Study on Optimization of Turning Parameters on Various Steel Grades: A Review

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Abstract - In this paper, an attempt is made to review the optimization of various parameters like surface roughness, MRR and tool wear during turning operations on various steel grades. The turning input parameters in various papers were cutting speed, feed rate and depth of cut whereas output parameters were surface roughness, cutting forces, tool wear and MRR. Various researches have used Taguchi and RSM approaches to design and for the optimization of the parameters. RSM was found more dominating methodology to design the experiments as well as analyze the outcomes from the experiments. This study was more focused upon the determination of most influencing input parameter for desirable or undesirable output, apart from it the main aim was selection of optimal parameters for improved surface finish and high productivity.

Index Terms - Surface Roughness, MRR, Tool wear, ANOVA, Taguchi, RSM.

1. INTRODUCTION

Turning is a versatile and useful machining operation. It is the most important operation and is widely used in most of the manufacturing industries due to its capability of producing complex geometric surfaces with reasonable accuracy and surface finish [1]. In the modern world scenario of manufacturing, optimization techniques in metal cutting is compulsory for manufacturing concern to respond effectively to severe competitiveness and growing demand of quality products in market [2].In a turning operation, a high verity single point cutting tool is strongly held in a tool post and is fed past a rotating work piece in a direction parallel to the axis of rotation of the work piece, at a steady rate, and unwanted material is removed in the form of chips giving rise to a cylindrical profile [6]. In a turning operation, the important task is to select cutting parameters for achieving high cutting performance [3]. Three cutting parameters namely feed rate, cutting speed and depth of cut need to be resolved in a turning operation [4]. Surface roughness is the most decisive parameter in machining process, as it is considered as basis of the product quality. It measures the refined inadequacy of the surfaces [5]. Turning produces three cutting force components the main cutting force i.e. thrust force, which acts in the cutting speed direction, feed force, which acts in the feed rate direction and the radial force, which acts in radial direction and which is normal to the cutting speed [7].Coated and uncoated tools are widely used in the metal-working industry and provide the best alternative for most turning operations [8].Better finished components increase the productivity & economics of the industry. A better machined surface surely improves fatigue strength, creep failure, corrosion resistance [10]. The most two popular coating processes are PVD and CVD, used for both single layer and multi-layer coatings [12]. Speed, feed and depth of cut are the input parameters which directly affect the performance of the cutting tool [17]. Aspects such as tool life and wear, surface finish, cutting forces, material removal rate, power consumption, cutting temperature decides the productivity, product quality, overall economy in manufacturing by machining and quality of machining [23].

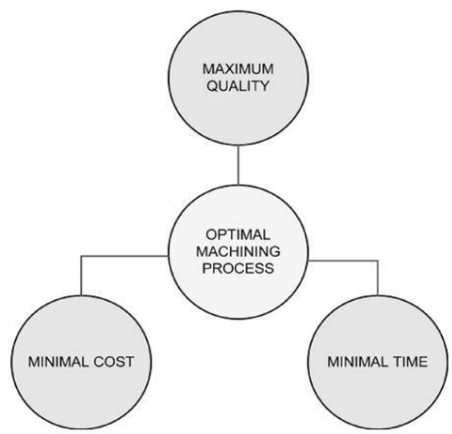

Fig-1 Possible Optimization Goals [1]

2. RELATED WORK

2.OPTIMIZATION TECHNIQUES

Optimization refers to the art and science of allocating scarce resources to the best possible effect [4].

2.1 Response Surface Methodology (RSM)

Response Surface Method (RSM) is a collection of mathematical and statistical tools which are useful for the modeling and analysis of problems in which an output response of interest is influence by several input variables and our objective is to optimize (minimize or maximize based on the need) the response [6].

2.2 Taguchi's Approach

Taguchi's parametric design is an effective tool for robust design. It offers a simple and systematic qualitative optimal design at a relatively low cost. The greatest advantage of this approach is to save the experimental time as well as the cost by finding out the significant factors [16].

3. RELATED WORK

3. LITERATURE REVIEW

A brief review of status of research work carried out by various investigators is given below.

3.1 Effect of feed, speed and depth of cut on surface roughness

Govindan P and Vipindas M P [1] used the Taguchi approach and examined that this approach has a potential for savings in experimental time and cost on product or process, development and quality improvement. It was concluded from study that cutting speed and feed has most significant effect on surface roughness.

Vipin Kumar Sharma et al. [2] applied the DOE techniques Taguchi & Response Surface Methodology to optimize the turning process parameters to obtain better surface finish. It was concluded from study that cutting speed and feed has most significant effect on surface roughness.

W.H. Yang and Y.S. Tarng [3] worked on Taguchi method to find the optimal cutting parameters for turning operations. The cutting characteristics of S45-C steel bars using tungsten carbide cutting tools were examined. It was concluded that feed rate has significant effect on surface roughness.

Harish Kumar et al. [4] have done experimental work for the optimization of input parameters to improve of surface quality of the product. Feed rate, spindle speed & depth of cut are taken as the input parameters and the dimensional tolerances as output parameter. The experimental work concluded that cutting speed is the key factor for reducing the dimensional variation for minimizing the surface roughness.

Ashvin J. Makadia and J.I. Nanavati [5] studied the application of RSM on the AISI-410 steel is carried out for turning operation. The surface roughness was found to increase with the increase in the feed rate and it decreased with increase in the tool nose radius. The surface roughness was found to increase with the increase in the feed and it decreased with increase in the tool nose radius.

Chandan Kumar et al. [6] applied the CCD based RSM approach to perform an experimental study on turning of AISI-202 steel by a TiAlN coated carbide insert tool. It is observed that feed is the most significant factor affecting the surface roughness, while the only significant factor affecting the tool wear was found to be the depth of cut.

L B Abhang, M Hameedullah [7] had done an experimental work to machine the EN-31 steel alloy by using tungsten carbide inserts. The data was analyzed using ANOVA technique, first order and second order power consumption prediction models were developed by using RSM. It is concluded that second-order model is more accurate than the first-order model. The main conclusion drawn from this study was that better surface finish is obtained by applying cooled lubricant.

Suraj R. Jadhav and Aamir M. Shaikh [8] conducted the experiments on the samples of EN-24 alloy steel material with the help of PVD coated TiAlN insert and uncoated carbide insert. It is concluded that spindle speed and depth of cut are prominent factors affecting surface roughness.

S. Thamizhmanii et al. [9] analyzed the most favorable cutting conditions to get minimal surface roughness in turning SCM-440 alloy steel by Taguchi method. Results showed that the depth of cut is most significant parameter affecting surface roughness followed by feed.

Puneet Saini et al. [10] in his research work used RSM approach to determine the optimum machining parameters leading to minimum surface roughness in turning process. It is also concluded that feed rate is the most significant factor affecting surface roughness followed by depth of cut.

D. Philip Selvaraj and P. Chandramohan [11] carried out the dry turning of AISI-304 Austenitic Stainless Steel. ANOVA results showed that feed rate, cutting speed and depth of cut affects the surface roughness.

D. Rajasekhar Reddy and AV Hari Babu [12] examined the multi-response optimization of turning technique in machining of EN-31 tool. It was seen from the results that cutting speed is the most significant parameter for surface roughness.

Mohd. Shadab Shiddique et.al [13] research work concerned with machining of the AISI-4140 alloy steel. It has found that the multilayer coated carbide inserts have performed well.

Muammer Nalbant et al. [14] studied the machining of AISI 1030 steel without using cooling liquids. The surface roughness effects of coating method, coating material, cutting speed and feed rate on the work piece have been investigated. Results showed coated tool gives better surface roughness values rather than uncoated tool.

3.2 Effect of feed, speed and depth of cut on MRR

H.K. Dave et al. [15] investigated the machining characteristics of different grades of EN materials during turning process using TiN coated cutting tools. It was concluded from ANOVA that the depth of cut has significant role for generation of higher MRR and generation of lower surface roughness.

Nithyanandan T et al. [16] examined the effects of process parameters on surface finish and MRR to obtain the optimal setting of these process parameters. The results revealed that the nose radius and feed rate are the most significant process parameters on surface roughness and the depth of cut and feed are the significant factors on MRR.

Santosh Kumar et al. [17] studied the Taguchi method and regression analysis to optimize the machining parameters during the turning of EN-45 spring steel by plain carbide cutting tool. The analyzed results revealed that the feed rate was the most dominating factor for surface roughness and the cutting speed is the most dominating factor for MRR and tool wear.

Rahul R Deshpande and Reena Pant [18] has studied the influence of input parameters feed, depth of cut and cutting speed on the output parameters on surface roughness and MRR. For coated insert the spindle speed is the most influencing factor and MRR followed by feed and depth of cut. For uncoated insert the depth of cut with is the most influencing and MRR followed by spindle speed and feed.

Mittal P Brahmbhatt et al. [19] examines the performance of MTCVD multicoated carbide inserts in dry turning of EN-9 steel. The analysis indicated that the parameter that has the biggest effect on surface roughness and MRR is feed.

Ravi Aryan et al. [20] in his experimental work analyzed the optimization of cutting parameters for surface roughness and MRR in the turning. For HSS, carbide and cobalt tool the optimum conditions are spindle speed of 615 rpm.

Praveen Kumar et al. [21] investigated the effect of process parameters during the machining of EN-31steel using. From results it was concluded that the feed rate is the most significant factor affecting the surface roughness and spindle speed is the most significant parameter affecting the MRR.

B Kumaragurubaran et al. [22] conducted an experimental work turning parameters on EN-9 steel with different cutting Feed rate is a dominating parameter of MRR of turning operation.

3.3 Effect of feed, speed and depth of cut on tool wear.

Meenu Sahu and Komesh Sahu [23] presented an optimization method of the cutting parameters in dry turning of AISI-D2 steel to achieve minimum tool wear, work piece surface temperature and maximum MRR. The results showed that depth of cut and cutting speed are the most dominating parameters affecting the tool wear.

Turgay K1vak [24] practiced the Taguchi method and regression analysis to figure out the machinability of Hadfield steel with PVD TiAlN and CVD TiCN/Al_2O_3 coated carbide inserts under dry milling conditions. The results showed that feed rate was the most important parameter affecting surface roughness and cutting speed was the important parameter affecting flank wear.

R. Suresh et al. [25] analyzed the correlation between cutting parameters with machining force, power, specific cutting force, tool wear and surface roughness on work piece. The analysis of the result revealed that, the optimal combination of low feed rate and low depth of cut with high cutting speed is beneficial for reducing machining force. The low feed rate and high cutting speed is crucial for minimizing the surface roughness.

Ashok Kumar Sahoo and Bidyadhar Sahoo [26] work deals with some machinability studies on flank wear, surface roughness, chip morphology and cutting forces in turning of AISI-4340 steel using uncoated and multilayer TiN and ZrCN coated carbide inserts. The results from analysis showed that multilayer coated tool inserts performed better than uncoated tool inserts and are responsible for steady growth of flank wear.

M. Kaladhar et al. [27] explored the influence of machining parameters on the performance measures, surface roughness and flank wear in turning of AISI-304 austenitic stainless steel. The results showed that the cutting speed influences both the surface roughness and tool flank wear.

Manish Chaudhari and K Karunamurthy [28] in their work examined the machining of EN-31 steel work piece is carried out using uncoated and coated carbide insert. The lowest tool wear was observed with coting tool. At the beginning of cutting, there was no significant difference amongst the coated tools, only the uncoated tool showing higher cutting force at lower parameters.

Varaprasad Bh. et al. [29] generates a model and predicts the tool flank wear of AISI-D3 hardened steel using Response Surface Methodology (RSM). The significant parameter for tool flank wear is depth of cut. The speed and feed have little influence on the total variation.

3.4 Effect of feed, speed and depth of cut on cutting forces

Dr. C. J. Rao et al. [30] examined the significance of cutting speed, feed rate and depth of cut on cutting forces and surface roughness while working with tool made of ceramic with an Al_2O_3+TiC matrix and the work material of AISI-1050 steel. The results have indicated that feed rate has significant effect on both the cutting force and surface roughness.

G. Basmaci and M. Ay [31] done an experimental optimization of cutting forces, surface roughness and the hardness of material after turning of AISI-316L stainless steel. The results suggested that the use of the wiper insert is an effective way, which significantly increases cutting efficiency, without changing the machined surface roughness in high feed turning operations.

Satish Chinchanikar and S.K. Choudhury [32] examined the performance of coated carbide tool by taking the effects of work material hardness and cutting parameters during turning of hardened AISI-4340 steel at different levels of hardness. Cutting speed followed by depth of cut become the most influencing factors on tool life in case of harder work piece.

Sudhansu Ranjan Das et al. [33] research work was on finish dry hard turning of AISI52100 steel with CBN tool to examine the effect of cutting parameters on cutting force and surface roughness. The results showed that feed rate and cutting speed affects the surface roughness, while depth of cut affects the cutting force.

M.Y. Noordin et al. [34] investigated the optimized parameters of AISI-1045 steel by multilayer tungsten carbide tool using RSM technique during turning. The input parameters taken were cutting speed, feed and the side cutting edge angle. The experimental results indicated that feed is the most significant factor affecting the surface roughness and cutting force.

Gaurav Bartarya and S.K. Choudhury [35] developed a force prediction model during machining of AISI-52100 steel using hone edge uncoated CBN tool. The models developed showed that the depth of cut was the most influential parameter affecting the three cutting forces. The response surface analysis showed that forces first decreased and then increased with increase in cutting speed.

B. Padma et al. [36] examined the optimization of machining process parameters for the turning of EN-9 carbon steel. The results indicated that depth of cut is an important factor on affecting cutting force and the surface roughness assessed by the feed, a speed and the cutting fluid.

3.5 Effect of feed, speed and depth of cut on cutting temperature

Suha K. Shihab et al. [37] studied the influence of cutting parameters on the cutting temperature in hard turning of AISI 52100 alloy steel using multilayer coated carbide (TiN/TiCN/Al_2O_3/TiN) insert. The results indicated that all the three cutting parameters have significant effect on the cutting temperature. G Harinath Gowd et al. [38] used geared lathe for doing experiments on EN-31 steel and depth of cut, cutting speed and feed were taken as process parameters and the output responses were force and temperature. It has been found that the speed and the depth of cut have great significance on the force and temperature.

3.6 Effect of feed, speed and depth of cut on energy consumption

Harsh Y Valera and Sanket N Bhavsar [39] performed an experimental study of power consumption and roughness quality of surface developed in turning operation of EN-31 alloy steel with (TiN+Al_2O_3+TiCN) coated tungsten carbide tool under different cutting parameters. It was concluded that feed has most significant influence on power consumption.

L. B. Abhang and M. Hameedullah [40] investigated the power consumption in turning EN-31 steel with tungsten carbide tool under different cutting conditions. It was concluded that second-order model is more accurate than the first-order model and fit well with the experimental data. The least the values of the cutting speed, feed rate, depth of cut and tool nose radius, minimal is the metal cutting power consumption

Carmita Camposeco-Negrete [41] studied the various cutting parameters and has been optimized to minimize cutting power, power consumed or cutting energy. The results showed that feed rate is the most significant factor to minimize the energy consumption and surface roughness.

Mariyeh Moradnazhad and Hakki Ozgur Unver [42] provided an overview of energy-saving strategies and opportunities for increasing energy efficiency in manufacturing operations with a focus on machining processes. This study provides the relationship between process energy consumption and process variables for MRR and optimization of cutting parameters to reduce energy consumption.

Sofiane Berkania et al. [43] investigated the machining of AISI-304 steel for machining force evolution, power consumption, specific cutting force and surface roughness. Results revealed that feed rate was the most preponderant factor affecting surface roughness. However, the depth of cut affects considerably cutting force and cutting power respectively.

Andrew A. Erameh [44] examined and structured a research methodology for prediction and modelling of machine energy consumption, determining the relationship between process energy consumption and process variables for material removal processes and optimization of cutting parameters to reduce energy consumption. Arun Kumar, Sukhdeep S. Dhami [45] represents various temperature measurement techniques and how cutting conditions during turning operation on materials affects the magnitude of heat generation thus tool wear, tool life and workpiece quality.

3.7 SUMMARY OF LITERATURE

The summary of literature is shown in table 1

Table 1 Summary

Objectives	DOE Used	Cutting Tool Used	Dominant Parameter

To maximize the surface roughness [1,2,3,4,5,6,7,8,9,10,11,12,13,14]	Taguchi/ RSM/ ANN	Multilayered coated and uncoated carbide tool	Cutting speed, Feed rate, Depth of cut
To increase the MRR [15,16,17,18,19,20,21,22]	Taguchi/ RSM	HSS, cobalt, plain carbide, multilayered coated tool	Feed rate, Depth of cut
To minimize the tool wear [23,24,25,26,27,28,29]	Taguchi/ RSM	PVD and CVD coated tool	Cutting speed
To increase the cutting forces [30,31,32,33,34,35,36]	Taguchi/ RSM/ Regression analysis	PVD coated, CVD coated tool, uncoated CBN tool	Depth of cut, Feed rate
To minimize the cutting temperature [37,38]	Taguchi/ ANN	Multilayered coated and uncoated	Cutting speed, Feed rate
To minimize the energy consumption [39,40,41,42,43]	Taguchi/ RSM	Ceramic coated tool, uncoated tool	Feed rate, Depth of cut

4. CONCLUSION

It is concluded that the feed rate and spindle speed are most influencing parameters in machining for surface roughness and MRR.

I. The surface roughness increases with increase in speed, feed and depth of cut.

II. The generation of cutting forces is more in the machining of hard material.

III. The generation of heat is more by speed and feed.

IV. Cutting speed is observed as a critical cutting parameter, which improves surface finish, when it is increased in value.

V. Power consumption is increased when speed, feed rate and of cut is increased.

VI. Metal removal rate is greatly influenced by the depth of cut and feed rate.

VII. Speed is the most significant parameter for achieving better tool life.

VIII. Speed and the depth of cut have great significance on the forces, whereas the feed has less significance on it.

FUTURE SCOPE

The experiment may be conducted in future by measuring the following parameters-cutting forces, temperature, power consumption, machining time

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