Multi-Objective Optimization of Machining Parameters by using Response Surface Methodology EN-31 Alloy Steel Metal

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Abstract - *In this paper deals with the literature review of various factors that affect the turning operation. Traditionally, Turning is done manually on lathe machine which require constant supervision of operator on lathe machine, or on automated lathe machine which does not require continuous supervision. Such type of automation is called computer numerical control or CNC. In this paper various process parameters like speed, depth of cut, feed, nose radius, etc. are studied. This study will help us in understanding, which parameters is significant parameter for Surface Roughness, Material Removal Rate, Feed Rate, Machining Time, Tangential Force, Tool Life, etc. After careful study of a spread of research papers on this subject , it had been decided that several input also because the output parameters would be considered including feed, depth of cut and cutting speed were taken because the input parameters whereas Material Removal Rate (MRR) and surface finish were taken because the output parameters. From the results of the research papers, it had been concluded that feed, depth of cut and cutting speed might be chosen as input parameters whereas MRR and surface finish would be the output parameters.*

The response model is verified based on the evaluation capability. Later, multi-objective optimization using the response surface methodology has been used to reduce the Machining Time and Maximize Material Remover Rate, resulting in a total desirability of 0.9931. The optimal values of Machining Time and Maximize Material Remover Rate are found to be 10.18 Second, 620 Gm. / Sec, respectively. To validate the results, confirmation tests are performed using optimal cutting criteria. This showed a 7.142 and 2.857 % error for Machining Time and Maximize Material Remover Rate

Key Words: Taguchi method, S/N ratio, RSM, Optimization, Orthogonal array, ANNOVA.

1. INTRODUCTION

Turning is one in every of the foremost unremarkably used metal removal operations in business due to its ability to get rid of material quicker giving fairly sensible surface quality. It's utilized in a range of producing industries together with region and automatic sectors. Throughout turning method we tend to expect highest metal removal rate so as to attain highest production at reduced time and value. Metals from the outer edge of a cylindrical l work piece square measure removed and also the volume of metal removed per unit time is thought as metal removal rate or MRR. A turning machine or shaper, work piece, fixture, and cutter square measure needed throughout the turning operation.

The work piece may be a piece of re-shaped metal that's secured to the fixture that it is hooked up to the turning machine, and allowed to rotate at high speeds. The cutter is usually a single-point cutter that's additionally secured within the machine. The cutter feeds into the rotating work piece and cuts away material within the kind of little chips to form the will form.

It is also necessary to optimize the input process parameters in order to improve the productivity, reduce operational cost and quality of the machined component. This paper also estimates the contribution and significance of process parameters via Analysis of Variance (ANOVA) technique. This paper deals with the optimization of the machining parameters by using Taguchi's robust optimization technique and to develop prediction model to select the best combination of input parameters towards maximum material removal rate for EN-31 materials. Taguchi's L9 orthogonal array has been designed with three parameters in three factors. The S/N magnitude relation is been calculated to structure the analysis of variance table and study the performance characteristics in turning method. ANOVA analysis provides the contribution proportion of each method parameter. Notation of orthogonal array is La wherever "L" is symbol for orthogonal array, "a" stands for the number of experiments required for this array. Taguchi methods (For the data analysis, Statistical Techniques of ANOVA was used) are performed find out significant parameters. it was concluded that feed, depth of cut and cutting speed could be chosen as input parameters whereas MRR and machining time would be the output parameters.

The major shaping machine operations embrace turning, facing, threading, and boring. However, with attachments, or any other acceptable means of improvisation, many other operations can be possible with lathe machines. These operations primarily involve surface generation with single purpose cutting tools.

The quality of the generated surfaces is a crucial considers industrial production or manufacture of machined components. It is a function of the machining condition, and cutting tool and work-piece material and geometry. Turning method, which is of interest in this work, involves externally cylindrical surface generation.

1.1 OVERVIEW OF MACHINING PROCESSES

Metals are formed into completely different usable forms through numerous processes during which no chip formation takes place. In these processes, the metal is formed under the action of heat, pressure or each. This class includes operations like shaping, drawing, spinning, rolling, extruding etc. A few of the important machining processes falling in this category are turning, milling, drilling, shaping, planning, broaching etc. Turning is that the most generally used among all the cutting processes. The increasing demands for turning operations is attaining new dimensions at the present, in which the growing competition needs all the efforts to be directed towards the economical manufacture of machined parts.

2. REVIEWS OF RELATED LITERATURE

Dileep Kumar C., et al (2014) [4] focused on an experimental study to find the effects of cutting parameters on surface finish and optimize them for better surface finish and high Material Removal Rate (MRR) during turning of Ti-6Al-4V. Uncoated WC/Co inserts are used for the machining purpose. A combined Taguchi method and Grey Relational Analysis (GRA) is used for the optimization. Analysis of Variance (ANOVA) is employed to find out contribution of each parameter. Four parameters are chosen as process variables: cutting speed, feed, depth of cut and nose radius each at three levels. The experiment plan is designed using Taguchi's L9 Orthogonal Array (OA). The results show that feed rate and nose radius are the most important parameters that affect the surface finish. A model is also developed separately for both surface finish and MRR using multiple regression analysis.

Basim A. K. et al (2015) [6] have experimented to develop a predictive model for surface roughness and temperature in turning operation of AISI 1020 mild steel using cemented carbide in a dry condition using the Response Surface Method (RSM). In this work,the input cutting parameters are cutting speed, feed rate and depth of cut. From the experiment it is found that Feed rate is the most significant factor on surface roughness.

Mohan S., Dharmpal D., et al (2010) [12] have investigated the robust design technique to minimize the variance of the response and orthogonal arrays. Experiments are designed and conducted based on Taguchi's L9 Orthogonal array design. This study discusses the use of Taguchi Parameter Design for optimizing surface roughness generated by a CNC turning operation.

J.B.Shaikh, J.S.Sidhu, et al (2014) [14] have determined the influence of lubricant on surface roughness and material removal rate (MRR) by using CNC LATHE Machine with AISI D2 steel as a work material and TiAIN coated carbide tool as a tool material. Different lubricant used on this experiment are Cotton seed oil, Servo cut and soya bean oil and machining parameters are cutting speed, feed rate and depth of cut. Experiments are designed and conducted based on Taguchi's L9 Orthogonal array design. After the Analysis of Variance was made, it is found that feed rate, Cotton seed oil, Servo cut and soya bean oil has got the greater influence on surface roughness.

M. Gupta, et al (2015) [15] they investigated the machinability of unidirectional glass fiber reinforced plastics (UD-GFRP) composite while carrying out turning operation. The parameters used to investigate their effect on output responses are tool nose radius, tool rake angle, feed rate, cutting speed, cutting environment (dry, wet and cooled) and depth of cut. Experiment are designed and conducted based on Taguchi's L18 Orthogonal array design.

S. A. Rizvi, et al (2015) [16] have analyzed that an effort was made to optimize the cutting parameters to achieve better surface finish and to identify the most effective parameter for cost evolution during turning by using CNC LATHE MACHINE with IS 2062 steel rods (35 mm diameter) as a work material and Chemical Vapour Deposition (CVD) coated carbide inserts as a tool material. In this work, the input parameters are cutting speed, Feed Rate and Depth of cut.

S. Sahu, B.B.Choudhury(2015) [17] have analyzed that the performance of multi-layer TiN coated tool in machining of hardened steel (AISI 4340 steel) as a work material under high speed turning uncoated tool use. In this work, the input parameters are cutting speed, Feed Rate and Depth of cut. Experiment are designed and conducted based on Taguchi's L16 Orthogonal Array design. From the Taguchi analysis it has been found that the feed is playing as a main parameter for reducing surface roughness, whereas depth of cut is having significant effect on the surface roughness.

T. Rajasekaran, K. Palanikumar, et al (2013) [19] during this work, the input parameter area unit cutting speed, feed rate and depth of cut in turning by victimisation typical shaper (MakeNAGMATI, INDIA). Experiment are designed and conducted based on Taguchi's L9 Orthogonal Array design. From the Taguchi analysis it has been found that primarily feed rate and secondarily cutting speed has got the greater influence on surface roughness.

Yusuf S., et al (2005) [20] have determined surface roughness model response surface methodology (RSM) with low-carbon steel as a piece material and TiN coated inorganic compound as a tool material. In this work, cutting parameters area unit cutting speed, feed rate and depth of cut from the experiment it's

Ilhan A., et al (2011) [21] have investigate the effect of cutting speed, feed rate and depth of cut using AISI 4140 (51 HRC) steel as a work material and Al_2O_3 and TiC coated carbide as a tool material. Experiment are designed and conducted based on Taguchi's L9 Orthogonal Array design. Through the experiment it is found that Feed rate is the most significant factor on surface roughness.

Satyanarayana K., et al (2015) [22] have determined that effect of process parameters on performance characteristics in finish hard turning of MDN350 steel using cemented carbide tool. In this work, the input cutting parameters are cutting speed, feed rate and depth of cut. Experiment are designed and conducted based on Taguchi's L9 Orthogonal Array design. From the experiment it is found that Feed and Cutting speed are the most significant factor on surface roughness and Cutting Force respectively.

Ashvin J. M., et al (2013) [23] have investigated the effect of turning parameters such as cutting speed, feed rate, tool nose radius and depth of cut on surface roughness with AISI 410 steel as a work material and ceramic as a tool material using Response Surface Methodology (RSM).In this study Feed rate is the most significant factor on surface roughness.

2.1 CONCLUSION OF RESEARCH REVIEW

The above literature review clearly shows that most of the research has taken the speed of the input parameters, feed and depth of cut, while some have explored its effect on performance parameters like MRR, surface roughness, cutting nose, Radius, smooth ness etc. Forces, tool wear and tool life.

Surface roughness: **-** The most important factor is the depth of feed and cut followed by speed. Also the lubricant and the radius of the nose have a significant effect in achieving a better effect

Rate of material removal: important factor after duplicate speed of cut and feed.

Tool wear: - The depth of feed and cut is the major factor after speed.

The feed force: - The depth of feed and cut is the important factor after speed and tool material.

The thrust force: **-** Feed and cut off depth is the major factor followed by speed and equipment content.

Tangential force: - The depth of cut and feed is the important factor after the speed.

Factor tool life: - Speed and feed are important factors followed by the depth of cut.

Nowadays the customer demands the best quality product. The above factors must be considered in order to achieve such demands.

3. Response surface methodology

Optimizing the cutting conditions has become a field of interest in recent years, with the arrival of several soft tools techniques, which reduced the trial and error methods, wastage of materials and more importantly they are time saving techniques. In this study, we tried to optimize the cutting conditions using Response Surface Methodology (RSM) using Minitab 17.0. Response Surface Methodology (RSM) may be a combination of mathematical theory and applied math techniques and helpful for modeling and analysing issues within which a response of the output is influenced by many parameters and also the objective is to optimize this response. RSM was introduced by Box and Wilson in 1951 and later it was popularized by Montgomery. As per the introduce of the thought, response surface methodology will be outlined as associate degree empirical applied math technique utilized for multiple correlation analysis by victimisation quantitative information obtained from properly designed experiments to solve multivariate equations simultaneously [9].

In modern day technology, it is very essential to optimize the process parameters to reach the higher efficiency or a greater success rate. In this study, an attempt has been done to minimize both surface roughness and flank wear by performing multi-objective optimization of cutting parameters using RSM.The RSM optimization has been carried out using MINITAB 17.0. The regression model with high R2 value has been considered for carrying out the RSM optimization. It has been observed that the full quadratic model gives the higher R2 value for the given input and the output variables. The RSM optimization has been carried tool inserts data. The plot obtained for RSM optimization for MRR and MT are shown in Figure 5(a) and 5(b).

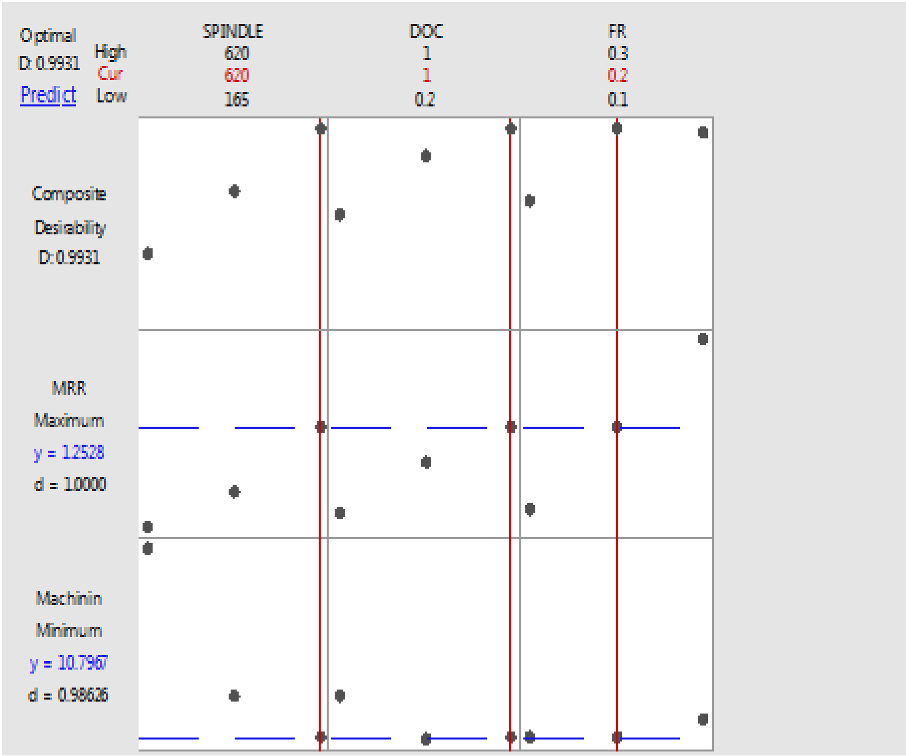

Fig. 3.1 Response optimization plot

D indicates the objective function of total desirability and r shows the response significance with other responses. If value of D is higher, it indicates the finest function and high desirability attaining the optimum values of response parameters [6,]. In this research, multi-objective optimization is performed using RSM for optimizing input parameters with respect to Material Removal Rate and Machining Time. The constraints used through the optimization process are summarized in Table 3.1 during optimization; equal weights are distributed among both responses (Ra, h). Figure 10 shows the composite desirability of 0.9931 for optimization of responses which indicates that the solution is acceptable. Optimal process parameters obtained are Material Removal Rate 1.2 Gm. /Sec. and Machining Time 10.8 Second.

Table 3.1 Table: Result of RSM Optimization

Tool Insert	Optimization Condition				
Cemented Carbide	Material Removal Rate	Machining Time Second	Cutting Speed Gm./Sec.	Feed Rate	Depth of Cut
	1.2	10.8	620	0.2	1

The optimization was carried through RSM optimization, in MINITAB 17.0. But to check its credentials, it is necessary to perform a validation experiment. Since the turning has been done using a CNC machine, the exact values of cutting conditions with decimal points can be set. The Table 3.2 shows the values of validation experiment for the optimized cutting conditions.

Table 3.2: Result of validation experiment

Tool Insert	Cutting Condition				
Cemented Carbide	Material Removal Rate	Machining Time	Cutting Speed	Feed Rate	Depth of Cut
	1.12	10.5	620	0.2	1

3.1 Validation of models:

Two fresh experiments are conducted for confirmation of models Eqs. (3) And (4), with achieved optimal values of cutting parameters. The average of measured values for Material Removal Rate and Machining Time are tabulated in Table 3.1 the accuracy of the models is analyzed on the basis percentage error. These errors are found to be 7.142 and 2.857% for Material Removal Rate and Machining Time respectively. It is possibly due to some vibrations during machining which affects the measurement techniques. Since the error is less than 10%, it is evidently proved that there is a good agreement between experimental and predicted values [41].It can be seen that the percentage error between RSM optimized value and the values from validation experiments, is little low.

Table 3.1: Comparison of optimized and validated values

Parameters	Tool insert	RSM Optimization	Measured Value	% Error
Material Removal Rate		1.2	1.12	7.142
Machining Time		10.8	10.5	2.857

CONCLUSION:

This paper has presented an application of parameter design of the taguchi method in the optimization of turning operations in centre lathe machine. The following conclusions will be drawn supported the experimental results of this study:

1. Taguchi's robust orthogonal array design method is suitable to analyze the machining time (metal cutting) as well as material removal rate problem.
2. It is additionally found that the various constant quantity style supported the Taguchi methodology provides a straight forward, systematic and efficient methodology for the optimization of the machining parameters.
3. From the above graph, the optimum values for the Machining Time are (a): Spindle Speed (RPM) (b): Depth of Cut (mm) (c): Feed Rate (mm/rev), .The grater S/N ratio values are considered for the smaller the- better criteria. Higher S/N ratio value gives the better result for both minimizing and maximizing response so always higher S/N ratio value are taken

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