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PARAMETRIC OPTIMIZATION IN TURNING USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT-*In this paper an attempt is made to give an overview on the optimization of parameters in turning process through literature review. The Taguchi design of experiments & response surface methodology techniques are being extensively employed in the current & past research works on turning process. There are different factors like tool geometry, tool type, cutting conditions, material type, etc. which could affect the machining during turning process. The researchers in the following literature review have worked on turning process by taking into consideration the above mentioned factors.*

Keywords: Design of experiments, Taguchi, response surface methodology, turning process, optimization.

I. Introduction

In turning, measured surface roughness is used to determine the surface quality of the products. A good quality turning surface can improve properties such as fatigue strength, corrosion resistance & thermal resistance. Focus has been made in the improvement of surface by increasing the alternative solutions. Minimum surface roughness is important due to increased customer demands for quality, less costly products, minimum friction, maximum lubrication & minimum wear. To produce desired surface roughness through a manufacturing operation there are various parameters needed to be considered. Selection of desired cutting parameters by experience or using handbook does not ensure that the selected cutting parameters are optimal for a particular m/c or environment. Hence, it is important to select right parameters so that high cutting performance can be achieved.

II. Need For Optimization

Traditionally the selection of cutting condition for metal cutting is left to the machine operator. In such cases the experience of the operator plays a major role, but even for a skilled operator it is very difficult to attain the desired output values each time by selecting the control parameters values on the basis of his knowledge. Nowadays, many academicians & companies are interested in optimizing manufacturing process in order to reduce cost, improve quality, & obtain high efficiency. To achieve this, analysis of data during manufacturing is needed to be carried out by using suitable statistical design. Statistical design of experiments refers to the process of planning the experiments so that the appropriate data can be analyzed to reach the desired conclusion. Design & methods such as factorial design, Taguchi methods, & response surface methodology are widely used in place of one factor at a time experimental approach which is time consuming & incurs more cost.

III. Methodology

To optimize the process parameters design of experimentation techniques are used which include different strategies such as:-
(i) Best guess approach
(ii) One factor at a time
(iii) Statistically designed experiments
In best guess approach there is no guarantee to obtain the best solutions as the selection of combination of factors is done on the basis of guess of the researchers. Whereas in one factor at a time approach a single factor is varied over its range keeping other factors constant. These are always less efficient than other methods based on a statistical approach. In statistically designed experiments factors are varied together instead of one at a time. Thus it helps to study the individual effect of the control factor on the output & to determine whether the factors interact. Sometimes these methods could take large number of experimental runs which will also

increase the time. To avoid this, alternate methods such as Taguchi and response surface methodology are being used.

IV. Factors Involved

While going through the experimentation there are certain factors that needed to be considered which are, factors related to the machine, cutting tools, cutting conditions & work material. These are said to be the input factors which can be controlled by varying its values. The other factors which need to be considered are the output factors such as surface roughness, material removal rate, tool life, and temperature& power consumption. The machining factors such as cutting speed, feed & depth of cut, cutting tool factors such as tool geometry & tool material, cutting condition factors such as dry, wet, & minimum quantity lubrication these entire if studied properly through experimentation can lead to achieve desired values of the output factors mentioned above.

V. Taguchi Design Of Experiment

It is one of the powerful D.O.E methods for analysis of experiments. It helps to arrive at the best parameter setting for optimal condition with least number of experimentation. It was developed by Dr. Genichi Taguchi, it is a method based on orthogonal array experiments which gives much reduced variability for the experiment with optimum setting of control parameters. The orthogonal arrays are the different tables which consist of the different combination of the control parameters with their respected value and the array is selected with the help of number of control parameters included in experimentation and its levels. Dr. Genichitaguchi's signal to noise ratios which are log functions of desired output serve as objective functions for optimization & also helps in data analysis and prediction of optimum results.

VI. Response Surface Methodology

In order to improve the process quality attention was given & methodology was developed for using experimental design, specifically for the following:-

- To design the product and processes so that they are robust to component variation.
- To minimize variability in output response of a product or process around a target value.
- To design product & processes so that they are robust to environment condition.

By robust means that the product or process performs consistently on target & is insensitive to factors that are difficult to control. These difficult to control factors are referred as noise factors by Taguchi, Response surface methodology assumes that these noise factors are uncontrollable in the field but can be controlled during process development for purpose of designed experiment.

-Steps in Response surface methodology:
Phase 1:- Screening experiments, Ideas should be generated considering which factors or variables are likely to be important in RSM. Objective of factor screening is to reduce the list of different variables to a few so that the experiment will be more efficient & require fewer runs or tests. The purpose is the identification of the important independent variables.
Phase 2:-In this step the objective is to determine if the current settings of the independent variables result in a value of the response that is near the optimum. If not then set of adjustments must be done to the process variable that will move process towards the optimum. This phase of RSM makes use of the first order model & an optimization technique called the method of steepest ascent/ descent.
Phase 3:- when the process is near the optimum, it is required to develop model that will accurately determine the true response function within a relatively small region around the optimum. As true response surface usually shows curvature near the optimum, a second order model should be used. This model may be analyzed to determine optimum conditions for the process. This sequential experimental process is usually performed within some region of independent variable space called the operability region or experimentation region or region of interest.

VII. Literature Review

SuleymanNeseli et.al (1), worked to find out the effect of cutting geometry parameters such as tool nose radius, rake angle & approach angle on surface roughness values using RSM. Turning of AISI 1040 steel with Al2o3/Tic was carried out on Harrison M300 lathe. For finding optimum value of geometry parameters the quadratic model of response surface methodology was used. Tool manufacturer's catalogue was used to select the values of cutting parameters. In this study 3 factors were studied with their low-middle-upper levels. In all experiment depth of cut, speed, cutting speed, feed rate were taken as fixed values. It was found that, Tool nose radius was the most significant factor on surface roughness. Interaction between all factors had no significant effect. Optimal combination of machining parameters found were (0.4, 60,-3) for tool nose radius, approach angle & rake angle respectively.

Ashvin J. Makadia et.al(2), made efforts to find out the effect of cutting speed, feed, depth of cut & cutting geometry on the surface roughness. 81 no. of experiments were carried out with AISI 410 steel. (3^4) full factorial design of experiment was used. All the experiments were carried out on Jobbler X1 made by Ace design. In order to understand the turning process the experimental results were used to develop the models using RSM. In this work Minitab 14 software was used for computation work. To verify the accuracy of the model 3 confirmation runs were performed. The goal was to minimize the surface roughness. Results found out were, feed rate as main influencing factor followed by tool nose radius & cutting speed. Depth of cut had no significant effect on the surface roughness. Interaction between most factors had no significant effect except feed rate & tool nose radius. Optimal combination of machining parameters found were (255.75m/min, 0.1mm/rev, 0.3mm, 1.2mm) for cutting speed, feed, depth of cut respectively.

IlhanAsiltürk et.al (3), in this study Firstly cutting parameters namely, cutting speed, depth of cut & feed rate were designed using the Taguchi method. AISI 304 austentic stainless steel work piece was machined by a coated carbide insert under dry condition. The influence of cutting parameters on surface roughness is examined. RSM was used to create models for surface roughness. ANOVA was used to check the adequacy of model. Taguchi L27 array was selected, after every experiment surface roughness values were measured. In order to better understand the interaction effect of variables on roughness parameters, three-dimensional (3D) plots for the measured responses were created based on model equations. The control factors settings found for Ra was: V1 (cutting speed 50 m/min), f1 (feed rate 0.15 mm/rev), a2 (depth of cut 1.5 mm). The optimized control factors settings for Rz were: V3 (cutting speed 150 m/min), f1 (feed rate 0.15 mm/rev), a1 (depth of cut 1 mm). The results demonstrated that this optimization method was efficient and greatly reduced the machining cost and the design process. The prediction models can be applied to determine the appropriate cutting conditions, in order to achieve desired surface roughness.

Jenn-TsongHorng et al (4), worked to investigate the machinability of Hadfield steel in hard turning. The Hadfield steels have excellent wear resistance properties and are largly used in engineering applications. The cutting tool used was an uncoated Al2O3/TiC mixed ceramics. The combined effects of four machining parameters, including cutting speed, feed rate, depth of cut and tool corner radius, on the basis of two performance characteristics—flank wear (VBmax) and surface roughness (*R*a), were investigated and the centered central composite design (CCD) and the analysis of variance (ANOVA) were used. The quadratic model of RSM associated with the sequential approximation optimization (SAO) method was used to find optimum values of machining parameters. Using the SAO method of RSM, the optimal setting of machining parameters were found, cutting speed of 209.29 m/min, feed rate of 0.08mm/rev., cutting depth of 0.25mm and nose radius of tool of 0.88mm.

M.Y. Noordin et al (5), worked to find out the performance of a multilayer tungsten carbide tool using response surface methodology (RSM) when turning AISI 1045 steel. Cutting tests were performed with constant depth of cut and under dry cutting conditions. The factors investigated were cutting speed, feed and the side cutting edge angle (SCEA) of the cutting edge. The main cutting force, i.e. the tangential force and surface roughness were taken as responses to study. Cutting tests were carried out on a 9.2kW Harrison M500 lathe machine under dry cutting conditions. The turning process was studied with a standard RSM design called a central composite design (CCD). Coated carbide tools have been known to perform better than uncoated carbide tools when turning steel, hence commercially available CVD coated carbide insert was used in this study. The work piece material used had a dimension of 300mm in length and 100mm in diameter. This material is suitable for a wide variety of automotive-type applications. The cutting performance tests involved 16 trials, For each experimental trial, a new cutting edge was used. Due to the limited number of inserts available, each experimental trial was repeated twice and each surface turned was measured at three different locations. The ANOVA revealed that feed was the most significant factor influencing the response variables investigated. The SCEA2 and the feed and SCEA interaction factors provided secondary contribution to the responses investigated. Additionally, the cutting speed also provided secondary contribution to the tangential force.

L.B. Abhang& M. Hameedullah (6), carried out work by turning EN-31 steel using tungsten carbide inserts. The experiments were performed on lathe LTM20, 10 H.P. The work material dimensions were 500mm in length & 60mm in dia. Authors concentrated on three main purposes, first to explain & demonstrate a systematic procedure of Taguchi parameter design, second to find out the optimal combination of process parameters & to know effect of each parameter through ANOVA analysis, third aim was to find out effect of lubricant temperature using MQL technique on the response. Cutting parameters namely feed rate, depth of cut, and lubricant temperature were taken into consideration. L9 orthogonal array was selected and the experimental result showed that lubricant temperature & feed rate are the main parameters. It was found that decreasing lubricant temperature decreases surface roughness value as the temperature increases surface finish degrades.

HamdiAouici et.al (7),focused on the effects of cutting speed, feed rate, work piece hardness and depth of cut on surface roughness and cutting force components in the hard turning were experimentally investigated. Turning experiments were performed in dry conditions using a universal lathe type SN 40C with 6.6 kW spindle power. The work piece material was AISI H11, hot work steel which is popularly used in hot form pressing. The cutting insert was a removable type and offered eight squared working edges. The chosen CBN tool is commercially known as CBN7020 manufactured by Sandvik Company. The data required to develop the computation were collected by designing the experiments based on Box–Behnken Designs (BBDs) and by varying each numeric factor over three levels. The ANOVA results indicate interaction work piece hardness and depth of cut on tangential force were not statistically significant; however, the lower tangential force is achieved with the smaller work piece hardness and the lower depth of cut. The study showed that the feed rate and work piece hardness have significant statistical influences on the surface roughness. The best surface roughness was achieved at the lower feed rate and the highest cutting speed.

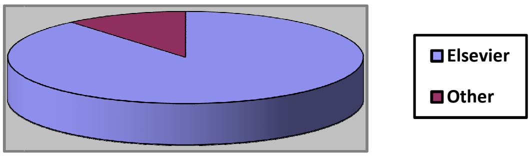
N.R. Dhar et.al (8), compares the mechanical performance of MQL to completely dry lubrication for the turning of AISI-1040 steel based on experimental measurement of cutting temperature, chip reduction coefficient, cutting forces, tool wears, surface finish, and dimensional deviation. Experiments were carried out by turning a 125mm diameter and 760mm long rod of AISI-1040 steel with rigid lathe (USA, 15hp) at different cutting velocities (Vc) and feeds (So) under both dry and MQL conditions. The ranges of the Vc and So were selected based on the tool manufacturer's catalogues and industrial practices. Depth of cut, being less significant parameter, was kept fixed. MQL delivery system has beendesigned, fabricated and used. The thin but high-velocity stream of MQL was projected along theauxiliary cutting edge of the insert, so that the coolant reaches as close to the chip–tool and the work–tool interfaces. Results showed that MQL reduced the cutting forces by about 5–15%, reduced flank wear and hence is expected to improve tool life. Surface finish and dimensional accuracy improved mainly due to reduction of wear and damage at the tool tip by the application of MQL.

M.Z.A.Yazid et.al (9), reports the results of an experimental works, where Inconel 718, a highly corrosive resistant, nickel-based super alloy, was finish-turning under high speed conditions. The main objective of this experimental work was to investigate the wear mechanism of the PVD coated TiAIN carbide tool under Dry and MQL conditions at various cutting speeds, feed rates and cutting depths. Work pieces of 157 mm in length and 103 mm in diameter were finish-turning with *COLCHESTER T4 6000* CNC Lathe using single layer PVD coated TiAIN carbide cutting tools. In machining Inconel 718 with PVD TiAlN coated carbide tool, the MQL conditions improved the tool life when compared with that of DRY condition. Employing MQL improves the tool life by 38% and 50% for MQL 50 and MQL 100 ml/h respectively. It was found that flank wear was the dominant wear that cause end of tool life.

VIII. Analysis of literature review

Techniques	*Authors*	*Tools used*	*Remarks*
Response surface methodology (RSM) & Taguchi design	SuleymanNeseli et.al (2010)	Effect of tool geometry parameters on surface roughness was determined. ANOVA is used.	Surface roughness increases with the increase in effect of approach angle & nose radius.
Full factorial D.O.E & RSM	Ashvin J. Makadia et.al. (2012)	Effect of cutting geometry & cutting parameters on surface roughness. Minitab 14 software is used.	feed rate as main influencing factor followed by tool nose radius & cutting speed. Depth of cut had no significant effect.
Taguchi D.O.E & RSM	IlhanAsiltürk et.al (2011)	Influence of cutting parameters on surface roughness is examined. ANOVA is used.	optimization method was efficient and greatly reduced the machining cost and the design process.
RSM design	Jenn-TsongHorng et al (2008)	Flank wear and surface roughness (*R*a), were investigated and the centered central composite design (CCD) and the analysis of variance (ANOVA) were used.	sequential approximation optimization (SAO) method was used to find optimum values of machining parameters.

RSM design	M.Y.Noordin et.al (2003)	The tangential force and surface roughness were investigated. central composite design (CCD) was used.	CVD coated carbide insert was used. ANOVA revealed that feed was the most significant factor
Taguchi D.O.E	L.B.Abhang et.al (2012)	Effect of cutting parameters & lubricant temperature on surface roughness were studied. ANOVA was used.	Decreasing lubricant temperature decreases surface roughness value as the temperature increases surface finish detroits.
RSM design	HamdiAouici et.al (2011)	Box–Behnken Designs (BBDs) was used. surface roughness and cutting force components were investigated. ANOVA was used.	Best surface roughness was achieved at the lower feed rate and the highest cutting speed.
Minimum Quantity Lubrication	N.R. Dhar et.al (2006)	Cutting temperature, chip reduction coefficient, cutting forces, tool wears, surface finish, and dimensional deviation were measured for comparison under MQL & dry condition	MQL reduced the cutting forces, flank wear and hence is expected to improve tool life. Surface finish and dimensional accuracy improved.
Multi level D.O.E	M.Z.A. Yazid et.al (2010)	Wear mechanism of the PVD coated TiAIN carbide tool under Dry and MQL conditions at various cutting speeds, feed rates and cutting depths were investigated.	MQL improves the tool life by 38% and 50% for MQL 50 and MQL 100 ml/h respectively. flank wear was the dominant wear that cause end of tool life.



Conclusion

The different researchers in the above literature review have put their efforts in optimizing the turning process by considering the different factors & such as cutting parameters which include cutting speed, feed, depth of cut. Some of them have considered the tool geometry parameters, different type of coated tools, minimum quantity lubrication, and different type of work material. The different factors were varied over its range in order to find out there effect on the output such as surface roughness, material removal rate, tool wear, vibrations, cutting force, type of chips, temperature etc. from these studies it was found that the Taguchi and response surface methodology techniques can help in reaching the desired outputs of the turning process.

Future Scope

The above researchers have successfully reached to the desired outputs through the experiments conducted. The parameters, experimentation techniques, analysis software's taken into consideration by these researchers can help the new researchers and students willing to carry out experimentation on the turning process.

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