A Review on Optimization of Cutting Parameters on Turning

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Abstract—*The purpose of this paper is to make an attempt to review the literature on optimization of cutting parameters for minimum surface roughness in turning. The cutting parameters like spindle speed (rpm), feed (mm/rev) and depth of cut (mm) are taken into consideration.*

Keywords—*Cutting parameters, Surface Roughness, Turning*

I. INTRODUCTION

Turning is a machining process used to obtain the desired dimension of round metal. The main objective in present industrial era is to produce low cost quality product with required dimensions in an optimum time. Therefore the optimum cutting parameters are to be recognized first.

In turning, the metal is in rotational motion and a cutting tool is used to shear away the unwanted metals. This process requires lathe or turning machine, cutting tool, work piece and fixture. The work piece is fixed in the fixture and is rotated in high speed. The cutting tool is fed in parallel to the axis of rotation as shown in Fig. 1. During this process the cutting parameters highly depends upon the work piece, cutting tool material, etc. These are determined by experience or machine hand book.
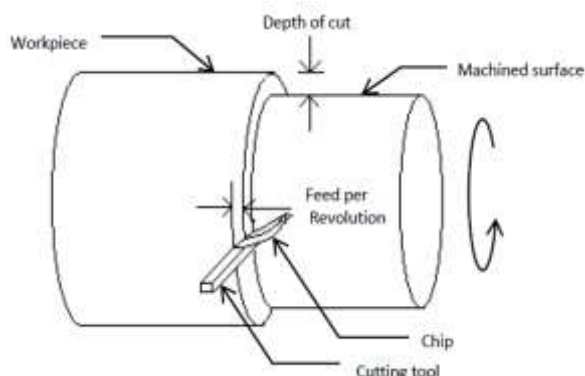

Fig. 1 Basic turning process

Surface roughness is the measure of surface texture i.e. the deviation of the surface from the reference plane. Greater the deviation greater is the roughness. To obtain better surface roughness better setting of cutting parameter is most essential. American National Standards Institute (ANSI) or International Standardization Organization (ISO) characterises the

roughness. Various terminologies like R_a, R_q, R_z, etc. are used to describe various roughness values.
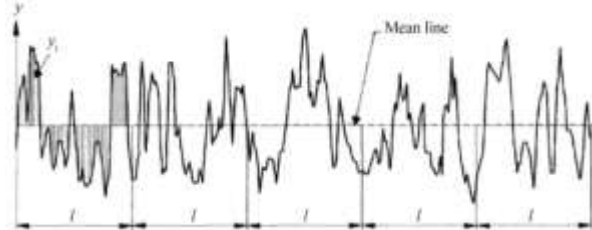

Fig. 2 Surface Roughness Profile [5]

In fig. 2, the curve line represents surface roughness. Y_1 is an instantaneous roughness value and l represents the profile length. The mean line is the mean roughness value of all the instantaneous points.

II. LITERATURE REVIEW

Thamizhmanii, S., et al. (2007) [1] analysed the optimum cutting conditions to get the lowest surface roughness in turning SCM 440 alloy steel by using coated ceramic tool. Taguchi's mixed level L_{18} orthogonal array was used. The results were analysed in Design-Expert software. It was found that depth of cut was a significant factor then feed in consideration of lowest surface finish.

Natarajan, C., et al. (2010) [2] designed an artificial neural network (ANN) to predict the surface roughness through back propagation network using Matlab 7 software. The cutting parameters evaluated were spindle speed, feed rate and depth of cut. The tests were performed in dry condition on C26000 metal in a CNC turning centre with a CNMG 120408 insert. A total of 36 specimens were experimented. The actual roughness values were matched with the predicted roughness values by using Matlab 7. The percentage of deviation between the roughness values was found to be 24.4%. The interactions between the parameters were also obtained through the model. It was found that the feed rate had huge effect on surface roughness then the other parameters.

Babu, V. Suresh, et al. (2011) [3] developed a second order model to predict the surface roughness in machining EN24 steel alloy using Response Surface Method. Two level three cutting parameters i.e. cutting speed, feed rate and depth of cut were considered for the experiment. A total of 17 experiments were carried out on Turnmaster-35 Kirloskar lathe machine. The experiments were designed and analysed on a commercial statistical

analysis software Design-Expert. From the normal probability plots it was observed that errors were distributed normally. It was found that feed rate has the highest significance than cutting speed and depth of cut. 3D plots were drawn to find out the optimum setting for minimum surface roughness.

Sahoo, P. (2011) [4] studied the roughness characteristic of surface profile created by turning AISI 1040 steel in CNC machine. The optimization of surface roughness was done using response surface method and genetic algorithm. Depth of cut, feed rate and spindle speed were considered as the machining parameters. A three level rotatable composite design was selecting for developing the mathematical model for predicting the surface roughness. R_a, R_q and R_{sm} were considered as response variables. For all these response variables second order response surface equations were fitted with Design Expert software. ANOVA was implemented to assure the performance and effect of these parameters on surface roughness. The regression model came to be significant though there were some insignificant terms. So the insignificant termed were removed by back elimination method of Design Expert software. Surface and contour plots were drawn for R_a considering the machining parameters. From this it was found that roughness values decreases with increases in depth of cut and spindle speed whereas roughness value increases with feed rate. The parameters considered for genetic algorithm were population size (40), mutation rate (1.0), cross over rate (0.8), and number of generations (1000). The confirmatory test showed good relation with the predicted test.

Barik, C. R., and Mandal, N. K., (2012) [5] studied the characteristics of surface roughness in turning of EN31 alloy by optimization of machining parameters using Genetic Algorithm. The machining parameters selected were three level parameters such as speed, feed and depth of cut. A total of 20 experiments were carried out which included codes values and observed responses. These experiments were done in CNC machine using carbide tool inserts. The second order model (quadratic model) was used to predict the accuracy of the machining responses. The F ratio was calculated considering 95% confidence level. 3D response plots were formed based on response surface method quadratic models. It was found that the surface roughness decreases with decrease in feed rate at constant speed. And surface roughness also decreases with decrease in depth of cut keeping speed constant. The predicted values were found to be in acceptable zone w.r.t. the experimental results.

Davis, R. and Alazhari, Mohamed (2012) [6] worked to optimized the cutting parameters (spindle speed, feed and depth of cut) in dry turning of mild steel with 0.21% C and 0.64% Mn with a HSS cutting tool. Taguchi's L_{27} orthogonal array was conducted to find out the lowest surface roughness. ANOVA and Signal to Noise ratio were utilised to find out the performance characteristics. Among the three cutting parameters only feed was found to be significant.

Kumar, K. A., et al. (2012) [7] analysed the optimum cutting conditions to get the lowest surface roughness in face turning by regression analysis. The cutting parameters investigated are spindle speed, feed and depth of cut on EN8 alloy. The performance and the effect of parameters on surface roughness were determined by multiple regression analysis and ANOVA using MINITAB. The experiments were conducted taking three levels of parameters in lathe machine using coated ceramic cutting tool. To analyse the performance and effect an empirical equation was formed. From this paper it was observed that cutting speed and feed were the significant factors affecting surface roughness.

Rodrigues, L.L.R., et al. (2012) [8] studied the effect of feed, speed and depth of cut on the surface roughness as well as cutting force in turning mild steel with HSS cutting tool. Experiments were carried out using high precision lathe machine. Full factorial design with two repetitions was used to find the optimal solution. Feed and the interaction between feed and speed were the main influencing factors in surface roughness whereas feed, depth of cut and the interaction between feed and depth of cut influenced the variance of cutting force significantly. They suggested that feed and depth of cut has significant effect on surface roughness and cutting force.

Sharma, N., et al. (2012) [9] applied L_{18} orthogonal array to optimize the surface roughness in turning. ANOVA and signal to noise ratio were applied to study the performance characteristics in turning AISI 410 steel bars using TiN coated P20 and P30 cutting tool. The cutting parameters considered were insert radius, depth of cut, feed and cutting speed. It was found that the insert radius and feed rate has significant effect on surface roughness with 1.91% and 92.74% contribution respectively.

Somashekara, H.M., and Swamy, N. L., et al. (2012) [10] obtained an optimal setting for turning Al6351-T6 alloy for optimal surface roughness. A model was generated for optimal surface roughness using regression technique. The turning parameters considered were speed, feed and depth of cut with three levels each. L_9 orthogonal array was implemented for the experiment. The roughness measure was done with three repetitions. The results found between regression model and experimental values were having error less than 2%. From ANOVA and S/N ratio, cutting speed was found to be highest significant parameter followed by feed and depth of cut.

Yadav, U. K., et al. (2012) [11] enquired the effect of machining parameters (speed, feed and depth of cut) on optimization of surface roughness in turning AISI 1045 steel alloy. The experiments were conducted on stallion 100HS CNC lathe using Taguchi's L_{27} orthogonal array. From ANOVA it was found that

feed has the maximum contribution of 95.23% on the surface roughness than cutting speed. Using the predictive equation the predicted value of optimum surface roughness at the optimal conditions was found to be 0.89μm whereas the calculated response was 0.93μm. Therefore the error between them comes out to be only 4.4%. So a good agreement was obtained between them. The results were evaluated by MINITAB 16 software.

Bala Raju, J., et al. (2013) [12] investigated the effect of cutting parameters such as cutting speed, feed and depth of cut in turning mild steel and aluminium using HSS cutting tool. It was carried out to achieve better surface finish and to decrease power requirement by flattening the cutting force in machining. The experiments were carried based on 2^k factorial techniques. ANOVA was used to find out the effect of cutting parameters in surface. And multiple regression analysis was used to develop cutting forces required for machining. It was found that feed has significant effect on both surface roughness and cutting force.

Krishan Prasad, D.V.V. (2013) [13] conducted full factorial design consisting of 243 experiments considering three machining parameters and two tool geometrical parameters to determine the impact of these parameters on surface roughness. The machining parameters were speed, feed and depth of cut whereas the tool geometrical parameters were back rake angle and side rack angle with three levels each. The metal used for turning was mild steel with HSS cutting tool. It was found that feed is the only significant factor during this experiment.

Koura, M. M., et al. (2014) [14] established a surface roughness model by using artificial neural network. The effect of the parameters i.e., cutting speed, feed rate and depth of cut on surface roughness in turning of mild steel using carbide inserts was inspected. The experiments were done in dry conditions. Total of 27 experiments were executed according to full factorial design. Various neural network structures were performed and among them the 3 layer network showed the best result. Among the 27 experiments 19 experiments were used for training the network and rest 8 experiments were performed for validation and performance of the network. In average only 5.4% error was found between the predicted values and measured values. It was concluded that increase in feed rate increases the roughness whereas increases in cutting speed decreases the roughness.

Lodhi, B. K. and Shukla, R. (2014) [15] attempted to optimize the surface roughness and MRR in machining AISI 1018 alloy with Titanium coated Carbide inserts. Among spindle speed, feed rate and depth of cut the optimal setting was obtained. Taguchi's L_9 orthogonal array was used to experiment in a CNC lathe machine. The optimal MRR was obtained at the highest levels of all three factors. The minimum surface roughness was given at level 1, 1

and 2 of each factor respectively. From ANOVA it was also obtained that the spindle speed is the most significant factor for MRR and surface roughness with 78.173% and 75.295% respectively.

Mohan, R., et al. (2014) [16] optimized the machining parameters (cutting speed, feed rate and depth of cut) for lower surface roughness. AISI 52100 steel alloy also known as bearing steels were used for optimization. Carbide inserted cutting tool with nose radius 0.80 were used for machining. Taguchi's L_9 orthogonal arrays were used to design the experiment. Contribution of each factor was analysed by ANOVA. It was found that feed has significant effect on surface roughness.

Shunmugesh, K., et al. (2014) [17] studied the machining process in turning of 11sMn30 alloy using carbide tip insert in dry condition. The optimal settings for the cutting parameters were obtained. The three level cutting parameters were cutting speed, feed rate and depth of cut. The turning experiment was conducted using L_{27} orthogonal array in CNC turning centre stallion 200. The roughness values R_a and R_z were measured in Mitutoyu SJ210 surface roughness tester. The statistical analysis was done by MINITAB 17. It was found that the feed rate is the most significant factor to affect surface roughness other than cutting speed and depth of cut.

Sharma, S. K. and Kumar, S. (2014) [18] applied Taguchi orthogonal design to optimize the setting of cutting parameters in surface roughness. The experiments were conducted in CNC machine taking the cutting parameters as cutting speed, feed and depth of cut using coated carbide single point cutting tool. The material taken for experiment was mild steel 1018. For three levels three factors L_{27} orthogonal array was used. ANOVA and signal to noise ratio were examined using MINITAB 16 software. It was found that there were 3.2% error between predicted value and experimental value. This experiment showed that feed has immense effect on surface roughness in turning mild steel 1018 with coated carbide single point cutting tool.

Quazi, T., and More, Pratik Gajanan (2014) [19] utilized Taguchi method to optimize the surface roughness in turning EN8, EM31 and mild steels. The three levels turning parameters considered were cutting speed and feed rate. The tool grades considered were TN60, TP0500 and TT8020. The experiments were carried on Supercut 5 turning machine. The roughness were measured by Wyko NT9100 Optical Profiling System. The Taguchi method was designed and analysed by Minitab statistical 16. L_9 orthogonal array was used for analysis of all the materials along with three cutting tools. It was observed that feed rate has highest effect on surface roughness for all the three alloys.

Francis, Vishal, et al. (2014) [20] optimized the cutting parameters of mild steel (0.18% C) in turning to obtain the factors effecting the surface roughness and MRR. To study the influence of cutting

parameters they applied ANOVA and Signal to Noise ratio. The cutting parameters like spindle speed, feed and depth of cut were taken into consideration. A total of 27 experiments were done which were designed according to Taguchi method. The experiments were performed by using HSS cutting tool in dry condition. For MRR the most significant factor was spindle speed whereas feed was the most significant factor for surface roughness.

Rajpoot, Bheem Singh, et al. (2015) [21] used Response Surface Methodology to scrutinize the effect of cutting parameters like cutting speed, feed and depth of cut on average surface roughness and material removal rate during turning of Al 6061 alloy.

To find out the effect of each factor independently on surface roughness faced centred design based on RSM was implemented. The roughness were measured at three different locations. The results of 20 experiments were further analysed in Design Expert 8.0.4.1 software to find out the surface roughness and material removal rate. A regression model was developed for evaluating surface roughness considering actual factors. ANOVA was performed to examine the significance of the regression model for a confidence level of 95%. Among the three cutting parameters depth of cut was found to be the significant factor for both surface roughness and MRR.

TABLE I
SUMMARY OF REVIEW PAPERS

Author's Name	Workpiece Material	Cutting Tool	Cutting Parameters	Method Used	Highest Affecting Factors	Optimal Surface Roughness Value (μm)
2007						
Thamizhmanii, S., et al.	SCM 440	Coated Ceramic Tool	Cutting Speed, Feed and Depth of Cut	Taguchi Method	Depth of Cut	0.41
2010						
Nataranjan, C., et al.	C26000 brass material	CNMG 120408 Insert	Spindle Speed, Feed Rate and Depth of Cut	Artificial Neural Network	Feed Rate	1.0533(experimental) 1.4056(predicted)
2011						
Babu, V. Suresh, et al.	EN 24	HSS Tool	Cutting Speed, Feed and Depth of Cut	Response Surface Method	Cutting Speed	1.39(experimental) 1.385(predicted)
Sahoo, P.	AISI 1040	Coated Carbide Tool	Depth of Cut, Spindle Speed and Feed	Response Surface Method and Genetic Algorithm	Feed	0.894 0.864(GA)
2012						
Barik, C.R. and Mandal, N.K.	EN 31	Carbide Tool	Speed, Feed and Depth of Cut	Genetic Algorithm and Response Surface Method	Feed	0.4273(predicted) 0.438(experimental)
Davis, R. and Alazhari, Mohamed	Mild Steel (0.21%C)	HSS Tool	Depth of Cut, Feed rate and Spindle Speed	Taguchi Method	Depth of Cut	3.443
Kumar, K.A., et al.	EN 8	Coated Ceramic Tool	Cutting Speed, Feed and Depth of Cut	Multiple Regression Analysis	Feed	2.18(experimental) 2.1479(predicted)
Rodrigues, L.L.R., et al.	Mild Steel	HSS Tool	Speed, Feed rate and Depth of Cut	Full Factorial Design	Feed Rate	3.96
Sharma, N., et al	AISI 410	TiN Coated Insert	Insert Radius, Depth of Cut, Feed and Cutting Speed	Taguchi Method	Insert Radius	0.92(predicted) 0.83(experimental)
Somashekara, H.M. and Swamy, N.L.	Al6251-T6 alloy	Uncoated Carbide Insert	Cutting Speed, Feed and Depth of Cut	Regression Technique and Taguchi Method	Cutting Speed	0.69

Yadav, U.K., et al	AISI 1045		Cutting Speed, Feed Rate and Depth of Cut	Taguchi Method	Feed rate	0.89(predicted) 0.93(experimental)
2013						
Bala Raju, J. et al.	Mild Steel and Aluminium	HSS Tool	Cutting Speed, Depth of Cut and Feed	Multiple Regression Analysis	Feed	0.29(Aluminium) 1.19(Mild Steel)

Author's Name	Workpiece Material	Cutting Tool	Cutting Parameters	Method Used	Highest Affecting Factors	Optimal Surface Roughness Value (µm)
Krishan Prasad, D.V.V.	Mild Steel	HSS Tool	Back Rack Angle, Side Rack Angle, Speed, Feed and Depth of Cut	Full Factorial Design	Feed	1.456
2014						
Koura, M.M., et al.	Mild Steel	Carbide inserts	Cutting Speed, Feed Rate and Depth of Cut	Artificial Neural Network	Feed Rate	1.27(experimental) 1.67(predicted)
Lodhi, B.K. and Shukla, R.	AISI 1018	Titanium Coated Carbide Inserts	Spindle Speed, Feed rate and Depth of Cut	Taguchi Method	Spindle Speed	4.8085(predicted) 4.6844(experimental)
Mohan, R., et al.	AISI 52100	Carbide Insert	Cutting Speed, Feed Rate and Depth of Cut	Taguchi Method	Feed	0.490
Shunmugesh, K., et al.	11SMn30	Carbide Tip Insert	Cutting Speed, Feed Rate and Depth of Cut	Taguchi Method	Feed Rate	1.854
Sharma, S.K. and Kumar, S.	Mild Steel 1018	Coated Carbide Tool	Cutting Speed, Feed Rate and Depth of Cut	Taguchi Method	Feed Rate	6.56(predicted) 6.23(experimental)
Quazi, T., and More, Pratik Gajanan	Mild Steel, EN 8 and EN 31	TN60, TP0500 and TT8020	Cutting Speed and Feed Rate	Taguchi Method	Feed Rate	1.180(EN8-TN60) 2.53(EN8-TP0500) 3.12(EN8-TT8020) 1.74(MS-TN60) 1.81(MS-TP0500) 2.01(MS-TT8020) 1.26(EN31-TN60) 0.652(EN31-TP0500) 0.5(EN31-TT8020)
2015						
Rajpoot, Bheem Singh, et al.	Al 6061	Tungsten Carbide Tool	Cutting Speed, Feed and Depth of Cut	Response Surface Methodology	Depth of Cut	1.06
Francis, Vishal, et al.	Mild Steel (0.18%C)	HSS Tool	Depth of Cut, Feed and Spindle Speed	Taguchi Method	Feed	22.5

The summary of all the research papers reviewed is tabulated in the form as shown in Table 1. Surface roughness is considered as the main response factor. Therefore the optimal surface roughness values for the papers reviewed are also tabulated. Along with the cutting parameters the highest affecting factor is also tabularized.
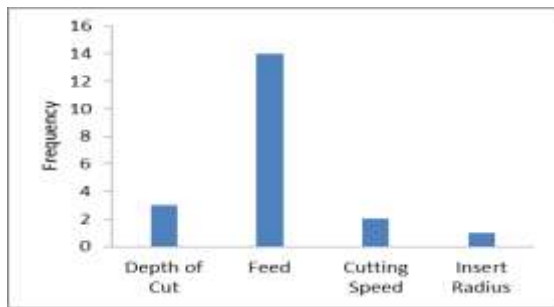
Fig. 3 Frequency of highest affecting factors

A bar diagram is designed to find out the frequency of the highest affecting factors in optimization of surface roughness in review of all these research papers. It is shown in Fig. 3. The distribution of various methods used during optimization is also plotted in pie chart as shown in Fig. 4.
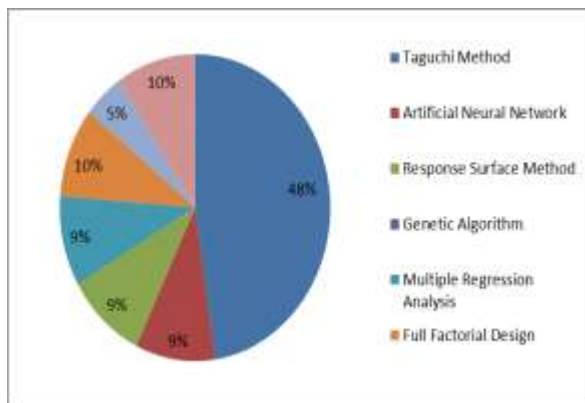

Fig. 4 Distribution of various methods in Optimization of Surface Roughness

III. CONCLUSIONS

From the above literature review it is observed that various methods are used to minimize surface roughness by optimizing cutting parameters like cutting speed, spindle speed, feed rate, depth of cut, tool angle, nose radius etc. Among all these methods it is observed that Taguchi Method is the most widely used method. The use of other methods like Genetic Algorithm, Response Surface Method and Artificial Neural Network are gradually increasing. In optimization of surface roughness feed is found to be the most affecting factor followed by depth of cut and cutting speed.

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