artificial Neural networks (ANN) program available in Matlab software is utilized to establish the relationships between the input process parameters and the output variables. The models were developed to prognosticate the MRR and Implement wear resistance through Artificial Neural Networks techniques. The best model is culled predicated on the best performance error for different network configurations. Additionally the models have been evaluated by denotes of the percentage deviation between the presaged values and the authentic values. Additionally the graphs were plotted between the quantified values and the ANN prognosticated results. It is shown that the ANN presaged results shows good accedence with the Experimental results, Hence ANN proved its efficiency in optimizing the End Milling process parameters. The developed ANN model can be further integrated with optimization algorithms like GA to optimize the End milling parameters."

Dimple Rani, et al [3] "in this study proposes an integrated optimization approach utilizing Taguchi method. In this paper, the average value of surface roughness and S/N ratio were calculated and were found to be within the range. Taguchi parameter design can provide a systematic procedure that can efficaciously and efficiently identify the optimum surface roughness in the process control of individual end milling machines. It withal sanctions industry to reduce process or product variability and minimize product defects by utilizing a relatively diminutive number of experimental runs and costs to achieve superior-quality products. This research only demonstrates how to utilize Taguchi parameter design for optimizing machining performance with minimum cost. This approach can be recommended for perpetual quality amendment and off-line quality of any engenderment process. As speed increases surface roughness decreases and victual increases surface roughness additionally increases. For achieving good surface finish on the D2 work piece, higher cutting haste, lower aliment and lower depth of cut are preferred."

P. M. Thakur, R. Rajesh [4] "this paper has presented integrated Taguchi-Fuzzy for optimization of process parameters of CNC end milling of Al-7075 T6 alloy with multiple performance characteristics. A fuzzy reasoning of multiple performances has been performed by fuzzy logic unit and a multi replication performance index (MRPI) was developed for each run. Predicated on experimental results and corroboration tests the conclusion can be drawn that the following parameter setting has been identified as to yield the best cumulation of parameters: A3B1C3D2.The experimental results showed that there was consequential amelioration in surface roughness and MRR.The most paramount parameters affecting replications have been identified as nasal perceiver radius and depth of cut."

Amit Joshi, Pradeep Kothiyal [5]





"In this paper, from the graph of S-N ratio it can be observed that optimal value of surface finish is obtained at first level of factor A third level of factor B and second level of factor C. Optimal value of surface finish is 3.0723μm. From the ANOVA it can be visually perceived that percentage contribution of aliment rate is maximum and it signifies Victual rate is the most dominating factor for modelling surface finish. Taguchi robust design is opportune for modelling surface finish in CNC milling."

Abhishek Kumbhar, et al [6] "in this paper study, the effects of cutting haste, victual and depth of cut on surface roughness and material abstraction rate during end milling of Stainless steel 304 were investigated utilizing Taguchi's experimental design method coalesced with Grey relational analysis. The conclusions can be made from performed experimental research that based on Grey Relational Grade analysis, the optimal process parameters for multi-objective optimization are as follows: Cutting speed at level 2 (75 m/min), victual at level 1 (0.15 mm/rev) and depth of cut at level 3 (1.5 mm) i.e. v2-f1-d3.Confirmatory test result was copacetic and has yielded reduction in surface roughness by 24.86 % and increment in material abstraction rate by 23.99 %. Thus we can observe amendment in performance characteristic.It has been established that Taguchi predicated Grey Relational Analysis is an efficacious multi-objective optimization implement."

B. Vijaya Krishna Teja, et al [7] "in this paper, Experiments are designed and conducted on CNC milling machine with tungsten carbide end mill and AISI 304 stainless steel as work material to optimize the milling parameters. The surface roughness and material abstraction rate are the replications. The proposed Grey predicated Taguchi method is constructive in optimizing the multi replications. It is identified that cutting speed (56.90%) influences more on milling of AISI 304 stainless steel followed by depth of cut (22.43%) and aliment rate (8.58%). The optimal process parameters predicated on Grey Relational Analysis for the milling of AISI 304 stainless steel include a 95 m/min cutting haste, 800 mm/min victual rate and
0.8mm depth of cut."

Ojolo Sunday Joshua, et al[8] "were carried out that the surface roughness (Ra) of a machined surface whether obtained in a dry or MQL environment could be prognosticated efficaciously by cumulating two of these parameters- spindle celerity, victual rate, depth of cut- while keeping one of them constant at a time and their interactions in the multiple regression model. It can additionally be concluded that machining with MQL (a good alternative to flooding lubrication/cooling), apart from being environmentally cordial, reduces the surface roughness value better when compared to dry machining. Surface roughness values were affected mostly by cutting victual, followed by spindle speed and depth of cut has the least impact on surface roughness values. The result additionally shows that spindle speed and cutting victual amalgamation has the best interaction while amalgamation of cutting aliment and depth of cut has the worst interaction leading to a poor surface finish. The model developed can be acclimated to cull the best amalgamation of cutting variables for achieving optimum conditions that will result in minimum surface roughness during cutting operation."

M.F.F.Ab.Rashid et al [9] "were carried out "Surface Roughness Prognostication for CNC Milling Process utilizing Artificial Neural Network". The purport for this research is to develop mathematical model utilizing multiple regression and artificial neural network model for artificial astute method. Spindle celerity, aliment rate, and depth of cut have been culled as prognosticators in order to prognosticate surface roughness. 27 samples of 400mmx100mmx50mm 6061. Aluminium were run with utilizing HSS End mill implement (No of flute = 4, Dia. D=10mm) carried out on FANUC CNC Milling α-T14E. The experiment is executed by utilizing full factorial design. Analysis of variances shows that the most consequential parameter is aliment rate followed by spindle speed and lastly depth of cut. After the soothsaid surface roughness has been obtained by utilizing both methods, average percentage error is calculated. The mathematical model developed by utilizing multiple regression method shows the precision of 86.7% which is reliable to be utilized in surface roughness presage. On the other hand, artificial neural network technique shows the precision of 93.58% which is feasible and applicable in presage of surface roughness. The result from this research is utilizable to be implemented in industry to reduce time and cost in surface roughness prognostication."

John D. Kechagias, et al [10] "were carried out that the influence of cutter geometry and cutting parameters during end milling on the surface texture of aluminium (Al) alloy 5083 was experimentally investigated. Eighteen pockets were manufactured having different cumulation of parameters values according to Taguchi L18 standard orthogonal array. Surface texture parameters (Ra, Ry, and Rz) were quantified on three different passes on side surface of pockets and analysed utilizing statistical techniques. The results reveal that the cutting haste, the peripheral 2nd mitigation angle, and the core diameter have paramount effect in surface texture parameters. In order to establish a relationship between the performance measures and the process parameters, a set of additive models was engendered. Conclusively, an evaluation (verification) experiment was performed. The acquired experimental values were found to be inside the confidence intervals provided by the additive models. These results attest the precision of the proposed modelling approach."

V K Lakshmi, et al [11] "this paper presents an experimental investigation on surface finish and material abstraction rate during the high speed end milling of En24 alloy steel in order to develop an opportune roughness presage model and optimize the cutting parameters utilizing RSM. Predicated on the replication surface concept and 3 level factorial, adequate numbers of experiments were performed to engender the roughness data. These results were habituated to develop a 2nd order quadratic model to prognosticate surface roughness. The general conclusions from the current study can- be summarized as RSM has been proven to be an efficient method to prognosticate the surface finish during end-milling of En 24 alloy steel. It additionally reduces the total numbers of experiment quite significantly.The quadratic second order models, developed to soothsay the surface roughness value, could provide prognosticated values of surface roughness pretty proximate to the genuine values found in the experiments. The model was checked at 95% confidence level for the adequacy.Feed possesses the most consequential effect on roughness followed by cutting haste. However, depth of cut appears to have very little effect over roughness value. An increment of cutting speed and decrement of aliment will result in better surface quality in terms of roughness.Interaction effects between cutting speed and depth of cut withal possesses a major effect over the surface roughness value."

B. Sidda Reddy, et al [12] "were carried out "Optimization of surface roughness in CNC end milling utilizing replication surface methodology and genetic algorithm". In this study, minimization of surface roughness has been investigated by integrating design of experiment method, Replication surface methodology (RSM) and genetic algorithm. The experiments were conducted on AISI P20 mould steel (100x100x10 mm) with CVD coated carbide implement inserts (TN 450) and CNC Vertical milling machine 600 II, KENAMETAL implement holder BT40ER40080M 20 ATC by utilizing Taguchi's L50 orthogonal array in the design of experiments (DOE) .Considering the machining parameters such as Nasal perceiver radius (R), Cutting speed (V), aliment (f), axial depth of cut (d) and radial depth of cut (rd). A predictive replication surface model for surface roughness is developed utilizing RSM. The replication surface (RS) model is interfaced with the genetic algorithm (GA) to find the optimum machining parameter values. To achieve the minimum surface roughness, the congruous process parameters are resolute. Nasal Perceiver radius, cutting haste, victual rate, axial depth of cut and radial depth of cut are considered as process parameters GA has reduced the surface roughness of the initial model significantly. Surface roughness is ameliorated by about 44.22%."

Pankaj Chandna, et al [13] "this paper work analyses different parameters of end milling to minimize the surface roughness for AISI D2 steel. D2 Steel is generally utilized for stamping or composing dies, punches, composing rolls, knives, slitters, shear blades, implements, scrap choppers, tyre shredders etc. Surface roughness is one of the main indices that determines the quality of machined products and is influenced by sundry cutting parameters. In machining operations, achieving desired surface quality by optimization of machining parameters, is a challenging job. In case of mating components the surface roughness become more essential and is influenced by the cutting parameters, because these quality structures are highly correlated and are expected to be influenced directly or indirectly by the direct effect of process parameters or their interactive effects (i.e. on process environment). In this work, the effects of culled process parameters on surface roughness and subsequent setting of parameters with the calibers have been accomplished by Taguchi's parameter design approach. The experiments have been performed as per the coalescence of calibers of different process parameters suggested by L9 orthogonal array. Experimental investigation of the terminus milling of AISI D2 steel with carbide implement by varying victual, speed and depth of cut and the surface roughness has been quantified utilizing surface roughness tester. Analyses of variance have been performed for mean and signal-to-noise ratio to estimate the contribution of the different process parameters on the process."

SANJEEV KUMAR PAL, RAHUL DAVIS[14] "the present work prosperously demonstrated the application of Grey relational analysis for optimization of process parameters in end milling of the two materials as Al 6061 and Al 6463 (aluminium alloys). The conclusions can be drawn from the present work were as the highest Grey relational grade of 1.0000 was observed for the experimental Process, shown in replication Table. The average Grey relational grade, which betokens the coalescence of control factors.The order of paramountcy for the controllable factors to the minimum surface roughness, in sequence, are the aliment rate and depth of cut.However, it is observed through ANOVA that the spindle haste is the most influential control factor among the four end milling process parameters investigated in the present work, when minimization of surface roughness is considered."

Gaurav Kumar, Rahul Davis [15] "in this paper author found for the milling operation of AISI Steel 410 was speed whose effect on the surface roughness has to be considered (p-value<0.05). While According to ANOVA Table none of the factor was found to be consequential for the milling operation of Aluminium 6061 (p-value>0.05).The contour plots exhibiting the graph between speed and depth of cut. For the contour plot of Surface Roughness the area in the light green colour designates surface is smooth while the dark green colour shows the surface is rough. While for the contour plot of MRR the area exhibiting the dark green colour shows the maximum MRR while Blue shows the lowest MRR. The smoothest surface and the maximum MRR was found at the celerity of 1400 RPM and 0.6 Depth of cut for both AISI 410 Steel and Aluminium 6061."

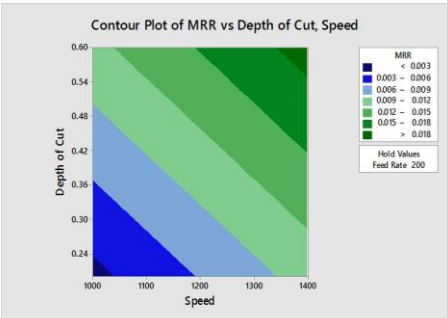


Fig.1 AISI 410 Steel contour plot, MRR

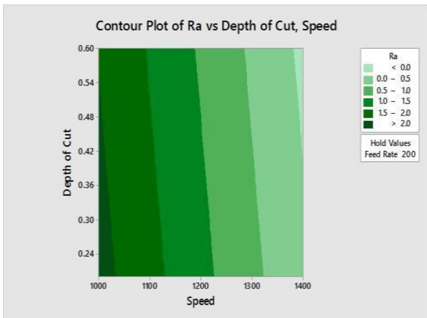


Fig.2 AISI 410 Steel contour plot, Ra

Fig.3 Aluminium 6061 contour plot, Ra

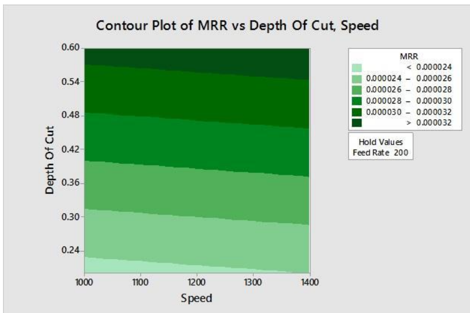


Fig.4 Aluminium 6061 contour plot, MRR

R. N. Nimase, Dr. P. M. Khodke [16] "in this research machining characteristic of Al-7075 alloy i.e. surface roughness is studied for end milling with four flute, 10mm diameter tungsten carbide implement. It is visually perceived From S/N ratio graphs optimal setting of machining parameters for low surface roughness obtained is 2500 rpm, 240 mm/min and 2.0 mm for spindle celerity, aliment rate and depth of cut respectively. It is observed from S/N ratio table that victual rate has more effect, spindle speed has moderate effect and depth of cut has less effect on surface roughness. Withal corroboration test by utilizing ANOVA shown that victual rate has more contribution 46.36%, spindle speed has moderate contribution 34.78% and depth of cut has less contribution."

Harshraj D. WathoreP, P. S. Adwani [17] "this paper presentsthe study of the parameter optimization of endmilling operation for H13 die steel withmultiresponsecriteria based on the Taguchi L9orthogonal array with the grey relationalanalysis. Surface roughness and materialremoval rate are optimized with considerationof performance characteristics namely cuttingspeed, feed rate and depth of cut. A greyrelational grade obtained from the greyrelational analysis is be used to solve the endmilling process with the multiple performancecharacteristics. Additionally, the analysis ofvariance (ANOVA) is to be applied to identifythe most significant factor.The important conclusions drawn from thepresent work are summarized as Multi-response problem was successfullyconverted into single response problem i.e.grey grade successfully which helped inoptimization of both parameterssimultaneously.The optimal cutting parameters for themachining process lies at 2500 rpm for cuttingspeed, 0.3 mm/revolution for feed rate and 1.2mm for depth of cut.Analysis of variance shows that depth ofcut is the most significant machiningparameter followed by cutting speed, affectingselected response characteristics i.e. surfaceroughness and material removal rate, with60.11% and 30.40% influence respectively.Taguchi grey relational analysis does notinvolve any complicated mathematical theoryor computation and thus can be employed bythe engineers without a strong statisticalbackground."

H.R. Krain, A.R.C. Sharman, K. Ridgway [18] "this paper initially reviews prior work on the influence of operating parameters on implement life when milling Inconel 718. Following this review, experimental work is described which evaluates the effect of varying aliment rate/chip thickness, immersion ratio (radial depth of cut), implement material and geometry on the implement life, implement wear and productivity obtained when end milling Inconel 718. The experimental work was conducted in two phases. The first phase utilized a fine-tuned implement material and geometry to examine the effects of sundry aliment rates and radial depth of cut. In the second phase, a reduced number of parameters were examined but sundry different implement materials and geometries were utilized. The results showed that no single implement material or geometry gave the best overall performance. However, areas were identified in which a categorical coalescence of implement material and geometry was superior. The findings of this work can be acclimated to optimise productivity depending on the volume of material to be abstracted. Implement life decremented with decrementing edge rounding and decrementing rake angle with the rake angle having a more pronounced effect."

Lohithaksha M Maiyar, et al [19] "this study investigated the parameter optimization of end milling operation for Inconel 718 super alloy with multi-replication criteria predicated on the Taguchi orthogonal array with the grey relational analysis. Nine experimental runs predicated on an L9 orthogonal array of Taguchi method were performed. Cutting celerity, victual rate and depth of cut are optimized with considerations of multiple performance characteristics namely surface roughness and material abstraction rate. A grey relational grade obtained from the grey relational analysis is utilized to solve the terminus milling process with the multiple performance characteristics. Supplementally, the analysis of variance (ANOVA) is supplementally applied to identify the most paramount factor. Conclusively, substantiation tests were performed to make a comparison between the experimental results and developed model. Experimental results have shown that machining performance in the cessation milling process can be ameliorated efficaciously through this approach. It has been established that grey relational analysis is an efficacious optimization implement for machining of Inconel 718 alloy in end milling. It has been adscititiously found that the optimal cutting parameters for the machining process lies at 75m/min for cutting velocity,0.06 mm/tooth for aliment rate and 0.4 mm for depth of cut. Further it has been observed that there is a 64.8%increase in material abstraction rate and at the same time a 9.52% decrease in surface roughness. This inspirits applying the grey concept for optimizing multi replication processing with multiple factors. Analysis of variance shows that the cutting velocity is the most consequential machining parameter followed by aliment rate affecting the multiple performance characteristics with 56.88% and 34.64% influence respectively."

III. Conclusion

From sundry literatures survey efforts to ascertained that many researchers have investigated number of process parameters like as cutting haste, victual and depth of cut of CNC milling. In this research work we optate to work on the Aluminium alloy 6061 work piece material with utilizing advanced carbide implement material as an insert to investigate influences of input process parameters like cutting haste, aliment rate, and depth of cut on replication parameters like surface roughness and MRR utilizing by Design of Experiments..

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