Multi-objective Optimization of CNC Turning Process Parameter's for AISI 1040 Alloy Steel Using Taguchi Based Approach: A Literature Review

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Abstract—**This paper shows the literature survey on optimization of various turning process parameters such as speed, feed, doc, cutting condition etc to optimize the various output parameters such as surface roughness, MRRetc and suggest the multi-objective optimization technique for optimizing input parameters of AISI 1040 alloy steel by using taguchi based approach.**

***Keywords*— Taguchi Method, MRR, Cutting Condition, Nose radius.**

I. INTRODUCTION

The challenge of modern machining industries is mainly focused on the achievement of high quality, in term of work dimensional accuracy, surface finish. surface texture is concerned with the geometric irregularities. the quality of a surface is significantly important factor in estimating the productivity of machine tool and machined parts. the surface roughness of machined parts is a significant effects on some functional attributes of parts, such as, contact causing surface friction, wearing, light reflection, ability of distributing and also holding a lubricant, load bearing capacity, coating and resisting fatigue. in manufacturing industries, manufacturers attentive on the quality and productivity of the product. there are many factors which affect the surface roughness and material removal rate (mrr) i.e. cutting conditions, tool variables and work piece variables. cutting conditions include speed, feed and depth of cut and also tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. and work piece variable include hardness of material and mechanical properties. it is very difficult to take all the parameters that control the surface roughness and material removal rate for a particular process. In a turning operation, it is very difficult to select the cutting parameters to achieve the high surface finish and material removalrate.Thereforemulti-objective optimization is one of the technique which helps to optimize the various input parameters to achieve the desired output.

II. LITERATURE SURVEY

1.**Quazi T Z, *etal*[1]**,In this paper an attempt is made 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.

2.**A.V.N.L Sharma, *etal* [2]**,This paper discusses an investigation into the use of Taguchi parameter Design and Regression analysis to predict and optimize the surface roughness and metal removal rate in turning operations using CVD cutting tool.

3.**KAdarsh Kumar *etal* [3],**The purpose of this research paper is focused on the analysis of optimum cutting conditions to get lowest surface roughness in facing by regression analysis. This present paper presents an experimental study to investigate the effects of cutting parameters like spindle speed, feed and depth of cut on surface finish on EN-8. A multiple regression analysis (RA) using analysis of variance is conducted to determine the performance of experimental measurements and to it shows the effect of cutting parameters on the surface roughness. Multiple regression modeling was performed to predict the surface roughness by using machining parameters. The investigation of influence of cutting conditions in facing operation of EN-8 in this paper. Machining was done using cemented carbide insert. The objective was to establish correlation between cutting speed, feed rate and depth of cut and optimize the turning conditions based on surface roughness. These correlations are obtained by multiple regression analysis (RA).

4.**Mittal PBrahmbhatt *etal* [4],**The present study illustrates the performance of MTCVD multicoated carbide insert in dry turning of EN9 steel. The effect of insert and cutting parameter on surface roughness and MRR is investigated. The experiments were conducted at three different spindle speed, feed and depth of cut. The cutting parameters are optimized using Taguchi method and the effect of cutting parameters and tool material on surface roughness was evaluated by the analysis of variance. The analysis indicated that the parameter that have the biggest effect on surface roughness and MRR is feed.

5.**AnandS.Shivade, *etal* [5]**,This paper presents the single response optimization of turning parameters for Turning on EN8 Steel. Experiments are designed and conducted based on Taguchi's L9 Orthogonal array design. This paper discusses an investigation into the use of Taguchi parameter Design optimize the Surface Roughness and Tool tip temperature in turning operations using single point carbide Cutting Tool. The Analysis of Variance (ANOVA) is employed to analyze the influence of Process Parameters during Turning. 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.

6.**Neerajsharma *etal* [6],**The present study applied extended Taguchi method through a case study in straight turning of mild steel bar using HSS tool for the optimization of process param. The study aimed at evaluating the best process environment which could simultaneously satisfy requirements of both quality as well as productivity with special emphasis on reduction of cutting tool flank wear, because reduction in flank wear ensures increase in tool life. The predicted optimal setting ensured minimization of surface roughness. From the present research of ANOVA it is found the Depth of cut is most significant, spindle speed is significant and feed rate is least significant factor effecting surface roughness.

7.**K Saravankumar *etal* [7]**,This paper is aimed at conducting experiments on Inconel 718 and investigation the influence of machining process parameters such as cutting speed (X1, m/min), feed rate(X2, mm/rev), and depth of cut (X3, mm) on the output parameters such as material removal rate and surface roughness.

8.**P.P.Shirpurkar *etal* [8],**In this study, the effects of cutting speed, feed rate,depth of cut, nose radius and cutting condition on surface roughness and vibration chatter in the turning were experimentally investigated. EN 24 steel was machined using carbide tool on CNC lathe machine.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. Results show that Nose Radius and the Cutting Speed and cutting condition are the three Parameters that influence the Surface Roughness more effectively. Finally, the ranges for best cutting conditions are proposed for serial industrial production.

9.**F Jafarian *etal* [9],**The goal is to propose a useful and effective method to determine optimal machining parameters in order to minimize surface roughness, resultant cutting forces and maximize tool life in the turning process. At first, three separate neural networks were used to estimate outputs of the process by varying input machining parameters. Then, these networks were used as optimization objective functions. Moreover, the proposed algorithm, namely, GA and PSO were utilized to optimize each of the outputs, while the other outputs would also be kept in the suitable range. The obtained results showed that by using trained neural networks with genetic algorithms as optimization objective functions, a powerful model would be obtained with high accuracy to analyze the effect of each parameter on the output(s) and optimally estimate machining conditions to reach minimum machining outputs.

10.**P Venkata Ramaiah *etal* [10]**,In this paper an attempt is made to obtain optimum turning parameters for minimum cutting forces and cutting temperature by using Fuzzy Logic. In this work, turning is performed on Al 6061 work material under dry conditions with CNMG cutting tool according to Taguchi experimental design. The Experimental responses like cutting temperature and cutting force are measured for different influential parameter combinations. The Experimental data is analyzed using Fuzzy Logic and optimum parameters combination is determined. The optimum parameters combination is tested by confirmation experiment and the result is satisfactory.

11.**MAdinarayana *etal* [11]**,The paper envisages the study to optimize the effects of process variables on surface roughness, MRR and power consumption of En24 of work material using PVD coated tool. In the present investigation the influence of spindle speed, feed rate, and depth of cut were studied as process parameters. The experiments have been conducted using full factorial design in the design of experiments (DOE) on a conventional lathe. A Model has been developed using regression technique. The optimal cutting parameters for minimum surface roughness, maximum MRR and minimum power consumption were obtained using Taguchi technique. The contribution of various process parameters on response variables have been found by using ANOVA technique.

12.**Yacov sahijpaul *etal* [12]**,The purpose of this experimental investigation was to analyse the effect of controlled cutting parameters namely cutting speed, feed rate, depth of cut, cutting fluid concentration and two cutting fluids with different base oils on surface roughness (Ra) of EN8 or AISI 1040 steel during turning operation by applying design of experiments, custom design method, analysis of variance, leverage plots and desirability profiling using JMP software to optimize surface roughness during wet CNC turning operation. The analysis reveals that feed rate has the most significant effect on surface roughness (Ra) and value of surface roughness does not significantly differ for two different cutting fluids used.

13.**Vaibhav B. Pansare *etal* [13]**,In this paper, attempt is made to obtain optimum turning parameters for minimum surface roughness value by using Ant Colony Optimization (ACO) algorithm in multipass turning operation. The cutting process has roughing and finishing stage. Also the relationship between the parameters and the performance measures were determined using multiple linear regression, this mathematical model is used to determine optimal parameters. The experimental results shows that the proposed technique is both effective and efficient.

14.**Er Sandeep Kumar *etal* [14]**, Engineering materials are presently in use at a very vast range in today's industries. As Mild steel 1018 has a wide variety of applications in construction of pipelines, products, construction as structural steel, car manufacturing industries and other major industries. The machining of these types of materials requires very important consideration. There are a number of parameters like cutting speed, feed and depth of cut etc. which must be given consideration during the machining of this alloy. So it becomes necessary to find out the ways by which it can be machined easily and economically. For the present work the parameter to be optimised selected is material removal rate that is optimised by using selected combination of machining parameters by using taguchi orthogonal array.

15.**Girish Tilak Shet *etal* [15]**,This paper presents the optimization of surface roughness parameters in turning EN1A steel on a CNC lathe. In this work, the Taguchi methods, a powerful statistical tool to design of experiments for quality, is used to find the optimal cutting parameters for turning operations. Analysis of Variance has been used to determine the influencing parameters on the output responses. Using Taguchi technique, we have reduced number of experiments from 27 to 9 there by the total cost of the project is reduced by 66.66%. The results obtained are encouraging and the concluding remarks are helpful for the manufacturing industries.

16.**Krishankant *etal* [16],**This paper reports on 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.

III. AIMS & OBJECTIVES

1.To Optimize Multiple Objectives Such As

a.Surface Roughness (SR)
b.Material Removal Rate(MRR)
c.Cutting Forces
d.Tool life
e.Tool Wear
f.Vibration
2.To Make The Process Standardize.

3.To Find The Optimal Setting For Process Parameters Such As

- a. Cutting Speed
- b. Feed rate
- c. Depth of Cut
- d. Cutting Condition
- e. Nose Radius

IV. METHODOLOGY

For optimization of various process parameters of turning process for AISI 1040 alloy steel, Following are the required steps which we are going to follow.

- Literature Survey,
- Data collection from relevant industries and reputed journals,
- Study of data collection,
- Planning of Experimental for turning AISI 1040 material,
- Experimental Set up,
- Measurement of multi- outputs,
- Application of Taguchi Method,
- Application of various Multi-objective optimization techniques,
- ANOVA,
- Finding optimal setting of cutting process parameters for each technique,
- Comparison of various Multi-objective optimization techniques,
- Conducting Confirmatory test.

V. TAGUCHI BASED DESIGN OF EXPERIMENTS

Among the available methods, Taguchi design is one ofthe most powerful DOE methods for analyzing ofexperiments. It is widely recognized in many fieldsparticularly in the development of new products andprocesses in quality control. The salient features of themethod are as follows:
a. A simple, efficient and systematic method tooptimize product/process to improve the performanceor reduce the cost.
b. Help arrive at the best parameters for the optimalconditions with the least number of analyticalinvestigations.
c. It is a scientifically disciplined mechanism forevaluating and implementing improvements inproducts, processes, materials, equipments andfacilities.
d. Can include the noise factor and make the designrobust.
e. Therefore, the Taguchi method has great potential inthe area of low cost experimentation. Thus it becomesan attractive and widely accepted tool to engineers andscientists.
Taguchi defines three quality characteristics in terms ofsignal to noise (S/N) ratio which can be formulated fordifferent categories which are as follows:

a. Nominal and small are best characteristics

Data sequence for surface finish and tool wear, whichare lower-the-better performance characteristics, arepre processed as per equations.
S/N = -10 log (ŷ/s2y)………………….1,
S/N = -10 log ((l/n) (Σy2))……….……2

b. Larger is best characteristics

Data sequence for material removal rate, which is higher-the better performance characteristics, is preprocessed as per equation 3.
S/N = -10 log ((1/n) (Σ (1/y2))……..…3,
Where, y is value of response variables and n is thenumber of observations in the experiments. Taguchimethod- based design of experiments involvedfollowing steps,
a. Definition of the problem
b. Identification of noise factors
c. Selection of response variables
d. Selection of control parameters and their levels
e. Identification of control factor interactions

f. Selection of the orthogonal array
g. Conducting the matrix experiments (experimental procedure and set-ups)
h. Analysis of the data and prediction of optimum level
a. Definition of the problem
A brief statement of the problem under investigation is“To optimize the turning process parameters tominimize surface roughness, increase tool life,minimize tool wear,reducedvibration,cuttingtemerature andmaximize the material removal rate.”

c. Identification of noise factors

The environment in which experiments are performedis the main external source of variation of performanceof turning process. Some examples of theenvironmental noise factors are temperature, vibrationsand human error in operating the process.

d. Selection of response variables

In any process, the response variables need tobe chosen so that they provide useful information aboutthe performance of the process under study. Variousparameters used while designing the experiments. Byconsidering all parameters given below and by takingliterature review as technical base Surface finish (Ra),MRR,Temperature, Toollife, Toolwear, Vibrations,Cutting forces are chosen as response variables.

VI. SELECTION OF WORK AND TOOL MATERIAL

A. Test Specimen

The work material used for the present study is EN8. EN8 is high tensile alloy steel well-known for its wearresistance properties and also where high strengthproperties are required.

C	Si	Mn	S	P
0.4%	0.25%	0.8%	0.015%	0..015%

Fig: Chemical Composition of EN8

B. Cutting Tool

The recently developed tool materials like coatedcarbides have improved the productivity levels ofdifficult to machine materials. Table gives thespecification of different tool material. The coatedcarbide tool reduces wear and tear between tool insertand workpiece. Thus coated carbide tool was selectedfor turning of cast iron. Cutting Tool used is carbideinsert tool CNMG120408 & CNMG120412 (ISOcatalog Number).

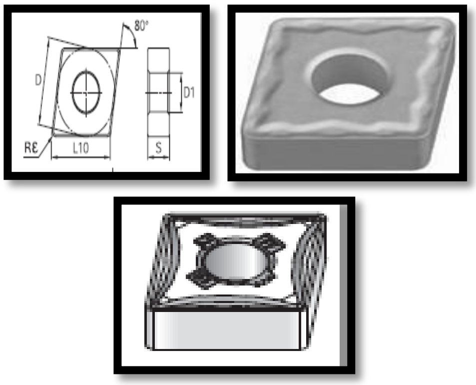

Fig: Cutting tool insert

Carbide Tool inserts (ISO Catalog Number)	D (mm)	L10(mm)	S (mm)	Rє (mm)	D1 (mm)
CNMG120404CT	12.7	12.9	4.76	0.4	5.16
CNMG120408CT	12.7	12.9	4.76	0.8	5.16
CNMG120412CT	12.7	12.9	4.76	1.2	5.16
CNMG120416CT	12.7	12.9	4.76	1.6	5.16

Fig: Specification of cutting tool inserts

VII.SELECTION OF ORTHOGONAL ARRAY

Selection of particular orthogonal array from thestandard O.A depends on the number of factors, levels of each factor and the total degrees of freedom.
i) Number of control factors = 5
ii) Number of levels for first four controlfactors = 4
iii) Number of levels for fifth control factor = 2
iv) Degree of freedom of each factor= number oflevel-1
v) Degree of freedom of first four controlfactors = 4-1=3
vi) Degree of freedom of fifth controlfactors = 2-1=1
vii) Total degrees of freedom of factors = sum ofDegree of freedom of allfactors= (3+3+3+3+3+1) =13
viii) Minimum number of experiments to beconducted =13+1=14.
Based on these values and the required minimum number of experiments to be conducted (14), the nearest O.A. fulfilling this condition is L16 .

DOE(FOR NOISE FACTOR V1)

Run	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	NOSE RADIUS (mm)	CUTTING CONDITION	TOOL TYPE
1	0.15	0.5	0.4	DRY	UNCOATED
2	0.15	1	0.8	WET	UNCOATED
3	0.15	1.5	1.2	MQL-I	CAOTED(PVD)
4	0.15	2	1.6	MQL-II	CAOTED(PVD)
5	0.2	0.5	0.8	MQL-I	CAOTED(PVD)
6	0.2	1	0.4	MQL-II	CAOTED(PVD)
7	0.2	1.5	1.6	DRY	UNCOATED
8	0.2	2	1.2	WET	UNCOATED

9	0.25	0.5	1.2	MQL-II	UNCOATED
10	0.25	1	1.6	MQL-I	UNCOATED
11	0.25	1.5	0.4	WET	CAOTED(PVD)
12	0.25	2	0.8	DRY	CAOTED(PVD)
13	0.3	0.5	1.6	WET	CAOTED(PVD)
14	0.3	1	1.2	DRY	CAOTED(PVD)
15	0.3	1.5	0.8	MQL-II	UNCOATED
16	0.3	2	0.4	MQL-I	UNCOATED

DOE(FOR NOISE FACTOR V2)

Run	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	NOSE RADIUS (mm)	CUTTING CONDITION	TOOL TYPE
1	0.15	0.5	0.4	DRY	UNCOATED
2	0.15	1	0.8	WET	UNCOATED
3	0.15	1.5	1.2	MQL-I	CAOTED(PVD)
4	0.15	2	1.6	MQL-II	CAOTED(PVD)
5	0.2	0.5	0.8	MQL-I	CAOTED(PVD)
6	0.2	1	0.4	MQL-II	CAOTED(PVD)
7	0.2	1.5	1.6	DRY	UNCOATED
8	0.2	2	1.2	WET	UNCOATED
9	0.25	0.5	1.2	MQL-II	UNCOATED
10	0.25	1	1.6	MQL-I	UNCOATED
11	0.25	1.5	0.4	WET	CAOTED(PVD)
12	0.25	2	0.8	DRY	CAOTED(PVD)
13	0.3	0.5	1.6	WET	CAOTED(PVD)
14	0.3	1	1.2	DRY	CAOTED(PVD)
15	0.3	1.5	0.8	MQL-II	UNCOATED
16	0.3	2	0.4	MQL-I	UNCOATED

DOE(FOR NOISE FACTOR V3)

Run	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	NOSE RADIUS (mm)	CUTTING CONDITION	TOOL TYPE
1	0.15	0.5	0.4	DRY	UNCOATED
2	0.15	1	0.8	WET	UNCOATED
3	0.15	1.5	1.2	MQL-I	CAOTED(PVD)
4	0.15	2	1.6	MQL-II	CAOTED(PVD)
5	0.2	0.5	0.8	MQL-I	CAOTED(PVD)
6	0.2	1	0.4	MQL-II	CAOTED(PVD)
7	0.2	1.5	1.6	DRY	UNCOATED
8	0.2	2	1.2	WET	UNCOATED
9	0.25	0.5	1.2	MQL-II	UNCOATED
10	0.25	1	1.6	MQL-I	UNCOATED
11	0.25	1.5	0.4	WET	CAOTED(PVD)
12	0.25	2	0.8	DRY	CAOTED(PVD)
13	0.3	0.5	1.6	WET	CAOTED(PVD)
14	0.3	1	1.2	DRY	CAOTED(PVD)
15	0.3	1.5	0.8	MQL-II	UNCOATED
16	0.3	2	0.4	MQL-I	UNCOATED

VIII. CONCLUSION

From above literature review, it is seen that a very few researchers have used a multi-objective optimization technique for AISI 1040 considering cutting speed, feed rate, depth of cut, nose radius, cutting condition and tool type to optimize surface roughness, MRR, cutting force, tool life and vibration. So, it becomes necessary to work in this field.

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