A REVIEW ON OPTIMIZATION OF MILLING PROCESS PARAMETERS

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Abstract : In any manufacturing process the surface roughness is a common parameter for quality and customer satisfaction. Customer will satisfy based on the physical appearance of a manufactured product. The surface roughness value of the machined product is depend on the different machining parameters like speed, feed, depth of cut(DOC), coolant flow rate etc.…

This paper presents a study on effect of machining parameters on surface roughness value for various materials. Many researchers done their work in this field to achieve the minimum surface roughness value by optimizing the machining or process parameters in end milling.

***IndexTerms* - End milling, machining parameters, and surface roughness.**

I. INTRODUCTION

Metal cutting is one of the most significant manufacturing processes in the area of material removal. Metal cutting is defined as the removal of metal chips from a workpiece in order to obtain a finished product with desired parameters of size, shape, and surface roughness. The objective of metal cutting is the solution to practical problems associated with the efficient and removal of metal from workpiece.

The surface roughness, material removal rate, machining time, power consumption, tool life etc. are some of the quality parameters which required optimizing for the selected process parameters. For the milling machine, the different process parameters are Spindle speed, feed rate, depth of cut, coolant, tool geometry etc. These parameters are considered according to the material that is selected for milling process.

These parameters have their own specifications based upon the work piece material and tool material.

Spindle speed: The spindle RPM necessary to give a desired peripheral speed depends on the size of the milling cutter. The best speed is determined by the kind of material being cut and the size and type of cutter used, width and depth of cut, finish required, type of cutting fluid and method of application, and power and speed available are factors relating to cutter speed.

Factors Governing Speed

There are no hard and fast rules governing the speed of milling cutters; experience has shown that the following factors must be considered in regulating speed.

- A metal slitting saw milling cutter can be rotated faster than a plain milling cutter having a broad face.
- Cutters having undercut teeth (positive rake) cut more freely than those having radial teeth (without rake); hence, they may run at higher speeds.
- Angle cutters must be run at slower speeds than plain or side cutters.
- Cutters with inserted teeth generally will stand as much speed as a solid cutter.
- A sharp cutter may be operated at greater speeds than a dull one.
- A plentiful supply of cutting oil will permit the cutter to run at higher speeds than without cutting oil.

FEEDS FOR MILLING

The rate of feed, or the speed at which the workpiece passes the cutter, determines the time required for cutting a job. In selecting the feed. there are several factors which should be considered. Forces are exerted against the workpiece, the cutter, and their holding devices during the cutting process. The force exerted varies directly with the amount of feed and depth of cut. and in turn are dependent upon the rigidity and power of the machine. Milling machines are limited by the power they can develop to turn the cutter and the amount of vibration they can resist when using coarse feeds and deep cuts. The feed and depth of the cut also depend upon the type of milling cutter being used. For example. deep cuts or coarse feeds should not be attempted when using a small diameter end milling cutter. Coarse cutters with strong cutting teeth can be fed at a faster rate because the chips maybe washed out more easily by the cutting oil.

Coarse feeds and deep cuts should not be used on a frail workpiece if the piece is mounted in such a way that its holding device is not able to prevent springing or bending.

Over speeding may be detected by the occurrence of a squeaking. scraping sound. If vibration (referred to as chattering) occurs in the milling machine during the cutting process. the speed should be reduced and the feed increased. Too much cutter clearance. a poorly supported workpiece, or a badly worn machine gear are common causes of chattering.

CUTTING OILS

The major advantage of using a coolant or cutting oil is that it dissipates heat, giving longer life to the cutting edges of the teeth. The oil also lubricates the cutter face and flushes away the chips, consequently reducing the possibility of marring the finish.

Depth of Cut

When setting the depth of cut, the workpiece should be brought up to just touch the revolving cutter. After a cut has been made from this setting, measurement of the workpiece is taken. At this point, the graduated dial on the traverse feed is locked and used as a guide in determining the depth of cut. When starting the cut, the workpiece should be moved so that the cutter is nearly in contact with its edge, after which the automatic feed may be engaged. When a cut is started by hand, care must be taken to avoid pushing the corner of the workpiece between the teeth of the cutter too quickly, as this may result in cutter tooth breakage. In order to avoid wasting time during the operation, the feed trips should be adjusted to stop the table travel just as the cutter clears the workpiece.

Feed rate

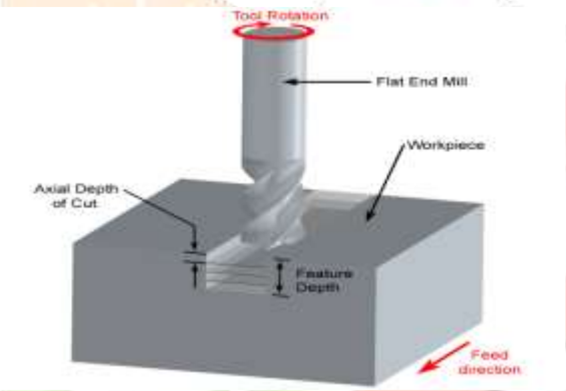
The speed of the cutting tool's movement relative to the workpiece as the tool makes a cut. The feed rate is measured in inches per minute (IPM) and is the product of the cutting feed (IPR) and the spindle speed (RPM).

Cutting speed

The speed of the workpiece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).

Cutting feeds

The distance that the cutting tool or workpiece advances during one revolution of the spindle and tool, measured in inches per revolution (IPR). In some operations the tool feeds into the workpiece and in others the workpiece feeds into the tool. For a multi-point tool, the cutting feed is also equal to the feed per tooth, measured in inches per tooth (IPT), multiplied by the number of teeth on the cutting tool.



II. Literature review:

1) Mohammed T. Hayajneh (2007);

This paper deals to develop a better understanding of the effects of spindle speed, cutting feed rate and depth of cut on the surface roughness and to build a multiple regression model. Such an understanding can provide the problem of controlling the surface finish when the process parameters are adjusted. The model, which includes the effect of spindle speed, cutting feed rate and depth of cut, and any two variable interactions, predicted the surface roughness values with an accuracy of about 12%. The result of average percentage deviation (φ) showed that if the (speed n=60) deviation is 11.645% and the testing data set (speed n=24) deviation is 12.134%. This means that the statistical model could predict the surface roughness (Ra) with about 88.355% accuracy of the data set and approximately 87.866% accuracy for respective speed input.

2) SHADAB ANWAR (2016):

This paper presents a study that investigates the effect of the end milling machining parameters on the surface roughness of the EN 31 steel. The end milling machining parameters considered are rotational speed, feed rate and depth of cut. The feed rate is found to be the most dominant parameter for surface roughness of EN 31 steel. End milling was done by using solid carbide tool. After completion of the experiment they concluded that the optimum parameters that are required to obtain a better surface finish are speed @ 300rpm, feed rate 500mm/min, depth of cut 0.15mm, and the surface roughness therefore achieved is a minimum of 1.184µm. And to minimize the surface roughness feed rate contributes maximum of 59.84% followed by spindle speed 29.58% and depth of cut 9.162%.

3) Amit Tiwari(2016):

This paper deals to observe that, using Taguchi approach, the quality of surface finish can be predicted within a reasonable degree of accuracy. Surface roughness is the critical factor which influences the quality of the machined parts. They conducted an experiment by using mild steel work pice to get the optimum parameters to get predicted surface roughness value. Finally they concluded that It is impossible to achieve surface roughness in controlled manner by „Trial and Error" method. It needs an in-depth analysis of the parameters affecting it. Surface roughness and cutting parameters (i.e. SS, FR and DC) have highly non -linear relationships among them. Amongst the cutting parameters, surface roughness is strongly affected by feed rate while the depth of cut and spindle speed has least effect on surface roughness. In end milling operation, while predicting the value of surface roughness major emphasis should be given to value of feed rate. Positive effect of cutting tools temperature was also identified on surface roughness while machining. It shows that to achieve accurate value of required surface roughness, effect of cutting tools temperature can also be considered. The fractional design approach is proven to be a best choice because it involves only a number of effective possible combinations of parameter values and gives minimum error rate hence shows accuracy of the experimental setup and statistical model and roughness values can be predicted up to close level of accuracy and precision. Validation run performed for fractional design of experiment approach shows the accuracy and effectiveness of the regression model because surface roughness values were predicted to a close degree of accuracy with least error. Cross relationship curves and Histograms drawn for actual vs. predicted surface roughness for both approaches show a close relationship among those roughness values proving effectiveness of Regression Model with least rate of error.

4) K.Kadirgama (2008):

This paper deals with optimization of the surface roughness when milling Mould Aluminium alloys (AA6061-T6) with carbide coated inserts. Optimization of milling is very useful to reduce cost and time for machining mould. The approach is based on Response Surface Method (RSM) and Radian Basis Function Network (RBFN). RBFN was successfully used by Tsoa and Hocheng in their recent research. The objectives are to find the optimized parameters, and to find out the most dominant variables (cutting speed, federate, axial depth and radial depth). The optimized value has been used to develop a blow mould. The first order model and RBFN indicates that the feedrate is the most significant factors effecting surface roughness. RBFN predict surface roughness more accurately compared to RSM. The feedrate has the most dominant effect on the surface roughness followed by the axial depth, cutting speed, and radial depth. A better surface roughness of 0.4261 μm, is obtained with the combination of low cutting speed=100m/min, axial depth=0.1mm, high federate= 0.2(mm/rev),, and radial depth=5.0mm. Surface roughness values obtained by experimentation and values predicted by first order model and RBFN. It is obvious that the predicted values by RBFN are very close to the experimental readings. The adequacy of first order model is verified using analysis of variance (ANOVA). The model was checked for its adequacy at a 95% level of confidence.

5) Amit Joshi (2012)

This paper deals with the process parameters like spindle speed, depth of cut, feed rate to investigate to reveal their Impact on surface finish using Taguchi Methodology. They had taken L9 orthogonal array to perform experiments. They found the optimal setting for selected process parameters and optimal value of surface finish was obtained at first level of factor A, third level of factor B and second level of factor C. From the ANOVA analysis they were found that feed rate is the most dominating factor for surface finish.

6) Amit Joshi(2013)

This paper deals with the End milling process, the material is removed by the end mill cutter. The effects of various parameters of end milling process like spindle speed, depth of cut, feed rate have been investigated to reveal their Impact on surface finish using Taguchi Methodology. Experimental plan is performed by a Standard Orthogonal Array. The results of analysis of variance (ANOVA) indicate that the feed Rate is most influencing factor for modelling surface finish. The graph of S-N Ratio indicates the optimal setting of the machining parameter which gives the optimum value of surface finish. The optimal set of process parameters has also been predicted to maximize the surface finish.it is observed form the s-n ratio cure that the optimum parameters are feed rate=100mm/min, depth of cut=0.3mm, spindle speed=800rpm and the Optimal value of surface finish is 3.0723 μm. From the ANOVA it can be seen that percentage contribution of feed rate is maximum and it means Feed rate is the most dominating factor for modelling surface finish.

7) Anish Nair et al. (2013)

The present paper deals with the effect of different process parameters on surface roughness on Brass material on CNC milling machine with TiN coated carbide insert tool. They analyzed the results using Taguchi method. PCA has been used to eliminate correlation among the responses and to convert the correlated responses into independent quality indexes; so as to meet the basic requirement of Taguchi method. They found for multi optimization that best combination of the cutting parameters was the set with Depth = 0.25mm, Speed = 2100 rpm, Feed = 550mm/min.

8) M.F.F. Ab. Rashid (2010)

This paper deals develop mathematical model using multiple regression and artificial neural network model for artificial intelligent method. Spindle speed, feed rate, and depth of cut have been chosen as predictors in order to predict surface roughness. The experiment is executed by using full factorial design. Analysis of variances shows that the most significant parameter is feed rate followed by spindle speed and lastly depth of cut. After the predicted surface roughness has been obtained by using both methods, average percentage error is calculated. The mathematical model developed by using multiple regression method shows the accuracy of 86.7% which is reliable to be used in surface roughness prediction. On the other hand, artificial neural network technique shows the accuracy of 93.58% which is feasible and applicable in prediction of surface roughness. The result from thisresearch is useful to be implemented in industry to reduce time and cost in surface roughness prediction.

9) Avinash A. Thakre(2013)

The present paper deals with the applied Taguchi methodology for optimize the process parameters for surface roughness in CNC milling machine. They have taken Cutting speed, Feed, Depth of cut & Coolant as input parameters. The results showed that coolant flow with the contribution of 60.69% is the most important parameter in controlling the surface roughness, followed by spindle speed. The optimal parameters for surface roughness was obtained as spindle speed of 2500 rpm, feed rate of 800 mm/min, 0.8 mm depth of cut, 30 lit/min coolant flow.

10) A.Venkata Vishnu(2015)

The present paper outlines an experimental study to optimize the effects of cutting parameters on Surface Roughness of Aluminium Alloy 6351 by employing Taguchi techniques. This paper deals with optimization of the selected milling parameters, i.e. Cutting Speed, Feed rate, Depth of cut and Coolant flow. Taguchi orthogonal array is designed with three levels of milling parameters and different experiments are done using L9 (34) orthogonal array, containing four columns which represents four factors, and nine rows which represents nine experiments to be conducted and value of each parameter was obtained. Analysis of Variance suggests that Coolant flow is the most significant factor for the surface roughness followed by Feed rate. Whereas, Depth of Cut and Cutting Speed appears to have very little effect over roughness value. An increment of Feed rate and Coolant Flow will result in better surface quality in terms of roughness. In the present experimentation the optimum speed obtained using Tauguchi technique is 2487rpm. Similarly the results obtained for feed and depth of cut are 1540mm/min and 1.5mm respectively. Hence it can be concluded that the parameters obtained are valid and within the range of Aluminium Alloy machining standards. The corresponding Optimum coolant flow is 4.8 lts/min.

11) B. Ramesh . (2011)

The present paper deals with the optimized the process parameters levels on conventional Milling of Beryllium Copper Alloy Using end mill. Taguchi analysis was performed for analyze the result data. They selected cutting speed, feed and depth of cut as process parameters and material removal rate, surface roughness and machining time as quality parameters. The experiments were conducted by using L9 orthogonal array. The results show that the optimal parameter levels for machining a straight groove with both higher material removal rate and lower surface roughness in the plate of beryllium copper alloy using CNC Vertical Machining Centre (VMC) are 6000 rpm spindle speed, 0.85 mm/rev feed and 4 mm depth of cut.

12) K. Kadirgama, M. M. Noor, K. A. Abou- El-Hossein, H. H. Habeeb, M. M. Rahman, B. Mohamad, R.A. Bakar (2010)

This work discussed the effect of the dry cutting on cutting force and tool life when machining aerospace materials(Haynes 242) with using two different coated carbide cutting tools (TiAlN and TiN/MT-TiCN/TiN). Response surface method (RSM) was used to minimize the number of experiments. ParTiAlN Swarm Optimisation (PSO) models were developed to optimize the machining parameters (cutting speed, federate and axial depth) and obtain the optimum cutting force and tool life. It observed that carbide cutting tool coated with TiAlN performed better in dry cutting compared with TiN/MT-TiCN/TiN.

13) B. Siddaet . (2011)

The present paper deals with the optimization for CNC end milling machining on Pre-hardened steel (P20) by using surface response methodology and genetic algorithm. They selected Nose radius (R), Cutting speed (V), feed (f), axial depth of cut (d) and radial depth of cut (rd) as process parameters. The experiments were conducted experiments using Taguchi's L50 orthogonal array. The RSM model was interfaced with an effective Genetic algorithm to find the optimum process parameter values. GA has reduced the surface roughness of the initial model significantly. Surface roughness was improved by about 44.22%.

14) R.Aroliadass (2011)

This paper deals with the advancement in automation and accuracy of machine tool made it possible to produce high quality industrial products. One of the main perceptions of quality in mechanical products is its physical appearance. One of the most important factors in physical appearance is the surface roughness. A number of research publications addressed this issue of surface roughness measurement and analyses. This research focuses on study and analyses of surface quality improvement in end milling operation of Al/SiCp metal matrix composite. These materials are selected as they are most widely used in automobile and aerospace industry. This research paper develops an improved mathematical model for surface roughness (Ra) prediction in end milling of Al/SiCp MMC. The impacts of spindle speed, feed rate, depth of cut and various percentage weight of silicon carbide are studied on surface roughness. The result obtained using Response Surface Methodology (RSM) gives a good prediction of surface roughness when compared with actual surface roughness. From the developed mathematical model, the optimal machining parametric combination, i.e., spindle speed (N) 4000rpm, feed rate (f) 0.020 mm/rev, depth of cut (d) 0.50 mm, and weight of silicon carbide (S) 5%. was found out to achievethe minimum surface roughness as 2.5946 μm.

15) D.Bhanuprakashetet . (2013)

The present paper deals with the surface response methodology with Genetic algorithm for optimizing the process parameters for CNC milling. The raw materials used in this investigation were Aluminum alloy 6082 and Cemented carbide end mill of 12mm diameter and 30° helix angle was used. They concluded that The Regression analysis was conducted to develop mathematical model. The Regression analysis had shown closeness of 94.4% with experimental data. The optimal surface roughness values estimated by RSM technique was 1.192 μm with the machining parameters of spindle speed = 3000 rpm, feed rate = 1000 mm/min, and depth of cut = 0.2 mm and for GA was 1.195 μm with spindle speed = 2997.64729 rpm, feed rate = 1005.94134 mm/min and depth of cut = 0.20862 mm. They also conclude that RSM found successful technique to perform analysis of surface roughness with respect to various combinations of machining parameters when compared to GA.

16) K. Jayakumar(2012)

This paper deals with influence of process parameters on CNC end milling characteristics of Aluminum alloy (A356) reinforced with 3 and 6 volume percentage of SiC particle reinforced metal matrix composite fabricated using stir casting method by utilizing Response Surface Methodology. A Box-Behnken based design of experiment technique was used to conduct the experiment and study the effects of selected process parameters, such as cutting speed, feed, depth of cut and volume % of SiCp on Surface roughness and Cutting force. The machining study was carried out using uncoated cemented carbide inserts without cutting fluid in Vertical Machining Center. Minimum value was obtained at higher cutting speed with lower feed. Similarly lower value cutting force was obtained at low depth of cut and small to medium value of feed of milling cutter. Cutting force value increased with increase in volume % of SiC particle in the composite and depth of cut. Lowest value of depth of cut with 0 and 3 volume % SiC particle reinforced composite consumes less cutting force compared with other composites. From the experimental runs, optimum value of responses (Ra = 1.34μm and RF = 48.15N) were obtained From the experimental results depth of cut and cutting speed were identified as the most significant factors for both responses.

17) Dr. K.G.Durga Prasad (2013)

The present paper deals with the optimized material removal rate and surface roughness simultaneously; Data Envelopment Analysis was employed along with Taguchi method. The materials used in this investigation were Aluminum and carbide tool was used. They performed experiments using Taguchi L9 orthogonal array. They concluded that the optimum condition for multi response parameters was meeting at cutting speed (A3), feed rate (B1), and depth of cut (C1).

18) Dhole N.S.(2012)

This paper discusses about Taguchi method which involves reducing the variation in a process through robust design of experiments. the method is to produce high quality product at low cost to the manufacturer. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and their appropriate levels. The experiments are conducted using L-18 orthogonal array on EN 33 material as suggested by Taguchi. Signal-to-Noise (S/N) ratio and Pareto Analysis of Variance (ANOVA) will be employed to analyse the effect of milling parameters on cutting force. It was observed that cutting speed & feed rate have the major influence on the cutting force the value of optimal cutting force is given as, LFF = 142.95 N. This value of cutting force is based on calculations or prediction by using results of S/N ratio and ANOVA. The 95% confidence interval of the predicted optimal cutting force is: [μFF − CI] < μFF <[μFF + CI] i.e. 144.96< μFF (N) < 140.93 and as the cutting speed increases cutting force decreases, but as the feed rate and depth of cut increases cutting force also increases particularly for this specific test range on specified materials. Use of Tin coated carbide tool produces less cutting force than H.S.S. & uncoated carbide tools. Also, it has been observed that cutting force is significantly reduced after using the selected optimum levels of parameters for all three work materials.

19) John D. Kechagiaset . (2011)

The present paper deals with the process parameters like core diameter, flute angle, rake angle, peripheral 2nd relief angle, cutting speed, feed and depth of cut to investigate to expose their Impact on surface finish using Taguchi Methodology. They had taken L9 orthogonal array to perform experiments. Eighteen pockets were manufactured having different combination of parameters values according to Taguchi L18 orthogonal array. In order to establish a relationship between the performance measures and the process parameters, a set of additive models was produced. The experimental results shown that the cutting speed, the peripheral relief angle 2nd, and the core diameters were the most important parameters that significant effect the surface texture indicators and other rest process parameters negligible effect on the surface texture parameters. Finally, a verification experiment was performed to verify the result.

20) Jignesh G. Parmar(2012)

This paper deals with the prediction of surface roughness by using artificial neural networks. The neural network model can be effectively find the best cutting parameters value for a specific cutting condition in milling operation and achieve minimum surface roughness. In the present work an experimental investigation of the end milling of M.S material up to 30 HRC with carbide tool by varying feed, speed and depth of cut and the surface roughness was measured using Mitutoyo Surface Roughness Tester. Neural Network Fitting Tool Graphical User Interface is used to establish the relationship between the surface roughness and the cutting input parameters(spindle speed, feed and depth of cut). It is identified minimum surface roughness value 0.18μm was obtained at the value of 0.03 mm/tooth, 140 m/min and 0.1 for feed rate, cutting speed and depth of cut respectively and maximum surface roughness value 0.35μm was obtained at the value of 0.06 mm/rev, 80 m/min and 0.2 mm for feed rate, cutting speed and depth of cut respectively. Surface roughness increase as feed rate increase. These model can be used to prediction of surface roughness in end milling process. The result from this research is useful to be implemented in industry to reduce time and cost in surface roughness prediction.

21) Milon D. Selvamet (2012)

The present paper deals with the optimized process parameters levels on Vertical CNC Milling for face milling operation using mild steel material. They have planned experiments using Taguchi L9 orthogonal array. The processing of the job was done by three zinc coated carbide tools inserted into a face miller of 25 mm diameter. The machining parameters considered were Number of passes, depth of cut, spindle speed and feed rate. The surface roughness evaluated through Taguchi technique was 0.975 μm with 4.308 % error from the predicted value and for genetic algorithm it was 0.88 μm with 4.625 % error from the predicted value.

22) Kishan Gupta (2016)

This paper deals with effects of various parameters of milling process like spindle speed, depth of cut, feed rate have been investigated to reveal their Impact on surface finish using Taguchi Methodology. Experimental plan is performed by a Standard Orthogonal Array. The results of analysis of variance (ANOVA) indicate that the feed Rate is most influencing factor for modeling surface finish. The graph of S-N Ratio indicates the optimal setting of the machining parameter which gives the optimum value of surface finish. The optimal set of process parameters has also been predicted to maximize the surface finish as Taguchi's robust design method is suitable to optimize the surface roughness in milling Aluminium alloy 6351 was resulted at level 3 for spindle speed and it was 1200 rpm, at level 1 for feed rate and it was 60 mm/min, at level 1 for depth of cut and it was 0.2 mm. The surface roughness evaluated through Taguchi technique is 0.294 μm with 4.987 % error from the predicted value. The optimal condition for surface roughness in milling

23) N. Nareshet (2013)

The present paper deals with the optimization for CNC end milling machining on Glass Fiber Reinforced Plastics by using Taguchi methodology and analysis of variance was also performed to determine which parameters are the significant effect on the quality parameters. They selected Fiber orientation angle (Θ), Helix angle (Φ), Spindle speed (N) and Feed rate (f) as process parameters and surface roughness, machining force, delamination factor were chosen as responding parameters. The experiments were conducted experiments using Taguchi's L27 orthogonal array. They found that fiber orientation angle was the most significant parameter and spindle speed was the least significant parameter for milling of GFRP composite with the objective of minimizing surface roughness, machining force and delamination factor. The optimal level of parameters for minimizing surface roughness, machining force and delamination factor were Θ1Φ1N3f1, Θ1 Φ3 N3 f1 and Θ1 Φ1 N3 f1 respectively. Fiber orientation angle was the cutting parameter that presents the highest statistical and physical impact on surface roughness (60.48 %), on machining force (56.34 %) and on delamination factor (51.05 %).

24) Pooja A. Sutar(2017)

This paper deals with on the influence of cutting speed, feed, depth of cut (doc) and type of coolant (dry and wet) on the surface roughness on AISI 316L stainless steel material during end milling. The experimental plan was based on Taguchi's technique L18 orthogonal array with four factors and three levels for each variables and studying the contribution of each factor on surface roughness. The ANOVA technique is employed to study the significance of each parameter. The parameters observed are the optimum values for the surface roughness, environment is dry, cutting speed is 1600 rpm, feed rate is 0.12 mm/min and depth of cut is 0.1mm.

25) Nitin Agrawal(2012)

The present paper deals with the effect of different process parameters (cutting speed, feed and depth of cut) on surface roughness on Aluminum alloy material on CNC milling machine with HSS milling cutter. They prepared 36 specimens of alloy have been machined on CNC milling machine then SJ 201 surface roughness tester has been used to determine the surface roughness value. They concluded that depth of cut is most significant parameter, followed by feed rate and spindle speed.

26) B.Sidda Reddy(2011)

This paper deals with minimization of surface roughness has been investigated by integrating design of experiment method, Response surface methodology (RSM) and genetic algorithm. To achieve the minimum surface roughness optimal conditions are determined. The experiments were conducted using Taguchi's L50 orthogonal array in the design of experiments (DOE) by considering the machining parameters such as Nose radius (R), Cutting speed (V), feed (f), axial depth of cut (d) and radial depth of cut(rd). A predictive response surface model for surface roughness is developed using RSM. The response surface (RS) model is interfaced with the genetic algorithm (GA) to find the optimum machining parameter values. The RSM model is interfaced with an effective GA to find the optimum process parameter values. GA has reduced the surface roughness of the initial model significantly. Surface roughness is improved by about 44.22%.

27) Rajesh Kumar (2014)

The present paper deals with the GRA based Taguchi method to investigate the optimized design of the cutting process in end milling for Al 6061 alloy in order to provide better surface finish as well as high material removal rate. The selected cutting parameters were coolant employment (C), spindle speed (S), feed (F), and depth of cut (D). The experiments were conducted on L18 (21 × 33) orthogonal array. GRA has been used to find the best end milling process parameters with multiple performance characteristics. In order to estimate the weighting values corresponding to various quality characteristics, principle component analysis (PCA) has been used so that their relative importance can be objectively described. They also found the optimum conditions for obtaining higher grey relational grade such as C1S2F3D2, (Coolant emp. on, speed 765 rpm, feed 50mm/min, Depth of cut 0.8mm) were obtained.

28) G Ramya (2017)

This paper deals with realistic issues associated with the green and particular removal of metal from work piece. It has been diagnosed that the dependable quantitative predictions of the numerous technological overall performance measures, preferably in the form of equations, are critical to broaden optimization techniques for deciding on slicing situations in procedure making plans. In this thesis experiments conducted to improve the floor end pleasant of aluminium alloy 6061 work piece by way of the use of carbide device, insert cutter, HSS and by using Taguchi's approach including L9 orthogonal array. After completing the project it can be observed that optimal value of surface finish is obtained at third level of Spindle Speed and it was 1200rpm, third level of Feed Rate and it was 250mm/min and third level of Depth of Cut and it was1.5mm. And the optimal value of material removal is obtained at third level of Spindle Speed and it was 1200rpm, second level of Feed Rate and it was 200mm/min and second level of Depth of Cut and it was1.0mm.

29) S. Y. Chavanet (2013)

The present paper deals with the effect of various process parameters (Cutting speed, Feed, Depth of cut & Coolant) on material removal rate and surface roughness on CNC milling. The L18 mixed orthogonal array used to perform experiments. They performed multi objective optimization by using grey-Taguchi method. The optimum milling parameters for multi performance in terms of lower Ra and higher MRR given by grey-Taguchi method was at flooded coolant (C), Cutting speed at 5600 rpm (N3), depth of cut 2.7 mm (d3) and feed rate 0.045 mm/rev (f3).

30) Harshraj D. Wathore(2015)

The present paper deals with the parameter optimization of end milling operation for H13 die steel with multi response criteria based on the Taguchi L9 orthogonal array with the grey relational analysis. Surface roughness and material removal rate are optimized with consideration of performance characteristics namely cutting speed, feed rate and depth of cut. A grey relational grade obtained from the grey relational analysis is be used to solve the end milling process with the multiple performance characteristics. Additionally, the analysis of variance (ANOVA) is to be applied to identify the most significant factor. Finally, confirmation tests are performed to make a comparison between the experimental results and developed model. The optimal cutting parameters for the machining process lies at 2500 rpm for cutting speed, 0.3 mm/revolution for feed rate and 1.2 mm for depth of cut.

31) Sanjeev Kumar Pal (2014)

The present paper deals with the surface roughness of the two materials (Al 6061 and Al 6463) and to analyze the influence of end milling cutting parameters (number of revolution, feed rate and depth of cut) on the surface roughness for Aluminum alloys. Principal component analysis (PCA) and grey relational analysis were performed to predict the surface roughness in end milling operation to analyze the pre measured test data. They found from ANOVA that the spindle speed is the most significant parameter among the four end milling process parameters investigated in the present work.

32) K. Srinivasa Rao(2015)

The present paper states that poor surface roughness will lead to the rupture of oil films on the packs of micro irregularities which lead to a state approaching dry friction and results in decisive wear of rubbing surfaces therefore finishing process are employed in machining the surface of many critical components to obtain a very high surface finish. Process variables surface roughness in milling depends on spindle speed, feed, number of flutes, and depth of cut and plan approach angle. As spindle speed increase the surface roughness value decreases. As the depth of cut increases, the surface roughness first increase and then decreases. Surface roughness decreases with increase in number of flutes. The proposed methodology has been validated by means of experimental data on milling and is found to be quite effective. In this technique, the equations are developed by using training data; further these are tested by using test data to predict the accuracy of developed model. Regression model gives better prediction , with an accuracy 91.33% in first order, 94.91% in second order and 82.4% in third order.

33) SanjitMoshatet al. (2010)

The present paper deals with the effects of milling parameters on surface roughness and material removal rate were investigated in end milling of Aluminum alloy with CVD coated carbide tools. The obtained experimental results were analyzed by PCA-based Taguchi method. They had taken Cutting speed, Feed and Depth of cut as control factors. The principal component, imposing highest accountability proportion, has been treated as single objective function for optimization (multi-response performance index). Finally Taguchi method has been adapted to solve this optimization problem.

34) Sarang S Kulkarni (2014)

The present paper deals with effect of process parameters on surface roughness on SAE 1541 material by carbide tools in face milling. In this study, parameters like cutting speed, feed, depth of cut and coolant flow rate considered. Series of experiments were studied by Design of Experiments (DOE). L9 Orthogonal array is selected and experiments were taken by the use of Taguchi method. Experimental Analysis is done by ANOVA and results were drawn out on the basis of analysis. It is investigated that cutting speed, feed and depth of cut are the influencing factors. the lower the better for surface roughness the lowest feed rate (B=150 mm/min), the highest cutting speed (A= 1600 rpm),lowest depth of cut (C=0.2 mm) and the lowest coolant flow (D=20 lit/min) lead to the lower surface roughness value In this study, feed and cutting speed are the most influencing factor compared to depth of cut. Coolant flow rate is the least significant factor for surface roughness.

35) Surasit Rawangwonget (2012)

The present paper deals with the effect of process parameters on the surface roughness in aluminium 7075-T6 face milling. The results of the research have been applied in the manufacture of automotive components and mold industry. The study was conducted by using CNC milling machine with Φ 63 mm fine type carbide tool with twin cutting edge. The controlled factors were the speed, feed rate and the depth of cut. They used factorial designs and the result showed that the factors affecting the surface roughness were the feed ratio and the speed while the depth did not significant effect the surface roughness. The optimal setting for the selected process parameters was speed at 2930 rpm and the feed rates at 808 mm/min. They also had given mathematical model for surface roughness in term of selected process parameters.

s.no	Year	Name of the author	Material used	Input Parameters	Methodology used	conclusion
1	2007	a) Mohammed T. Hayajneh b) Montasser S. Tahat c) Joachim Bluhm	Aluminium	spindle speed, cutting feed rate and depth of cut	Anova	The most important interactions, that Effect surface roughness of machined surfaces, were between the cutting feed and depth of cut, and between cutting feed and spindle speed.
2	2016	a) Shadab Anwar b) Saleem Uz Zaman Khan	EN31 Steel	Rotational speed, feed rate and depth of cut	Taguchi	It shows that high spindle speed with small feed rate produce better surface finish and the effect of depth of cut is found to be negligible.
3	2016	a) Amit Tiwari b) Manish Pokharna	Mild steel	spindle speed, depth of cut and feed rate	L16 orthogonal array	Amongst the cutting parameters, surface roughness is strongly affected by feed rate while the depth of cut and spindle speed has least effect on surface roughness
4	2008	a) K.Kadirgama b) M.M.Noor c) M.M. Rahman	Aluminium alloys (AA6061-T6)	Cutting speed, federate, axial depth and	RBFN, ANOVA	Both RSM and RBFN model reveal that federate is the most

				radial depth		significant design variable in determining surface roughness response as compared to others. With the model equations obtained, a designer can subsequently select the best combination of design variables for achieving optimum surface roughness
5	2012	a) Amit Joshi b) Pradeep	Aluminium cast heat-treatable alloy	Cutting speed, Feed and Depth of cut	Taguchi, ANOVA	It was found that feed rate is the most dominating factor for surface finish
6	2013	a) Amit Joshi b) Pradeep Kothiyal	Aluminium cast heat-treatable alloy	Spindle speed, feed rate, depth of cut	Taguchi	The results of analysis of variance (ANOVA) indicate that the feed Rate is most influencing factor for modelling surface finish.
7	2013	a) Anish Nair b) P Govindan	Brass	Cutting speed, Feed and Depth of cut	Hybrid Taguchi Method, Principal components analysis	They found for multi optimization that best combination of the cutting parameters was the set with Depth = 0.25mm, Speed = 2100 rpm, Feed = 550mm/min
8	2010	a) M.F.F. Ab. Rashid b) M.R. Abdul Lani	Mild Steel	Spindle speed, feed rate, and depth of cut	multiple regression, artificial neural network	The result of the prediction is favourable with 6.42% average percentage of error, meaning that neural network is capable to predict the surface roughness up to 93.58% accurate. As a conclusion, artificial neural network provided better accuracy to predict surface roughness in CNC milling process.
9	2013	a) Avinash A. Thakre	MS 1040	Cutting speed, Feed, Depth of cut & Coolant	Taguchi	The optimal parameters for surface roughness was obtained as spindle speed of 2500 rpm, feed rate of 800 mm/min, 0.8 mm depth of cut, 30 lit/min coolant flow
10	2015	a) A.Venkata Vishnu b) K. B. G. Tilak c) G.Guruvaiah Naidu	Aluminium Alloy 6351	Speed, feed, depth of cut, coolant flow	Tauguchi	Analysis of Variance suggests that Coolant flow is the

		d) Dr.G.Janardhana Raju				most significant factor for the surface roughness followed by Feed rate. Whereas, Depth of Cut and Cutting Speed appears to have very little effect over roughness value. An increment of Feed rate and Coolant Flow will result in better surface quality in terms of roughness
11	2011	a) B. Ramesh, b) R. Venkatesh.	Beryllium copper alloy	Cutting speed, Feed and Depth of cut	Taguchi, ANOVA, Regression Analysis	The results show that the optimal parameter levels for machining a straight groove with both higher material removal rate and lower surface roughness in the plate of beryllium copper alloy using CNC Vertical Machining Centre (VMC) are 6000 rpm spindle speed, 0.85 mm/rev feed and 4 mm depth of cut
12	2010	a) K. Kadirgama, b) M. M. Noor c) K. A. Abou-El-Hossein d) H. H. Habeeb e) M. M. Rahman f) B. Mohamad g) R.A. Bakar	Haynes 242	Cutting speed, federate and axial depth	Taguchi method, Genetic Algorithm, Neural Network, ANOVA	It observed that carbide cutting tool coated with TiAlN performed better in dry cutting compared with TiN/MT-TiCN/TiN.
13	2011	a) B. Sidda Reddy, b) J. Suresh Kumar c) K. Vijaya Kumar Reddy	Pre-hardened steel (P20)	Nose radius, Cutting speed, feed , axial depth of cut and radial depth of cut	RSM and Genetic algorithm	GA has reduced the surface roughness of the initial model significantly. Surface roughness was improved by about 44.22%.
14	2011	a) R. Arokiadass b) K. Palaniradja c) N. Alagumoorthi	Al/SiCp	spindle speed, feed rate, depth of cut	Response surface method (RSM)	In the order of their influence, Feed rate, Spindle speed, % wt. of SiCp, Feed rate-Spindle speed interaction and Feed rate-% wt. of SiCp interaction has most influence on surface roughness
15	2013	a) D.Bhanuprakash b) G.RamaBalaji	Aluminium Alloy 6082	Cutting speed, Feed and Depth of cut	RSM and Genetic algorithm	Hence they concluded that RSM found successful technique to perform analysis of surface roughness with respect to various combinations of machining parameters

						when compared to GA.
16	2012	a) K. Jayakumar b) Jose Mathew c) M.A. Joseph	Aluminium alloy (A356)	cutting speed, feed, depth of cut and volume % of SiCp	Response surface method (RSM)	From the experimental results depth of cut and cutting speed were identified as the most significant factors for both responses.
17	2010	a) Bharat Chandra Routara, b) SaumyaDarsanMohant y c) Saurav datta d) Asish Bandyopadhyay e) SibaSankar	UNS C34000 medium leaded brass	Cutting speed, Feed and Depth of cut	Utility Concept, Taguchi	They concluded that the optimum condition for multi response parameters was meeting at cutting speed (A3), feed rate (B1), and depth of cut (C1).
18	2012	a) Dhole N.S b) Naik G.R c) Prabhawalkar M.S.	EN 33	Depth of cut, feed rate and cutting speed	Taguchi	It was observed that cutting speed & feed rate have the major influence on the cutting force and as the cutting speed increases cutting force decreases, but as the feed rate and depth of cut increases cutting force also increases particularly for this specific test range on specified materials.
19	2013	a) Dr. K.G.Durga Prasad b) M.V.Prasad.	Aluminium	Cutting speed, Feed and Depth of cut	DEA based Taguchi method	The most important parameters that significant affect the surface texture indicators and other rest process parameters negligible effect on the surface texture parameters.
20	2012	a) Jignesh G. Parmar b) Alpesh Makwana	Mild Steel	spindle speed, feed and depth of cut	Neural Network	Surface roughness increase as feed rate increase
21	2011	a) John D. Kechagias b) Christos K. Ziogas	Al Alloy 5083	Core Diameter, Flute Angle, Rake Angle, Peripheral 2nd Relief Angle, Cutting Speed, Feed and Depth of Cut	Analysis of mean	The surface roughness evaluated through Taguchi technique was 0.975 μm with 4.308 % error from the predicted value and for genetic algorithm it was 0.88 μm with 4.625 % error from the predicted value.
22	2016	a) Kishan Gupta b) JaideepGangwar c) Hasrat Nawaz Khan d) Nitya Prakash Sharma e) Adhirath Mandal f) Sudhir Kumar	Aluminium alloy (Al 6351)	Spindle speed, depth of cut, feed rate	Taguchi	It can be seen that all the three factors are significantly affect the response (Surface Roughness). Spindle Speed has highest effect on the response, Feed rate has second highest effect on response and depth of cut has least effect on

						surface roughness.
23	2012	a) Milon D. Selvam b) Dr.A.K.Shaik	Mild Steel	Number of passes, Cutting speed, Feed and Depth of cut	Taguchi technique and Genetic Algorithm	Fiber orientation angle was the cutting parameter that presents the highest statistical and physical impact on surface roughness (60.48 %), on machining force (56.34 %) and on delamination factor (51.05 %).
24	2017	a) Pooja A. Sutar b) A.J. Gujar	AISI 316L stainless steel	Cutting speed, feed, depth of cut	Taguchi	The optimum values for the surface roughness, environment is dry, cutting speed is 1600 rpm, feed rate is 0.12 mm/min and depth of cut is 0.1mm.
25	2013	a) N. Naresh, K. Rajasekhar b) P. VijayaBhaskara Reddy	Glass Fiber Reinforced Plastics (GFRP) Composite	Fibre Orientation Angle, Helix Angle, Spindle Speed and Feed Rate	Taguchi, ANOVA, Regression Analysis	They concluded that depth of cut is most significant parameter, followed by feed rate and spindle speed.
26	2011	a) B. Sidda Reddy b) J. Suresh Kumar c) K. Vijaya Kumar Reddy	Pre-hardened steel (P20)	Nose radius(R), Cutting speed (V), feed (f), axial depth of cut (d) and radial depth of cut(rd)	Response surface methodolog y	It is observed that the RSM model is interfaced with an effective GA to find the optimum process parameter values. GA has reduced the surface roughness of the initial model significantly. Surface roughness is improved by about 44.22%.
27	2012	a) Nitin Agrawal	Aluminium	Cutting speed, Feed and Depth of cut	Multiple regression and t-test	They concluded that the optimum conditions for obtaining higher grey relational grade such as C1S2F3D2, (Coolant emp. on, speed 765 rpm, feed 50mm/min, Depth of cut 0.8mm) were obtained.
28	2017	a) G.Ramya b) B.Satish Kumar c) N. Gopikrishna	Aluminium alloy 6061	Spindle speed, feed and depth of cut	Taguchi	The optimal value of surface finish is obtained at third level of Spindle Speed and it was 1200rpm, third level of Feed Rate and it was 250mm/min and third level of Depth of Cut and it was1.5mm.
29	2014	a) Rajesh Kumar b) M. K. Pradhan c) Rishi Kumar	Aluminum 6061 Alloy	Cutting speed, Feed, Depth of cut & Coolant	GRA based Taguchi & PCA	The optimum milling parameters for multi performance in

						terms of lower Ra and higher MRR given by grey-Taguchi method was at flooded coolant (C), Cutting speed at 5600 rpm (N3), depth of cut 2.7 mm (d3) and feed rate 0.045 mm/rev (f3).
30	2015	a) Harshraj D. Wathore b) P. S. Adwani	H13 die steel	speed, feed and depth of cut	Taguchi L9 orthogonal array	Analysis of variance shows that depth of cut is the most significant machining parameter followed by cutting speed, affecting selected response characteristics i.e. surface roughness and material removal rate, with 60.11% and 30.40% influence respectively.
31	2013	a) S. Y. Chavan b) V. S. Jadhav	Al-Si7Mg Aluminium Alloy	Cutting speed, Feed, Depth of cut & Coolant	GRA	They found from ANOVA that the spindle speed is the most significant parameter among the four end milling process parameters investigated in the present work
32	2015	a) K. Srinivasa Rao b) N. Sravani c) N.V.Aravind Prasad d) M.Sindhuja e) D. Lohith	Aluminium alloy 6081	spindle speed, feed rate, depth of cut and number of flutes	Taguchi	As the depth of cut increases, the surface roughness first increase and then decreases. Surface roughness decreases with increase in number of flutes.
33	2014	a) Sanjeev Kumar Pal b) Rahul Davis	Al 6061 and Al 6463	Feed and Depth of cut	PCA, Grey relation analysis,	The principal component, imposing highest accountability proportion, has been treated as single objective function for optimization (multi-response performance index).
34	2014	a) Sarang S Kulkarni b) M.G.Rathi	SAE 1541	Cutting speed, feed, depth of cut and coolant flow rate	Taguchi	In this study, feed and cutting speed are the most influencing factor compared to depth of cut. Coolant flow rate is the least significant factor for surface roughness.
35	2010	a) SanjitMoshat, b) SauravDatta c) Asish Bandyopadhyay d) Pradip Kumar Pal	Aluminium	Cutting speed, Feed and Depth of cut	PCA based Taguchi	The optimal setting for the selected process parameters was speed at 2930 rpm and the feed rates at 808 mm/min. They also

						had given mathematical model for surface roughness in term of selected process parameters

CONCLUSION:

- Majority of the researchers have done their work by considering the machining parameters like speed, feed, and depth of cut.
- Taguchi method is mostly suggested for optimizing the machining parameters.
- For any manufacturing industries the quality is the most important quality parameters. So, most of the researchers have taken surface roughness as the quality parameters.

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