International journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.1., Issue.4., 2013

REVIEW ARTICLE

ISSN:2321-7758

MULTI OBJECTIVE OPTIMIZATION OF CUTTING PARAMETERS IN TURNING OPERATION BY PCA & TAGUCHI METHOD

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Article Received: 10/02/2014 | Article Revised on:18/02/2014 | Article Accepted on:19/02/2014

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ABSTRACT

In machining operations, achieving desired surface quality features of the machined product, is really a challenging job. Because, these quality features are highly correlated and are expected to be influenced directly or indirectly by the direct effect of process parameters or their interactive effects (i.e. on process environment). However, the extents of significant influence of the process parameters 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. In the present work, Design of Experiment (DOE) with Taguchi L9 Orthogonal Array (OA) has been explored to produce 9 specimens on copper barred by straight turning operation. Collected data related to surface roughness have been utilized for optimization. Principal Component Analysis (PCA) has been applied to eliminate correlation among the responses and to evaluate independent or uncorrelated quality indices called principal components. Based on quality loss of individual principal components with respect to the ideal condition, CQL (COMBINED QUALITY LOSS) has been calculated to serve as the single objective function for optimization. Finally, Taguchi method has been adopted for searching optimal process condition to yield desired surface quality. Result of the aforesaid optimization procedure has been verified through confirmatory test. The study illustrates the detailed methodology of PCA based Taguchi method and its effectiveness for multi-response surface quality optimization in turning operation.

Keywords –Turning operation, PCA, Taguchi method

INTRODUCTION

The challenge of modern machining industries is mainly focused on the achievements of high quality in terms of work piece dimensional accuracy ,surface finish, high production rate, less wear on the cutting tool ,economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact. Surface roughness plays an important role in many areas and is factor of great importance in evaluation of machining accuracy. Turning is the process whereby a single point cutting tool removes unwanted material from the cylindrical work piece and the tool is fed parallel to the axis of rotation. It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not. In turning operation vibration is a frequent problem .Vibration in machine tool is directly affecting the surface finish of the work material in turning process

LITERATURE REVIEW

Lee et al. (2001) used computer vision techniques to inspect surface roughness of a work piece under a variation of turning operations. The surface image of the work piece was first acquired using a digital camera and then the feature of the surface image was extracted. A polynomial network using a self-organizing adaptive modeling method was applied to construct the relationships between the feature of the surface image and the actual surface roughness under a variation of turning operations for predicting surface roughness with reasonable accuracy if the image of the turned surface and turning conditions were given.

Hocheng et al. (2004) studied the surface roughness obtained from the diamond turning of a phosphor bronze lens mold with various tool nose radii, spindle speeds, feed rates and cutting depths. The surface roughness was measured in the time domain using a Form Talysurf instrument (a stylus-type surface roughness meter) and then transformed into the frequency domain using the fast Fourier transform. Based on the magnitude of the intensity, the tool geometry, low-frequency vibration and the measuring instrument are identified as the main influencing factors of the generated surface roughness.

Sahin et al. (2004) proposed a surface roughness model in the turning of AISI 1040 carbon steel was developed in terms of cutting speed, feed rate and depth of cut using response surface methodology. Machining tests were carried out using PVD-coated ceramic tools under different cutting conditions. The established equation showed that the feed rate was found to be main influencing factor on the surface roughness.

Ozel et al. (2005) utilized neural network modeling to predict surface roughness and tool flank wear over the machining time for variety of cutting conditions in finish hard turning. Regression models were also developed in order to capture process specific parameters. A set of sparse experimental data for finish turning of hardened AISI 52100 steel obtained from literature and the experimental data obtained from performed experiments in finish turning of hardened AISI H-13 steel had been utilized. The data set from measured surface roughness and tool flank wear were employed to train the neural network models. Trained neural network models were used in predicting surface roughness and tool flank wear for other cutting conditions. Predictive neural network models were found to be capable of better predictions for surface roughness and tool flank wear within the range that they had been trained.

Saparudin et al. (2006) focused on the analysis of optimum cutting conditions to get lowest surface roughness in turning SCM 440 alloy steel by Taguchi method. The results were analyzed using analysis of variance (ANOVA) method. Taguchi method had shown that the depth of cut has a significant role to play in producing lower surface roughness followed by feed. The Cutting speed has lesser role on surface roughness from the tests.

Tozu et al. (2006) optimized the machining characteristics of Inconel 718 bars using tungsten carbide and cement cutting tools based on Taguchi method, the signal-to-noise (S/N) ratio and the analysis of variance

(ANOVA). The roundness and flank wear of the conventionally machined work pieces were measured and compared & the optimal cutting parameters for turning operations were obtained.

Sardinas et al. (2006) presented a multi-objective optimization technique, based on genetic algorithms, to optimize the cutting parameters in turning processes: cutting depth,
 feed and speed. Two conflicting objectives, tool life and operation time, were simultaneously optimized. The proposed model used a micro genetic algorithm in order to obtain the non-dominated points and build the Pareto front graph. An application sample was developed and its results were analyzed for several different production conditions.

Daniel Kirby (2006) discussed an investigation into the use of Taguchi Parameter Design for optimizing surface roughness generated by a CNC turning operation. Controlled factors included spindle speed, feed rate, and depth of cut; and the noise factor was slightly damaged jaws. The noise factor was included to increase the robustness and applicability of this study. The study produced a verified combination of controlled factors and a predictive equation for determining surface roughness with a given set of parameters.

Doniavi et al. (2007) attempted to develop an imperial model with the use of response surface methodology, a widely adopted tool for the quality engineering field. The model showed that the feed rate was found to be main influencing factor on the surface roughness. The results for analysis of variance showed that the first order term of depth of cut was not significant. But the first order term of cutting speed and feed rate were significant.

Ozel et al. (2007) investigated surface finishing and tool flank wear in finish turning of AISI D2 steels (60 HRC) using ceramic wiper (multi-radii) design inserts. Multiple linear regression models and neural network models were developed for predicting surface roughness and tool flank wear. In neural network modeling, measured forces, power and specific forces were utilized in training algorithm.

Gopalsamy et al. (2009) applied Taguchi method to find optimum process parameters for end milling while hard machining of hardened steel. A L16 array, signal-to-noise ratio and analysis of variance (ANOVA) were applied to study performance characteristics of machining parameters (cutting speed, feed, depth of cut and width of cut) with consideration of surface finish and tool life. Results obtained by Taguchi method match closely with ANOVA and cutting speed is most influencing parameter.

Suhail et al. (2010) presented experimental study to optimize the cutting parameters using two performance measures, work piece surface temperature and surface roughness. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The experimental results showed that the work piece surface temperature can be sensed and used effectively as an indicator to control the cutting performance and improves the optimization process. Thus, it is possible to increase machine utilization and decrease production cost in an automated manufacturing environment.

EXPERIMENTATION

The present study has been done through the following plan of experiment.

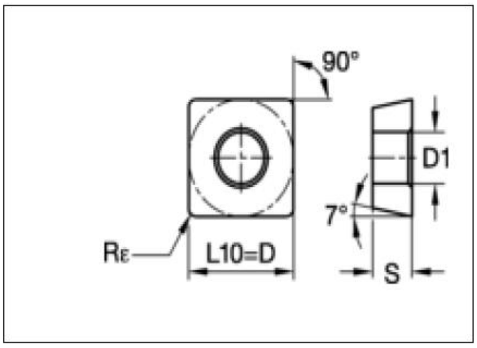
a) Checking and preparing the Centre Lathe ready for performing the machining operation.

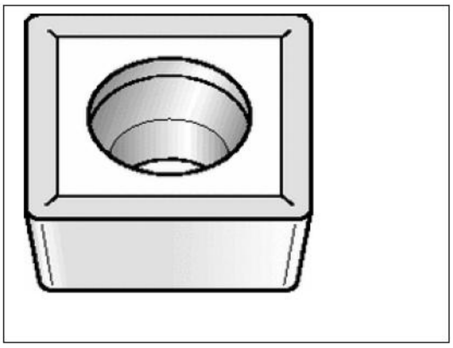
b) Cutting ***Copper*** bars by power saw and performing initial turning operation in Lathe to get desired dimension (of diameter 32mm and length 40mm) of the work pieces.

c) Performing straight turning operation on specimens in various cutting environments involving various combinations of process control parameters like spindle speed, feed and depth of cut.

d) Measuring surface roughness and surface profile with the help of a portable stylus-type *Talysurf*(Taylor Hobson, Surtronic 3+, UK)

CUTTING TOOL is carbide insert tool **SCMT 09T308 TN5120** (ISO catalog number)



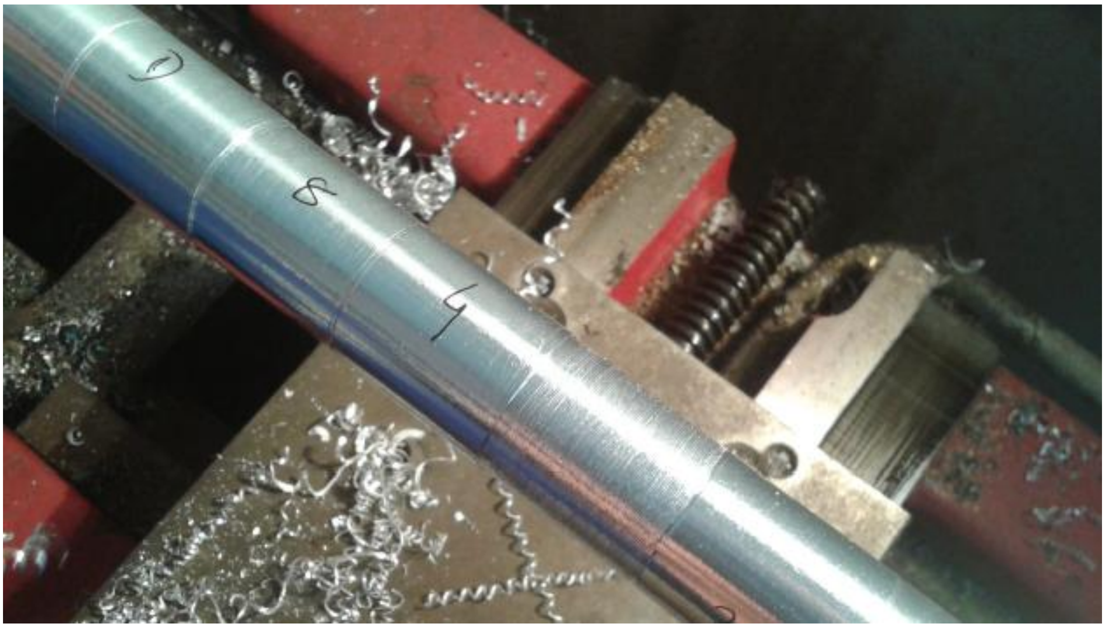


Specification of tool –

ISO Catalog number	Tip	Dimension(mm)				
		D	L10	S	Re	D1
SCMT 09t308 TN5120	Carbide	9,53	9,53	3,97	0,8	4,40

The selected work piece material for this experiment is commercially available 6061 grade Aluminum**.** The composition of the 6061 Aluminum work piece is

Aluminum	Al	Si	Fe	Cu	Mn	Mg	Ti	Zn	Cr
6061 (% by weight)	95.86-98.56	0.4-0.8	0.7	0.15-0.4	0.15	0.8-1.2	0.15	0.25	0.04-0.35



Factors	Symbol and unit	Code	Level of factors		
			1	2	3
Cutting speed	N (m/min)	A	11.86	18.65	30.52
Depth of cut	d (mm)	B	0.5	0.75	1
Feed Rate	f (mm/rev)	C	0.044	0.089	0.178

TAGUCHI METHOD

Taguchi methods are statistical methods developed to improve the quality of manufactured goods, and more recently also applied to engineering, biotechnology, marketing and advertising.

Taguchi's work includes three principal contributions to statistics:

- A specific loss function , Taguchi loss function;
- The philosophy of off-line quality control; and
- Innovations in the design of experiments.

Taguchi philosophy was mostly used for engineering optimization processes. It should be carried in three step approach i.e. system design, parameter design, tolerance design. In system design, scientific and engineering principles and experience are used to create a prototype of the product that will meet functional requirements. Parameter design is to optimize the settings of process parameter values for improving performance characteristics. And in tolerance design, tolerances are set around the target a value of the control parameter identified in the parameter design phase and is done only when the performance variation achieved by the settings identified in the parameter design stage is not acceptable. [4]Taguchi also defined a performance measure known as the signal to noise ratio (S/N) and aims to maximize it by properly selecting the parameter levels.

Spindle speed: $A = \frac{N - N_0}{\Delta N}$
(1)

Feed rate: $B = \frac{f - f_0}{\Delta f}$
(2)

Depth of cut: $C = \frac{d \quad d_0}{\Delta d}$
(3)

CONCLUSIONS

The foregoing study deals with optimization of multiple surface roughness characteristics of Copper obtained in straight turning operation (using HSS tool) in search of an optimal parametric combination (favorable process environment) capable of producing desired surface quality. The study proposes an integrated optimization approach using Principal Component Analysis (PCA) in combination with Taguchi's robust design methodology. The following conclusions may be drawn from the results of the experiments and analysis of the experimental data in connection with correlated multi-response optimization in cylindrical grinding.

1) Application of PCA has been recommended to eliminate response correlation by converting correlated responses into uncorrelated quality indices called principal components which have been as treated as independent response variables for optimization.

2) Based on accountability proportion (AP); treated as individual response weights, the adopted method can combine individual principal components into a single multi-response performance index MPI to be taken under consideration for optimization. This is really helpful in situations where large number of responses have to be optimized simultaneously.

3) Concept of Combined Quality Loss (CQL) imposes meaningful physical interpretation to the objective function. Moreover, the value of CQL being always positive thus facilitating computation of S/N Ratio required in Taguchi's optimization approach.

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