RESEARCH ARTICLE OPEN ACCESS

A Review on Optimization of Process Parameters for Surface Roughness and Material Removal Rate for SS 410 Material During Turning Operation

Jitendra Thakkar *, Mitesh I Patel **
*Jitendra Thakkar (Research Scholar, Gujarat Technological University, Ahmedabad, Gujarat)
** Mitesh I Patel(Assistant Professor Department of Mechanical Engineering, S. P. B. Patel Engineering College, Mehsana, Gujarat)

ABSTRACT
In machining operations, the extents of significant influence of the process parameters like speed, feed, and depth of cut are different for different responses. Therefore, optimization of surface roughness is a multi-factor, multi-objective optimization problem. Therefore, to solve such a multi-objective optimization problem, it is felt necessary to identify the optimal parametric combination, following which all objectives could be optimized simultaneously. In this context, it is essential to convert all the objective functions into an equivalent single objective function or overall representative function to meet desired multi-quality features of the machined surface. The required multi-quality features may or may not be conflicting in nature. The representative single objective function, thus calculated, would be optimized finally. All experiment conduct on CNC turning machine on SS410 material. In the present work, Design of Experiment (DOE) with full factorial design has been explored to produce 27 specimens on SS410 by straight turning operation. Material removal rate(MRR) will be calculated from MRR equation and software available for it and then compare it. Collected data related to surface roughness have been utilized for optimization.
Keywords – optimization, ANOVA, cutting parameter, MRR, surface roughness

I. INTRODUCTION

The CNC system has a computer in it, which controls the functions. In the conventional system the control is hard wired and therefore any modifications or addition in facility call for many changes in the controller which may or may not be possible due to limitations of basic configurations. As compared to this in a CNC system a bare minimum of electronic hardware is used while software is used for the basic function. That is why it is sometimes termed as software control. This assists in adding extra facilities conveniently without much problem and cost. Since these computers are dedicated type, they need comparatively much less storage and with the present cost and high reliability.

Fig.1 CNC machine

II. CNC TURNING

A CNC Lathe produces parts by "turning" rod material and feeding a single-point cutter into the turning material. Cutting operations are performed with a cutting tool fed either parallel or at right angles to the axis of the workpiece. The tool may also be fed at an angle relative to the axis of the workpiece for the machining tapers and angles. The workpiece may originally be of any cross-section, but the machined surface is normally straight or tapered. Have many possible shape can produce in CNC turning such as variety of plain, taper, contour, fillet and radius profiles plus threaded surfaces. CNC turning also can be used to create shafts, rods, hubs, bushes and pulleys.

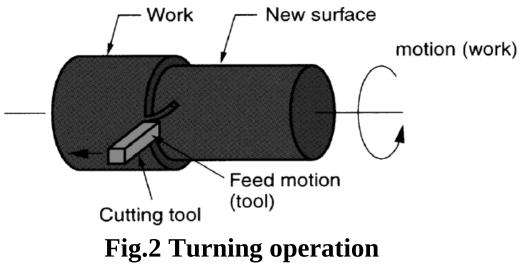
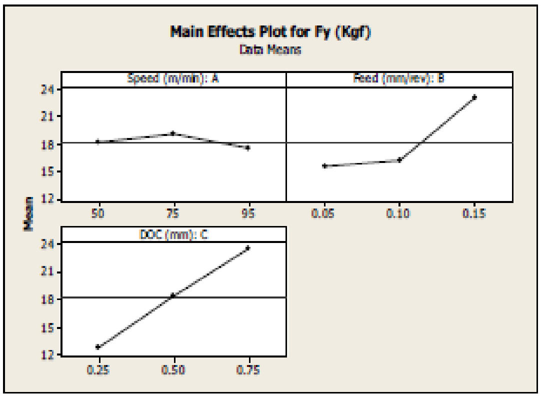


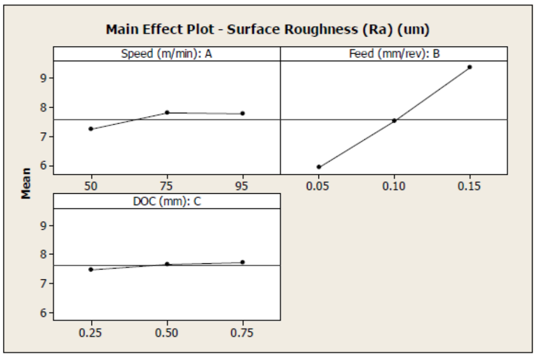
Fig.2 Turning operation

III. LITERATURE REVIEW

Dr. C. J. Rao[1], were carried out "Influence of cutting parameters on cutting force and surface finish in turning operation". they describes the significance of influence of speed, feed and depth of cut on cutting force and surface roughness while working with tool made of ceramic with an Al2O3+TiC matrix (KY1615)and the work material of AISI 1050 steel (hardness of 484 HV). Experiments were conducted using Johnford TC35 Industrial type of CNC lathe. Taguchi method (L27 design with 3 levels and 3 factors) was used for the experiments. Analysis of variance with adjusted approach has been adopted. The results have indicated that it is feed rate which has significant influence both on cutting force as well as surface roughness. Depth of cut has a significant influence on cutting force, but has an insignificant influence on surface roughness. The interaction of feed and depth of cut and the interaction of all the three cutting parameters have significant influence on cutting force, whereas, none of the interaction effects are having significant influence on the surface roughness produced. If power consumption minimization is to be achieved for the best possible surface finish, the most recommended combination of feed rate and depth of cut is also determined.



(a)



(b)

Fig.3 effect of cutting parameters on (a)cutting force and (b)surface roughness

M.kaladhar[2], were carried out "Determination of Optimum Process Parameters during turning of AISI 304 Austenitic Stainless Steels using Taguchi method and ANOVA". They investigated the effects of process parameters feed,speed,depth of cut and nose radius on surface finish and material removal rate (MRR) to obtain the optimal setting of these process parameters. And the Analysis Of Variance (ANOVA) is also used to analyze the influence of cutting parameters during machining. In this work, AISI 304 austenitic stainless steel work pieces are turned on computer numerical controlled (CNC) lathe by using Physical Vapour Deposition (PVD) coated cermets insert (TiCN- TiN) of 0.4 and 0.8 mm nose radii. The results revealed that the feed and nose radius is the most significant process parameters on work piece surface roughness. However, the depth of cut and feed are the significant factors on MRR. Optimal range and optimal level of parameters are also predicted for response. The aim of experimental investigation is to evaluate the effects of the process parameters on AISI 304 austenitic stainless steel work piece surface roughness and material removal rate by employing Taguchi's orthogonal array design and Analysis of Variance (ANOVA) using PVD coated Cermets tool on CNC lathe under dry environment.

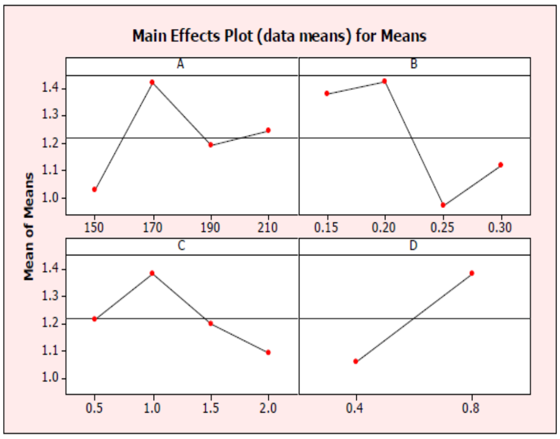


Fig.4 (a)Main effect plot for SR

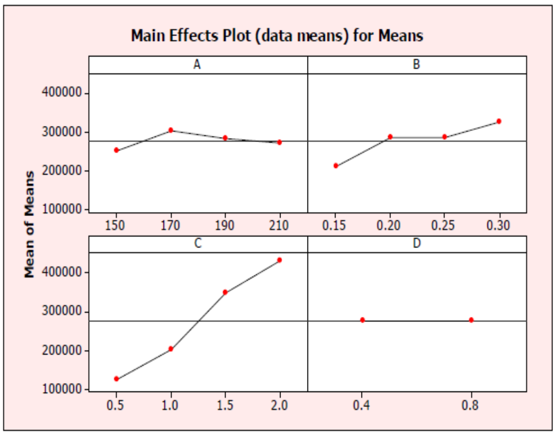
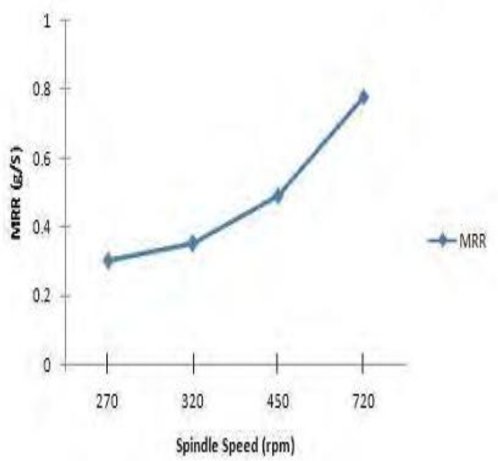


Fig.4 (b)Main effect plot for MRR

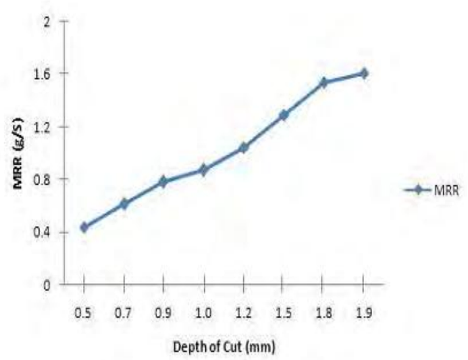
Hamdi Aouici[3], were carried out "Analysis of surface roughness and cutting force components in hard turning with CBN tool: Prediction model and cutting conditions optimization".they describes the effects of cutting speed, feed rate, workpiece hardness and depth of cut on surface roughness and cutting force components in the hard turning were experimentally investigated. AISI H11 steel was hardened to (40; 45 and 50) HRC, machined using cubic boron nitride (CBN 7020 from Sandvik Company) which is essentially made of 57% CBN and 35% TiCN. Four-factor (cutting speed, feed rate, hardness and depth of cut) and three-level fractional experiment designs completed with a statistical analysis of variance (ANOVA) were performed. Mathematical models for surface roughness and cutting force components were developed using the response surface methodology (RSM). Results show that the cutting force components are influenced principally by the depth of cut and workpiece hardness; on the other hand, both feed rate and workpiece hardness have statistical significance on surface roughness. Finally, the ranges for best cutting conditions are proposed for serial industrial production.

Gaurav Bartarya[4], were carried out "Effect of cutting parameters on cutting force and surface roughness during finish hard turning AISI52100 grade steel". The present work is an attempt to develop a force prediction model during finish machining of EN31 steel (equivalent to AISI52100 steel) hardened to 60±2 HRC using hone edge uncoated CBN tool and to analyze the combination of the machining parameters for better performance within a selected range of machining parameters. A full factorial design of experiments procedure was used to develop the force and surface roughness regression models, within the range of parameters selected. The regression models developed show that the dependence of the cutting forces i.e. cutting, radial and axial forces and surface roughness on machining parameters are significant, hence they could be used for making predictions for the forces and surface roughness. The predictions from the developed models were compared with the measured force and surface roughness values. To test the quality of fit of data, the ANOVA analysis was undertaken. The favourable range of the machining parameter values is proposed for energy efficient machining.

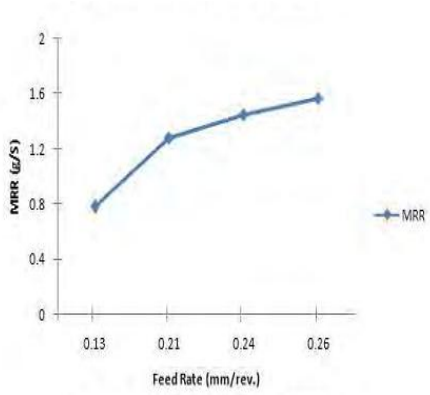
Deepak Mittal[5], were carried out "An investigation of the effect of process parameters on MRR in turning of pure titanium (grade-2)". They investigate the effect of process parameters in turning of Titanium grade 2 on conventional lathe. A single point high speed steel (MIRANDA S-400) tool is used as the cutting tool. The round bar of Titanium grade 2, 40mm diameter and 50 mm length is used as the work piece. Three parameters namely spindle speed, depth of cut and feed rate are varied to study their effect on material removal rate and tool failure. The experiments are conducted using one factor at a time approach. A Total of 30 experiments were performed. The MRR was calculated by measuring the weight of the specimen before and after machining on the digital balance meter with a least count of 10 mg of Sansui (Vibra), model no. AJ3200E. Moreover, a few random experiments are also carried to study the phenomenon of tool failure. The study reveals that material removal rate is directly influenced by all the three process parameters. However the effect of spindle speed and feed rate is more as compared to depth of cut. An optimum range of input parameters has been bracketed as the final outcome for carrying out further research.



(a)



(b)



(c)

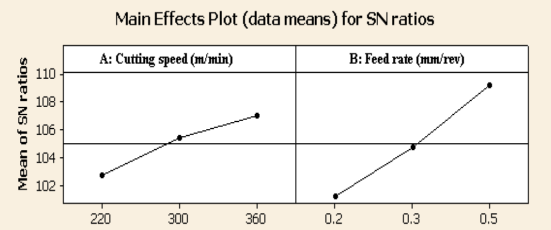
Fig.5 effect of (a)speed,(b)DOC and (c)feed rate on MRR

Tian-Syung LAN[6], were carried out “Parametric Deduction Optimization for Surface Roughness”. They investigated with four parameters (cutting depth, feed rate, speed, tool nose runoff) with three levels (low, medium, high) were considered to optimize the surface roughness for Computer Numerical Control (CNC) finish turning. The finishing diameter turning operation of S45C (□45 mm×250 mm) work piece on an ECOCA-3807 CNC lathe is arranged for the experiment. The TOSHIBA WTJNR2020K16 tool holder with MITSUBISHI NX2525 insert is utilized as the cutting tool. In investigation, the variable quantification and deduction optimization for CNC turning operations were proposed using fuzzy set theory and Taguchi method respectively. Additionally, twenty-seven fuzzy control rules using trapezoid membership function with respective to seventeen linguistic grades for the surface roughness was constructed. Considering thirty input and eighty output intervals, the defuzzification using center of gravity was moreover completed. Through the Taguchi experiment, the optimum general deduction parameters can then be received. The confirmation experiment for optimum deduction parameters was furthermore performed on an ECOCA-3807 CNC lathe. It was shown that the surface roughness from the fuzzy deduction optimization parameters are significantly advanced comparing to those from benchmark. This study not only proposed a parametric deduction optimization scheme using orthogonal array, but also contributed the satisfactory fuzzy approach to the surface roughness for CNC turning with profound insight.

J.S.Senthilkumaar[7], were carried out “Selection of machining parameters based on the Analysis of surface roughness and flank wear in finish Turning and facing of inconel 718 using Taguchi Technique”. Single pass finish turning and facing operations were conducted in dry cutting condition in order to investigate the performance and study the wear mechanism of uncoated carbide tools on Inconel 718 in the form of cylindrical bar stock of diameter 38 mm. The experiments were conducted on the L16 ACE designer CNC lathe with constant speed capability. Uncoated carbide inserts as per ISO specification SNMG 120408-QM H13A were clamped onto a tool holder with a designation of DSKNL 2020K 12 IMP for facing operation and DBSNR 2020K 12 for turning operation. Cutting experiments were conducted as per the full factorial design under dry cutting conditions. The effects of the machining parameters on the performance measures surface roughness and flank wear were investigated. The relationship between the machining parameters and the performance measures were established using the non-linear regression analysis. Taguchi’s optimization analysis indicates that the factors level, its significance to influence the surface roughness and flank wear for the tuning and facing processes. Confirmation tests were conducted at an optimal condition to make a comparison between the experimental results foreseen from the mentioned correlations. Based on Taguchi design of experiments and analysis, the cutting speed is the main factor that has the highest influence on surface roughness as well as flank wear of turning and facing processes. Optimal machining parameters for minimum surface roughness were determined. The percentage error between experimental and predicted result is 8.69% and 8.49% in turning and facing process respectively. Optimal machining parameters for minimum flank wear, the percentage error between experimental and predicted result is 4.67% for turning process and 2.63% for facing process. Based on the Taguchi’s optimization analysis for the turning process the cutting speed and depth of cut are the dominant factors whereas in facing process cutting speed and feed are dominant factors which affecting the performance measures.

H. Yanda[8], were carried out “Optimization of material removal rate, surface roughness and tool life on conventional dry turning of fcd700”. They investigate the effect of the cutting speed, feed rate and depth of cut on material removal rate (MRR), surface roughness, and tool life in conventional turning of ductile cast iron FCD700 grade using TiN coated cutting tool in dry condition. The machining condition parameters were the cutting speed of 220, 300 and 360 m/min, feed rate of 0.2, 0.3 and 0.5 mm/rev, while the depth of cut (DOC) was kept constant at 2 mm. The effect of cutting condition (cutting speed and feed rate) on MRR, surface roughness, and tool life were studied and analyzed.

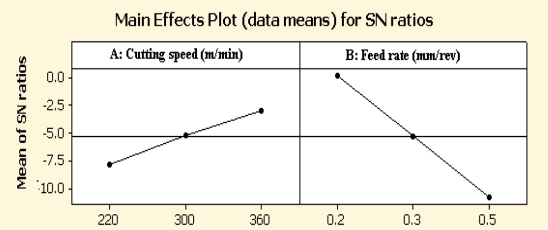
Experiments were conducted based on the Taguchi design of experiments (DOE) with orthogonal L9 array, and then followed by optimization of the results using Analysis of Variance (ANOVA) to find the maximum MRR, minimum surface roughness, and maximum tool life. The optimum MRR was obtained when setting the cutting speed and feed rate at high values, but the optimum tool life was reached when the cutting speed and feed rate were set as low as possible. Low surface finish was obtained at high cutting speed and low feed rate. Therefore time and cost saving are significant especially is real industry application, and yet reliable prediction is obtained by conducting machining simulation using FEM software Deform 3D. The results obtained for MRR using the proposed simulation model were in a good agreement with the experiments.



Level	A: Cutting speed	B: Feed rate
1	102.7	101.2
2	105.4	104.7
3	107	109.2
Delta	4.3	8
Rank	2	1

Signal-to-noise: Larger is better

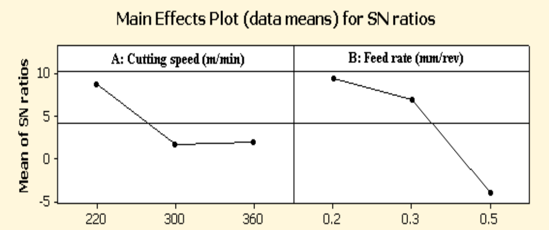
Fig. 6(a) effect of cutting speed and feed rate parameters in the S/N ratio on MRR



Level	A: Cutting speed	B: Feed rate
1	-7.8369	0.1752
2	-5.189	-5.3704
3	-2.9743	-10.8049
Delta	4.3	8
Rank	2	1

Signal-to-noise: Smaller is better

Fig.6(b) effect of cutting speed and feed rate in the S/N ratio on surface roughness



Level	A: Cutting speed	B: Feed rate
1	8.713	9.397
2	1.652	6.856
3	1.933	-3.956
Delta	4.3	8
Rank	2	1

Signal-to-noise: Larger is better

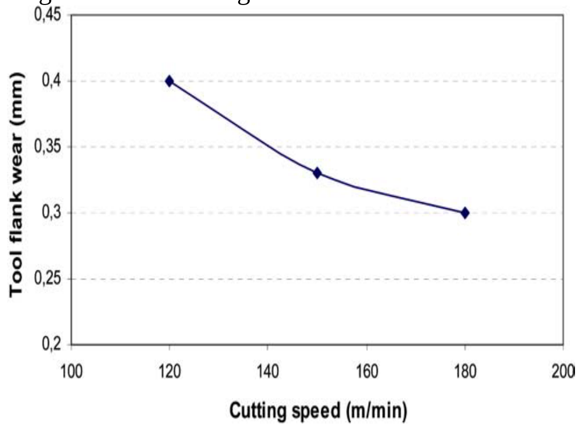
Fig.6(c) effect of cutting speed and feed rate parameters in the S/N ratio on tool life

Anderson P. Paiva[9], were carried out "A multivariate hybrid approach applied to AISI 52100 hardened steel turning optimization". This paper presents an alternative hybrid approach, combining response surface methodology (RSM) and principal component analysis (PCA) to optimize multiple correlated responses in a turning process. Since a great number of manufacturing processes present sets of correlated responses, this approach could be extended to many applications. As a case study, the turning process of the AISI 52100 hardened steel is examined considering three input factors: cutting speed (*V*c), feed rate (*f*) and depth of cut (*d*). The outputs considered were: the mixed ceramic tool life (*T*), processing cost per piece (*K*p), cutting time (*C*t), the total turning cycle time (*T*t), surface roughness (*R*a) and the material removing rate (MRR). The aggregation of these targets into a single objective function is conducted using the score of the first principal component (PC1) of the responses' correlation matrix and the experimental region (*Ω*) is used as the main constraint of the problem. Considering that the first principal component cannot be enough to represent the original data set, a complementary constraint defined in terms of the second principal component score (PC2) is added. The original responses have the same weights and the multivariate optimization lead to the maximization of MRR while minimize the other outputs. The kind of optimization assumed by the multivariate objective function can be established examining the eigenvectors of the correlation matrix formed with the original outputs. The results indicate that the multiresponse optimization is achieved at a cutting speed of 238 m/min, with a feed rate of 0.08 mm/rev and at a depth of cut of 0.32 mm. It was observed that to maximize the material removal rate while minimizing the cutting times, costs and surface quality simultaneously.

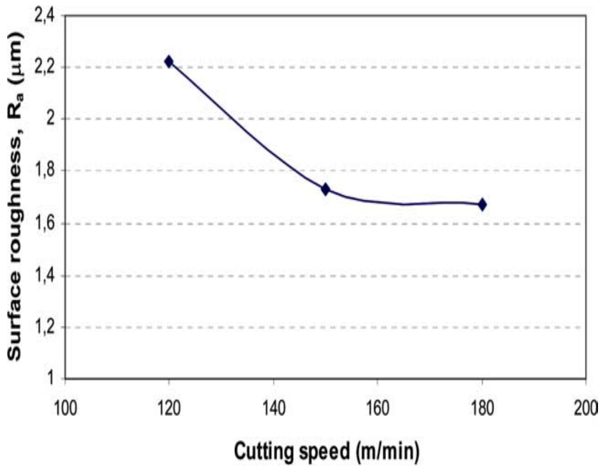
Muammer Nalbant[10], were carried out "Comparison of Regression and Artificial Neural Network Models for Surface Roughness Prediction with the Cutting Parameters in CNC Turning". The experimental results corresponding to the effects of different insert nose radii of cutting tools (0.4, 0.8, 1.2 mm), various depth of cuts (0.75, 1.25, 1.75, 2.25, 2.75 mm), and different feed rates (100, 130, 160, 190, 220 mm/min) on the surface quality of the AISI 1030 steel workpiece have been investigated using multiple regression analysis and artificial neural networks (ANN). Regression analysis and neural network-based models used for the prediction of surface roughness were compared for various cutting conditions in turning. The data set obtained from the measurements of surface roughness was employed to and tests the neural network model. The trained neural network models were used in predicting surface roughness for cutting conditions. A comparison of neural network models with regression model was carried out. Coefficient of determination was 0.98 in multiple regression model. The scaled conjugate gradient (SCG) model with 9 neurons in hidden layer has produced absolute fraction of variance (R2) values of 0.999 for the training data, and 0.998 for the test data. Predictive neural network model showed better predictions than various regression models for surface roughness. However, both methods can be used for the prediction of surface roughness in turning.

B Sidda Reddy[11], were carried out "Surface roughness prediction technique for CNC technique". They developed a surface roughness prediction model for machining aluminum alloys using multiple regression and artificial neural networks. The experiments have been conducted using full factorial design in the design of experiments on CNC turning machine with carbide cutting tool. A second order multiple regression model in terms of machining parameters has been developed for the prediction of surface roughness. The adequacy of the developed model is verified by using co-efficient of determination, analysis of variance, residual analysis and also the neural network model has been developed using multilayer perception back propagation algorithm using train data and tested using test data. To judge the efficiency and ability of the model to predict surface roughness values percentage deviation and average percentage deviation has been used. The experimental result show, artificial neural network model predicts with high accuracy compared with multiple regression model.

Ihsan Korkut[12], were carried out "Determination of optimum cutting parameters during machining of AISI 304 austenitic stainless steel"they describes that High strength, low thermal conductivity, high ductility and high work hardening tendency of austenitic stainless steels are the main factors that make their machinability difficult. In this study determination of the optimum cutting speed has been aimed when turning an AISI 304 austenitic stainless steel using cemented carbide cutting tools. The influence of cutting speed on tool wear and surface roughness was investigated.



(a)



(b)

Fig.7 effect of cutting speed on (a)Tool Flank wear and (b)Surface roughness

IV. CUTTING PARAMETERS

The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course but these three are the ones the operator can change by adjusting the controls, right at the machine

Speed

Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same

v=□ DN/1000

Here, v is the cutting speed in turning, D is the initial diameter of the work piece in mm, and N is the spindle speed in RPM.

Feed

Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.

$$F = f\,N \text{ mm min}^{-1}$$

Here, F is the feed in mm per minute, f is the feed rate in mm/rev and N is the spindle speed in RPM.

Depth of Cut

Depth of cut is practically self explanatory. It is the thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is important to note that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

Depth of cut = D-d/2 mm

Here, D and d represent initial and final diameter (in mm) of the job respectively.

V. RESPONSE PARAMETERS

Material Removal Rate(MRR)

The material removal rate (MRR) in turning operations is the volume of material/metal that is removed per unit time in mm^3/min. For each revolution of the work piece, a ring shaped layer of material is removed. MRR= (vfd×1000) in mm^3/min.

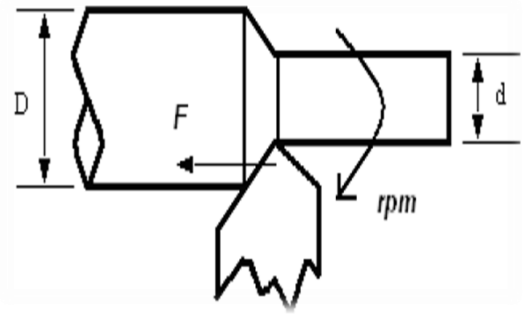


Fig.8 MRR in turning

$$MRR=\left(\frac{\pi D^2}{4}-\frac{\pi d^2}{4}\right)\times F\times rpm$$

Where,
D= diameter of workpiece before cutting
d= diameter of workpiece after cutting

Surface Roughness(SR)

Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties like fatigue behavior, corrosion resistance, creep life, etc. surface roughness tester to measure surface roughness of work piece.

Fig.9 Surface roughness tester

VI. CONCLUSION

From the above literature survey we found that most effected parameters to cutting condition are cutting speed, feed rate and depth of cut and they are easily controlled by operator at the machine at same time. All turning operation will be performed on CNC turning machine. In which input parameters are cutting speed, feed rate and depth of cut and the response parameters are surface roughness and material removal rate. We will use surface roughness tester to measure surface roughness and MRR will measured by mathematical equation. We will use AISI 410 work piece material for turning operation. For Experimental design we will use full factorial method ($L=m^n$) to find out number of readings. To find out percentage contribution of each input parameter for obtaining optimal conditions, we will use ANOVA method.

REFERENCES

Journal Papers:

[1] Dr. C. J. Raoa, Dr. D. Nageswara Raob, P. Srihari," Influence of cutting parameters on cutting force and surface finish in turning operation", International Conference On Design And Manufacturing, *Procedia Engineering 64 (2013) 1405 – 1415.*

[2] M.kaladhar, K.venkata subbaiah, ch.srinivasa rao," determination of optimum process parameters during turning of AISI 304 austenitic stainless steel using taguchi method and ANOVA", *international journal of lean thinking volume-3,issue 1(june 2012).*

[3] Hamdi Aouici, Mohamed Athmane Yallese, Kamel Chaoui, Tarek Mabrouki, Jean-François Rigal, "Analysis of surface roughness and cutting force components in hard turning with CBN tool: Prediction model and cutting conditions optimization", *Measurement 45 (2012) 344–353.*

[4] Gaurav Bartaryaa, S.K.Choudhury, "Effect of cutting parameters on cutting force and surface roughness during finish hard turning AISI52100 grade steel", *5th CIRP Conference on High Performance Cutting 2012, Procedia CIRP 1 (2012) 651 – 656.*

[5] Deepak Mittal, M. P. Garg, Rajesh Khann**a,**" An Investigation Of The Effect Of Process Parameters On Mrr In Turning Of Pure Titanium (Grade-2)", *International Journal of Engineering Science and Technology (IJEST), Vol. 3 No. 8 August 2011.*

[6] Tian-Syung Lan, "Parametric Deduction Optimization for Surface Roughness". *American Journal of Applied Sciences 7 (9): 1248-1253, 2010 ISSN 1546-9239.*

[7] J.S.Senthilkumaar,P.Selvarani,RM.Arunachalam,"Selection of machining parameters based on the Analysis of surface roughness and flank wear in finish Turning and facing of inconel 718 using Taguchi Technique". *Emirates Journal for Engineering Research, 15 (2), 7-14 (2010).*

[8] H. Yanda, J.A. Ghani, M.N.A.M. Rodzi, K. Othman and C.H.C. Haron., "optimization of material removal rate, surface roughness and tool life on conventional dry turning of FCD 700", *International Journal of Mechanical and Materials Engineering (IJMME), Vol.5 (2010), No.2, 182-190.*

[9] Anderson P. Paiva, Joao Roberto Ferreira, Pedro P. Balestrassi, "A multivariate hybrid approach applied to AISI 52100 hardened steel turning optimization". *Journal of Materials Processing Technology 189 (2007) 26–35.*

[10] Muammer Nalbant, Hasan Gokkaya, and ˙Ihsan Toktas, "Comparison of Regression and Artificial Neural Network Models for Surface Roughness Prediction with the Cutting Parameters in CNC Turning", *Hindawi Publishing Corporation Modelling and Simulation in Engineering Volume 2007, Article ID 92717, 14 pages.*

[11] B sidda reddy, G.Padmanabhan and K.Vijay Kumar Reddy, "Surface roughness prediction technique for CNC technique". *Asian journal of scientific research 1 (3): 256-264, 2008 ISSN 1992-1454.*

[12] Ihsan Korkut, Mustafa Kasap, Ibrahim Ciftci, Ulvi Seker, "Determination of optimum cutting parameters during machining of AISI 304 austenitic stainless steel". *Materials and Design 25 (2004) 303–305*