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A Review on Optimization of Cutting Parameters in Machining Using Taguchi Method

Umashankar M. Rawat*
M. E. (Mech) Student

Prof. V. V. Potdar
Assistant Professor & Vice Principal

Department of Mechanical Engineering,
A.G. Patil Institute of Technology, Solapur University, Solapur

Abstract— In this paper an attempt is made to review the literature on optimisation of cutting parameters in machining using Taguchi method. The settings of machining parameters were determined by using Taguchi's experimental design method. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the analysis of variance (ANOVA) are employed to find the optimal levels and to analyse the effect of the cutting parameter.

Keywords—Taguchi method, Signal to noise ratio, ANOVA, optimization, cutting parameters

I. INTRODUCTION

The need for selecting and implementing optimal machining conditions and the most suitable cutting tool has been felt over the last few decades. In machining, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the workpiece material, tool material, tool size, and more. Machining parameters that can affect the processes are: a) Cutting speed - The speed of the work piece surface relative to the edge of the cutting tool during a cut, The cutting speed is measured in meter per minute, b) Feed rate - The speed of the cutting tool's movement relative to the work piece as the tool makes a cut. The feed rate is measured in mm per revolution. c) Depth of cut - The depth of the tool along the radius of the work piece as it makes a cut, as in a turning or boring operation. A large depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is often machined in several steps as the tool moves over at the depth of cut. The Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization and this is a powerful tool for the design of high quality systems.

1.1 Taguchi Method

Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. This is an engineering methodology for obtaining product and process condition, which are minimally sensitive to the various causes of variation, and which produce high-quality products with low development and manufacturing costs. Signal to noise ratio and orthogonal array are two major tools used in robust design. The S/N ratio characteristics can be divided into three categories when the characteristic is continuous a) Nominal is the best b) Smaller the better c) Larger is better characteristics. The influence of each control factor can be more clearly presented with response graphs. Optimal cutting conditions of control factors can be very easily determined from S/N response graphs, too. Parameters design is the key step in Taguchi method to achieve reliable results without increasing the experimental costs.

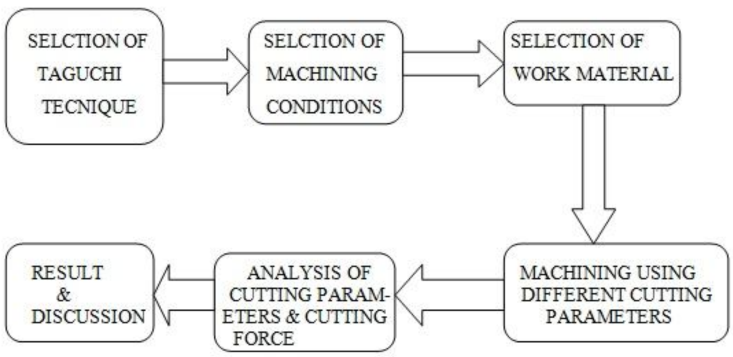

Fig. 1 Flow Chart of Taguchi Method

1.2 Surface Roughness Parameters

Surface roughness most commonly refers to the variations in the height of the surface relative to a reference plane. It is measured either along a single line profile or along a set of parallel line profiles (surface maps). It is usually characterized by one of the two statistical height descriptors advocated by the American National Standards Institute (ANSI) and the International Standardization Organization (ISO). These are (1) Ra, CLA (centre-line average), or AA (arithmetic average) and (2) the standard deviation or variance (σ), Rq or root mean square (RMS). Two other statistical height descriptors are skewness (Sk) and kurtosis (K); these are rarely used. Another measure of surface roughness is an extreme-value height descriptor R_t (or R_y, R_{max}, or maximum peak-to-valley height or simply P–V distance).

Four other extreme-value height descriptors in limited use, are: R_p(maximum peak height, maximum peak-to-mean height or simply P–M distance), R_v(maximum valley depth or mean-to-lowest valley height), R_z (average peak-to-valley height), and R_{pm} (average peak-to-mean height). The height parameters R_a and R_t are most commonly specified for machine components.

For the complete characterization of a profile or a surface, none of the parameters discussed earlier are sufficient. These parameters are seen to be primarily concerned with the relative departure of the profile in the vertical direction only; they do not provide any information about the slopes, shapes, and sizes of the asperities or about the frequency and regularity of their occurrence. There are two methods used for measuring surface roughness. 1. Surface inspection by comparison method e.g. tough inspection, visual inspection, scratch inspection, microscopic inspection, visual inspection, surface photography, reflected light intensity etc. and 2. Direct instrument method e.g. light section method, Forster surface roughness tester, Profilograph, Tomlinson surface roughness meter, Telysurf etc.

1.3 Material Removal Rate

Material Removal rate (MRR) in turning is the material/metal that is removed per unit time in mm^3/sec. For each revolution of the work piece, a ring shaped layer of material is removed.

Material Removal Rate (MRR) = $v \times f \times d$ mm^3/sec

Where,
v = cutting speed in mm/sec
d = depth of cut in mm
f = feed in mm/rev

A process which removes metal at faster rate may not be the economical process, since the power consumed and cost factor taken into account. Due to this, to compare two processes, the amount of metal removed per unit of power consumed is determined. This is called "specific metal removal rate" and is expressed as, mm^3/W/min, if the power consumption is measured in watts.

II. LITERATURE REVIEW

An Nithyanandhan T. et al. [1] have investigated the effects of process parameters on surface finish and material removal rate (MRR) to obtain the optimal setting of 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 stainless steel work pieces are turned on conventional lathe by using tungsten carbide tool. 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.

D. Philip Selvaraj et al. [2] have studied the Taguchi optimization method was applied to find the optimal process parameters, which minimizes the surface roughness during the dry turning of AISI 304 Austenitic Stainless Steel. A Taguchi orthogonal array, the signal to noise (S/N) ratio and the analysis of variance (ANOVA) were used for the optimization of cutting parameters. ANOVA results shows that feed rate, cutting speed and depth of cut affects the surface roughness by 51.84%, 41.99% and 1.66% respectively. A confirmation experiment was also conducted and verified the effectiveness of the Taguchi optimization method.

Samruddhi Rao et al. [3] presented a detailed overview of Taguchi Method in terms of its evolution, concept, steps involved and its interdisciplinary applications. It could be concluded that this method with its perfect amalgamation of statistical and quality control techniques was one of the effective and effi-cient methods of its kind to highlight the benefits of designing quality into products upstream rather than inspecting out bad products downstream. It offers a quantitative solution to iden-tify design factors to optimize quality and reduce cost. Also the application of this method is not confined to a particular domain but also to other fields like product and service sec-tors. It thus is a powerful method as compared to the other intuitive and more cumbersome methods encompassing a large number of fields in terms of application.

Krishnakant et al. [4] analyzed that an optimization of turning process by the effects of machining parameters applying Taguchi methods to improve the quality of manufactured goods, and engineering development of designs for studying variation. EN24 steel is used as the work piece material for carrying out the experimentation to optimize the Material Removal Rate.

Quazi T Z et al. [5] have made an attempt to review the literature on optimizing machining parameters in turning processes by Taguchi method. The settings of turning parameters were determined by using Taguchi's experimental design method. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the analysis of variance (ANOVA) are employed to find the optimal levels and to analyze the effect of the turning parameters.

Atul Kulkarni et al. [6] used Taguchi method to optimize cutting parameters during dry turning of AISI304 austenitic steel with AlTiCrN coated tool.

W. H. Yang et al. [7] have discussed an application of the Taguchi method for optimizing the cutting parameters in turning operations. The Taguchi method provides a systematic and efficient methodology for the design optimization of the cutting parameters with far less effect than would be required for most optimization techniques. It has been shown that tool life and surface roughness can be improved significantly for turning oerations.

M. Adinarayana et al. [8] have presented in paper the multi response optimization of turning parameters for Turning on AISI 4340 Alloy Steel. Experiments are designed and conducted based on Taguchi's L27 Orthogonal array design. This paper discusses an investigation into the use of Taguchi parameter Design and Regression analysis to predict and optimize the Surface Roughness, Metal Removal Rate and Power Consumption in turning operations using CVD Cutting Tool. The Analysis of Variance (ANOVA) is employed to analyze the influence of Process Parameters during Turning. This paper also remarks the advantages of multi-objective optimization approach over the single-objective one. The useful results have been obtained by this research for other similar type of studies and can be helpful for further research works on the Tool life and Vibration of tools etc.

Vikas B. Magdum et al. [9] This study used for optimization and evaluation of machining parameters for turning on EN8 steel on Lathe machine.

This study investigates the use of tool materials and process parameters for machining forces for selected parameter range and estimation of optimum performance characteristics. Develop a methodology for optimization of cutting forces and machining parameters.

Sijo M. T. et al. [10] analyzed that for solving machining optimization problems, various conventional techniques had been used so far, but they are not robust and have problems when applied to the turning process, which involves a number of variables and constraints. To overcome the above problems, Taguchi method is used in this work. Since Taguchi method is experimental method it is realistic in nature. According to this study the prime factor affecting surface finish is feed rate.

Elso Kuljanic et al. [11] analyzed that assessment of the machinability rating of an engineering material is a fundamental activity to increase the productivity and decrease the machining cost. It is also necessary to optimize materials selection in design of mechanical parts. However, it is not a simple task to summarize chemical, mechanical and tribological properties in simple statistical parameters and therefore a more reliable solution is to make machining tests. This paper deals with machinability index, short machinability testing, conventional machinability testing, effect of tool life data analysis on tool life equation, ISO standards for tool life testing and computerized machinability data system developed according to the Integrated Machinability Testing Concept.

Kompan Chomsamutr et al. [12] objective of research is to compare the cutting parameters of turning operation the work pieces of medium carbon steel (AISI 1045) by finding the longest tool life by Taguchi methods and Response Surface Methodology: RSM. This research is to test the collecting data by Taguchi method. The analyses of the impact among the factors are the depth of cut, cutting speed and feed rate. This research found that the most suitable response value; and tool life methods give the same suitable values, i.e. feed rate at 0.10 mm/rev, cutting speed at 150 m/min, and depth of cut at 0.5 mm, which is the value of longest tool life at 670.170 min, while the average error is by RSM at the percentage of 0.07 as relative to the testing value.

Sunil Kumar Sharma et al. [13] have analyzed that Taguchi optimization technique pair with grey relational analysis has been adopted for evaluating parametric complex to carry out acceptable surface roughness lower is better, material removal rate higher is better of the AISI 8620 steel during turning on a CNC Lathe Trainer. After identify the optimal process parameters setting for turning operation, ANOVA is also applied for finding the most significant factor during turning operation. In this study it is concluded that the feed rate is the most significant factor for the surface roughness and material removal rate together, as the P-value is less than 0.05. Cutting speed and depth of cut is found to be insignificant from the ANOVA study.

Anand S. Shivade et al. [14] have analyzed that the application of single characteristics optimization approaches for turning processes. These approaches utilized in many fields to optimize the single and multi performance characteristics efficiently. Turning is one of the most basic machining processes in traditional manufacturing process.

TABLE I

SUMMARY OF REVIEW PAPERS

Journal No.	Year	Author's Name	Material	Input Parameter	Output Parameter	Most Significant	
1	2014	Nithyanandhan et al	AISI 304	Speed, Feed, DOC	Cutting force, Tool Wear	Speed	DOC
2	2010	D. Philip Selvaraj et al	AISI 304	Speed, Feed, DOC	Surface Roughness	Speed	DOC
3	2013	Samrudhi Rao et al	Overview of Taguchi method, concept and application				
4	2012	Krishnakant et al	EN24 steel	Speed, Feed, DOC	MRR	Speed	Feed
5	2013	Quazi T. Z. et al	EN24 steel	Speed, Feed, DOC	Surface Roughness, Tool wear, MRR	CNMG coated insert	CNMG uncoated insert
6	2013	Atul Kulkarni et al	SS304	Speed, Feed, Coating thickness of cutting tool	Cutting force, Average flank wear	Speed	Feed
7	1997	W. H. Yang	Rotating cylindrical workpiece	Speed, Feed, DOC	Tool life, Surface roughness	DOC	Feed
8	2014	M. Adinarayana et al	AISI 4340 medium alloy steel	Speed, Feed, DOC	Surface roughness, MRR in mm^3/min, Power consumed in KWConsumed	Feed	DOC
9	2013	Vikas Magdum et al	EN8 steel	Tool shape & material, Speed, Feed, DOC	Cutting force, Thrust force (Ft), Feed Force (Ff)	Thrust force	Feed force
10	2011	Sijo M. T. Et al	Mild steel	Speed, Feed, DOC, Nose Radius, Hardness (BHN)	Surface roughness	Speed, feed	Nose Radius
11	2011	Elso Kuljanic et al	Titanium alloys	Speed, Cutting time	Machinability, Tool Wear	Tool life	Machinabi lity
12	2012	Kompan Chomsamutr et al	AISI 1045	Speed, Feed, DOC	Tool life	Feed	DOC
13	2014	Sunil Kumar Sharma	AISI 8620	Speed, Feed, DOC	Surface roughness	Speed	DOC
14	2014	Anand S. Shivade et al	EN8	Speed, DOC	Surface roughness, Tool tip temp	Speed	DOC

III. CONCLUSION

From the above literature review we observed that most of the researcher have taken input parameters (controllable factors): cutting speed, feed rate and depth of cut and only few researcher taken input parameter: nose radius, coating thickness of cutting tool, hardness, environment and output parameters: Cutting force, surface roughness, material removal rate (MRR), tool wear, average flank wear, power consumption and machinability. We also found that for surface roughness the most significant parameters are speed, feed and nose radius and least significant parameter is DOC and for MRR the most significant parameters are DOC, feed and speed and least significant parameter is nose radius.

IV. FUTURE WORK

Material like low carbon austenitic stainless steel are used in industries for the different applications. Very low carbon content in austenitic stainless steel AISI 904L make machining environment gummy and results in rapid tool wear. Chip removal (continuous chip) is difficult in machining. Poor machinability and high material cost of AISI 904L is also one of the reason for less research work. High contents of chromium, nickel, molybdenum and copper, AISI 904L has good resistance to general corrosion particularly in sulphuric and phosphoric acid conditions. Therefore studies on machinability must be carried out by making use of the proven experimental design procedure. No work is done on quality parameters like MRR, surface roughness for facing, power consumption etc. Taguchi approach help to determine optimal parameter condition for required output with help of lesser number of experiment (with help Orthogonal Array) & ANOVA approach help to determine which parameters is most significant.

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